ONLINE APPENDIX

THE TAX GRADIENT: SPATIAL ASPECTS OF FISCAL COMPETITION

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This document includes all of the referenced material in the text of Agrawal (forthcoming); additional results not mentioned in the published paper can be found in the working paper version: Agrawal (2011).

1 Supplementary Appendix: Theory

1.1 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:

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

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:

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

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.

1.2 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:

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

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 $\mathbf{A}^{-1}\mathbf{b}$. □

1.3 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.[1] 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 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.

1.4 Proof of Corollary 2

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:

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

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

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

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:

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

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.

$\square$

2 Supplementary Appendix: Data

2.1 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 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.

2.2 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.[2] Figure 1 shows the methodology graphically.

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

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.[3] 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

[3] 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.

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.[4] Let b index each Census block point given by population P_b and has latitude ϕ_b and longitude λ_b. The population weighted center of place i is the latitude $\bar{\phi}$ and the longitude $\bar{\lambda}$ given by:

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

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

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

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

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.[5] 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 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.[6] 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

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

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

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

2.3 Map Analysis and Summary Statistics

Figure 2 presents the distribution of the county tax rate plus the average municipal tax rate with the county. Figure 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 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.

3 Supplementary Appendix: Additional Empirical Results

3.1 Additional Robustness Checks

Before proceeding, recall the definition of the tax gradient.

Definition 1. 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 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 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.

3.2 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 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.

3.3 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 6 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.

References

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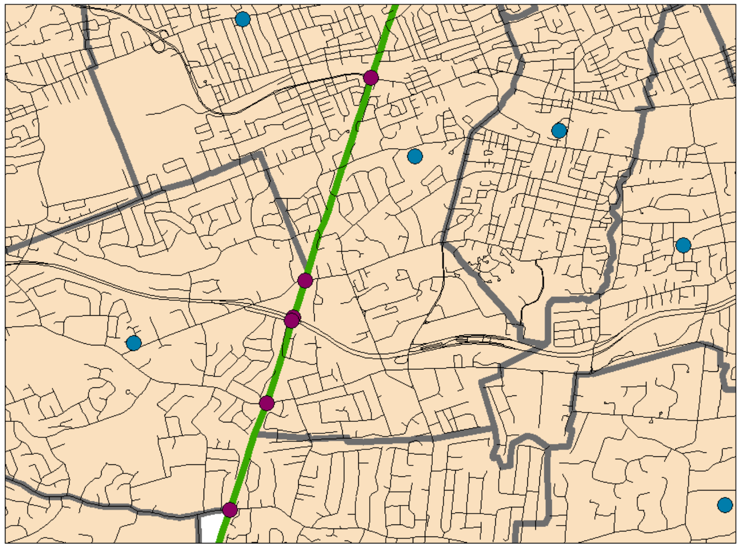
Table 1: ProSales Tax Summary Statistics by State (April 2010)

	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

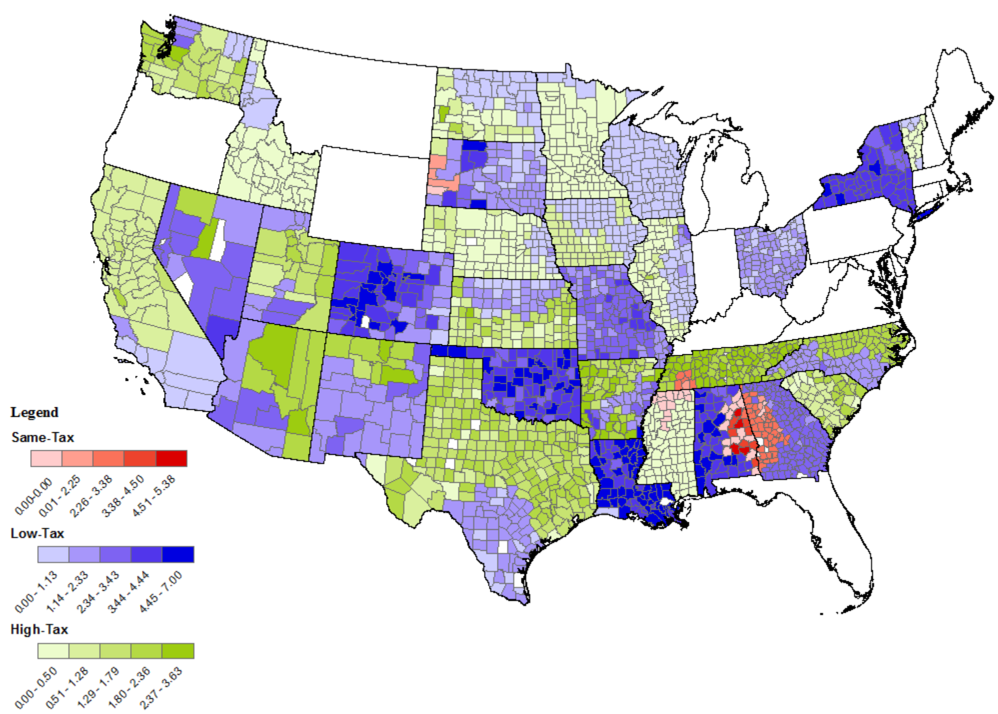
Yes means that the maximum value in the ProSales Tax dataset is non-zero.

Figure 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 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 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 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 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 6: 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%