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Crossing the Line: The Effect of Cross Border Cigarette Sales on State Excise Tax Revenues

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Abstract

Differences in excise tax rates across jurisdictions create incentives for consumers to cross the border and purchase in lower-tax jurisdictions. This paper introduces a discrete choice model to examine tax avoidance and state border-crossing in the market for cigarettes. We exploit a rich dataset of consumer location choices and demographics to estimate a consumer's tradeoff between distance and price when choosing a location to maximize utility. Using the estimates from our location and demand models, we reconsider a recent public policy issue among states and simulate tax avoidance under alternative cigarette excise tax levels.

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1 Introduction

Differences in cigarette taxes create incentives for consumers to cross borders, either physically or online, and make purchases in lower-tax jurisdictions. In many cases, the potential savings to smokers are substantial: state cigarette excise taxes vary from \$0.07 a pack in South Carolina to \$2.46 a pack in Rhode Island. Consumer avoidance of cigarette taxes (and other excise or sales taxes more generally) has important fiscal implications. As noted during Maryland's 2003 debate over increasing cigarette taxes

> Increasing the tobacco tax by \$.36 to \$1.36 will increase revenues by \$73.9 million . . . Currently there is an incentive for Maryland residents to travel to Delaware, Virginia, Pennsylvania or West Virginia because of the lower tax rates in the states. Increasing the tobacco tax will further increase this incentive.
> -Maryland General Assembly, Department of Legislative Services,
> 2003 Session, SB 324.

Since January 2002, thirty states and the District of Columbia have substantially increased their cigarette taxes in order to reduce budget deficits (Goolsbee, 2004). In 2006, California considered a statewide initiative that would have raised cigarette taxes by \$2.60 per pack. The fiscal impact of such policies depend on the extent to which consumers evade the higher taxes by crossing state borders.

This paper revisits the estimation of consumer response to differential state taxation. Unlike previous studies that infer the amount of border-crossing through reduced-form regressions, we have the distinct advantage of directly observing the location of purchase and price paid by a consumer. Our rich dataset of consumer-level demographics, cigarette consumption, and location of purchase allows us to estimate how demographics and distance interact to influence an individual's purchase decision. We specify a discrete choice model to explicitly estimate a consumer's choice of jurisdiction as part of a utility maximization problem. As a result, we are able to estimate an individual's tradeoff between price and distance when deciding where to purchase cigarettes, and we are able to directly calculate a consumer's marginal cost of travel for purchasing cigarettes. To our knowledge, these are the first direct estimates of travel incentives for cigarettes. We find that an individual is willing to travel 2.7 miles to save one dollar on a pack of cigarettes, and the marginal cost of travel for the average consumer is approximately 37 cents per mile. Moreover, we separately estimate the extensive and intensive price margins of cigarette smoking; we calculate the price elasticity conditional on smoking and the effect of price on a smoker's participation decision.

Our approach directly ties economic theory to the measurement of cross-border sales and provides a framework to formulate and test counterfactual public policies. To illustrate the potential effects of border-crossing on state revenues, we examine the particular case of Maryland, which in 2003 considered increasing the state tobacco tax from \$1.00 per pack to \$1.36 per pack. Legislators debated over the impact of these changes on tax revenues for Maryland and worried about whether Maryland residents would cross the border to lower-tax jurisdiction to avoid the tax increase. We find that without accounting for border-crossing, we would tend to overestimate the percentage increase in tax revenues from Maryland's increase by 30 percent instead of 28. If we consider the impact on a smaller jurisdiction where consumers have more ample opportunities to border-cross, such as the District of Columbia, the difference is even more stark; after accounting for border crossing, D.C.'s tax revenues would rise by only 20 percent after a 36 cent increase instead of the predicted 30 percent.

In addition, the richness of our data enables us to consider two extensions to our discrete choice model of location. First, we are able to observe individuals who choose to purchase cigarettes from "other" locations, which include the Internet, Indian reservations, and international purchases (e.g., Canada).[1] Our model allows for substitution between purchasing in-state, physically crossing a border to a lower tax jurisdiction, and virtually crossing a border by purchasing cigarettes over the Internet. Secondly, by separately estimating travel costs for light and heavy smokers, we can infer how stockpiling behavior varies between the two groups. Consistent with optimal stockpiling, we estimate that heavy smokers purchase approximately 2.7 times more cigarettes

[1] Some online merchants are located on Indian reservations (Goolsbee, et al, 2007).

when crossing borders than light smokers.

The paper is presented as follows, Section 2 discusses the previous literature. Section 3 provides descriptive statistics of the data and state cigarette excise taxes, and Section 4 develops our model of location choice and presents the empirical results. In section 5, we discuss the counterfactual experiments and the accompanying quantity regressions. Section 6 discusses some extensions to our baseline model of location choice, and Section 7 concludes.

2 Previous Literature

A well-developed literature studies consumer tax avoidance in response to differential excise taxation of cigarettes. The literature examines how differences in state cigarette taxes create incentives for consumers to cross the border from high tax states (such as Massachusetts) to low tax states (such as New Hampshire). The standard approach in the existing literature, including Yurekli and Zhang (2000) and Coats (1995), exploits state-level data and regresses per capita cigarette sales on cigarette price, tax, demographics, and metrics capturing the strength of the incentive for smokers to travel from or to a particular state. Stehr (2005) uses a similar approach, but incorporates cigarette consumption from the Behavioral Risk Factor Surveillance System to better measure untaxed sales of cigarettes. The metrics tend to be functions of the difference between home-state and neighboring tax rates as well as the size of the population near boundaries of low tax jurisdictions. Several studies also investigate tax avoidance and cross-border sales of alcohol (Baltagi and Goel, 1990, Baltagi and Griffin, 1995, Beard, et al, 1997, Stehr, 2007). The previous literature finds consistent evidence of a significant negative correlation between per capita cigarette sales and the magnitude of the incentive for smokers to travel to neighboring states, consistent with a story in which residents of high-tax jurisdictions purchase their cigarettes in low tax jurisdictions.[2]

[2]Other empirical papers on cigarette demand include the incentive for border crossing by consumers. Sung, Hu, and Keeler (1994) empirically estimate cigarette demand under a rational addition model, and Keeler, Hu, Barnett, Manning, and Sung (1996) study price discrimination by manufacturers in response to

A smaller set of papers infer cross-border sales from consumer-level data. Lovenheim (2006) develops a model that includes an individual's probability of border-crossing and estimates a reduced form regression of sales. He finds evidence that consumers nearby cost jurisdictions consume more cigarettes, and he estimates some of the primitives of his model.[3] Hyland et al. (2005) use the COMMIT study to investigate responses by cigarette smokers when asked whether they purchased cigarettes from different lower-tax jurisdictions (including nearby states, countries, tribal lands, or the Internet); his samples consists of twelve communities in the US. Emery, White, Gilpin and Pierce (2000) also examine individual survey data to study the extent to which California smokers avoided a $0.50 per pack increase in the excise taxes by purchasing from lower-tax jurisdictions. Finally, Crawford and Tanner (1995) use household expenditure data for the United Kingdom to identify whether households close to France are more sensitive to local alcohol taxes.

Our data has the advantage that it reports both location and quantity choice for a large representative sample of U.S. smokers. We use data on the smoking habits and purchase decisions of individual smokers to estimate a discrete model of location choice and a continuous model of cigarette consumption. Rather than inferring border crossing from reduced-form regressions of consumption decisions, we explicitly model a consumer's choice of venue as a tradeoff between the price and distance to each neighboring state.[4] Our approach allows us to identify substitution between home-state purchases, cross border purchases, and Internet purchases.

Our paper also relates closely to work on the competition across different retail venues. For example, Goolsbee (2000) studies competition between online and traditional retailers. He finds that eliminating the sales tax differential between online and traditional retailers would reduce the number of online buyers by 24 percent. Gools-

state excise taxes.

[3] A related paper is Manuszak and Moul (2006) which examines gas and cigarette taxes in the Chicago area and infers information about willingness to travel to avoid gasoline and/or cigarette excise taxes from the location and density of gas stations in Chicago.

[4] Although our paper focuses on avoidance by consumers rather than commercial cigarette smuggling, Gruber, Sen, and Stabile (2003) and Thursby and Thursby (2000) find evidence of commercial cigarette smuggling in response to heterogenous taxation.

bee and Slemrod (2004) quantify the extent to which consumer avoid state taxation through Internet purchases. In other markets, Chiou (2006) examines a consumer's choice of retailer for DVDs, and Ellison and Ellison (2007) also examine the extent of consumer tax avoidance in the market for offline and online computer parts. Our approach allows for multiple venue choices for each consumer (not just in-state versus out-of-state), and we combine this discrete choice model with estimates of quantity consumed to predict sales under different counterfactual scenarios.

3 Data

We obtained information on individual purchase quantities and locations from the CPS Tobacco Use Supplement (TUS) for February, June, and November 2003. The 2003 wave of the TUS asks each individual the last quantity of cigarettes purchased, price paid per pack of cigarettes, and the location of the purchase. The dataset also includes questions on the frequency of smoking (e.g., daily, occasional) and the history of smoking within the past year. We restrict our sample to individuals with non-missing data on demographics and who report their county of residence. The final dataset consists of 9745 smokers who report the location of their last cigarette purchase and 9588 smokers who report their daily quantity of cigarettes consumed.

The main advantage of our dataset is that we directly observe each consumer's location of purchase. Consumers did not travel very far to purchase cigarettes. Approximately 98 percent of consumers traveled less than 40 miles to purchase their cigarettes, and 96 percent purchased from within their home state. Forty percent of consumers live within 40 miles of another state with 17 percent living nearby at least 3 other states. Approximately 0.8 percent of consumers report purchasing cigarettes from "other" locations, which include the Internet, Indian reservations, and international purchases (e.g., Canada).[5] These consumers have similar demographics compared to consumers who purchase goods within the 50 states and D.C. with the exception that they have

[5] We assume that individuals who purchase cigarettes through Indian reservations report these locations as "other" in the CPS.

a slightly higher income.

Substantial variation in daily consumption of smoking exists; on average, consumers reported smoking 15 cigarettes per day with a standard deviation of 10. Individuals that report smoking everyday smoked an average of 16.7 cigarettes with a standard deviation of 9.3 whereas individuals that report only smoking “some days” smoked an average of 6.3 cigarettes a day with a standard deviation of 5.7. Smokers are slightly older and less wealthy than the US population; the average age is 43 years, and 27 percent have an annual household income above $60,000. Sixty-two percent of smokers report buying cigarettes only by the pack as opposed to the carton.

Smokers living within 40 miles of another state have similar characteristics (e.g., income, age, marital status, gender composition) to those living “far” (more than 40 miles) from state borders with the exception of racial composition. Among consumers living “far” from borders, 17 and 6 percent are self-identified as black and Hispanic compared to 7 and 12 percent among consumers living “near” state borders. Consumers are located across a wide variety of states in the U.S. with 20 percent in the northeast, 20 percent in the midwest, 30 percent in the south, and 30 percent in the west. The largest state represented in the sample is California with 11 percent of all sales.

In addition to the TUS data, we use state-level data on cigarette taxes and average cigarette prices from various issues of the *Tax Burden on Tobacco*. For each individual, we computed the distance to each of the nearby states using the latitude and longitude of her county’s centroid and the nearest county in a neighboring state.

Combined state and federal cigarette taxes vary considerably across locations. Average cigarettes taxes across all 50 states and the District of Columbia is 94 cents per pack, varying from a high of $1.86 in New Jersey to 39 cents in Virginia. For consumers that live within a 40-mile radius of another state, taxes vary across borders on an average of 66 cents per pack. Conditional on having a neighboring state with a higher or lower tax rate, the average difference between the tax rate in the home state and the tax rate of the neighbors with the highest and lowest tax rates are 48 cents and 58 cents. Substantial savings potentially exist from border-crossing to lower tax jurisdiction; given that daily cigarette consumption is 15 cigarettes on average (approximately 0.75 of a pack of 20 cigarettes), total savings in a year could amount to \$130. Average cigarette prices also vary by state from \$3.10 in Kentucky to \$5.54 in New York.

During 2003, seventeen states increased their cigarette excise tax. The average tax increase during the study period is \$0.37 per pack. Vermont and New Mexico increased cigarette taxes most, by \$0.70 per pack, while, conditional on increasing the tax rate, Kansas increased cigarette prices least, by \$0.09 per pack. In 2003, tax rates more than doubled in eight of the seventeen states: Delaware, Georgia, Idaho, Montana, Nevada, New Mexico, West Virginia, and Wyoming. Relative to the tax rates in 2002, the change in taxes represents an average increase of 123 percent.

4 Location Choice

In our model of demand, each consumer faces prices and excise tax rates that vary by location of purchase. We first consider a consumer's choice of location conditional on the decision to purchase cigarettes. We assume that consumer i perfectly observes prices p_j and taxes τ_j for cigarettes in each of the jurisdictions. Then the utility of consumer i purchasing from location j is given by:

$$U_{ij} = \delta_1(p_j + \tau_j) + \delta_2(p_j + \tau_j) * INC_i - \alpha d_{ij} * INC_i - \gamma f(d_{ij}) + \epsilon_{ij} \tag{1}$$

where p_j and τ_j are the tax-exclusive price and tax rate (in cents per pack) reported in Tax Burden on Tobacco for in state j, INC_i is a dummy for whether consumer i's income is above \$60,000, d_{ij} is the distance in miles between consumer i's county of residence reported in the TUS data and the nearest county in state j.[6] The variable ϵ_{ij} is an idiosyncratic error term that captures preferences for purchase jurisdiction, and it follows a Type I Extreme Value distribution. Consistent with the TUS reporting, we

[6] Although a subset of individuals in the TUS report the price for their last pack of cigarettes, we use prices from *Tax Burden on Tobacco* because we need to observe prices for all alternatives in a consumer's choice set.

define the outside good as purchasing cigarettes from a location other than the 50 states and D.C., such as the Internet, an Indian reservation, or international purchases (e.g., Canada). Since we do not observe the specific nature of the outside good, we normalize the price and distance of the outside good to zero, and we incorporate a dummy for the outside good into the location model to capture its attractiveness relative to other alternatives. We restrict a consumer's choice set to all states that lie within a 40 mile radius of her county of residence.

We include interactions of price with income to allow an individual's price sensitivity to vary by income. Similarly, we include an interaction of distance with income to allow the disutility of distance to vary by income. We allow distance to enter in linearly, quadratically and non-parametrically through successive 10-mile incremental dummy variables.

We estimate the model using Maximum Likelihood. For each consumer, we calculate the predicted probability of her making her observed location choice. Conditional on the vector $\theta = (\delta_1, \delta_2, \alpha, \gamma)$ of parameters to be estimated and right-hand side variables X, we express the predicted probability of consumer i choosing location j is:

$$prob_{ij}(\theta) = \frac{exp(X_{ij}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta)} \tag{2}$$

We form the log likelihood function from the predicted probabilities and maximize this expression over θ. Table 1 reports the results of the discrete choice model. As expected consumers experience a negative marginal utility from price. Utility declines by 0.005 units for every one cent increase in price per pack.

We consider alternative specifications of the distance function $f(.)$. Column (2) gives the estimates under a quadratic specification of distance. The marginal disutility of distance is given by $-0.341 + 2(0.006)d$ where d denotes distance in miles. For the most part, the coefficients on the interactions of price and distance with income are not significant. In Column (3), we obtain similar results when we allow the disutility of distance to vary linearly among different ranges of distance: 0-10 miles, 10-20 miles, 20-30 miles, and 30-40 miles.

The impact of a state tax change on instate purchase decisions depend upon the tradeoffs that consumer's face between price and distance. If we take the ratio of the marginal disutility of price and distance, we can calculate the number of miles a consumer is willing to travel to save $1 per pack of cigarettes. Under our benchmark specification in Column (1), a consumer is willing to travel 2.7 miles to save $1 on a pack of cigarettes.

We can calculate the marginal cost of each mile of travel by taking the ratio of the marginal disutility of distance to price. As expected, the marginal cost of travel declines with distance in Column (3). For the first 10 miles, the marginal cost of traveling an additional mile is 65 cents; afterwards the marginal cost of travel declines to 34, 21, and 20 cents within the ranges of 10-20, 20-30, and 30-40 miles. The magnitudes of the marginal costs seem reasonable, and they capture the cost of transport as well as the consumer's implied value of time. The U.S. General Services Administration estimates this marginal cost as 31 cents per mile in a privately owned vehicle.[7]

5 Counterfactuals

In this section, we use the results of our location model to simulate tax revenues under different counterfactual scenarios. First, we estimate a consumer's quantity of cigarettes consumed, and then we calculate own- and cross-price elasticities of sales among state. Then we apply these results with the location model to predict sales under different tax scenarios. We examine how the extent and magnitude of border-crossing affects changes in tax revenues.

[7]Please refer to U.S. General Service Administration (GSA), May 23, 1996, Federal Register page 25802, Vol. 61, no. 101.

5.1 Quantity Choice

In our model, the quantity of cigarettes consumed depends upon the location of purchase only through prices and taxes. To obtain an estimate of the quantity of cigarettes consumed, we regress the daily quantity of cigarettes smoked on the price paid and a consumer's demographics using state tax rates as an instrument for the tax-inclusive price faced by consumers. Previous studies with micro data had to include additional variables that measured the strength of the border-crossing incentive (e.g., average prices of neighboring states), since the exact location of purchase and therefore price paid were not observed (Chaloupka and Warner, 2000). In contrast, we do not need these additional metrics, since we observe the exact location of purchase for each consumer.

We recover the relationship between the quantity of cigarettes consumed, price, and the demographics of a consumer i through the following regression:

$$logQty_i = \beta Z_i + \gamma_1 log(\tau_i + p_i) + \epsilon_i, \tag{3}$$

where $logQty_i$ is the log daily quantity of cigarette consumed by consumer i, Z_i is a vector of demographics, and p_i and τ_i are the price and tax in consumer i's state of purchase.[8] Since our sample is restricted to smokers, estimating equation (3) estimates the intensive margin on which behavior changes - how smoking intensity changes in response to a change in price, conditional on smoking.

We estimate the quantity regression using $log(tax)$ as an instrument for the full price paid by consumers. Table 2 reports the OLS, first stage, and 2SLS results. Columns (1)-(3) use average prices of the consumer's reported purchase locations from *Tax Burden on Tobacco*, and Columns (4)-(6) use the consumer's reported prices from the TUS.[9] Note that the *Tax Burden on Tobacco* dataset does not contain prices for cigarettes

[8]Following the previous literature, we log the dependent variable. If individuals tend to underreport the quantity of cigarettes smoked by reporting a given percentage of actual consumption, then estimates of the price elasticity will not biased (Stehr, 2005).

[9]For the TUS regressions, we use $log(tax + 1)$ as an instrument, since we assume that taxes are zero for the outside good.

purchased online whereas the TUS does. The results are qualitatively similar across the two datasets. We estimate a price elasticity of -0.27 using more comprehensive data from *Tax Burden on Tobacco.* Restricting the sample to observations for which respondents reported the price of their last pack of cigarettes, we estimate more inelastic price elasticities of -0.13 and -0.11 using prices from the TUS or Tax Burden on Tobacco, respectively. Higher income individuals consume less while older individuals consume more. Race and gender also affect the quantity of cigarette consumption.[10]

We can obtain the full price elasticity of smoking by estimating the extensive margin - how prices affect the decision to smoke. Table 3 reports the results from the probit estimation of the decision to smoke on price and several demographic factors. The regression follows the standard specification in the literature (Lewit and Coate, 1981 and Lewit, et al, 1981) with demographics and home state price. In Column (2), we include, *diffmin*, the difference between the tax rate in state j and the lowest tax rate in a neighboring state to capture the border-crossing incentive. In our two specifications, we estimate negative and signficant elasticities of participation of -0.18 and -0.16, respectively. Together with our estimates of the conditional price elasticity of smoking, we find that the total price elasticity of smoking lies between -0.4 to -0.5.[11] The estimates lie within the spectrum of elasticities found by previous studies, which range from -0.14 to -1.23 with most studies falling in a narrower range from -0.3 to -0.5 (Chaloupka and Warner, 2000).

5.2 Elasticities

With the estimates from our location and quantity choice models, we can calculate the own- and cross-price elasticities among states, and we can also examine the change in

[10]When we restrict the sample to individuals who live more or less than 40 miles from the nearest state, the results are qualitatively similar across the different specifications.

[11]The full margin (quantity of cigarettes smoked by all individuals) consists of two parts: the decision to smoke (extensive margin) and the quantity smoked conditional on smoking (intensive margin). Let Q be the quantity of cigarettes smoked. Then $Q = Prob(smoke)(Q|smoke)$ where $Q|smoke$ is the quantity of cigarettes smoked, conditional on the decision to smoke. Since $dlnQ/dlnPrice = dlnQsmoke/dlnPrice + dlnProb(smoke)/dlnPrice$, we can calculate the total price elasticity by summing the conditional price elasticity and participation price elasticity.

tax revenues under different counterfactual scenarios.

We can predict the expected quantity of purchase for an individual at each possible location. Conditional on traveling to location j, consumer i's quantity of purchase depends upon her demographics Z_i as well as the price and tax of cigarettes at that location p_j and τ_j. Under our model, a consumer's quantity of consumption varies by location only through the differences in prices and taxes. Her expected consumption at location j is given by:

$$q_{ij}^e = \hat{q}(Z_i, p_j, \tau_j) * \hat{prob}_{ij} \tag{4}$$

where $\hat{q}(Z_i, p_j, \tau_j)$ is her optimal choice of cigarettes at location j, and $\hat{prob}_{ij}$ is her predicted probability of traveling to location j.[12]

We can use equation (4) to calculate price elasticities under border-crossing. The conditional price elasticity of -0.27 given by our quantity regression in the previous section captures demand responsiveness when there is no change in border-crossing behavior. This gives the percentage decrease in the optimal consumption, irrespective of location of purchase. Tables 4 and 5 report the own- and cross-price elasticities under the location choice model when border-crossing can occur.[13] The optimal quantities for each location are now weighted by the probability of an individual traveling to that location. Note that own-price elasticities are higher in states such as Connecticut (-2.9) and Maryland (-2.2) where individuals live in close proximity to other states.

To obtain the full price elasticity, we add the participation elasticity found earlier (-0.16) to the conditional price elasticities for each state. Note that certain states do not appear in Table 4, as individuals within those states did not report their location

[12] If the quantity regression is given by $lnq = X\beta + \epsilon$ where N = number of observations and k = number of independent variables. Then the equation for quantity is given by $q = exp(X\beta + \epsilon) = exp(X\beta)Exp(\epsilon)$, and $E[q|X] = exp(X\beta)E[exp(\epsilon)]$. If ϵ is normally distributed with variance σ^2, then $E[exp(\epsilon)] = exp(\sigma^2/2)$. As a result, we can calculate predicted quantities as follows: $\hat{q} = exp(X\hat{\beta})exp(s^2/2)$ where $s^2 = \frac{1}{N-k}\sum_{i=1}^{N} e_i^2$ is an unbiased and consistent estimate of σ^2, and e is the residual from the quantity regression.

[13] We calculate the percentage change in expected quantity at each location under a 10 percent change in the price or distance of a given location, and then we divide the two numbers to obtain the elasticities. The standard errors of the elasticities were obtained by a parametric bootstrap where we draw from the asymptotic distribution of the estimated parameters 100 times. For each draw, we calculate the elasticity matrix, and then we calculate the sample standard deviation of the elasticities over the draws.

of purchase.

5.3 Simulation of Tax Changes in Maryland and D.C.

In the Introduction, we described a particular debate in the Maryland legislature regarding a tax increase from \$1.00 to \$1.36 per pack in 2003. We use Maryland as an example to illustrate the impacts of border-crossing behavior on tax revenues because potentially large gains from border-crossing exist for Maryland residents due to the proximity of neighboring states, and in our dataset, we observe smokers in Maryland and all its neighboring states.

To calculate the effect of border-crossing on tax revenues, we simulate the percentage change in tax revenues under this increase. Using our estimates of location and quantity choice, we consider Maryland's tax increase under two counterfactual scenarios. In the first scenario, we examine what would happen if no change in the border-crossing incentive occurred. This could correspond to a situation where all states surrounding Maryland coordinated and increased their taxes in such a way that a consumer's choice of location does not change. Alternatively, this can be interpreted as a naive calculation of the effects of a tax change, assuming individuals did not change their current location decisions. In the second scenario, we allow for consumers to respond to changes in the tax rate by changing their location of purchase.

Under our first scenario, if no changes occurred in consumers' purchase locations, we can see from equation (4) that the probability of choosing a given location $\hat{prob}$ is held constant. Consequently, the percentage change in expected quantity at each location is due solely to the percentage change in the optimal quantity of cigarettes $\hat{q}$ given by the quantity regression. Recall that the quantity regression from the previous section gives the relationship between the price and the optimal quantity of cigarettes to smoke, irrespective of location of purchase. The percentage change in tax revenues can be calculated as follows (Goolsbee and Slemrod, 2003):

$$log(Rev_1) - log(Rev_0) = log(t_1) - log(t_0) + log(q_1) - log(q_0) \tag{5}$$

$$log(Rev_1) - log(Rev_0) = log(t_1) - log(t_0) + \eta[log(p + t_1) - log(p + t_0)) \quad (6)$$

where η is the estimate of elasticity is obtained from our quantity regression, and the values of taxes, revenues, prices, and quantities are given by t, Rev, p, and q. When no changes to the border-crossing incentive occur, tax revenues in Maryland will increase by 30 percent when the Maryland tax is increased by \$0.36 per pack.[14]

For our second scenario, we allow for border-crossing. Consequently, we need to account for how changes in taxes affect the probability of traveling to a given location. Equation (4) reveals that the overall change in expected quantity can be decomposed into two parts: the change in the probability of choosing a given location $\hat{prob}$ and in the optimal quantity of cigarettes $\hat{q}$. First, we predict the probability of a consumer choosing a given location under the new set of taxes, and then we predict the optimal quantity at each location. We take all smokers in the 2003 TUS and calculate the predicted changes in their quantities under a given change in price and distance for a given location. In order to simulate each consumer's expected quantity of purchase at each location, we need to observe all prices that the consumer faces at each possible location, so we use the average prices reported by *Tax Burden on Tobacco*. Since we do not observe the full set of online prices for each consumer, we cannot predict quantities purchased online. However, our estimates of quantities purchased at all offline locations will still take into account substitution to the online option through the predicted location choice probabilities.

We present the results of our simulation in Table 6.[15] We estimate that increasing the tax by 36 cents from \$1.00 to \$1.36 per pack in Maryland increases state tax revenues by 28 percent in Maryland, by 8 percent in West Virginia, and by smaller amounts in neighboring states. Absent additional border crossing by Maryland con-

[14]Using equation (6), we let $t_0 = \$1.00$ and $t_1 = \$1.36$. We use the average price of a pack of cigarettes \$4.105 as reported in Tax Burden on Tobacco in 2003 for Maryland. For the elasticity, we consider values between -0.15 and -0.25 as given in Table 2.

[15]The standard errors of the percentage change in revenues were obtained by a parametric bootstrap where we draw from the asymptotic distribution of the estimated parameters 100 times. For each draw, we calculate the percentage change in revenues, and then we calculate the sample standard deviation of the percentage change over the draws.

sumers, we estimate that Maryland tax revenues would increase 30 percent.

Table 6 also presents the results from simulating a similar tax increase in D.C. from \$1.02 per pack to \$1.38. A tax increase of 36 cents in D.C. increases tax revenues by 30 percent absent a change in border-crossing and by only 20 percent once consumers reoptimize their location of purchase.[16]

Our simulation conditions on the decision to smoke; we assume that the simulated tax changes do not affect the decision to smoke. In addition, we implicitly assume that a one cent increase in the tax will lead to a one-cent increase in the price paid by consumers. Chaloupka and Warner (2000) note that early studies have produced inconsistent findings regarding the relationship between taxes and prices in the U.S.; Keeler et al. (1996) estimated that a one-cent increase in a state's cigarette tax would raise retail prices in that state by 1.11 cents. Finally, the tax revenues calculated for each state include both federal and state taxes collected.

6 Extensions

We used our baseline model of location and quantity choice to generate estimates of consumption and the decision to cross the border. In this section, we consider two extensions to our model of location choice. We examine how stockpiling and varying access to the Internet affect our model of location choice.

6.1 Stockpiling

An implicit assumption in our base model (and other existing studies of cigarette purchases) is that the marginal cost of traveling and the stockpiling behavior for light and heavy smokers is similar. If heavy smokers purchase more cigarettes when crossing to a lower cost jurisdiction than light smokers, the heavy smokers capture a greater benefit from the differences in taxes than does a light smoker. In this case, a specification

[16]Using equation (6), we let $t_0 = \$1.015$ and $t_1 = \$1.375$. We use the average price of a pack of cigarettes \$4.104 as reported in Tax Burden on Tobacco in 2003 for D.C. For the elasticity, we consider values between -0.15 and -0.25 as given in Table 2.

which estimates a common travel cost for all smokers would underestimate the number of heavy smokers who border-cross and would overestimate the number of light smokers who border-cross.

We separately estimate our earlier specification for smokers that report smoking "everyday" versus "some days" in the TUS. Smokers who report smoking "everyday" have a significantly lower marginal cost of traveling than smokers who only report smoking "some days". Columns (4) and (5) of Table 1 indicate that the marginal cost of travel for an "everyday" and "some days" smoker are 30 cents (= 0.178/0.006) and 82 cents (= 0.245/0.003).

After conditioning on smoker characteristics which affect travel costs, we would expect smoking intensity to affect the marginal cost of travel solely through stockpiling decisions. In this case, the ratio of marginal travel costs between "everyday" and "some days" smokers provide an estimate of relative stockpiling behavior of the mean member of each of these groups. Based on the estimated coefficients for marginal cost of travel between these two groups, we estimate that "everyday" smokers purchase approximately 2.7 times as many cigarettes when crossing a border than do "some day" smokers.

We also consider a finer distinction and separately estimate the location choices of consumers who smoke more and less than the average number of cigarettes 14 in a day.[17] As shown on Columns (6)-(7) of Table 1, individuals who smoke less than 14 cigarettes a day have a higher marginal cost of traveling of 55 cents per mile than individuals who smoke more than 14 cigarettes a day of 28 cents per mile. The pattern is similar whether we consider a threshold of 10 or 20 cigarettes as well.

6.2 Incorporating Internet Usage

Internet access may vary by consumers, so as an extension to the initial specification, we specify a discrete model of location choice which allows for possibility that the outside

[17] Technically, consumption of cigarettes will vary by location due to differences in prices. Here we take the reported daily consumption given an individual's current purchase location. This measure is intended to identify "heavy" from "light" smokers.

option may not exist in certain consumers' choice sets. We assume that purchases from the outside option are made through the Internet. Our approach is to estimate the discrete choice model in a two step procedure. First, we use data from the CPS Internet usage survey from Oct 2003 to estimate the probability that an individual has Internet access, conditional on demographics. We then use predicted probability of Internet access to weight the choice probabilities for each individual's decision in our discrete model of location choice.

Let $\hat{r}_i$ denote the predicted probability that individual i has Internet access. Analogous to our utility specification from the previous section, we assume that consumer i's utility from purchasing at location j is given by $U_{ij} = X_{ij}\theta + \epsilon_{ij}$. If an individual has Internet access, then the conditional probability that she chooses location j is given by

$$prob_{ij|Internet} = \frac{exp(X_{ij}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta) + exp(X_{ic}\theta)} \tag{7}$$

where choice c denotes purchasing online.

If an individual does not have Internet access, then the conditional probability of choosing location j is given by

$$prob_{ij|noInternet} = \frac{exp(X_{ij}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta)}. \tag{8}$$

Weighting the two, we can derive the unconditional probability that an individual purchases from a particular location or over the Internet.

The unconditional probability of purchasing from location j is given by:

$$prob_{ij} = \hat{r}_i \frac{exp(X_{ij}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta) + exp(X_{ic}\theta)} + (1 - \hat{r}_i) \frac{exp(X_{ij}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta)}, \tag{9}$$

and the unconditional probability of purchasing online is given by:

$$prob_c = \hat{r}_i \frac{exp(X_{ic}\theta)}{\sum_{k=1}^{K} exp(X_{ik}\theta) + exp(X_{ic}\theta)}. \tag{10}$$

To estimate our first stage, we use data from the CPS Internet usage survey in

October 2003 on computer and Internet penetration. We consider four measures of computer and Internet access: (1) home computer ownership, (2) home Internet access, (3) use of e-mail, and (4) purchase of goods online. Sixty-nine percent and 61 percent of respondents own a home computer and have Internet access at home. 47 percent of participants have used e-mail, and 26 percent have made an online purchase.

First, we use a probit regression to estimate Internet access conditional on an individual's demographics. We regress each of the four measures of computer and Internet access on educational attainment, gender, income bracket, ethnicity, state of residence, and a quadratic function of age. We find that the explanatory variables do a fairly good job of predicting our Internet use variables; the pseudo R-squared for each of the regressions lies between .2 and .25.

Table 7 presents the results of the four regressions on online use. We find similar relationships between demographics and each of our four metrics. Internet usage is positively and significantly correlated with educational attainment and income. We estimate that women are slightly more likely to have a home computer or home Internet access and are substantially more likely to have used e-mail. Blacks and Native Americans are significantly less likely to have home computers or Internet access, and they are also less likely to have used e-mail or purchased goods online. Finally, we find that the quadratic age term is negative and significant across each of the four regressions, consistent with computer and Internet penetration among younger individuals.

We take the estimated coefficients on Internet use and predict the probability of Internet access for individuals from our TUS sample. Across individuals in the TUS sample, the average predicted probabilities are 66 percent with a computer at home, 59 percent with Internet at home, 51 percent with e-mail, and 30 percent with an online purchase. We incorporate these probabilities and estimate an extension of the location model where the probability of access to the outside good ("Internet") varies by individual. We estimate the model using a Quasi-Newton method with a numeric gradient; we also obtain similar coefficient estimates when we use a non-derivative simplex search instead.

Table 8 contains the results of the extended location model under our four different measures of Internet access. The estimated disutility of price and traveling are approximately the same as our baseline model where all individuals were assumed to have access to the Internet, since variation in price and distance among the states (i.e., offline options) drive the identification of these coefficients.[18] As expected, the disutility of the outside good has declined slightly, since individuals now may not have access to the outside good (online) with some positive probability. The coefficients on the interactions between price and income are now positive, indicating that higher income individuals are less price sensitive. Higher income individuals are more likely to have Internet access and therefore buy online when they face higher offline prices.

7 Conclusion

In this paper, we estimate individuals' decisions to travel across borders in response to differential tax rates. Unlike previous studies, our rich dataset allows us to directly observe a consumer's location of purchase as well as demographics. Consequently, we can apply a discrete choice model to directly estimate a consumer's choice of purchase location.

Our ultimate goal is to investigate the public policy implications of tax changes and differences in taxes across neighboring jurisdictions. We apply the estimated parameters from our location model and consumption regression to simulate several counterfactual tax scenarios. In particular, we examine the effect of a 36 cent increase in the tobacco tax as debated by the Maryland General Assembly.

We find that the effects of border-crossing on tax revenues vary substantially by state. We estimate that, absent a change in border-crossing, a 36 cent increase (from $1.00 to $1.36) in Maryland's cigarette tax will increase tax revenues by 30 percent. Accounting for border crossing modestly decreases this estimate - Maryland tax revenues will increase by 28 percent after a subset of smokers shift their purchase location

[18] The outside good was assumed to have price and distance equal to zero; we included an outside good dummy to capture its relative attractiveness.

to nearby states. In the case of D.C., we find that ignoring border crossing incentives leads to a larger overestimate of the change in tax revenues. Not accounting for border-crossing over-estimates the increase in tax revenues to be 30 percent instead of only 20 percent for a 36 cent increase in tax per pack (from \$1.02 to \$1.38).

Cigarette taxes serve two purposes, revenue generation and smoking deterrence. From our estimates of the total price elasticity of demand for cigarette sales, we can determine whether the per pack excise tax in a state falls short of, equals, or exceeds the revenue maximizing tax rate.[19] If we assume a full passthrough of cigarette taxes to the tax-inclusive price[20], the revenue maximizing tax rate in Maryland (with an own-price elasticity of -2.36), would be 73 percent, or approximately \$3.00 per pack on top of an average tax-exclusive price of \$4.10 per pack. Although states consider the border-crossing effects when determining their tax rates, we find that existing cigarette taxes fall below the tax-revenue maximizing levels.

In addition, we consider two extensions to our location model. In the first, we allow Internet access to vary probabilistically by individual. In the second, we re-estimate the location model for light and heavy smokers separately to infer the relationship between stockpiling and travel costs.

Our results highlight the regulatory importance of geographic scope and inter-jurisdictional heterogeneity. Cigarette taxes may be levied for a variety of public concerns from reducing smoking to generating tax revenues. The efficacy of any such regulation depends upon the policies of neighboring jurisdictions as well as the geographic distribution of consumers within the jurisdiction. This suggests the need for coordination among policymakers across different geographic locales or at the very least, incorporating these constraints when determining regulation stringency.

[19]Following an analogous derivation to the Lerner Index, the revenue maximizing tax rate t^* satisfies $\frac{t^*}{p+t^*}\left[1+\frac{\partial p}{\partial t}\right] = -\frac{1}{\epsilon}$ where p denotes the tax-exclusive price and ϵ denotes a state's own tax-inclusive price elasticity. Note that we use the total price elasticity of demand that incorporates both the decision to smoke and the quantity to smoke. While the preceding simulations conditioned on the decision to smoke, we need to incorporate the change in the extensive margin when considering potentially larger changes in prices.

[20]If the incidence of taxation falls only partially on consumers, the revenue maximizing tax rate will be greater. If, as Keeler (1996) finds, cigarette taxes are more than fully passed through to the consumer, the revenue maximizing tax rate will be lower.

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Table 1. Baseline Location Choice Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All	All	All	Everyday smoker	Some days smoker	quantity<=14	quantity>14
price+tax	-0.005**	-0.006**	-0.007**	-0.006**	-0.003*	-0.004**	-0.007**
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
(price+tax)*income	-0.001	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
distance	-0.187**	-0.341**		-0.178**	-0.245**	-0.218**	-0.161**
	(0.007)	(0.013)		(0.007)	(0.021)	(0.012)	(0.008)
distance*income	0.024*	0.011	0.009	0.023*	0.041	0.036*	0.014
	(0.010)	(0.008)	(0.008)	(0.011)	(0.031)	(0.017)	(0.012)
distance^2		0.006**					
		(0.000)					
0≤distance≤10 miles			-0.456**				
			(0.024)				
10<distance≤20 miles			-0.241**				
			(0.011)				
20<distance≤30 miles			-0.146**				
			(0.007)				
30<distance≤40 miles			-0.137**				
			(0.007)				
outside good	-7.550**	-7.984**	-8.749**	-7.906**	-6.494**	-6.849**	-8.528**
	(0.276)	(0.316)	(0.348)	(0.313)	(0.628)	(0.389)	(0.422)
Observations	3724	3724	3724	2801	687	1824	1803

Notes: Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
Price and tax are measured in cents per pack.

Table 2. Log of Quantity Regression

	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	OLS	1st stage	2SLS	OLS	1st stage
log(price)	-0.273**	-0.257**		-0.125+	-0.219**	
	(0.043)	(0.040)		(0.069)	(0.036)	
income	-0.113**	-0.114**	0.012**	-0.149**	-0.141**	0.068**
	(0.019)	(0.019)	(0.002)	(0.026)	(0.025)	(0.008)
log(age)	0.343**	0.343**	0.004+	0.216**	0.211**	-0.077**
	(0.023)	(0.023)	(0.002)	(0.030)	(0.030)	(0.009)
marital status	-0.017	-0.017	-0.002+	-0.056*	-0.058*	-0.020**
	(0.018)	(0.018)	(0.002)	(0.023)	(0.023)	(0.007)
male	0.179**	0.179**	-0.002	0.210**	0.209**	-0.007
	(0.016)	(0.016)	(0.001)	(0.021)	(0.021)	(0.006)
log(tax)			0.467**			0.321**
			(0.002)			(0.007)
Constant	0.524**	0.548**	-0.008	1.959**	2.531**	4.656**
	(0.109)	(0.107)	(0.009)	(0.433)	(0.244)	(0.046)
Dataset of prices	Tax Burden on Tobacco	Tax Burden on Tobacco	Tax Burden on Tobacco	Tobacco Use Supplement	Tobacco Use Supplement	Tobacco Use Supplement
Observations	9362	9362	9582	6201	6201	6201
R-squared	0.11	0.11	0.89	0.09	0.09	0.28

Notes: Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
Regressions also include dummies for race.
Price and tax are measured in cents per pack.

Table 3. Smoking Participation

	(1)	(2)
	Probit marginals	Probit marginals
homestate price	-0.006**	-0.005**
	(0.001)	(0.001)
income	-0.072**	-0.072**
	(0.003)	(0.003)
marital status	-0.032**	-0.032**
	(0.003)	(0.003)
male	0.042**	0.042**
	(0.003)	(0.003)
diffmin		-0.010+
		(0.005)
price elasticity at mean	-0.186	-0.162
	(0.039)	(0.041)
Observations	79800	79800

Notes: Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
The regressions also include age and dummies for race.
Price is measured in dollars per pack.

Table 4. Own-price elasticities by state

State	Estimate	Standard Error
Alabama	-0.268	0.041
Alaska	-0.294	0.038
Arizona	-0.278	0.037
California	-0.281	0.039
Colorado	-0.265	0.037
Connecticut	-2.946	0.188
Delaware	-1.106	0.077
District of Columbia	-1.915	0.167
Florida	-0.266	0.038
Georgia	-0.652	0.048
Hawaii	-0.310	0.034
Idaho	-2.171	0.146
Illinois	-2.137	0.156
Indiana	-0.919	0.058
Iowa	-1.331	0.084
Kansas	-1.736	0.104
Kentucky	-1.491	0.097
Louisiana	-0.266	0.042
Maine	-0.288	0.039
Maryland	-2.174	0.158
Michigan	-1.019	0.076
Minnesota	-1.059	0.071
Missouri	-0.314	0.040
Nebraska	-0.272	0.041
Nevada	-0.271	0.040
New Jersey	-2.461	0.165
New Mexico	-0.269	0.039
New York	-1.426	0.088
North Carolina	-0.889	0.059
North Dakota	-0.294	0.037
Ohio	-0.722	0.057
Oklahoma	-0.265	0.039
Oregon	-0.906	0.059
Pennsylvania	-1.406	0.101
South Carolina	-0.783	0.058
South Dakota	-0.297	0.037
Tennessee	-1.282	0.097
Texas	-0.445	0.046
Utah	-0.273	0.046
Virginia	-1.267	0.078
Washington	-0.426	0.043
West Virginia	-2.038	0.137
Wisconsin	-1.299	0.085

Notes: These elasticities are conditional on smoking.
States that do not appear in the table were not in the final sample.

Table 5. Own- and Cross-Price Elasticities for 1% Change in Price of Maryland

State	Estimate
Delaware	0.812
	(0.085)
District of Columbia	0.362
	(0.026)
Maryland	-2.176
	(0.158)
New Jersey	0.013
	(0.001)
Pennsylvania	0.404
	(0.044)
Virginia	0.304
	(0.037)
West Virginia	0.007
	(0.001)

Notes: Standard errors in parentheses.
The elasticities are conditional on smoking.

Table 6. Simulated Percentage Change in Tax Revenues from a tax increase of 36 cents in Maryland and the District of Columbia

	Maryland	District of Columbia
Delaware	2.545%	-
	(0.026)	
District of Columbia	3.139%	19.804%
	(0.213)	(1.376)
Maryland	28.105%	1.484%
	(0.591)	(0.064)
New Jersey	0.003%	-
	(0.001)	
Pennsylvania	0.047%	-
	(0.006)	
Virginia	1.877%	4.180%
	(0.167)	(0.322)
West Virginia	7.823%	-
	(0.802)	

Notes: Standard errors in parentheses.
Simulation is conditional on the decision to smoke.

Table 7. Marginal Effects of Probit Model for Online Access

	(1)	(2)	(3)	(4)
	Computer at Home	Internet in Home	Email	Online Purchase
age	0.001	0.000	-0.008	0.009
	(0.000)**	(0.001)	(0.001)**	(0.001)**
age^2	-0.000	-0.000	-0.000	-0.000
	(0.000)**	(0.000)**	(0.000)**	(0.000)**
High school	0.064	0.076	0.143	0.157
	(0.004)**	(0.005)**	(0.005)**	(0.006)**
Some college	0.165	0.190	0.321	0.321
	(0.004)**	(0.005)**	(0.005)**	(0.006)**
BA degree	0.190	0.228	0.409	0.465
	(0.004)**	(0.005)**	(0.004)**	(0.006)**
MA/PH.D. degree	0.200	0.242	0.411	0.500
	(0.004)**	(0.005)**	(0.004)**	(0.007)**
Female	0.009	0.006	0.079	0.022
	(0.003)**	(0.004)+	(0.004)**	(0.003)**
Black	-0.111	-0.135	-0.150	-0.141
	(0.006)**	(0.007)**	(0.007)**	(0.005)**
Native American	-0.113	-0.164	-0.124	-0.122
	(0.018)**	(0.019)**	(0.019)**	(0.015)**
Asian	0.014	0.016	-0.055	-0.086
	(0.010)	(0.011)	(0.011)**	(0.008)**
Other	-0.003	-0.014	-0.012	-0.009
	(0.012)	(0.013)	(0.014)	(0.012)
Observations	89701	89701	89701	89701

Notes:
Robust standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
Regressions also include income dummies.

Table 8. Location Choice with Internet Choice Probabilities

	coefficient
price	-0.00529
	(0.00047)
price*income	0.00028
	(0.00039)
distance	-0.18778
	(0.00682)
distance*income	0.02584
	(0.01028)
outside	-7.01310
	(0.27692)
Log-likelihood	-1319.96
Observations	9656

Notes: Standard errors in parentheses.
Each consumer's choice set is weighted by the predicted probability that she has Internet access at home.
Price and tax are measured in cents per pack.