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Excise Tax Avoidance: The Case of State Cigarette Taxes

Philip DeCicca,
NBER & Department of Economics, McMaster University, Hamilton, Ontario Canada

Donald Kenkel, and
NBER & Department of Policy Analysis & Management & Department of Economics, Cornell University, Ithaca NY 14850

Feng Liu
School of Economics, Shanghai University of Finance and Economics, Shanghai 200433, China

Philip DeCicca: decicca@mcmaster.ca; Donald Kenkel: dsk10@cornell.edu; Feng Liu: liu.feng@mail.shufe.edu.cn

Abstract

We conduct an applied welfare economics analysis of cigarette tax avoidance. We develop an extension of the standard formula for the optimal Pigouvian corrective tax to incorporate the possibility that consumers avoid the tax by making purchases in nearby lower-tax jurisdictions. To provide a key parameter for our formula, we estimate a structural endogenous switching regression model of border-crossing and cigarette prices. In illustrative calculations, we find that for many states, after taking into account tax avoidance the optimal tax is at least 20 percent smaller than the standard Pigouvian tax that simply internalizes external costs. Our empirical estimate that tax avoidance strongly responds to the price differential is the main reason for this result. We also use our results to examine the benefits of replacing avoidable state excise taxes with a harder-to-avoid federal excise tax on cigarettes.

Keywords

cigarette taxes; smoking; border-crossing

1. Introduction

Many countries impose excise taxes on alcohol, cigarettes, gasoline, and environmentally-related goods (Cnossen, 2005). Excise taxes are relatively small but non-trivial sources of revenue. On average across the OECD, they account for almost 11 percent of government revenues (OECD 2012, Table 3.4). However, it is widely agreed that the revenues are not the main explanation for which goods are taxed. As Hines (2007, p. 50) argues: “Instead, excise taxes are intended to discourage consumption of the specific taxed goods, thereby preventing some potential consumers from contributing to pollution, traffic congestion, injury, and poor health.” In neoclassical welfare economics substantial excise taxes on certain goods, including cigarettes, can be justified as efficient Pigouvian taxes that internalize external costs.[1] Work in behavioral economics suggests that much higher excise taxes may sometimes be justified to correct the “internalities” consumers impose on their future selves by unhealthy time-inconsistent decisions, possibly including their decisions to smoke (O'Donoghue and Rabin 2003, 2006, Gruber and Koszegi 2004).

The potential for corrective cigarette excise taxes might be limited because smokers can avoid excise taxes by making purchases from nearby tax jurisdictions with lower tax rates. In this paper we conduct an applied welfare economics analysis of cigarette tax avoidance. To our knowledge, we are the first study to develop an extension of the standard formula for the optimal Pigouvian corrective tax to incorporate tax avoidance.[2] To provide a key parameter for our formula, we estimate a structural endogenous switching regression model of border-crossing and cigarette prices. When we use our formula and empirical results in illustrative calculations, we find that for many states, after taking into account tax avoidance the optimal tax is at least 20 percent smaller than the standard Pigouvian tax that simply internalizes external costs. Our empirical estimate that tax avoidance strongly responds to the price differential is the main reason for this result. Regardless of how large smoking's externalities or internalities are, tax avoidance reduces the effectiveness of state excise taxes as a corrective policy tool. If tax avoidance and evasion directly generate external costs, such as traffic fatalities or illegality costs, the optimal state excise tax on cigarettes is even lower. We also use our results to examine the benefits of replacing avoidable state excise taxes with a harder-to-avoid federal excise tax on cigarettes.

Our paper contributes to policy-relevant lines of research in health economics. Our new empirical results add to estimates from a few recent studies that directly examine cigarette tax avoidance in the US (Chiou and Muehlegger 2008, Merriman 2010, Harding, Leibtag and Lovenheim 2012). Another line of research in health economics attempts to control for legal consumer tax avoidance and illegal smuggling of cigarettes, but these studies lack direct measures of tax avoidance and mostly focus on developing unbiased estimates of the price elasticities of demand.[3] We estimate that the elasticity of border-crossing with respect to the home-state price of cigarettes is 3.1. This implies that border-crossing accounts for almost one quarter of the response of home-state purchases to changes in the home-state price. While this is a strong response, it is smaller than estimates from several previous studies. Gruber, Sen, and Stabile's (2003) estimates suggest that tax avoidance accounts about one-third of the response of tax paid sales in Canada. Stehr (2005) estimates that tax avoidance accounts for up to 85 percent of the response of tax paid sales in the U.S. Lovenheim (2008) estimates that approximately all of the response in home-state sales is due to tax avoidance. Because these studies lack direct measures of border-crossing they use an indirect approach to infer the extent of tax avoidance. Although we believe our direct measure of cross-border purchases by consumers has important advantages, an advantage of the indirect approach is that it might better capture organized cigarette smuggling over longer distances, which might help explain at least part of the difference in estimates.

Our applied welfare analysis provides a systematic framework for thinking about current cigarette tax policy debates. Since 2000, 48 states and the District of Columbia have enacted over 100 cigarette tax hikes (Federation of Tax Administrators 2013). Cigarette tax rates currently range from a low of $0.17 per pack in Missouri to a high of $4.35 per pack in New York. Some localities also tax cigarettes, the most notable being New York City's $1.50 per pack tax since 2002, and Chicago and Cook County's combined $2.68 per pack tax since

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[1]Based on data from the mid-1980s, the seminal study by Manning *et al.* (1989) concludes that on average cigarette taxes were high enough to correct for the external costs. Cnosssen and Smart (2005, pp. 36 – 37), and Sloan *et al.* (2004) review more recent empirical evidence on the external costs of cigarettes.

[2]The extensive body of theoretical and empirical research on tax evasion and compliance focuses almost entirely on income taxes, not corrective excise taxes (Andreoni, Erard, and Feinstein 1998, Sandmo 2005, Slemrod 2007, Chetty 2009a).

[3]Cigarette demand studies that emphasize the role of tax avoidance and smuggling include Coats (1995), Saba *et al.* (1995), Thursby and Thursby (2000), Yurekli and Zhang (2000), Stehr (2005), and Lovenheim (2008).

2006. Policy makers have realized the potential for tax avoidance created by these large differences in tax rates between sometimes very nearby jurisdictions. In an approach targeted to discourage border crossing, in 2012 Arkansas established low-tax zones on its side of its borders with lower-tax states (Tax Foundation 2012). In an approach targeted to encourage border crossing, in 2011 New Hampshire reduced its cigarette tax by $0.10 per pack to encourage residents of other states to purchase cigarettes in New Hampshire (Love 2013). While these changes in tax policies seem to have been mainly driven by revenue concerns, our normative analysis examines the impact of taxes and tax avoidance on social welfare more broadly.

The remainder of the paper is organized as follows: section 2 describes the data; section 3 presents the endogenous switching regression model; section 4 summarizes the applied welfare economics analysis; and section 5 concludes.

2. Data

In our empirical study, we use individual-level data on cross-border cigarette purchases. The data are from the 2003 and 2006 – 2007 cycles of the Tobacco Use Supplements to the U.S. Current Population Survey (TUS-CPS). Each TUS-CPS cycle provides a large nationally representative sample and sub-samples that are representative at the state level (Hartman et al 2002). In addition to standard questions about smoking, in the cycles we use the TUS-CPS asked smokers whether their last purchase of cigarettes was in a state other than their state of residence, or over the internet or by other means. The "last purchase" can be considered to be a random draw from the distribution of each smoker's purchases. The responses should provide an accurate snapshot of consumer behavior, even though for a specific smoker the last purchase might not be typical of his or her purchases. Smokers might not take the question literally and instead based their responses on their typical or modal purchase location. It is difficult to judge the magnitude or direction of the resulting measurement error. Compared to literal responses, responses about typical purchases might even contain less of the random noise created by non-typical purchases. In any case, because most smokers make fairly frequent cigarette purchases, self-reported data on their most recent purchases seem likely to be reasonably accurate.[4]

We use geographic information on the respondents' location to merge data on excise taxes in their home states and bordering states, as well as to measure their distance to the state border. In order to calculate distance to the state border for each respondent, we restrict the sample to residents of 234 Metropolitan Statistical Areas (MSAs) identified in the TUS-CPS. Our sample of analysis consists of 29,377 smokers who lived in an MSA and provided valid responses to the questions about border-crossing and cigarette price paid.[5] We used Google Maps to calculate the driving distance from the geographic center of each respondent's MSA of residence to the closest lower-tax border state. We match cigarette excise tax rates from Orzechoswski and Walker (2008) to respondents, based on their MSA, the closest border state, and their interview month. When MSAs span state lines, we match

[4]Comparisons of reported consumption to sales suggests that smokers substantially under-report their true consumption (Stehr 2005). But validation research that uses biological evidence of nicotine use suggests that people fairly accurately report whether they smoke (Patrick et al., 1994). Given that the TUS-CPS respondents admit that they smoke, it is not clear why they would inaccurately report their cross-border purchases, which are generally legal when for personal consumption.

[5]The TUS-CPS also provides county of residence. There are two advantages to using MSA of residence. First, because MSAs are defined based on commuting patterns and the degree of economic integration in a geographic area, they are a natural geographic unit for a study of consumer purchases and travel. Second, the TUS-CPS provides more complete information about MSAs than about counties. Of the 234 identified MSAs, the county is missing for almost half. In an earlier study of border crossing that uses the 2003 TUS-CPS, Chiou and Muehlegger (2008) limit their sample to the 9,745 smokers with identified county of residence. Our 2003 TUS-CPS sample includes 16,745 smokers with identified MSA of residence, and includes virtually all of the respondents with identified county of residence. 41 of the identified MSAs contain multiple identified counties, but we do not use that information.

tax rates and assign distance to the closest lower-tax border state based on the respondents' state of residence.[6] Respondents in the Chicago and New York City MSAs are also assigned the applicable local cigarette taxes. We do not add state and local general sales taxes. Most states' sales taxes are in the range of 4 to 7 percent of the purchase price (Tax Foundation 2013). Average cigarette prices in our data are around $3.00 – $3.50 (Table 1), so the lack of state sales tax data will usually distort the comparison of home- and border-state taxes on cigarette purchases by less than $0.11 (3 percent of $3.50).[7]

Table 1 provides descriptive statistics from the TUS-CPS for the variables used in the empirical models below. About five percent of TUS-CPS smokers report that their last cigarette purchase was made across a state border, and less than one percent report that their last purchase was over the internet or other means.[8] Therefore, we focus on cross-border purchases in the empirical work below. Table 1 cross-tabulates the means for the other variables by border-crossing status. The average border crosser lives about 70 miles closer to a lower-tax state and pays about $0.60 less for a pack of cigarettes. The difference between the median distance to the border by border-crossing status is also about 70 miles (20 miles versus 93 miles).

In addition to data on border-crossing, in the endogenous switching regression model we use novel data on self-reported cigarette prices. The TUS-CPS asked smokers to report how much they paid for their last pack or carton of cigarettes, after using discounts or coupons. To provide some evidence on the accuracy of the self-reported prices, in DeCicca, Kenkel and Liu (2013b) we compare them to two other sources of price data. The TUS-CPS state-average prices are highly correlated (r = 0.94) with the state-average prices reported by Orzechowski and Walker (2008). The TUS-CPS MSA-average prices are also highly correlated (r = 0.86) with MSA-average prices in Nielsen supermarket scanner data. Within states and MSAs, the coefficients of variation for cigarette prices – a standard measure of price dispersion – are in a fairly narrow range from around 20 to 40 percent. This degree of price dispersion is generally comparable to that seen for other goods (Baye, Morgan and Scholten 2006, Table 1a). Overall, several lines of evidence suggest that the TUS-CPS provides reasonably high-quality data on border-crossing and self-reported cigarette prices.

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[6]For example, the Kansas City MSA spans Kansas and Missouri. We assign Kansas City MSA residents who live in Kansas the Kansas tax of $0.79, and assign them a distance of 10 miles to the closest lower-tax state (Missouri). We assign Kansas City MSA residents who live in Missouri the Missouri tax rate of $0.17, and assign them a distance of 421 miles to the closest lower-tax state (Kentucky). Because we do not have more precise geocode information, this method might introduce measurement error into our measures of tax rates and distances. As a robustness check, we excluded the 23 percent of our sample who live in MSAs that span state lines, and re-estimated reduced-form versions of the border-crossing model reported below. The results (available upon request) from the sub-sample analysis are generally similar to the full sample analysis, but suggest a somewhat weaker response to distance and taxes.

[7]Chetty, Looney and Kroft (2009, p. 1146) provide empirical evidence from a field experiment that because of the lack of salience, "most consumers do not normally take the sales tax into account" when purchasing commodities in a grocery store. It is not clear if this generalizes to consumers' border-crossing choices for general shopping or cigarettes. If sales tax differences across states are more salient, some consumers might make cross-border cigarette purchases during their general shopping trips across borders to lower-sales tax states. A more complete examination of these issues is beyond the scope of our data and study.

[8]The low prevalence of internet purchases might seem surprising, and could reflect TUS-CPS respondents' reluctance to report actions of questionable legality. As Goolsbee, Lovenheim, and Slemrod (2010) point out, there is very little systematic evidence about the volume of internet cigarette sales. In a study of cigarette packs discarded as litter, Merriman (2010) finds that only seven percent of littered packs had no tax stamp at all which might indicate an internet purchase, compared to 26 percent with an out-of-state tax stamp. This corroborates the TUS-CPS evidence that cross-border purchases are much more common than internet purchases. In a few states, another way to avoid state taxes is to purchase cigarettes on an Indian reservation (DeCicca, Kenkel and Liu 2013a). Given the wording of the TUC-CPS survey question, unless these purchases also involved crossing a state border, respondents might not have reported them. Or, the purchases might be part of the less than one percent of purchases reported as being "by other means." During our study period, in many states with Indian reservations existing legal agreements minimized the tax incentives to purchase cigarettes on reservations.

3. Endogenous Switching Regression Model

An Empirical Model of Border-Crossing and Cigarette Prices

In this section we estimate a structural endogenous switching regression model of border-crossing and cigarette prices in two regimes: the home price (P^H)and the border price (P^B). Depending on whether individual i crosses the border (B_i = 0 or 1), the price paid by individual i switches between the two regimes:

$$P_i{}^H=\beta_1+\beta_2\,T_i{}^H+\beta_3\,X_i+\varepsilon_i{}^H \quad \text{if } B_i=0 \quad (1a)$$

$$P_i{}^B=\gamma_1+\gamma_2\,T_i{}^B+\gamma_3\,X_i+\varepsilon_i{}^B \quad \text{if } B_i=1 \quad (1b)$$

The tax rates are the main drivers of the home-price and the border-price; the coefficients β_2 and γ_2 show the rates at which taxes are passed through to prices. The price an individual pays for cigarettes also varies for other reasons, for example between discount versus premium brands. To capture these influences, equations (1a) and (1b) also include a vector of socioeconomic variables X. We have no strong a priori predictions about the associated parameter vectors β_3 and γ_3.

The individual is assumed to make cross-border purchases of cigarettes if doing so increases his or her utility. Assume the individual receives utility from a composite consumption good g, disutility from miles of distance traveled m, and utility from cigarette consumption c. The latent utility difference behind the observed border-crossing decision is given by:

$$\Delta\,u=u\,(g^*,m^*,c^*)-u\,(g^{**},m^{**},c^{**}) \quad (2)$$

where g*, m*, and c* are the optimal choices given border crossing and g**, m**, and c** are the optimal choices given no border crossing.

To develop an empirical version of equation (2), consider a first-order Taylor series approximation of the utility function:

$$u\,(g^*+\Delta g,m^*+\Delta m,c^*+\Delta c)=u\,(g^*,m^*,c^*)+u_g\,\Delta g+u_m\,\Delta m+r \quad (3)$$

where u_g and u_m are partial derivatives of the utility function and r is the remainder term for the Taylor series approximation (including the terms related to Δc). Because g is the composite consumption good, the difference between the optimal choice of g with and without border-crossing is simply the potential savings from purchasing less expensive cigarettes across the border: $\Delta g = g^* - g^{**} = c\,(P^B - P^H)$. The difference between the optimal choice of m with and without border crossing is the distance to the border: Δm = m* - m** = miles to the border.

Making these substitutions and plugging equation (3) into (2) thus yields:

$$\Delta u=u_g\,c\,(P^B-P^H)+u_m\,(\text{miles to the border})+r \quad (4)$$

Equation (4) motivates the structural equation for the latent utility difference behind observed border-crossing:

$$\Delta u=\delta_0+\delta_1\,(P_i{}^B-P_i{}^H)+\delta_2\,(\text{miles to the border})_i+\delta_3\,W_i+\zeta_i \quad (5)$$

Equation (5) underlies the empirical model that shows the probability of border-crossing as a function of the price differential P^B - P^H and other explanatory variables. The Taylor series remainder term r in equation (4) is captured in equation (5) by the constant term, the vector of exogenous variables W, and the error term ζ.[9] The empirical model reported below includes quadratic terms and interaction terms corresponding to a second-order Taylor series approximation; the higher order terms are suppressed in equation (5) for expositional ease. The use of a Taylor series approximation is justified on the grounds that border crossing to purchase lower-price cigarettes results in small changes relative to the typical consumer's total purchases of all goods and total travel for all purposes.

Comparing equation (5) to (4) reveals that the ratio of the estimated coefficients δ_2 / δ_1 is proportional to the ratio of the marginal utility of distance over the marginal utility of the composite consumption good. As a result, the ratio δ_2 / δ_1 provides an estimate of the shadow price of distance, i.e. the dollar value of a marginal change in distance.[10] In essence, the price savings required to induce consumers at different distances to cross the border reveals consumer preferences for the non-market good "distance traveled."[11]

To estimate the endogenous switching model, we use the standard assumption that the error terms ε_i^H, ε_i^B, and ζ_i have a trivariate normal distribution with non-zero covariances. First, we jointly estimate the price equations (1a) and (1b) and a reduced-form version of the border-crossing equation that does not include the endogenous price variables on the right hand side. Next, we use the estimated price equations to predict P^H and P^B for each smoker in the sample. Finally, we estimate the structural border-crossing equation as a function of the predicted price differential P^B - P^H and the other explanatory variables.[12]

The endogenous switching model has several advantages. First, it solves the problem Chiou and Muehlegger (2008) face in their study of border crossing: cigarette prices are only observed for the location of purchase chosen by the consumer.[13] The switching model provides predicted values of both P^H and P^B for all consumers, corrected for the endogenous selection of purchase location. Second, the parameters of the structural border-crossing equation can be more tightly linked to a model of consumer behavior. We have also estimated a reduced-form equation that shows the probability of border-crossing as a function of home-state and border-state tax rates and other explanatory variables.[14] However, here we rely on the results of the switching model because the interpretation is cleaner. Substituting equations (1a) and (1b) into equation (5) shows that the reduced-form coefficients on the tax variables combine two structural parameters: δ_1, which captures the

[9]The remainder term r includes the terms related to Δc in the Taylor series approximation of the utility function. The socioeconomic variables included in the vector W will help capture heterogeneity across consumers in cigarette consumption. An extension to our empirical model could endogenize cigarette consumption as well as border-crossing and price paid. This extension might be important for the estimates of δ_1 and δ_2 if tax differences between states are large enough so that cigarette consumption varies with location of purchase.

[10]The parameters in discrete choice models based on random utility maximization have analogous interpretations (Train 2003, Small, Winston and Yan 2005).

[11]In environmental economics the travel cost method is used to estimate consumers' willingness to pay for public goods such as recreation sites (Freeman 1979). Studies that use this method typically begin with an assumption about the cost of travel to the recreation site. The studies then use consumers' revealed preferences to incur the assumed travel costs to estimate the value of the recreation site. In contrast, instead of making an assumption about travel costs, we examine revealed preferences to infer consumers' values for distance traveled.

[12]Our estimation method follows Maddala (1983, pp. 236 – 239). Lee (1978) and Willis and Rosen (1979) are seminal examples that use this method to estimate structural endogenous switching models.

[13]Chiou and Muehlegger explain in their footnote 13 that to solve this problem they merge the TUS data on border crossing with data on state-average cigarette prices from Orzechowski and Walker. Thus, in their model of border-crossing Chiou and Muehlegger do not exploit the TUS-CPS individual-level data on cigarette prices. But as they note in another part of their study, compared to state-average prices, the TUS-CPS prices "better capture within-state variation in prices paid by consumers." (Chiou and Muehlegger 2008, p. 3)

[14]The reduced-form results are reported in the earlier NBER working paper version of this paper (DeCicca, Kenkel and Liu 2010).

relationship of interest reflecting consumers' incentives to cross borders to obtain lower cigarette prices; and β_2 or γ_2, which capture the pass-through of home- or border-state taxes to consumer prices. DeCicca, Kenkel and Liu (2013b) find systematic differences in the pass-through rates β_2 and γ_2 of home- versus border-state taxes, which makes it problematic to draw inferences about δ_1 from the reduced-form estimates.

The structural endogenous switching model is identified by differences in the vectors of explanatory variables in equations (5), (1a) and (1b). Specifically, the exclusion restrictions are that: distance and distance-squared only enter the border-crossing equation (5); and the home-and border-state tax variables only enter the home- and border-state price equations (1a) and (1b), respectively.[15]

The exclusion restrictions are supported by the argument that there is enough competition in retail cigarette markets so that within each state the price is driven down to approximately the retailers' marginal cost plus the state tax rate. This implies that the consumer's distance to the border does not directly enter the price equations (1a) and (1b). It also implies that retailers in the home state can not change their prices in response to border-state taxes, and *vice versa*. Anecdotal evidence suggests that retail cigarette markets are instead equilibrated by changes in the volume of cigarette sales and the entry and exit of cigarette retailers. For example, Fleenor (1998, p. 5) relates that after the 1995 Michigan cigarette tax increase: "One Michigan convenience store located approximately four miles from the Indiana border lost 98 percent of its cigarette carton sales...." Efrati (2007) relates more recent anecdotes along these lines, including a fivefold increase in cigarette sales in Sunland Park, New Mexico after a cigarette tax hike across the border in El Paso, Texas. These large swings in the volume of sales are consistent with price-taking behavior within a state where retailers near borders can not change their prices in response to border-state taxes. To further explore the issue empirically in the TUS-CPS data, we examine the geographic patterns of cigarette prices paid by consumers who purchased their cigarettes in their home state. Prices do not vary systematically with distance to the border of states with either lower or higher cigarette taxes.[16]

Regarding the strength of our identification strategy, in ordinary least squares models of reduced-form versions of equations (5), (1a), and (1b), the F-statistics on the identifying variables are 25.8, 388.5, and 9.2 respectively. We are unaware of specific tests of weak identification in the endogenous switching model. The values for the F-statistics in two of the reduced-forms exceed the common rule of thumb for linear instrumental variables models that the F-statistic on the excluded IVs should be greater than 10 (Staiger and Stock 1997, Stock, Wright, and Yogo 2002). The F-statistic for the border-state tax variable suggests that this might be marginally weak, perhaps due to the much smaller sample size of border crossers whom we can observe paying the border price.

[15]These exclusion restrictions meet the identification conditions described by Maddala (1983, p. 239).

[16]Using price data collected from retail outlets before-and-after Wisconsin's 2008 tax hike, Hanson and Sullivan (2009) find statistically imprecise evidence of a weak gradient with distance to the border. For example, after the $1 tax hike, prices at stores within 25 miles of the border of the lower-tax state of Illinois rose by about $0.04 less than prices at stores in other parts of the state (p. 688). Manuszak and Moul (2009, p. 753) cite their own empirical results and several other studies' results as supporting the assumption that retail gasoline prices do not vary with distance to the border of a lower-tax state. Doyle and Samphantharak (2008) find mixed evidence about whether the effects of gasoline taxes on prices depend on the distance from the border. Although they conclude that their results are "generally consistent with the effect of the tax extending across state borders" (p. 880), there are important differences between the retail market for gasoline they study, and the retail market for cigarettes. In particular, because convenience stores and other cigarette retailers sell a variety of products, entry and exit into selling cigarettes as a product line is relatively easy and large swings in sales volume are feasible. In contrast, the fixed costs of gasoline storage tanks and pumps create more frictions in the retail market for gasoline.

Results

Table 2 reports estimates of the structural endogenous switching model. The probability of border crossing is estimated to decrease with distance from the border and to increase with the differential between home- and border-state cigarette prices. The marginal effect of distance is around −0.05.

We use the estimated marginal effect of the price differential to calculate that the cross-price elasticity $\eta^B = 3.1$ (with a boot-strapped standard error of 0.497, so it is statistically significantly different from zero at above the 99 percent confidence level). This is a “cross” price elasticity in two senses. First, η^B shows the elasticity of the probability of border crossing with respect to the home-state price of cigarettes.[17] Recall that the baseline level of cross-border purchases is five percent. Our elasticity estimate implies that a 10 percent increase in the home-state price, holding the border-state price constant, increases the probability of border crossing by 1.55 percentage points (31 percent of 5 percent).

Second, η^B is also a cross-price elasticity in the sense that it shows the elasticity of border-state purchases with respect to the home-state price. As such, it plays a key role in our optimal tax formula below. To see this interpretation, note that border-state purchases are the product of the probability of border-crossing times the quantity purchased conditional on having crossed the border. We assume that conditional upon having crossed the border, the quantity purchased across the border does not depend on the home-state price. As a result, the elasticity of border-state purchases equals the elasticity of the probability of border-crossing. In an exercise described more completely in the Appendix, we combine our estimate that $\eta^B = 3.1$ with a benchmark estimate that the price-elasticity of home-state purchases is −0.8 (Coats 1995). Our exercise shows that if a 10 percent price increase causes home-state purchases to fall by 8 percent, after taking into account the increase in border-state purchases, home-state cigarette consumption only falls by 6.1 percent. Put differently, border-crossing accounts for almost one quarter of the response of home-state purchases to changes in the home-state price. As we note in the introduction, this is smaller than several previous estimates (Gruber, Sen, and Stabile 2003, Stehr 2005, and Lovenheim 2008).

Turning to other results in Table 2, the ratio of the marginal effect of distance to the marginal effect of the price differential provides an estimate of the shadow price of distance traveled. The shadow price calculation also requires an estimate of the quantity of cigarettes purchased (c in equation 4). If we assume the average border crosser purchases one carton of 10 packs of cigarettes per trip, and that distance traveled on a round trip is twice the distance to the border, the implied shadow price of distance is \$0.06 per mile.[18] We use this estimate below to quantify the benefits of replacing avoidable state taxes with a harder-to-avoid federal tax. Our estimate of the shadow price of distance traveled is lower than standard

[17]We define $\eta^B = [\partial \Pr\{B = 1\} / \partial P^H] [P^H / \Pr\{B=1\}]$ and calculate it at the sample average P^H and Pr{B=1}. Because we model the border-crossing decision as a function of the price differential ($P^H - P^B$), it might seem more natural to use the results to calculate the price elasticity of the probability of border crossing with respect to the price differential, instead of with respect to the home-state price (P^H). We define η^B with respect to P^H to facilitate comparisons with previous research and to use in the formula for the optimal Pigouvian tax rate we develop in section 5. The comparison of η^B with respect to P^H and the elasticity of border-crossing with respect to the price differential is straight-forward. The partial derivative terms are the same, because holding P^B constant, $[\partial \Pr\{B = 1\} / \partial P^H] = [\partial \Pr\{B = 1\} / \partial (P^H - P^B)]$. The next term is adjusted to express the marginal change as a percentage of the price differential rather than the home-price level. So the elasticity of border-crossing with respect to the price differential = $\eta^B (P^H - P^B) / (P^H) = (3.1)(0.63/3.54) = 0.55$.

[18]Several pieces of evidence suggest that it is reasonable to assume that the average border-crosser purchases one carton per trip. The TUS-CPS data do not provide a measure of the quantity of cigarettes purchased per trip. However, we do know from the TUS-CPS data that about two-thirds of TUS-CPS respondents who report making a cross-state purchase also report that they usually purchase cigarettes by the carton, rather than by the pack. Lovenheim (2013, personal communication) reports that in the Nielsen Homescan data: the modal quantity of cigarettes purchased across a state border is one carton of 10 packs of cigarettes; and the mean and median are around 8 packs of cigarettes. mile to the total benefits, where the value of the total benefits equals the sum of the values placed on the various services that jointly flow from the travel.19 Our approach isolates one component of the total value.

estimates of travel costs, but this is reasonable if consumers travel to jointly produce cross-border cigarette purchases and other activities. Suppose consumers make travel decisions by comparing the total travel cost per mile to the total benefits, where the value of the total benefits equals the sum of the values placed on the various services that jointly flow from the travel.[19] Our approach isolates one component of the total value.

Although we will not provide a complete discussion of all the results in Table 2, we note that the results also show that some socioeconomic factors such as income have similar effects on the probability of border crossing and on the price paid for cigarettes in either regime.

4. Implications of Excise Tax Avoidance for State Tax Policy

Tax Avoidance and Optimal Taxation

In this section, we discuss the implications of tax avoidance for an applied welfare economic analysis of state cigarette taxes. In state policy debates, the most common concern is that tax avoidance reduces tax revenues. Of course, taking a somewhat broader perspective, some of the higher-tax states' revenue losses are revenue gains for neighboring lower-tax states. Applied welfare economics takes a still broader perspective and focuses on the impact of taxes on the welfare of all members of society, not state budgets. Typically from this perspective when tax revenues fall it is simply a transfer: the losses to state budgets are gains for the taxpayers.[20] From the broad social welfare perspective, cigarette excise taxes are justified as a Pigouvian solution to the negative externalites from secondhand smoke, third-party medical costs for smoking-related illnesses, and so on (Sloan *et al.* 2004). Consequently, we next consider the implications of tax avoidance for the optimal corrective Pigouvian tax rate.

In the Appendix we sketch a simple general equilibrium model that provides an expression for social welfare as a function of the home state cigarette tax. We assume that the smoker can consume home-state cigarettes (c^H) or border-state cigarettes (c^B). We consider the case of a home state that borders a state where the cigarette tax is too low to correct for the external costs of smoking: $T^B < E^C$. Following Harberger's (1964) seminal approach to the welfare cost of taxation, the thought experiment is to raise the home-state tax T^H while returning home-state tax revenues to the taxpayer and adjusting for border-state tax revenues via lump sum transfers. Appendix equation (A4) provides the expression for social welfare (W) as a function of the home-state tax T^H. Applying the envelope theorem when we differentiate our expression for social welfare yields the marginal social welfare gain from a marginal change in home-state tax:

$$\mathrm{dW}/\mathrm{dT}^{H}=T^{H}\underset{(-)}{[\mathrm{dc}^{H}/\mathrm{dT}^{H}]}-E^{C}\underset{(+)}{[\mathrm{dc}^{H}/\mathrm{dT}^{H}]}+(T^{B}-E^{C})\underset{(-)}{[\mathrm{dc}^{B}/\mathrm{dT}^{H}]} \quad (6)$$

[19]The assumption that consumers compare total travel costs to benefits is based on the neoclassical model of the consumer. An alternative assumption, more consistent with insights from behavioral economics, is that consumers make travel decisions based on relative distances, for example by comparing the distance to purchase cigarettes to the distance they drive on average for shopping. Our sample is restricted to residents of MSAs, so their average driving distances probably do not vary too much. To further explore this idea, we estimated reduced-form models of border crossing separately for residents of the central city with residents of the balance of the MSAs. The estimated marginal effects of distance on border-crossing are similar across the sub-samples (results available upon request). This provides suggestive evidence that in our sample, the assumption that travel decisions are based on total distances is reasonable. We thank an anonymous referee for suggesting this exercise.

[20]State budgets are not precisely "members of society." The implicit assumption is that when tax revenues fall, either other taxes are raised or government programs are cut. To re-state the transfer more precisely: the losses to other taxpayers, or the losses to the beneficiaries of state government spending, are gains for cigarette taxpayers.

Equation (6) is an example of what Chetty (2009b) calls the “sufficient statistic” approach to applied welfare economics: it shows the welfare consequences of the excise tax as a function of high-level elasticities rather than deep structural parameters. The first two terms of equation (6) reflect the standard tradeoff in Pigouvian taxation. Integrated over a change in tax, the first term is the Harberger triangle of excess tax burden for cigarette consumers. The second term is the social gain from reducing the negative externalities. The third term in equation (6) is the social welfare loss that stems from interactions between the home-state and border-state cigarette markets. Because the border-state cigarette tax is below the external cost of smoking, there is a welfare loss when an increase in the home-state tax increases border-state cigarette purchases.

Chetty (2009b) and Goulder and Williams (2003) stress a point also made in Harberger’s (1964) original work: in an n-th best world with many distorted markets, the excess burden of a new tax reflects general equilibrium interactions with the other distorted markets. Goulder and Williams show that the interactions will be important for excess burden calculations for goods that are strong complements to or substitutes for the newly taxed good. Our case is an extreme version: except for the need to travel across the border, cigarettes purchased in the home-state and border-state are perfect substitutes. The border-state cigarette market is distorted not by the presence of a tax, but by the fact that the tax is not high enough to correct for the externality. (Below, we discuss further extending our analysis to include the additional distortion created if tax avoidance directly generates an externality, such as traffic fatalities or illegality costs).

It is interesting that equation (6) does not include an explicit term for the travel costs of tax avoidance. These costs are internal to consumers and fully accounted for in their optimizing decisions. Feldstein (1999) and Chetty (2009a, 2009b) discuss an analogous result for measuring the social welfare cost of income tax avoidance.

We show in the Appendix that setting $dW/dT^H = 0$ and solving for the social welfare maximizing Pigouvian tax yields:

$$T^H * = E^C - (E^C - T^B) \cdot (\eta^B/\eta^H) \cdot (C^B/C^H) \quad (7)$$

If there are no opportunities for tax avoidance and $\eta^B = 0$, the second term of equation (7) drops out and the expression simplifies to the simple Pigouvian tax: $T^H* = E$. This applies to the important example of a federal excise tax, unless there is cross-country tax avoidance. If the border-state tax is high enough to internalize the external costs of smoking ($T^B = E^C$), the second term again disappears and the expression again simplifies to the simple Pigouvian tax.

Equation (7) shows that the home state’s optimal tax rate depends on border crossing only in the second-best world where its neighbor set its cigarette tax too low. In this second-best world, as long as there is some tax avoidance, the optimal tax rate that takes into account tax avoidance is always smaller than the standard Pigouvian tax rate that simply internalizes the externality. In the second-best world, the optimal tax is lower: when the border-state tax (T^B) is lower; when the price-elasticity of border-crossing (η^B) is higher; and when the ratio of cross-border sales to home-state sales (C^B/C^H) is higher.

Illustrative Calculations of the Optimal Tax with Tax Avoidance

To develop illustrative calculations of the optimal cigarette tax T^H* given by equation (7), we combine standard estimates of E^C and η^H with our estimates of η^B and C^B / C^H.

Based on standard estimates, during our study period most states had neighbors that set their cigarette taxes below the external costs of smoking. Sloan *et al.* (2004, p. 255) estimate that smoking generates $2.20 of external costs per pack. However, some of these external costs have been addressed by the current (during our study period of 2003 – 2007) federal excise tax of $0.39 per pack, and the national legal settlement with the tobacco industry, which is equivalent to a tax of about $0.45 per pack (Bulow and Klemperer 1998). So we estimate that for all U.S. states, E^C is $1.36 per pack, which is an estimate of the remaining external costs of smoking that are relevant for the optimal tax at the state level ($2.20 - $0.39 - $0.45 = $1.36). We then compare this estimate to the current (2003 or 2006 – 2007) tax rates for each state's border-state tax T^B. In 2003, 42 states and D.C. faced a border-state tax below the estimated external cost per pack of $1.36. By 2006 – 2007, only 36 states and D.C. were in this situation.

To complete our illustrative calculations of the optimal tax rates, we use a benchmark estimate that η^H, the elasticity of home purchases with respect to the home price, is 0.8 in all states. We evaluate our estimates of the marginal effect of the price differential on the probability of border-crossing at each state's averages, to develop state-specific estimates of η^B, the cross-price elasticity of border purchases with respect to the home-state price. We also use state-specific estimates from our data for the ratio of cigarettes purchased from a border state over cigarettes purchased at home, C^B / C^H.

Using these parameter estimates in equation (7) provides illustrative calculations of the optimal tax in each state that faced a border-state tax below the external costs of smoking. Table 3 presents the results. In 2003, in 20 states the optimal tax that accounts for tax avoidance is at least 20 percent smaller than the simple Pigouvian rate of $1.36. The lowest optimal taxes are $0.66 in D.C. and $0.87 in Maryland, which make sense because of their proximity to the low-state tax of Virginia. The results for 2006–2007 are broadly similar. Because Virginia increased its tax to $0.30 in 2005, the optimal taxes in D.C. and Maryland in 2006 – 2007 rise slightly to $0.81 and $0.95, respectively. To take an example of a state that does not border Virginia or any other very low-tax state, we calculate that the optimal tax in Massachusetts is $1.09 in 2003 and $1.14 in 2006 – 2007.

Our illustrative calculations show the "optimal" tax in a second-best world: given that they border states with low cigarette taxes, it is optimal for many states to set their taxes below the simple Pigouvian rate. One possible policy prescription based on these calculations is that some currently high-tax states might need to re-consider their cigarette excise tax rates. An alternative policy prescription is to focus on the possible gains from moving closer to a first-best world. For example, when low-tax states like Virginia increase taxes (as, for the first time since 1966, it did in 2004 and 2005), the optimal corrective tax in the bordering states also increases.

Another possible policy prescription is to replace avoidable state excise taxes with a harder-to-avoid federal excise tax on cigarettes. We consider this exercise in the Appendix, for a home state with a currently high tax and a low-tax border state. Under a simple assumption, replacing the home-state tax with the same-sized federal tax leaves home-state cigarette consumption unchanged. The external costs of home-state smoking are also unchanged, while the new federal tax revenues exceed the sum of home-state and border-state tax revenues previously collected from home-state residents. More importantly, social welfare in the home-state increases because smokers no longer incur travel costs to avoid the home-state tax. With the incentives created by differences in state excise taxes, consumer tax avoidance uses resources –the travel costs – that are deadweight losses, compared to an equal-sized federal tax. Using our estimated shadow price per mile, we calculate that replacing state taxes with a federal tax saves the median border crosser in our sample about \$0.32 per pack in travel costs that were deadweight losses to home-state social welfare.

Sensitivity Analyses

We next explore the sensitivity of our illustrative calculations of the optimal tax to different assumed parameters. First, we consider the implications of a much higher estimate of E^C. Using a higher estimate of E^C is a simple way to incorporate the argument from behavioral public economics that higher cigarette taxes might be justified based on internalities that consumers impose on their future selves (O'Donoghue and Rabin 2003, 2006, Gruber and Koszegi 2001, Gruber and Koszegi 2004). Gruber and Koszegi (2004, p. 1980) and Sloan *et al.* (2004, p. 252) estimate that the private costs smokers impose on themselves are around \$35 per pack. However, Gruber and Koszegi (2001) show that unlike Pigouvian externalities, because the sophisticated time-inconsistent consumer helps the government by limiting her consumption, the optimal internality tax is smaller than the internality costs. Using various parameter estimates they estimate the optimal internality tax is in the range of \$1 to \$3 per pack. If we increase our estimate of E^C by \$3, from \$1.36 per pack to \$4.36 per pack, from equation (7) the optimal tax in D.C. increases to \$2.22. Not surprisingly, the policy prescription – whether the current cigarette tax is too low or too high – can be sensitive to using a much higher estimate of E^C to capture the idea of internalities. But the qualitative result, that taking into account tax avoidance sharply reduces the optimal tax on cigarettes, still holds.

In another extension, we consider the possibility that tax avoidance itself directly generates external costs, E^A. These costs might take several forms. First, automobile travel to purchase cigarettes out-of-state creates externalities related to pollution, congestion, and traffic safety. As relevant examples, empirical evidence suggests that traffic fatalities increase due to consumer avoidance of local bans of smoking in bars (Adams and Cotti 2008) and teen avoidance of state minimum drinking age laws (Lovenheim and Slemrod 2010). However, gasoline taxes already correct for at least some of the external costs of travel (Parry and Small 2005). Second, and probably more significantly, illegal smuggling of cigarettes might generate significant externalties. Cigarette smuggling has been linked to organized crime and even terrorism.[21] Shelley *et al.* (2007) report ethnographic research about attitudes towards "the \$5 Man," that is, the typical cigarette bootlegger in Central Harlem in New York City. They report that "Bootleggers were uniformly viewed as a justifiable and appreciated response to the high price of cigarettes," caused by the combined New York City and State excise taxes (p. 1486).

In the Appendix, we show that considering the external costs of tax avoidance adds a term involving E^A to the optimal tax formula (equation A8). Even though our empirical study captures tax avoidance and not smuggling, it is interesting to speculate on the implications of the costs of illegal smuggling. However, estimating the external costs of smuggling would require quantifying the social costs of funding organized crime and terrorism and of contributing to community norms favoring illegal behavior. Instead, we ask a related question: How high would E^A have to be to drive the optimal tax to zero? Using our other baseline parameters in equation (7), if the external cost of tax avoidance exceeds \$1.40 per pack of cigarettes, the optimal tax in D.C. drops from a baseline of \$0.69 to zero. In Massachusetts, the optimal tax drops from a baseline of \$1.08 to zero if the external cost of tax avoidance exceeds \$2.50 per pack. These results hinge in part on our baseline estimate

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[21]As discussed by the Advisory Commission on Intergovernmental Relations (1977) and Fleenor (2008), the links between cigarette smuggling and organized crime have been longstanding. The president of Americans for Tax Reform, Grover Norquist, recently repeated this concern: "By raising cigarette taxes you help fund the mob." (Sarlin 2008). In 2002 a cigarette smuggler was convicted of funneling profits from a multi-million smuggling operation to Hezbollah (Horwitz, 2004).

that the external costs of smoking amount to $1.36 per pack. But at least from a neoclassical welfare economic perspective that focuses on externalities, it seems plausible that tax avoidance costs related to illegal smuggling might be high enough to drive the optimal tax close to zero in some jurisdictions.

5. Discussion

Our empirical models of cigarette tax avoidance show that consumers respond to the incentives created by excise tax differentials across states. We show that taking into account tax avoidance reduces the optimal Pigouvian tax rate on goods that generate negative externalities or internalities. Combining an existing estimate that the external cost of smoking is $1.36 per pack with our empirical parameter estimates, our illustrative calculations suggest that some states may already impose cigarette excise taxes that are higher than optimal, and there is a strong policy trend towards even more states hiking cigarette taxes. In another exercise, we suggest there are substantial benefits if the US moved towards replacing avoidable state cigarette taxes with a higher harder-to-avoid federal cigarette tax.

One direction for future research is to explore whether insights from behavioral economics might shed more light on cigarette tax avoidance. For example, Khwaja, Silverman, and Sloan (2007) suggest that smokers might purchase their cigarettes by the pack instead of the carton as a commitment device to limit their smoking. An interesting question for future research is whether, as a commitment device to limit their smoking, some smokers also avoid opportunities to avoid cigarette taxes.

Several policy trends suggest additional directions for future research. First, some policy advocates argue that using higher taxes to discourage unhealthy consumption might be a lesson for obesity control to be learned from tobacco control (Chaloupka 2011). A number of states are considering new taxes on soft drinks and other sugar-sweetened beverages. Given our results and other recent research on cigarette tax avoidance, another lesson to be learned is that higher state-level excise taxes on soft drink taxes might result in substantial tax avoidance. If states begin to impose new taxes to combat obesity, it will create a rich new set of policy experiments for research on excise tax avoidance in different contexts with different goods and different consumers. A second policy trend is that the US Food and Drug Administration’s regulatory authority over the tobacco industry means that non-tax tobacco control initiatives are likely. For example, the FDA is considering a complete ban or new restrictions on the sales and promotion of menthol cigarettes. Future research on regulation avoidance could address one of the FDA’s concerns: “If menthol cigarettes could no longer be legally sold, is there evidence that illicit trade in menthol cigarettes would become a significant problem?” (FDA 2013).

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Appendix. Elasticities of border-crossing and cigarette demand

As noted in the text, because η^B can be interpreted as the elasticity of border-state purchases, we can compare it to results from cigarette demand studies. Using capital letters for aggregate consumption, home-state residents' total cigarette consumption is the sum of their consumption of cigarettes purchased at home and their consumption of cigarettes purchased in the border state: $C^{TOTAL} = C^H + C^B$. The elasticity of total consumption with respect to P^H is the weighted difference of the elasticities of home-state and border-state purchases:

$$\eta^{\text{TOTAL}}=[C^H/(C^H+C^B)]\,\eta^H-[C^B/(C^H+C^B)]\,\eta^B \quad \text{(A1)}$$

where η^H is the absolute value of the elasticity of home-state purchases with respect to P^H. The weights are the fractions of total purchases accounted for by home-state and border-state purchases, which in our data are 0.95 and 0.05 respectively.

Equation (A1) allows us to compare our results about the price elasticity of border crossing to estimates from cigarette demand studies. Our estimate contributes to a growing body of evidence that while a state cigarette tax hike reduces home-state purchases and thus sales, it is not as effective in reducing the total consumption of home-state smokers. As a benchmark, we assume that the absolute value of the elasticity of home-state purchases η^H is around 0.8 (Coats 1995). Combining this with our estimate of η^B implies that the absolute value of the elasticity of total consumption is 0.605.[22] Put differently, border-crossing accounts for about 25 percent of the response of home-state purchases to changes in the home-state price.

Optimal tax

Our extension of the formula for the Pigovian tax on cigarettes follows the approach of Chetty (2009b), who provides a useful exposition of Harberger's (1964) measure of the welfare cost of an excise tax. It is also related to the approach used in several studies of the optimal tax on alcohol (Pogue and Sgontz 1989, Kenkel 1996). In this Appendix we provide more detail about the background and steps in this approach.

For our applied welfare economic analysis, we adopt the perspective of a home-state policy maker setting a cigarette excise tax, T^H. We assume the home-state tax T^H is fully passed through to prices, so the price consumers pay in the home state increases from P to $P^H = P + T^H$. The price consumers pay in the border state is given by $P^B = P + T^B$, where the border-state tax T^B is exogenous to the home-state policy maker.

[22]We use Coats' estimate because it specifically applies to the elasticity of home-state purchases or sales. Chaloupka and Warner's (2000) review identifies price-elasticity estimates ranging from −0.14 to −1.23; Gallet and List's (2003) meta-analysis finds an even wider range from −3.12 to +1.41. Chaloupka and Warner (2000, p. 1547) describe a "consensus range" from −0.3 to −0.5. Because the consensus range is based on a variety of empirical approaches, it is ambiguous whether it refers to the price elasticity of home-state purchases or the price-elasticity of total consumption, although it is often interpreted as referring to the latter. It is interesting to note that combining our estimate of η^B with a benchmark estimate that $\eta^H = 0.8$ implies a value of η^{TOTAL} about in the consensus range.

As a preliminary, it is useful to consider the consumer's optimal choices of cigarettes purchased in the home state, c^H, and cigarettes purchased in the border state, c^B. In the text we assume that the consumer receives utility from a composite good g, disutility from miles of distance traveled m, and utility from cigarette consumption c: u = u(g,m,c). Following Chetty (2009b), we now assume utility is quasi-linear in the composite good g, and the price of g is normalized to 1. We also assume that cigarettes purchased in the home state and cigarettes purchased in the border state are perfect substitutes in consumption. However, purchases of c^B require travel, so the miles of distance traveled, m, is a function of c^B, where m' > 0. This captures the idea that the consumer needs to made additional trips for each pack of cigarettes, but abstracts from complications like stockpiling. The consumer has an income of Z, and is assumed to solve the following maximization problem:

$$\max\ g+u\left(m, c^H+c^B\right)$$

subject to

$$\begin{gathered}\left(P+T^H\right)c^H+\left(P+T^B\right)c^B+g=Z\\ m=m(c^B)\end{gathered}$$

Substituting in the constraints the problem becomes to choose c^H and c^B to solve the maximization problem:

$$\max\left[u\left(m(c^B), c^H+c^B\right)+Z-\left(P+T^H\right)c^H-\left(P+T^B\right)c^B\right] \quad \text{(A2)}$$

The first order conditions for the utility maximizing choices of $c^{H}*$ and $c^{B}*$ are:

$$\begin{aligned} &\partial[\ ]/\partial c^H=u_c\left(m(c^B*),\ c^H*+c^B*\right)-\left(P+T^H\right)=0\\ &\Longleftrightarrow\quad u_c\left(m(c^B*),\ c^H*+c^B*\right)=\left(P+T^H\right)\\ \text{and}\quad &\partial[\ ]/\partial c^B=u_m\left(m(c^B*),\ c^H*+c^B*\right)m'+u_c\left(m(c^B*),\ c^H*+c^B*\right)-\left(P+T^B\right)=0\\ &\Longleftrightarrow\quad u_c\left(m(c^B*),\ c^H*+c^B*\right)-u_m\left(m(c^B*),\ c^H*+c^B*\right)m'+\left(P+T^B\right) \end{aligned} \quad \text{(A3)}$$

The FOCs have the standard interpretations. The consumer sets the marginal utility per dollar spent on cigarettes equal to the "full price" of cigarettes. Recall that $u_m < 0$ and m' > 0, so the first term on the LHS of the second FOC is positive ($-u_m$ m' > 0): the travel costs required to purchase cigarettes in the border state increase the "full price" of c^B.

In addition to standard assumptions about second derivatives, to guarantee an interior solution, we also assume that the home-state tax is higher than the border-state tax: $T^H > T^B$. Because of the travel costs, when the border-state tax is equal to or more than the home-state tax, the consumer (with positive miles of distance to the border) would choose a corner solution and only purchase home-state cigarettes.

Still following Chetty (2009b), we specify a complete general equilibrium model, with price-taking firms who face a cost function k ( ). Following Chetty, who is following Harberger (1964), the thought experiment is to measure the net loss in welfare from raising the tax and returning the tax revenue to the taxpayer through lump-sum rebates. As Chetty explains: "With quasi-linear utility, the consumer will always choose to allocate the lump-sum rebate to consumption of the numeraire good..... Social welfare can therefore be written by the sum of the [representative] consumer's utility, producer profits, and tax revenue.....

[and then re-written to] effectively recast the decentralized equilibrium as a planner's allocation problem." (This rewriting replaces the prices in the consumer's budget constraint with the costs from the firm's problem.) We also extend Chetty's equation to include external costs E^C per pack of cigarettes, to obtain our expression for social welfare as a function of the home-state tax on cigarettes:

$$W(T^H)=\{\max\ u\,(m(c^B*),c^B*+c^H*)+Z-T^H\,c^H*-T^Bc^B*-k\,(c^H*+c^B*)\}+T^H\,c^H*+T^B\,c^B*-E^C\,[c^H*+c^B*] \quad \text{(A4)}$$

We are assuming that the home-state policy maker chooses the tax rate to maximize social welfare. The policy maker takes the border-state tax rate as given, but adopts a "national" perspective and counts the border state's revenues from taxing c^B as a social welfare gain. Although not very realistic, this assumption is in the same spirit as Harberger's original thought experiment: we want to focus on the efficiency aspects of taxation, not the distributional implications (even across state borders).

Chetty points out that the individual treats tax revenue as fixed when making choices, failing to internalize the effects of his behavior on the lump-sum transfer he ultimately receives. Similarly, in our extension, we assume that the individual also fails to internalize the external costs generated by his smoking. Both assumptions are justified by the intuitive argument that the economy has a large number of consumers, so each individual has a negligible impact on tax revenues and external costs.

With these assumptions, the term in { } measures private surplus, while the following terms measure tax revenues and external costs.

The quick derivation of dW/dT^H uses the envelope theorem: the behavioral responses [dc^H/dT^H]and [dc^B/dT^H] in the { } can be ignored. The long derivation is to take the derivative and plug in the FOCs. When terms are collected, the behavioral response terms in the { } are multiplied by the FOCs, which = 0, so they drop out. This yields text equation (6):

$$\begin{aligned}\mathrm{dW}/\mathrm{dT}^H&=-c^H+c^H+T^H\,[\mathrm{dc}^H/\mathrm{dT}^H]+T^B[\mathrm{dc}^B/\mathrm{dT}^H]-E^C\,[\mathrm{dc}^H/dT^H]-E^C\,[\mathrm{dc}^B/dT^H])\\&=T^H\,\underset{(-)}{[\mathrm{dc}^H/\mathrm{dT}^H]}-E^C\,\underset{(+)}{[\mathrm{dc}^H/\mathrm{dT}^H]}+(T^B-E^C)\,\underset{(-)}{[\mathrm{dc}^B/dT^H]})\end{aligned} \quad \text{(A5)}$$

To find the optimal home-state tax, set $dW/d\,T^H = 0$ and solve to find the optimal $T^{H}*$:

$$\begin{gathered}\mathrm{dW}/\mathrm{dT}^H=T^H*[\mathrm{dc}^H/\mathrm{dT}^H]+T^B\,[\mathrm{dc}^B/\mathrm{dT}^H]-E^C\,[\mathrm{dc}^H/dT^H]-E^C\,[\mathrm{dc}^B/dT^H])=0\\T^H*[\mathrm{dc}^H/\mathrm{dT}^H]=-T^B[\mathrm{dc}^B/\mathrm{dT}^H]+E^C\,[\mathrm{dc}^H/dT^H]+E^C\,[\mathrm{dc}^B/dT^H])\\-T^H*\eta^H\,C^H=-T^B\,\eta^B\,C^B-E^C\,\eta^HC^H+E^C\,\eta^B\,C^B\\T^H*=(T^B\,\eta^B\,C^B)/(\eta^H\,C^H)+E^C-E^C\,(\eta^B\,C^B)/(\eta^H\,C^H)\end{gathered}$$

Re-arranging yields text equation (7):

$$T^H*=E^C-(E^C-T^B)\bullet(\eta^B/\eta^H)\bullet(C^B/C^H) \quad \text{(A6)}$$

where η^B and η^H are defined as in the text.

Replacing state taxes with a federal tax

Another exercise is to consider replacing the avoidable state excise taxes with a harder-to-avoid federal excise tax on cigarettes. The exercise is for a home state with a currently high

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tax that faces a low-tax border state: $T^H > T^B$. Consider setting the federal tax equal to the home-state tax: $T^F = T^H$. Because the federal tax also applies to purchases from the border state, the consumer no longer has any incentive to make cross-border purchases so also has no incentive to incur travel costs: $c^{B}** = 0$ and $m^{**}=0$. This assumes the federal tax can not be avoided at all, for example by making purchases from other countries. The first order condition (equation A3) for the utility maximizing choice of cigarettes purchased c** becomes:

$$\begin{aligned}\partial[\,]/\partial c = u_c\,(0,\, c^{**}) - (P + T^F) = 0\\ \iff\ u_c\,(0, c^{**}) = (P + T^F)\end{aligned} \qquad \text{(A7)}$$

With the new federal tax set at the old home-state tax so $T^F = T^H$, inspection of the FOCs (A3) and (A7) reveals that at the consumer's optimum the marginal utility of cigarette consumption must be the same under either tax regime. Under the simple assumption that the mileage driven does not change the marginal utility of cigarette consumption ($u_{cm} = 0$), this implies that home-state cigarette consumption is unchanged after the new federal tax replaces the old home-state tax: $c^{**} = c^{H*} + c^{B*}$.

Examining the terms of equation (A4) shows the welfare implications in the home state of replacing the state taxes with a federal cigarette tax. The federal tax revenues collected exceed the sum of home-state and border-state tax revenues previously collected: $T^F c^* > T^H c^{H*} + T^B c^{B*}$. But because these are re-distributed back to the taxpayer via lump-sum rebates, this increase cancels out in equation (A4). Because cigarette consumption is unchanged, the private costs of producing cigarettes k( ) and the external costs of cigarette consumption are also unchanged. On net, home-state social welfare is higher because the home-state consumer's utility is higher with the new federal tax:

$$u\,(0, c*) > u\,(m(c^B*), c* = c^H* + c^B*)$$

Recalling that mileage of travel (m) is a source of dis-utility, the key to the welfare gain is that the home-state consumer no longer incurs travel costs to avoid state taxes. With the incentives created by differences in state excise taxes, consumer tax avoidance uses resources – the travel costs – that are deadweight losses, compared to an equivalent federal tax.

Extending the formula to include external costs of tax avoidance

We consider a further extension to include the external costs of tax avoidance E^A per pack of cigarettes purchased without paying the home-state tax. These costs add a term to the expression for social welfare:

$$W(T^H) = \{\max\ u\,(m(c^B), c^B + c^H) + Z - T^H\,c^H - T^B\,c^B - k\,(c^H + c^H)\} + T^H\,c^H + T^B c^B - E^C\,[c^H + c^B] - E^A\,[c^B]$$

As above, setting the derivative $dW/dT^H = 0$ and solving for the optimal tax rate yields:

$$T^H* = E + (T^B - E^C)\,(\eta^B/\eta^H)\,(C^B/C^H) - E^A\,(\eta^B/\eta^H)\,(C^B/C^H) \qquad \text{(A8)}$$

Table 1

Descriptive Statistics

Variable	Mean for non-crossers	Mean for border-crossers
Price paid	3.54 (1.13)	2.91 (1.18)
Home state tax	0.95 (0.64)	1.23 (0.65)
Distance to low-tax state border (100 miles)	1.20 (1.05)	0.52 (0.76)
Age 15–29 (omitted category)	0.22	0.12
Age 30–39	0.22	0.17
Age 40–49	0.25	0.28
Age 50–59	0.18	0.22
Age 60+	0.13	0.21
Female	0.51	0.51
White (omitted category)	0.76	0.82
Black	0.11	0.10
Hispanic	0.09	0.04
Other races	0.04	0.04
Less than high school	0.17	0.13
High school (omitted category)	0.38	0.37
Some college	0.30	0.29
College or higher	0.15	0.20
Family income < 25k (omitted category)	0.32	0.26
Family income 25k–40k	0.22	0.20
Family income 40k–75k	0.29	0.32
Family income 75k+	0.18	0.22
Household size	2.66	2.35
Married	0.42	0.44
Employed (omitted category)	0.68	0.66
Unemployed	0.07	0.05
Retired	0.08	0.14
Not in the labor force	0.17	0.15
Northeast (omitted category)	0.20	0.32
Midwest	0.28	0.33
South	0.30	0.25
West	0.22	0.10
Feb. 2003 (omitted category)	0.17	0.17
June 2003	0.21	0.20
Nov. 2003	0.19	0.20
May 2006	0.16	0.15
Aug. 2006	0.12	0.13
Jan. 2007	0.16	0.14

Variable	Mean for non-crossers	Mean for border-crossers
N	27,878	1,499

The numbers in parenthesis are the standard deviations of the continuous variables.

Table 2

Structural Endogenous Switching Regression Model

VARIABLES	Probability of Border Crossing	Home-state price paid	Border-state price paid
Distance to border	−0.044***		
	(0.012)		
Distance^2	0.007***		
	(0.002)		
Price difference	0.095***		
	(0.017)		
Price difference * distance	−0.078***		
	(0.018)		
Price difference * distance^2	0.017***		
	(0.004)		
Home-state tax		0.866***	
		(0.043)	
Border-state tax			0.399***
			(0.136)
Age 30–39	0.009*	−0.146***	−0.134
	(0.004)	(0.020)	(0.107)
Age 40–49	0.014***	−0.323***	−0.445***
	(0.004)	(0.018)	(0.095)
Age 50–59	0.012**	−0.409***	−0.633***
	(0.005)	(0.024)	(0.113)
Age 60+	0.027***	−0.497***	−0.741***
	(0.008)	(0.032)	(0.134)
Female	0.001	−0.003	0.065
	(0.003)	(0.013)	(0.060)
Black	−0.005	0.272***	0.516***

VARIABLES	Probability of Border Crossing	Home-state price paid	Border-state price paid
	(0.008)	(0.027)	(0.077)
Hispanic	−0.004	0.230***	0.421**
	(0.006)	(0.027)	(0.177)
Other races	0.004	0.057	0.105
	(0.008)	(0.038)	(0.167)
Less than high school	−0.005	−0.011	−0.036
	(0.004)	(0.014)	(0.097)
Some college	0.005	0.034***	0.097
	(0.003)	(0.012)	(0.068)
College or higher	0.015**	0.192***	0.281***
	(0.006)	(0.020)	(0.082)
Family income 25k–40k	0.006*	0.063***	0.081
	(0.004)	(0.017)	(0.085)
Family income 40k–75k	0.012***	0.116***	0.137*
	(0.004)	(0.017)	(0.081)
Family income 75k+	0.020***	0.228***	0.392***
	(0.005)	(0.024)	(0.084)
Household size	−0.007***	−0.004	−0.067***
	(0.001)	(0.005)	(0.024)
Married	0.003	−0.075***	−0.039
	(0.003)	(0.015)	(0.080)
Unemployed	−0.000	−0.043**	0.079
	(0.005)	(0.019)	(0.120)
Retired	0.016**	−0.117***	−0.040
	(0.007)	(0.028)	(0.108)
Not in labor force	0.002	−0.113***	−0.138**
	(0.004)	(0.017)	(0.069)

VARIABLES	Probability of Border Crossing	Home-state price paid	Border-state price paid
Marginal effect of distance[(a)]	−0.052		
Marginal effect of price difference[(a)]	0.044		

Robust standard errors (clustered at MSA level) in parentheses

*** p<0.01,

** p<0.05,

* p<0.1

All models also include a constant term and a set of dummies for MSA size, region, and survey month. Sample size for all models is 29,377.

(a) Marginal effect is calculated at the mean for the sample.

Table 3

Estimates of Optimal Tax by State

State	Tax in 2003	Optimal tax in 2003	Tax in 2006/2007	Optimal tax in 2006/2007
Alabama	0.17	1.25	0.43	1.15
Alaska	1.00	1.36	1.73	1.36
Arizona	1.18	1.32	1.73	1.32
Arkansas	0.51	1.15	0.59	1.19
California	0.87	1.33	0.87	1.34
Colorado	0.20	1.23	0.84	1.26
Connecticut	1.38	1.36	1.51	1.36
Delaware	0.34	1.36	0.55	1.36
District of Columbia	1.00	0.66	1.00	0.81
Florida	0.34	1.20	0.34	1.36
Georgia	0.20	1.20	0.37	1.22
Hawaii	1.23	1.36	1.53	1.36
Idaho	0.47	1.31	0.57	1.36
Illinois	0.98	1.03	0.98	0.96
Indiana	0.56	1.18	0.56	1.23
Iowa	0.36	1.23	0.36	1.23
Kansas	0.79	1.00	0.79	1.11
Kentucky	0.03	1.34	0.30	1.28
Louisiana	0.36	1.19	0.36	1.17
Maine	1.00	1.11	2.00	1.14
Maryland	1.00	0.87	1.00	0.95
Massachusetts	1.51	1.09	1.51	1.14
Michigan	1.25	1.17	2.00	1.27
Minnesota	0.48	1.25	0.82	1.17
Mississippi	0.18	1.25	0.18	1.36
Missouri	0.17	1.24	0.17	1.36
Montana	0.53	1.36	1.70	1.36
Nebraska	0.64	1.03	0.64	0.95
Nevada	0.50	1.17	0.80	1.27
New Hampshire	0.52	1.36	0.80	1.36
New Jersey	1.68	1.24	2.52	1.40
New Mexico	0.44	1.27	0.91	1.32
New York	1.50	1.30	1.50	1.36
North Carolina	0.05	1.13	0.33	1.13
North Dakota	0.44	1.19	0.44	1.36
Ohio	0.55	1.20	1.25	1.13
Oklahoma	0.23	1.29	1.03	1.26

State	Tax in 2003	Optimal tax in 2003	Tax in 2006/2007	Optimal tax in 2006/2007
Oregon	1.28	1.32	1.18	1.33
Pennsylvania	1.00	1.10	1.35	1.19
Rhode Island	1.45	1.35	2.46	1.36
South Carolina	0.07	1.15	0.07	1.36
South Dakota	0.46	1.07	0.86	0.98
Tennessee	0.20	1.05	0.20	1.25
Texas	0.41	1.23	0.74	1.26
Utah	0.70	1.17	0.70	1.23
Vermont	1.02	1.15	1.59	1.32
Virginia	0.03	1.36	0.30	1.30
Washington	1.43	1.34	2.03	1.31
West Virginia	0.42	1.08	0.55	1.10
Wisconsin	0.77	1.31	0.77	1.31
Wyoming	0.28	1.36	0.60	1.36