

Excise Tax Avoidance:
The Case of State Cigarette Taxes

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ABSTRACT

This paper is an empirical study of consumers' decisions to avoid cigarette excise taxes. We use data from the U.S. 2003 Tobacco Use Special Cessation Supplement, which asked smokers directly about their purchases of cigarettes across state borders. Results from reduced-form models show that the probability of cross-border cigarette purchases responds in predictable ways to the economic incentives created by the distance to the border and state tax differentials. We extend our empirical analysis to estimate a structural endogenous switching regression model. In the structural border-crossing equation, the decision to cross the border depends on the difference between the endogenous home- and border-state prices. We estimate that the elasticity of border crossing with respect to the home-state price is 3.86, suggesting a strong consumer tax avoidance response. We use our results to extend the standard formula for the optimal Pigouvian tax to incorporate tax avoidance. Using an estimate that smoking generates external costs of \$1.36 per pack, after taking into account tax avoidance the optimal state tax is only \$0.33. Regardless of how large smoking's externalities or internalities are, tax avoidance reduces the effectiveness of state excise taxes as a corrective policy tool.

1. Introduction

Many countries impose excise taxes on alcohol, cigarettes, gasoline, and environmentally-related goods (Gnossen, 2005). Excise taxes are relatively small but non-trivial sources of revenue: they account for almost 12 percent of government revenues on average across the OECD (OECD 2005). However, it is widely agreed that the revenues are not the main reason for excise taxes. 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 can be justified as efficient Pigouvian taxes that internalize external costs.¹ Recent 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 (O’Donoghue and Rabin 2003, 2006, Gruber and Koscegi 2004).

In the U.S. excise taxes are imposed at the federal, state, and local level. In recent years states have been particularly active increasing the excise taxes on cigarettes. Since 2000, 40 states and the District of Columbia enacted a total of over 70 cigarette tax hikes (Federation of Tax Administrators 2008). According to a trade group, 22 state legislatures are considering cigarette tax hikes in 2008 (Sack 2008). Cigarette tax rates currently range from a low of \$0.07

¹The seminal study by Manning *et al.* (1989) concluded that the external costs of excessive alcohol consumption justified higher alcohol taxes in the U.S. However, it also included that U.S. cigarette taxes were already high enough to internalize the external costs of smoking. Smith (2005, pp. 67 - 73), Gnossen and Smart (2005, pp. 36 - 37), and Sloan *et al.* (2004) review more recent empirical evidence on the social costs of alcohol and cigarettes. Parry, Walls, and Harrington (2007) review empirical evidence on externalities related to automobile use.

per pack in South Carolina to a high of \$2.575 per pack in New Jersey. Some localities also tax cigarettes, the most notable being New York City's \$1.50 per pack tax since 2002. Alcohol and gasoline excise taxes also vary widely across states, although not as widely as cigarette taxes (Federation of Tax Administrators 2008). In the contiguous U.S., beer tax rates currently range from \$0.019 per gallon in Wyoming to \$1.05 per gallon in South Carolina. Perhaps not coincidentally, some of the very highest beer taxes are in the geographically isolated states of Alaska (\$1.07 per gallon) and Hawaii (\$0.93 per gallon). Gasoline tax rates in the contiguous U.S. range from \$0.14 per gallon in Wyoming to \$0.455 per gallon in California.²

Consumers can legally avoid national, state, and local excise taxes on alcohol, cigarettes, and gasoline by making purchases from nearby tax jurisdictions with lower tax rates.³ Twelve percent of the E.U. population lives near the border with another member nation (Cnossen 2005, p. 45), and about 40 percent of the U.S. population lives in counties that border another state or nation (Vedder 1997). Although policy makers in high-tax jurisdictions understandably worry about the potential lost tax revenues, empirical economic research on excise tax avoidance is limited. The extensive body of theoretical and empirical research on tax evasion and compliance focuses almost entirely on income taxes, not excise taxes (Andreoni, Erard, and Feinstein 1998, Sandmo 2005, Slemrod 2007). Some health economics studies attempt to control for legal consumer tax avoidance and illegal smuggling of cigarettes and alcohol, but

²The lowest gasoline tax is in Alaska, at \$0.08 per gallon, probably reflecting the importance of the oil industry for the Alaskan economy and politics.

³In most states, cross-border purchases are legal if intended for personal consumption. For cigarettes, this is usually implemented through limits on the quantity purchased, typically 20 - 30 packs (2 - 3 cartons of 10 packs each).

these studies lack actual measures of tax avoidance and their primary goal is to develop unbiased estimates of the price elasticities of demand.⁴ To our knowledge: we are the first study to examine direct measures of consumer excise tax avoidance in individual-level data; and we are the first study to explore the impact of tax avoidance on the optimal Pigouvian tax.

In our empirical study of consumers' decisions to avoid cigarette excise taxes we use data from the U.S. 2003 Tobacco Use Special Cessation Supplement (TUSCS) to the Current Population Survey. In addition to standard questions about smoking, the TUSCS asked smokers directly about their actions to avoid cigarette taxes. We use geographic information on the respondents' location to merge data on excise taxes in their home states and bordering states, as well as their distance to the state border. Another special feature of the TUSCS is that it asked consumers about the prices they actually paid for their cigarettes.

Section 2 describes the data sets in more detail and provides an overview of the extent of tax avoidance. Cross-border purchases appear to be the most common form of cigarette tax avoidance. About five percent of the smokers in the TUSCS sample report that their last purchase of cigarettes was in a state other than their state of residence. As with excise tax rates, the rate of cross-border purchases varies widely across states, from under one percent of smokers

⁴Chaloupka and Warner (2000) provide a comprehensive review of cigarette demand studies. 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), Gruber, Sen and Stabile (2003), Stehr (2005), and Lovenheim (2008). As Merriman (2007) notes, "none of the widely used approaches is fully satisfactory because they require researchers to infer tax avoidance based on discrepancies in observed data (e.g. the difference between tax revenues collected and smoking observed in surveys of the smoking public)." Cook and Moore (2000) provide a comprehensive review of alcohol demand studies. Alcohol demand studies that address border-crossing include Baltagi and Goel (1990), Baltagi and Griffin (1995), Beard, Gant and Saba (1997), and Stehr (2007). Asplund, Friberg and Wilander (2007) estimate the responsiveness of Swedish alcohol sales to foreign prices.

in several low-tax states to over 20 percent in the District of Columbia. The prevalence of cross-border cigarette purchases as directly measured in the TUSCS is higher than most previous estimates based on indirect evidence from cigarette demand models.

In section 3 we report results from reduced-form models of the probability of cross-border cigarette purchases. The results show that this form of tax avoidance responds to economic incentives in predictable ways: the probability of border crossing depends on the consumer's distance to the border and on the home- and border-state cigarette taxes. Socioeconomic factors seem to play a different role in border crossing than is usually found in cigarette demand models. For example, although previous studies find a negative income-elasticity of cigarette demand, the probability that a smoker crosses the border to purchase cigarettes increases with income.

In section 4 we extend our empirical analysis to estimate a structural endogenous switching regression model of border-crossing and cigarette prices. Depending on whether the individual crosses the border, the price paid for cigarettes switches between two regimes: the home-state price and the border-state price. In the structural border-crossing equation, the decision to cross the border depends on the difference between the endogenous home- and border-state prices. We estimate that the elasticity of border-crossing with respect to the home-state price is 3.86, suggesting that consumer tax avoidance strongly responds to price differentials created by state tax differences. The price savings required to induce consumers at different distances to cross the border reveals consumer preferences for the non-market good "distance traveled." Comparing the relative impacts of the price differential and distance implies that consumers use a "shadow price" of about \$0.05 per mile when making their border-crossing

decisions. This low shadow price is plausible if consumers jointly produce cross-border cigarette purchases with other activities such as commuting to work or other shopping.

In section 5 we discuss the implications of our empirical study of tax avoidance for applied welfare economic analysis of state excise taxes. In addition to reducing state tax revenues, consumer tax avoidance uses resources that are deadweight losses to efficiency. An implication is that there are clear social welfare gains from simultaneously cutting state taxes while increasing the harder-to-avoid federal cigarette tax, even if the state tax cuts were smaller than the federal tax hike. We extend the standard formula for the optimal Pigouvian tax to incorporate tax avoidance. Using an estimate that smoking generates external costs of \$1.36 per pack, after taking into account tax avoidance the optimal state tax is only \$0.33. 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.

The concluding Section 6 includes a discussion of the relevance of the results for other common excise taxes.

2. Data

Beginning in 1992, the Tobacco Use Supplements (TUS) have been sponsored by the National Cancer Institute and administered as part of the Consumer Population Survey (CPS) (Hartman *et al.* 2002). Each cycle provides a large nationally representative sample and sub-samples that are representative at the state level. In addition to questions about smoking behaviors, respondents were asked other questions that varied somewhat over the TUS-CPS cycles. The 2003 TUSCS 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. They were also asked how much they paid for their last pack (or carton) of cigarettes. In order to calculate distance to the state border for each respondent, we restrict the sample to residents of Metropolitan Statistical Areas (MSAs). Our sample of analysis consists of 16,900 smokers who live in an MSA and provided valid responses to the questions about border-crossing and cigarette price paid. We used Google Maps to calculate each respondent's distance to the closest lower-tax border state. We match cigarette excise tax rates from Orzechowski and Walker (2007) to respondents based on their state of residence, the closest border state, and their interview month. Respondents in the Chicago and New York City MSAs are also assigned the applicable local cigarette taxes.

Table 1 provides descriptive statistics from the TUSCS for the variables used in the empirical models below. About five percent of TUSCS 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.⁵ 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 50 miles closer to a lower-tax state and pays about \$0.60 less per pack of cigarettes.

As shown in Table 2, the rate of cross-border purchases varies widely across states. In

⁵The low prevalence of internet purchases might seem surprising, and could reflect TUSCS respondents' reluctance to report actions of questionable legality. As Goolsbee, Lovenheim, and Slemrod (2007) point out, there is very little systematic evidence about the volume of internet cigarette sales. Goolsbee, Lovenheim and Slemrod estimate a model of state taxable cigarette sales that includes a measure of internet penetration in the state. Their model implies that, compared to a counter-factual with no internet sales, in 2000 internet sales reduced home-state cigarette sales by 3.3 percent.

Kentucky, North Carolina, and South Carolina, where the cigarette excise taxes are very low, less than one percent of smokers report a cross-border purchase. The highest rates of cross-border purchases are in the District of Columbia (21 percent) and Maryland (16 percent). Not only are cigarette taxes relatively high at \$1.00 per pack in these two jurisdictions, but they both border Virginia, where in 2003 the tax rate was only \$0.025 per pack.

To the best of our knowledge, the TUSCS provides the first national estimates based on direct measures of consumer tax avoidance. Estimates from a few state- or locality-specific studies are generally in line with the TUSCS national estimates. Emery *et al.* (2002) find that 3.1 percent of California smokers report making cross-border purchases after the 1999 cigarette tax hike, compared to our estimate of 2.4 percent in the 2003 TUSCS. DeCicca, Kenkel and Liu (2008a) analyze data from the 2003 - 2006 New York State Adult Tobacco Survey (NYS-ATS). They find that in the NYS-ATS almost five percent of New York City smokers report that they make cross-border purchases “all the time,” compared to a little more than six percent of New York City smokers in the TUSCS who report that their last purchase was made across a state border. The comparison between the NYS-ATS and the TUSCS is similar for upstate New York residents (three percent in the NYS-ATS versus five percent in the TUSCS). Merriman (2007) uses a novel method to measure tax avoidance in the Chicago area based on littered cigarette packs. He finds evidence of high levels of avoidance of the Illinois, Chicago, and Cook County taxes; for example, 26 percent of the littered packs in Chicago and Cook County had Indiana tax stamps. Because of sharp hikes in Chicago and Cook County cigarette taxes, at the time of Merriman’s study the Illinois, Chicago, and Cook County taxes totaled \$4.05 per pack, which was \$3.13 per pack higher than in Indiana. In the 2003 TUSCS, about nine percent of Chicago

MSA residents reported border crossing, but at that time the total Chicago-Indiana tax differential was only \$0.735.

Several studies use cigarette demand models to develop indirect estimates of the extent of cross-border purchases and illegal smuggling. The indirect estimates of the prevalence of border crossing range from under one percent to as high as 25 percent. The first set of indirect estimates are from a series of academic studies and consulting reports that estimate models of state cigarette sales. Although the details of the specifications differ, the basic approach is to include variables related to border-crossing incentives in the cigarette demand models. The estimated model parameters are then used to predict the extent of cross-border purchases. Saba *et al.* (1995) estimate that from 1973 through 1986 almost all states experienced trivial losses (usually less than 1 percent of sales) to border crossing. A notable exception is their estimate that in 1986 the high-tax jurisdiction of D.C. lost 51 percent of sales to its lower-tax border states. Using updated data from 1970 through 1995, Yurekli and Zhang (2000) estimate that nationally in 1995 only 1.5 percent of state tax revenues were lost to border-crossing. The consulting reports also suggest that border-crossing is very uncommon (Fleenor 1999, Farrelly and Nimsch 2003, O'Connor 2008).⁶ Stehr (2005) compares individual cigarette consumption data with state sales data. His regression model shows the association between changes in incentives to avoid taxes and changes in the difference between consumption and sales. He estimates that border-crossing effects are very small and account for less than 1 percent of total sales in 2001. In contrast, based on a demand model estimated with individual-level data from

⁶Several other studies including Coats (1995), Thursby and Thursby (2000), and Gruber, Sen, and Stabile (2003) estimate the extent of illegal smuggling of cigarettes, but do not separately estimate the extent of legal border-crossing.

1992 - 2002, Lovenheim (2008) estimates that between 13 and 25 percent of consumers make cross-border purchases. The direct TUSCS estimate of about 5 percent suggests that border-crossing is neither as trivial as suggested by earlier studies nor as prevalent as suggested by Lovenheim.

3. Reduced-Form Model of Border Crossing

In this section we report alternative specifications of a reduced-form model of the probability of making a cross-border cigarette purchase. Border crossing is based on whether the consumer's most recent purchase of cigarettes was made in some state other than his or her state of residence. In the basic linear probability model, border crossing is a function of distance to the border, distance-squared, and a set of socioeconomic variables measuring age, gender, race/ethnicity, schooling, family income, household size, and marital status. In additional model specifications, we add the home-state and border-state cigarette tax rates the consumer faces, and then we add interactions of these variables with the distance measures. Finally, we explore whether the results are sensitive to the use of probit instead of the linear probability model, or to the inclusion of a measure of state anti-smoking sentiment. Individual respondents in the TUSCS are clustered within MSAs, and our models include variables measured at both the individual- and MSA-level. We use Stata's *robust* and *cluster* commands to obtain robust standard errors that account for potential clustering at the MSA level.

The results for the linear probability models of border-crossing are reported in the first three columns (A - C) of Table 3. The fourth column (D) of Table 3 reports results from a probit model of border-crossing that includes the full set of distance, tax, and interaction terms. To help compare the results across model specifications, Table 3 also reports the implied marginal

effect of distance on the probability of border-crossing, evaluated at the sample averages of the relevant variables. Distance to the border statistically significantly decreases the probability of border crossing. The size of the marginal effect of distance falls at higher distances. The implied marginal effect of distance is fairly stable across specifications and suggests that at the mean distance each additional mile reduces the probability of border crossing by about 0.03 percentage points. Taking into account the quadratic distance term, the predicted probability of border crossing approaches zero at a distance to the border of about 300 miles. Comparing Model C to D, the substantive results are not very sensitive to the use of probit instead of the linear probability model.⁷

In the specifications reported in columns C through E of Table 3, a higher home-state tax increases the probability of border-crossing, while a higher border-state tax decreases the probability of border-crossing. As expected the estimated coefficients on the home- and border-state tax variables are virtually identical in size: consumers apparently cross the border in response to a tax difference regardless of whether it is caused by a high home-state tax or a low border-state tax. A tax difference of \$1.00, which is approximately the difference between Maryland and Virginia or D.C. and Virginia, is predicted to increase the probability of border crossing by about 8 percentage points. In the models reported in columns C, D and E, there are statistically significant interaction terms between the distance and tax variables. These results

⁷The magnitudes of the probit coefficients can not be directly compared to the linear probability model coefficients, but their sign and statistical significance levels are comparable, as are the implied marginal effects (available upon request). The models in columns A - C and E suffer from the well-known drawback of the linear probability model and predict negative probabilities at distances above 300 miles or so. However, these distances are outside the range of virtually all of the data.

suggest that: when the home-state tax is higher, the effect of distance is larger in absolute value; and when the border-state tax is higher, the effect of distance is smaller. Put differently, when the tax differential is very small, consumers do not cross the border even at low distances.

Additional model specifications, which are not reported in Table 3 but are available upon request, explore more possible determinants of border crossing. In one set of models, we explore the hypothesis that recent tax hikes have greater salience for border-crossing decisions than longer-standing taxes.⁸ We add to our model an indicator variable for consumers who face a recent tax hike, i.e. a tax hike within either 3, 6, or 12 months before the date they were surveyed. Farrelly, Nimsch, and James (2003) provide suggestive evidence that there may be a surge in cigarette tax avoidance immediately after a tax hike, which then quickly subsides within several months. Our results are consistent with this pattern. Our point estimate is that consumers who face a tax hike within the past 3 months are 3.9 percentage points ($t=1.65$) more likely to cross the border, which is a very large effect compared to the sample proportion of 5 percent border-crossing. The effect of a tax hike within the past 6 months falls to 3.1 percentage points ($t=2.29$), and the effect of a tax hike within the past 12 months falls to just under 2 percentage points ($t=2.09$).

In another set of additional specifications, we include state gasoline, beer, and sales taxes in our models of cross-border cigarette purchases. High gasoline taxes increase the travel costs of border crossing. At the same time, some consumers may be able to jointly avoid several taxes when they make a cross-border cigarette purchase. We do not find evidence that cross-border purchases of cigarettes respond much to the level of the gasoline tax or to gasoline-, beer-, or

⁸Chetty, Looney and Kroft (2007) find that excise taxes have greater salience than sales taxes as determinants of alcohol demand in both the short- and long-run.

sales-tax differentials. The lack of evidence might reflect the fact that in general, gasoline, beer, and sales taxes vary much less across states than cigarette taxes.

Another specification issue concerns the role of unobserved state-level influences. In empirical studies of cigarette demand there is a concern that state cigarette taxes are endogenous because they are correlated with anti-smoking sentiment or some other hard-to-observe state-level influence. Although the decision to purchase cigarettes across the border is much different than the decision to smoke, the state tax variables might also be endogenous in our models. To address this concern, a common specification with repeated cross-sectional data is to include location fixed effects. However, a location fixed effects specification is somewhat problematic in a study of a mainly time-invariant characteristic like distance to the border.⁹ In any case, we can not take this approach because we only have data from a single cross-sectional survey. Instead, we include a direct measure of state anti-smoking sentiment (DeCicca *et al.* 2008). The measure is based on responses about attitudes towards smoking reported in earlier TUS-CPS cycles and is similar to the measures used by Gilpin, Lee and Pierce (2004) and Alamar and Glantz (2006). The measure of state anti-smoking sentiment has been merged with several different data sets to estimate cigarette demand models (DeCicca *et al.*, 2008, DeCicca, Kenkel, and Mathios forthcoming, Carpenter and Cook 2008, Liu forthcoming). In these studies, higher state anti-smoking sentiment is strongly associated with less smoking. The estimated effects of cigarette taxes or prices on smoking are also typically very sensitive to the inclusion of

⁹Lovenheim (2008) includes MSA fixed effects in his study of the effect of distance to the border on cigarette demand. Even though distance to a specific state border is time invariant, home- or border-state price changes create within-MSA variation in distance to the closest lower-price border. However, the within-MSA variation is limited in Lovenheim's study: between most survey years around 80 percent or more of the MSAs do not experience a change in distance to a lower price border.

sentiment measure.

The model of border-crossing reported in column E of Table 3 includes the measure of state anti-smoking sentiment. Although previous research suggests that the measure of state anti-smoking sentiment is a useful control variable in cigarette demand models, we do not find evidence that anti-smoking sentiment is an important determinant of border crossing. The coefficient on the sentiment measure in column E is small and not statistically significantly different from zero. Comparing the models in columns C and E, the estimated coefficients on the tax variables are not sensitive to the inclusion of the sentiment measure. When we include measures of both home- and border-state anti-smoking sentiment, the results are similar (not reported but available upon request). An alternative approach to control for hard-to-observe differences across states yields similar results (not reported in Table 3 but available upon request). In the alternative approach we use “imported” estimates of the state fixed effects from Liu’s (forthcoming) models of smoking participation.¹⁰ The estimated coefficient on this alternative state-level control is again not statistically significantly different from zero, and the estimated coefficients on the tax variables are again robust to its inclusion.

It is impossible to rule out all possible sources of state-level heterogeneity that might create bias in our estimates of the impact of state cigarette taxes on border crossing. However, we find no evidence of the most likely source – policy endogeneity bias related to state anti-smoking sentiment. We also note that many sources of heterogeneity should lead to different

¹⁰Liu (forthcoming) uses data from cycles of the TUS-CPS to estimate a standard model of smoking participation that includes a set of state dummy variables. The 48 estimated coefficients on each state dummy provide estimates of the 48 state fixed effects. We include this single imported variable with 48 values as a control variable in an alternative specification of the model in column E.

biases in our estimates of the effects of home-state taxes versus border-state taxes.¹¹ Therefore, the fact that the home-state and border-state tax coefficients are virtually identical provides additional suggestive evidence that these estimates are not biased by endogeneity.

Finally, we note that the different model specifications show consistent patterns between border-crossing and the socioeconomic variables. In cigarette demand studies, people with more schooling are much less likely to smoke, and the income elasticity of demand is typically negative (e.g., Wasserman *et al.* 1991, Colman and Remler 2008). In contrast, in the results in Table 3 the probability of border crossing does not vary much across smokers with different levels of schooling. Instead of a negative income elasticity, the probability of border crossing increases with income. It also decreases with household size. Blacks and Hispanics are less likely to report purchasing cigarettes across a state border. Several of the socioeconomic variables might tend to proxy for car ownership and other factors that provide easier access to border-crossing.

4. 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

¹¹For example, suppose that there is still some remaining unmeasured anti-smoking sentiment that is positively correlated with state tax rates. Based on the economics of consumer price search (Baye, Morgan, and Scholten 2006), heavier smokers will search more intensively for lower-price cigarettes, so they may be more likely to cross the border. To the extent unmeasured anti-smoking sentiment reduces heavier smoking, it will also tend to reduce border crossing. If unmeasured sentiment is positively correlated with the home state tax rate, the coefficient on the home-state tax in the border-crossing equation is biased towards zero and thus away from the coefficient on the border-state tax. More generally, it is unlikely that unobservable heterogeneity will lead to the same bias in the estimates of the effects of home- and border-state taxes. Of course, the biases in the coefficients could be equal by accident, so the equality of the coefficients is consistent with, but not definitive proof of, the tax exogeneity assumptions.

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:

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

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

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 distance traveled d , and utility from cigarette consumption c . The latent utility difference behind the observed border-crossing decision is given by:

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

where g^* , d^* , and c^* are the optimal choices given border crossing and g^{**} , d^{**} , 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:

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

where u_g and u_d 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 d with and without border crossing is the distance to the border: $\Delta d = d^* - d^{**} = \text{distance to the border}$.

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

$$(4) \quad u = u_g c (P^B - P^H) + u_d (\text{distance to the border}) + r$$

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

$$(5) \quad u = \alpha_0 + \alpha_1 (P_i^B - P_i^H) + \alpha_2 (\text{distance to the border})_i + \alpha_3 W_i + \epsilon_i$$

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 ϵ . 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 α_2 / α_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 α_2 / α_1 provides an estimate of the shadow price of distance, i.e. the dollar value of a marginal change in distance.¹² 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."¹³

¹²The parameters in discrete choice models based on random utility maximization have analogous interpretations (Train 2003). For example, Small, Winston and Yan (2005) estimate a model of commuters' choices between paying a toll to use express lanes versus free regular lanes. They define the values of travel time and reliability as the ratios of the marginal utilities captured by the parameters of their model of the random utility difference (their equations 1 and 2, p. 1370).

¹³In 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.

To estimate the model, we use the standard assumption that the error terms ϵ_i^H , ϵ_i^B , and ϵ_i have a trivariate normal distribution with non-zero covariances. The model is estimated by maximum likelihood using Stata's command *movestay*. Stata's *movestay* command yields estimates of the price equations (1a) and (1b) and a reduced-form version of equation (5) that does not include the endogenous price variables on the right hand side. We use the estimated price equations to predict P^H and P^B for each smoker in the sample. We then estimate the structural border-crossing equation as a function of the predicted price differential $P^B - P^H$ and the other explanatory variables.¹⁴

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

The validity of the exclusion restrictions rests in part on the nature of competition in retail cigarette markets. We assume that retail cigarette markets are competitive. At the industry level cigarette manufacturing is a tight oligopoly (Bulow and Klemperer 1998). Across states,

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 to purchase lower-priced cigarettes.

¹⁴Our 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.

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

Keeler *et al.* (1996) find evidence that cigarette manufacturers are able to engage in a small degree of price discrimination (3 - 6 cents worth) by state.¹⁶ However, imperfect competition at the industry- and state-level is not necessarily inconsistent with our assumption that the retail markets are reasonably competitive. We assume that there is enough competition at the retail level so that within each state the price is driven down to the retailer's marginal cost plus the state tax rate. This implies that retailers in the home state can not change their prices in response to border-state prices, and *vice versa*. Instead, the retail markets are equilibrated by changes in the volume of cigarette sales and the entry and exit of cigarette retailers. Anecdotal evidence suggests that cigarette tax hikes cause large swings in sales volume near state borders.¹⁷ To further explore the issue empirically in the TUSCS 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. This is consistent with our assumption that distance can be excluded from the price equations (1a) and (1b). Moreover, the lack of within-state price variation related to distance to the border is also consistent with the assumption that the border-state tax does not enter the home

¹⁶Keeler *et al.* (1996, p. 509) estimate that varying the Herfindahl index from the observed minimum to the observed maximum values in their data would change retail prices by 1 to 2 percent. In terms of the 2003 TUSCS prices, this degree of price discrimination corresponds to between 3 and 6 cents per pack.

¹⁷Fleener (1998, p. 5) notes that after the 1995 Michigan cigarette tax increase: "According to a survey conducted by Price Waterhouse, many Indiana merchants in the border region saw their cigarette sales rise by 40 percent or more while those located on the Michigan side of the border saw a corresponding decline. 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 where retailers near borders can not change their prices in response to border-state taxes.

state price equation, and *vice versa*.

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 18.25, 553.04, and 6.62 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 somewhat weak, perhaps due to the much smaller sample size of border crossers whom we can observe paying the border price.

Results

Table 4 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 -0.03, very similar to the reduced-form results.

We use the estimated marginal effect of the price differential to calculate that the cross-price elasticity $\epsilon^B = 3.86$. This is a “cross” price elasticity in two senses. First, ϵ^B shows the elasticity of the probability of border crossing with respect to the home-state price of cigarettes.¹⁸

¹⁸We define $\epsilon^B = [\partial \Pr\{B=1\} / \partial P^H] [P^H / \Pr\{B=1\}]$ 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 ϵ^B with respect to P^H to facilitate comparisons with previous research and to use in the formula for the optimal Pigouvian tax rate

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 1.9 percentage points (38.4 percent of 5 percent).

Second, ϵ^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. 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.

Because ϵ^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:

$$(6) \quad \epsilon^{TOTAL} = [C^H / (C^H + C^B)] \epsilon^H - [C^B / (C^H + C^B)] \epsilon^B$$

we develop in section 5. The comparison of ϵ^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 = $\epsilon^B (P^H - P^B) / (P^H) = (3.84) (0.61/3.34) = 0.701$.

where O^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 (6) allows us to compare our results to estimates from cigarette demand studies. Our estimate contributes to a growing body of evidence that while a state cigarette tax reduces home-state sales, it may not be an effective way to reduce the consumption of home-state smokers. As a benchmark, we assume that the absolute value of the elasticity of home-state purchases (= the elasticity of home-state tax paid sales) is around 0.3.¹⁹ Combining this with our estimate of O^H implies that the absolute value of the elasticity of total consumption is only 0.093. Put differently, border-crossing accounts for about two-thirds of the response of home-state purchases to changes in the home state price. By comparison, 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. However, in both of these studies, the predominant form of tax avoidance is long-distance cigarette smuggling, not legal cross-border purchases. Although our results are similar in that they suggest a strong cigarette tax avoidance response, we find a

¹⁹Chaloupka 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. We use an estimate at the low end of the consensus range from -0.3 to -0.5 described by Chaloupka and Warner (2000, p. 1547). 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. We use a value at the low end of the range because recent estimates suggest that the earlier consensus may have over-stated the price-elasticity of cigarette demand (Tauras 2005, Levy and Meara 2006, Colman and Remler 2008). On the other hand, Goolsbee, Lovenheim and Slemrod (2007) estimate that Internet smuggling has caused the sales price-elasticity to increase in recent years.

much different channel for the response. Like our study, Lovenheim (2008) also focuses on legal cross-border purchases, but he finds an even stronger response and estimates that approximately all of the response in home-state sales is due to tax avoidance.

Turning to other results in Table 4, 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 a carton of 10 packs of cigarettes per trip, the implied shadow price of distance is \$0.05 per mile. For sensitivity analysis: if the average purchase is only one pack per trip, the implied shadow price is \$0.005 per mile; if the average purchase is 3 cartons (the legal maximum in a number of states), the implied shadow price is \$0.15 per mile.

Our estimates of the shadow price of distance traveled are lower than standard estimates of travel costs, but this is reasonable if consumer travel jointly produces cross-border cigarette purchases and other activities. In 2003 the Internal Revenue Service allowed taxpayers to deduct business mileage at \$0.36 per mile, while the American Automobile Association estimated the average operating and ownership costs of driving a new car at \$0.52 per mile (AAA 2003). Adding the value of time increases travel costs by at least \$0.10 to \$0.20 per mile (Victoria Transport Policy Institute 2008), so the total travel cost might be around \$0.70 per mile. Suppose the consumer makes 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. Our approach isolates one component of the total value. Many consumers jointly produce cross-border cigarette purchases with activities like

shopping for other goods, commuting, or recreation. If the value of the total benefits is \$0.70 per mile, our estimate that the value component due to cross-border cigarette purchases is only \$0.05 per mile out suggests that consumers derive \$0.65 per mile of benefits from these other activities.

Table 4 also shows estimates of the determinants of the prices consumer pay for cigarettes in the home- and border-state regimes. We estimate that the home-state tax is passed through to the home-state price at a rate of slightly greater than one-for-one. This degree of tax pass-through is consistent with previous estimates from studies that examine the relationship between state-level or country-level prices and cigarette taxes in the U.S. and Europe ((Barzel 1976, Johnson 1978, Sumner and Ward 1981, Keeler *et al.* 1996, and Delipalla and O'Donnell 2001). In sharp contrast to our results for home-state prices, we estimate that the border-state cigarette tax is passed through to the border-state price at a rate of only about 0.5. One explanation for the low rate of tax pass-through to border-state prices is that border crossers generally engage in more price search. They are also more likely to obtain volume discounts by purchasing cigarettes by the carton instead of the pack. DeCicca, Kenkel and Liu (2008b) examine in more detail the impact of these price-search behaviors on the incidence of cigarette taxation.

The results in Table 4 suggest that some socioeconomic factors have similar effects on the probability of border crossing and on the price paid for cigarettes in either regime. For example, smokers with higher incomes are more likely to cross the border, and they pay higher prices for their cigarettes either at home or in the border state. It should be kept in mind that the TUSCS did not ask respondents about which brand of cigarettes they purchased. Previous research suggests that younger smokers, smokers with higher incomes, and smokers with more

schooling are more likely to purchase the higher-priced premium brand cigarettes (Cummings *et al.* 1997, Hyland *et al.* 2005, Office of Applied Studies Substance Abuse and Mental Health Services Administration 2007). The patterns across socioeconomic groups for the prices paid for cigarettes reflect differences in brand or quality preference as well as differences in consumers' price search.

5. Implications of Excise Tax Avoidance for State Tax Policy

The Impact of Tax Avoidance on Revenues and Taxpayer Costs

In this section, we discuss the implications of our empirical study of tax avoidance for the policy analysis of state cigarette taxes. In policy circles, the most common concern is that tax avoidance reduces tax revenues. The first four columns of Table 5 present our estimates of the impact of consumer tax avoidance on cigarette excise tax revenues for 26 higher-tax states. We estimate that these 26 states lost almost \$600 million, or about 7.5 percent of their potential cigarette tax revenues due to cross-border purchases. A number of states lost 10 percent or more of their potential cigarette tax revenues. Of course, taking a somewhat broader perspective, some of the higher-tax states' revenue losses are gains for lower-tax states. We estimate that after accounting for lower-tax states' gains, the net loss of state cigarette tax revenues is about \$250 million, or about 3 percent of the 2003 tax revenues collected by the 26 higher-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 However, with tax avoidance, the taxpayers incurred costs to obtain these gains. In

²⁰State 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

fact, for the marginal tax avoider who is almost indifferent between crossing the border or paying the higher home-state tax, the costs of tax avoidance are approximately equal to the tax revenues he or she avoids paying. So although the revenue loss is not part of the societal welfare loss *per se*, its size sheds light on the size of the deadweight efficiency cost of tax avoidance.

The last two columns of Table 5 present illustrative calculations to shed more light on the size of consumers' avoidance costs. We estimate that consumers traveled a total of about 4 billion miles to avoid higher cigarette excise taxes. Using our estimate of the shadow price of distance developed above, the value of the miles traveled to avoid cigarette taxes is almost 50 percent of the net revenue losses. These deadweight costs of tax avoidance could also be viewed as the potential benefits of replacing state cigarettes taxes with a harder-to-avoid higher federal tax.

The relative impact of tax avoidance on estimated revenues and taxpayers' costs varies across jurisdictions. For example, in D.C. the consumers' tax avoidance costs are only five percent of the net revenue losses. Because D.C. is so close to the low-tax state of Virginia, most tax avoiders are far from indifferent to crossing the border: they enjoy a large "tax avoiders' surplus." By contrast, we estimate that in California and some other states tax avoiders incur costs that are nearly as large as the tax revenues they avoid paying.

A Framework for Optimal Pigovian Taxes with Tax Avoidance

As we noted in the introduction, a common justification for excise taxes is that they reduce socially undesirable consumption. Consequently, we next consider the implications of

the transfer more precisely: the losses to other taxpayers, or the losses to the beneficiaries of state government spending, are gains for cigarette taxpayers.

tax avoidance for the optimal corrective Pigouvian tax rate. The social welfare gain (W) from the tax (T^H) is given by:

$$(7) \quad W = E (\Delta C^H - \Delta C^B) - A \Delta C^B - \frac{1}{2} T^H \Delta C^H$$

In equation (7): E is the external cost per pack of cigarettes; A is tax avoidance cost per pack of cigarettes; ΔC^H is the absolute value of the change in aggregate consumption of cigarettes purchased in the home state; and ΔC^B is the change in aggregate consumption of cigarettes purchased in the border state. The first term in equation (7) measures the net reduction in external costs of smoking, after taking into account tax avoidance. The second term measures the deadweight efficiency cost incurred by the tax avoiders. The last term in equation (7) is the standard triangle of deadweight consumers' surplus loss due to taxation in the home-state market, incurred by the consumers who do not avoid the tax. This last term approximates the amount by which the compensating variation in income for the tax T^H exceeds the tax revenues. The approximation reflects the use of a linear ordinary demand curve instead of a compensated demand curve.²¹

As can be seen in equation (7), one of the key determinants of the social welfare gains from cigarette taxation is the net reduction in cigarette consumption by home-state consumers, given by $\Delta C^H - \Delta C^B$. The size of this term determines the gains from reducing the external costs of smoking. Lovenheim (2008, p. 23) reports results that, on average, because of border-crossing home-state cigarette taxes “have a negligible effect on cigarette demand.” If so, the optimal state tax is obviously zero: the tax fails to reduce the external costs of smoking but still

²¹The tax avoidance term is also an approximation of the compensating variation in income for the extra distance tax avoiders travel to avoid taxes. These approximations are discussed in more detail in the Appendix.

generates avoidance costs and deadweight consumers' surplus losses. However, our direct estimate suggest a smaller tax avoidance response than Lovenheim's indirect estimate, so our estimate implies that the optimal Pigouvian state tax is not necessarily zero.

Assuming the optimal tax is not zero, we show in the Appendix that the optimal Pigouvian tax that maximizes social welfare can be expressed as:

$$(8) \quad T^{H*} = E - (E + A) \left[\frac{\epsilon^B}{\epsilon^H} \right] \left[\frac{C^B}{C^H} \right]$$

If there are no opportunities for tax avoidance and $\epsilon^B = 0$, equation (8) simplifies to the standard Pigouvian tax $T^{H*} = E$. As long as there is some tax avoidance, the optimal tax rate that takes into account tax avoidance is always smaller than the Pigouvian tax rate that ignores tax avoidance. The optimal tax rate decreases with the cross-price elasticity ϵ^B and the magnitude of cigarette purchases by home state residents from the border state C^B . These two factors work to make the home-state tax less effective in reducing the socially costly consumption of cigarettes, which pushes the optimal tax rate lower. The optimal tax rate also decreases with the per unit avoidance cost A . All three factors (ϵ^B , C^B , and A) work to mean that the tax generates more socially costly tax avoidance, which also pushes the optimal tax rate lower.

Illustrative Calculations of the Optimal Tax with Tax Avoidance

To develop illustrative calculations of the optimal cigarette tax T^{H*} given by equation (8), we combine standard estimates of E and ϵ^H with our estimates of ϵ^B , A , and C^B / C^H . 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 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 E 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. As discussed above: we use a benchmark estimate that ϵ^H , the elasticity of home purchases with respect to the home price, is 0.3; and we estimate that ϵ^B , the cross-price elasticity of border purchases with respect to the home-state price, is 3.86. We estimate that the shadow price of distance traveled to avoid cigarette taxes is \$0.05 per mile. For a border crosser who travels 30 miles (round trip) to purchase a carton of 10 packs of cigarettes, this implies that A, the avoidance cost per pack, is \$0.15. Based on the prevalence of border crossing in our data, we estimate that C^B / C^H , the ratio of cigarettes purchased from a border state over cigarettes purchased at home, is 0.053.

Using these parameter estimates in equation (8) provides an illustrative calculation that the optimal state excise tax on cigarettes is \$0.33 per pack. If there were no tax avoidance, the optimal state tax on cigarettes would be \$1.36 per pack, the external costs that remain after national corrective policies. In 2003 (when the TUSCS data were collected) the retail price of cigarettes included on average \$0.73 of state and local taxes per pack (Orzechowski and Walker 2007). For these parameter estimates, taking into account tax avoidance dramatically changes the policy prescription: on average states should be cutting, not hiking, cigarette excise taxes.

We next explore the implications of much higher levels of E and A on the calculations of the optimal tax. Using a higher estimate of E is a simple way to incorporate the argument from behavioral public economics that higher cigarette taxes might be justified based on externalities that consumers impose on their future selves (O'Donoghue Rabin 2003, 2006, Gruber and Koscegi 2004). Gruber and Koscegi (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 Koscegi (2004) 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 from \$1.36 per pack to \$4.36 per pack, from equation (8) the optimal tax increases to \$1.28. The policy prescription is now that most, but not all, states need to increase cigarette taxes. But the qualitative result, that taking into account tax avoidance sharply reduces the optimal tax on cigarettes, still holds. With externalities and internalities amounting to \$4.36 per pack, the tax avoidance costs of \$0.15 per pack become a more trivial component on the optimal tax calculation. However, tax avoidance still sharply reduces the optimal tax because it means that state taxation is not as effective at reducing either externalities or internalities.

The effect of a much higher value for A on the optimal cigarette tax sheds light on the relative importance of illegal smuggling versus legal cross-border purchases. The tax avoidance costs from cross-border purchases stem from the consumers' travel costs. Illegal but organized and large-scale smuggling might lower this component of A for consumers, through economies of scale in transporting cigarettes. However, the common argument is that illegal smuggling has consequences that are much costlier for other parts of society. Cigarette smuggling has been linked to organized crime and even terrorism.²² Shelley *et al.* (2007) report ethnographic

²²As discussed by the Advisory Commission on Intergovernmental Relations (1977) and Fleenor (2008), the links between cigarette smuggling and organized crime have been long-standing. 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).

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).

Developing a reasonable estimate of the tax avoidance costs A due to illegal 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 A have to be to drive the optimal tax to zero? Using our other baseline parameters in equation (8), if tax avoidance costs exceed \$0.63 per pack of cigarettes, the optimal state tax becomes zero. This result hinges in part on our baseline estimate 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 to zero.

6. Discussion

Our empirical models of cigarette tax avoidance show that consumers respond to the incentives created by excise tax differentials across states. It is not clear that there is anything particularly special about cigarettes that drives this consumer behavior. The other most commonly taxed goods in the U.S. – alcoholic beverages and gasoline – share some key similarities with cigarettes. All three goods are frequently purchased, which should lead to similar levels of consumer price search (Baye, Morgan, and Scholten 2006). In quantities intended for personal consumption beer and gasoline are about as easily transported as cigarettes and involve roughly similar expenditures. In fact, in certain localities convenience stores offer

“one-stop” tax avoidance. For example, in 2007 a consumer in Ohio who crossed the border into Kentucky could avoid \$5.20 of taxes on a carton of cigarettes, \$0.23 of taxes on a case of beer, and \$0.83 of taxes on 10 gallons of gasoline.

Of course, one key difference between the commonly taxed goods is that cigarettes are addictive to virtually all consumers. Based on insights from behavioral economic models of addiction, it has been suggested that smokers might purchase their cigarettes by the pack instead of the carton as a commitment device to limit their smoking (Khwaja, Silverman, and Sloan 2007). In exploratory regressions (available upon request), we find that smokers who report that they intend to quit within the next six months are less likely to make cross-border purchases and are less likely to purchase their cigarettes by the carton. Although not the only explanation, one interpretation is that some smokers refrain from purchasing less expensive cigarettes (across the border or by the carton) as a commitment device. To the extent fewer consumers of beer and gasoline see the need for a commitment device, consumers may be more likely to cross the border in response to beer and gasoline tax differentials than in response to cigarette tax differentials. A more complete examination of cigarette purchase practices as commitment devices is an interesting direction for future work.

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, we find that taking into account tax avoidance sharply reduces the optimal state cigarette tax to \$0.33 per pack. All but a handful of states already impose much higher cigarette taxes. At current levels of beer- and gasoline-tax differentials there is probably relatively little tax avoidance, so it might not seem to

matter as much for beer and gasoline tax policy. However, previous research estimates that current levels of both beer and gasoline taxes in the U.S. might be far below the optimal Pigouvian rate (as calculated without taking into account tax avoidance).²³ If one state unilaterally hiked beer or gasoline taxes to be closer to these estimates of the Pigouvian rate, it could stimulate substantial tax avoidance. The higher level of tax avoidance, in turn, would have important implications for the optimal tax rate in that state.

While we adopt the Pigouvian framework, we recognize that different criteria used in public economics to judge the desirability of taxes can lead to different conclusions. However, regardless of which of several common criteria are used, taking into account tax avoidance makes state cigarette taxes less desirable. The Ramsey inverse elasticity rule favors taxing inelastically demanded goods like cigarettes as a relatively efficient way to raise revenues at low deadweight loss. But tax avoidance makes state cigarette sales more elastic and hence makes cigarette taxes a less attractive way to raise revenue. In terms of tax fairness, cigarette taxes are regressive because the poor are more likely to smoke (Colman and Remler 2008). Our empirical results suggest that tax avoidance increases with income. Because richer smokers avoid more taxes, state cigarette taxes may be even more regressive than commonly estimated (DeCicca, Kenkel and Liu 2008b).

Political economy models introduce another set of criteria to judge the desirability of excise taxes (Seiglie 1990). Several empirical studies of states' tax-setting policies suggest that

²³Studies that suggest current beer taxes are far below the optimal Pigouvian rate include Manning *et al.* (1989), Pogue and Sgontz (1989), Kenkel (1996) and Parry *et al.* (2006). Similarly, Parry and Small (2005) and Harrington, Parry, and Walls (2007) suggest that current gasoline taxes fall far short of the Pigouvian rate. Both lines of research also suggest that other policy tools, such as penalizing drunk driving or imposing a vehicle-miles-traveled tax, have advantages over excise taxes on beer or gasoline.

tax avoidance makes the cigarette tax less politically desirable (Benjamin and Dougan 1997, Nelson 2002, Goel and Nelson 2007). This leaves something of a puzzle. Compared to state and local taxes, consumers have fewer opportunities to legally avoid the U.S. federal cigarette tax. Because of less tax avoidance, the federal cigarette tax seems to be more efficient, more equitable, and is predicted to even be more politically popular than state excise taxes. However, U.S. federal cigarette tax hikes have been less frequent and smaller than state tax hikes. Perhaps some idiosyncratic effect at work in U.S. federal politics helps explain the reluctance to tax cigarettes, compared either to U.S. state politics or to European politics that also have led to much higher national excise taxes on cigarettes (Cnossen 2005).

Appendix

Our extension of the formula for the Pigovian tax on cigarettes follows an 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.

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 $P^H = P + T^H$. Consumers who do not avoid the tax suffer a welfare loss which can be measured by the compensating variation (CV) in income that leaves them as well-off paying P^H as they were before the tax when they paid P . From the dual approach to the theory of the consumer, the CV can be defined as the difference in the minimum expenditures required to achieve a utility level v^* at the different prices:

$$(A1) \quad CV^{\text{NON-AVOIDER}} = e(P^H, v^*) - e(P, v^*)$$

In equation (A1) there are no other prices in the expenditure function $e(\cdot)$ because the price of the composite commodity g is unity and distance traveled is a non-market good. By Shephard's Lemma, the derivative of the expenditure function with respect to the price of cigarettes is the compensated or Hicksian demand function for cigarettes (Varian 1978). Because integrating the compensated demand curve $c(P, v)$ yields the expenditure function:

$$(A2) \quad CV^{\text{NON-AVOIDER}} = e(P^H, v^*) - e(P, v^*) = \int c(P, v) dP$$

Using Willig's (1976) results, the consumer's surplus measured using an ordinary demand curve is close to the CV measured using the compensated demand curve because expenditures on cigarettes are a relatively small share of most consumers' budgets. Approximating the ordinary demand curve as linear, the amount by which the compensating variation in income for the tax exceeds the tax revenues is approximately:

$$(A3) \quad CV^{\text{NON-AVOIDER}} - T^H = \int c(P, v) dP - T^H = \frac{1}{2} T^H$$

The term $\frac{1}{2} T^H$ enters text equation (7) as the deadweight welfare loss the tax creates for consumers who do not avoid it.

Consumers who purchase cigarettes across the border avoid paying a higher price for cigarettes but incur costs related to the distance traveled. Distance traveled is a non-market good, so to measure this welfare cost it is useful to use the theory of consumer behavior under rationing (Neary and Roberts 1980). The tax avoider pays the same price P both before and after the tax, but travels a longer distance d^{**} because of the tax. The CV to keep the tax avoider's utility at v^* is therefore equal to the CV required to keep the consumer's utility at v^* while rationing him or her to consume d^{**} instead of his or her optimal choice d^* :

$$(A4) \quad CV^{\text{AVOIDER}} = e(P, v^*; d = d^{**}) - e(P, v^*)$$

where $e(P, v^*; d = d^{**})$ is the constrained expenditure function showing the minimum

expenditures needed to achieve utility v^* when the consumer is constrained to consume the rationed amount d^{**} (Neary and Roberts 1980). Define Q^* and Q^{**} as the virtual prices for distance that would induce the consumer to optimally choose d^* and d^{**} , respectively. Because $d^* < d^{**}$, the virtual price Q^{**} must be less than the virtual price Q^* . Neary and Roberts (1980) show that the constrained expenditure function is related to the unconstrained expenditure function evaluated at the virtual price:

$$(A5) \quad e(P, v^*; d = d^{**}) = e(P, Q^{**}, v^*) + (Q^* - Q^{**}) d^{**}$$

Using this relationship, equation (A4) becomes:

$$(A6) \quad CV^{AVOIDER} = (Q^* - Q^{**}) d^{**} + e(P, Q^{**}, v^*) - e(P, Q^*, v^*)$$

The difference in the expenditure functions $e(P, Q^{**}, v^*) - e(P, Q^*, v^*) < 0$ because lower expenditures are required to achieve utility v^* at the lower virtual price Q^{**} . As above, the difference of the expenditure functions is the integral of the compensated demand curve for distance traveled $d(Q, v)$. Assuming the demand curve for distance traveled is approximately linear, substituting this into (A6) implies:

$$(A7) \quad CV^{AVOIDER} = (Q^* - Q^{**}) d^{**} - \int_{d^*}^{d^{**}} d(Q, v) dQ = \frac{1}{2} (Q^* - Q^{**}) (d^{**} - d^*)$$

where $Q = Q^* - Q^{**}$ and $d = d^{**} - d^*$. In relationship to the unobserved demand curve for distance as a function of its virtual price, the CV for the extra distance traveled to avoid taxes is given by a “triangle” of welfare cost. In the text, we describe how our empirical model yields an estimate of the shadow price of the extra distance traveled. The shadow price can be interpreted as the average of Q . Put differently, in the text we cite evidence from other approaches that the average cost or virtual price of distance traveled might be around \$0.70 per mile. If $Q^* = \$0.70$, our shadow price estimate implies that to induce d^{**} the virtual price would have to fall to \$0.65. The welfare cost of the extra distance is therefore approximated as the triangle with the area given by $\frac{1}{2} Q d = \$0.025 d$. We then put the avoidance costs on a per pack basis, denoted A in text equation (7).

Using these expressions for the welfare costs of taxation for non-avoiders and avoiders, and adding in the welfare gains from reducing the externality costs of smoking, yields text equation (7) showing the social welfare gain from the tax:

$$(A8) \quad W = E(C^H - C^B) - A C^B - \frac{1}{2} T^H C^H$$

Using the elasticities defined in the text implies that: $C^H = \epsilon^H C^H (T^H/P)$; and $C^B = \epsilon^B C^B (T^H/P)$. So the expression for the welfare gain can be re-written as:

$$(A9) \quad W = (1/P) \{ (E)(T^H) [\epsilon^H C^H - \epsilon^B C^B] - (A)(T^H) \epsilon^B C^B - \frac{1}{2} (T^H)^2 \epsilon^H C^H \}$$

To find the optimal tax T^{H*} that produces the maximum social welfare gain, take the derivative with respect to T^{H*} and set the first order condition to zero:

$$(A10) \quad \frac{dW}{dT^{H*}} = (1/P) \{ (E) [\sigma^H C^H - \sigma^B C^B] - (A) [\sigma^B C^B - T^{H*} \sigma^H C^H] \} = 0$$

Solving for T^{H*} yields text equation (8):

$$(A11) \quad T^{H*} = E - (E + A) \left[\frac{\sigma^B}{\sigma^H} \right] \left[\frac{C^B}{C^H} \right]$$

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Table 1: Descriptive Statistics

| Variable | Mean for Non-Crossers | Mean for Crossers |
|--|------------------------------|--------------------------|
| Price paid per pack of cigarettes (\$) | 3.32 | 2.71 |
| Home-state tax (\$) | 0.80 | 1.09 |
| Distance to lower-tax state (100 miles) | 1.31 | 0.82 |
| State anti-smoking sentiment | 0.19 | 0.20 |
| Age | 41.96 | 47.46 |
| Female | 0.52 | 0.52 |
| Black | 0.11 | 0.10 |
| Hispanic | 0.08 | 0.04 |
| Other race | 0.04 | 0.03 |
| Less than high school education | 0.17 | 0.14 |
| Some college | 0.30 | 0.29 |
| College or more | 0.15 | 0.19 |
| Family income \$25,000 - \$39,999 | 0.22 | 0.22 |
| Family income \$40,000 - \$74,999 | 0.29 | 0.31 |
| Family income \$75,000 or more | 0.17 | 0.20 |
| Household size | 2.68 | 2.38 |
| Married | 0.43 | 0.46 |
| Sample size | 16,033 | 867 |

Table 2: Prevalence of Cross-Border Cigarette Purchases and State Taxes

| State | % Smokers who Cross Border | State Excise Tax, 2003 (\$) | State | % Smokers who Cross Border | State Excise Tax, 2003 (\$) |
|---------------|-----------------------------------|------------------------------------|----------------|-----------------------------------|------------------------------------|
| Alabama | 3.04 | 0.165 | Montana | 1.81 | 0.70 |
| Alaska | 2.92 | 1.00 | Nebraska | 8.30 | 0.64 |
| Arizona | 1.83 | 1.18 | Nevada | 1.32 | 0.35 |
| Arkansas | 6.01 | 0.59 | New Hampshire | 1.15 | 0.52 |
| California | 2.38 | 0.87 | New Jersey | 12.27 | 1.50 |
| Colorado | 0.72 | 0.20 | New Mexico | 2.77 | 0.21 |
| Connecticut | 6.02 | 1.51 | New York | 5.64 | 1.50 |
| Delaware | 0.62 | 0.24 | North Carolina | 0.11 | 0.05 |
| D.C. | 21.49 | 1.00 | North Dakota | 0.99 | 0.44 |
| Florida | 1.36 | 0.339 | Ohio | 5.28 | 0.55 |
| Georgia | 1.24 | 0.12 | Oklahoma | 1.06 | 0.23 |
| Hawaii | 1.53 | 1.30 | Oregon | 1.40 | 1.28 |
| Idaho | 1.77 | 0.57 | Pennsylvania | 4.46 | 1.00 |
| Illinois | 11.13 | 0.98 | Rhode Island | 8.29 | 1.32 |
| Indiana | 5.08 | 0.555 | South Carolina | 0.87 | 0.07 |
| Iowa | 2.76 | 0.36 | South Dakota | 1.53 | 0.53 |
| Kansas | 8.90 | 0.79 | Tennessee | 6.04 | 0.20 |
| Kentucky | 0.53 | 0.03 | Texas | 1.30 | 0.41 |
| Louisiana | 1.41 | 0.36 | Utah | 5.72 | 0.695 |
| Maine | 6.66 | 1.00 | Vermont | 17.90 | 0.93 |
| Maryland | 15.67 | 1.00 | Virginia | 2.91 | 0.025 |
| Massachusetts | 14.59 | 1.51 | Washington | 7.72 | 1.425 |
| Michigan | 6.05 | 1.25 | West Virginia | 11.97 | 0.55 |
| Minnesota | 1.89 | 0.48 | Wisconsin | 2.40 | 0.77 |
| Mississippi | 2.76 | 0.18 | Wyoming | 1.15 | 0.12 |
| Missouri | 1.55 | 0.17 | | | |

Table 3: Reduced-Form Models of Border-Crossing

| | A | B | C | D | E |
|--|---------------------|---------------------|---------------------|---------------------|---------------------|
| distance to border | -0.065*** (5.77) | -0.057*** (5.53) | 0.002 (0.10) | -0.306* (1.70) | -0.001 (0.05) |
| distance² | 0.012*** (4.35) | 0.011*** (4.63) | -0.005 (1.28) | 0.007 (0.20) | -0.004 (1.04) |
| home-state tax | | 0.080*** (3.62) | 0.185*** (4.52) | 1.116*** (4.14) | 0.183*** (4.55) |
| border-state tax | | -0.076*** (3.14) | -0.172*** (4.10) | -1.008*** (3.81) | -0.172*** (4.18) |
| (home-state tax) * distance | | | -0.200*** (3.69) | -0.961** (2.44) | -0.197*** (3.66) |
| (home-state tax) * distance² | | | 0.056*** (4.69) | 0.323*** (3.80) | 0.055*** (4.64) |
| (border-state tax) * distance | | | 0.178*** (2.91) | 0.821 (1.48) | 0.176*** (2.89) |
| (border-state tax) * distance² | | | -0.046*** (3.32) | -0.238* (1.87) | -0.046*** (3.35) |
| state anti-smoking sentiment | | | | | 0.027 (1.26) |
| female | -0.0004 (0.13) | -0.0009 (0.31) | -0.0009 (0.31) | -0.058 (0.50) | -0.0008 (0.27) |
| age | 0.0005 (0.69) | 0.0005 (0.70) | 0.0006 (0.90) | 0.015** (2.19) | 0.0006 (0.91) |
| age² | 0.0007 (0.93) | 0.0007 (0.87) | 0.0005 (0.69) | -0.005 (0.63) | 0.0005 (0.67) |
| Black | -0.016 (1.43) | -0.018* (1.91) | -0.022*** (2.83) | -0.238** (2.31) | -0.022*** (2.79) |
| Hispanic | -0.019*** (2.62) | -0.017** (2.12) | -0.013* (1.86) | -0.245** (2.47) | -0.014** (2.08) |
| other race | -0.007 (0.82) | -0.006 (0.65) | -0.007 (0.74) | -0.076 (0.65) | -0.008 (0.86) |

| | | | | | |
|--|---------------------|---------------------|---------------------|--------------------|---------------------|
| less than high school | -0.002 (0.44) | -0.0009 (0.18) | -0.002 (0.35) | -0.022 (0.35) | -0.002 (0.32) |
| some college | 0.002 (0.40) | 0.003 (0.79) | 0.003 (0.64) | 0.025 (0.58) | 0.002 (0.57) |
| college or more | 0.008 (1.17) | 0.008 (1.29) | 0.007 (1.13) | 0.062 (1.15) | 0.007 (1.10) |
| income \$25,000 - \$39,999 | 0.008 (1.54) | 0.008 (1.52) | 0.008 (1.50) | 0.082 (1.55) | 0.007 (1.47) |
| income \$40,000 - \$74,999 | 0.012** (2.28) | 0.012** (2.31) | 0.011** (2.20) | 0.126** (2.35) | 0.011** (2.16) |
| income \$75,000 or more | 0.012* (1.90) | 0.010 (1.62) | 0.009 (1.51) | 0.105 (1.63) | 0.009 (1.46) |
| household size | -0.004*** (2.81) | -0.004*** (2.87) | -0.004*** (2.67) | -0.043** (2.42) | -0.004*** (2.73) |
| married | 0.002 (0.37) | 0.003 (0.72) | 0.003 (0.74) | 0.030 (0.66) | 0.003 (0.77) |
| marginal effect of distance^(a) | -0.034 | -0.028 | -0.031 | -0.029 | -0.028 |
| N | 16,900 | 16,900 | 16,900 | 16,900 | 16,900 |

Absolute values of t-ratios are in parenthesis. Models A, B, C, and E are OLS linear probability models. Model D is maximum likelihood probit. All models also include a constant term and a set of dummies for MSA size. Standard errors adjusted for non-independence of observations within MSAs.

(a) Marginal effect of distance is calculated at the mean distance for the sample. Distance is measured in units of 100 miles.

Table 4: Structural Endogenous Switching Regression Model

| | Probability of Border Crossing | Home-state price paid | Border-state price paid |
|---|---|----------------------------------|------------------------------------|
| distance to border | -0.021** (2.00) | | |
| distance² | 0.003 (1.65) | | |
| price difference | 0.100*** (4.53) | | |
| price difference * distance | -0.079*** (3.48) | | |
| price difference *distance² | 0.020*** (3.68) | | |
| home-state tax | | 1.077*** (30.55) | |
| border-state tax | | | 0.520*** (5.05) |
| female | 0.002 (0.75) | -0.011 (0.81) | 0.046 (0.59) |
| age | -0.0006 (0.79) | -0.026*** (7.47) | -0.045*** (3.01) |
| age² | 0.001* (1.67) | 0.015*** (3.81) | 0.028* (1.91) |
| Black | -0.005 (0.50) | 0.226*** (8.07) | 0.409*** (3.70) |
| Hispanic | 0.014 (1.17) | 0.253*** (7.93) | 0.800*** (3.25) |
| other race | 0.010 (0.98) | 0.011 (0.26) | 0.338 (1.56) |
| less than high school | -0.007 (1.24) | -0.042** (2.10) | -0.147 (1.31) |
| some college | 0.010** (2.07) | 0.033** (2,08) | 0.147** (2.04) |

| | | | |
|--|---------------------|---------------------|---------------------|
| college or more | 0.013* (1.89) | 0.189*** (6.69) | 0.259*** (2.56) |
| income \$25,000 - \$39,999 | 0.011** (1.98) | 0.091*** (4.32) | 0.142 (1.22) |
| income \$40,000 - \$74,999 | 0.009* (1.80) | 0.156*** (7.61) | 0.137 (1.42) |
| income \$75,000 or more | 0.014** (2.26) | 0.268*** (9.64) | 0.386*** (3.52) |
| household size | -0.008*** (4.77) | -0.015** (2.29) | -0.097*** (3.23) |
| married | 0.009** (2.25) | -0.052*** (3.07) | 0.050 (0.59) |
| correlation (ρ_{i^H, \cdot_i}) | | -0.050 (1.29) | |
| correlation (ρ_{i^B, \cdot_i}) | | | 0.017 (0.15) |
| marginal effect of distance^(a) | -0.029 | | |
| marginal effect of price difference^(a) | 0.058 | | |
| N | 16,900 | 16,033 | 867 |

Absolute values of t-ratios are in parenthesis. Each equation also includes a constant term and a set of dummies for MSA size. Standard errors adjusted for non-independence of observations within MSAs.

(a) Marginal effect of distance and price are calculated at the sample means. Distance is measured in units of 100 miles.

Table 5: Impact of Tax Avoidance on Revenues and Taxpayer Costs

| State | Tax revenues lost (\$1,000s) | Percentage of total cigarette tax revenues | Tax revenues gained by border state (\$1,000s) | Net loss of state tax revenues (\$1,000s) | Miles traveled to avoid taxes (1,000s) | Value of miles traveled to avoid taxes (\$1,000s) |
|--------------|------------------------------|--|--|---|--|---|
| Arizona | 5,298 | 2.18 | 3,247 | 2,050 | 41,144 | 946 |
| Arkansas | 6,632 | 6.27 | 2,912 | 3,720 | 61,518 | 3,814 |
| California | 23,691 | 2.31 | 9,531 | 14,160 | 481,911 | 11,084 |
| D.C. | 4,194 | 20.11 | 105 | 4,089 | 3,355 | 208 |
| Georgia | 1,377 | 0.93 | 365 | 1,011 | 54,508 | 1,254 |
| Idaho | 630 | 1.80 | 168 | 462 | 42,528 | 978 |
| Illinois | 74,639 | 10.89 | 30,465 | 44,174 | 466,719 | 28,937 |
| Indiana | 13,630 | 4.08 | 737 | 12,893 | 341,461 | 7,854 |
| Kansas | 12,081 | 10.22 | 3,058 | 9,022 | 78,908 | 4,892 |
| Maine | 6,119 | 6.54 | 3,182 | 2,937 | 22,516 | 1,396 |
| Maryland | 36,699 | 13.97 | 8,227 | 28,472 | 73,398 | 4,551 |
| Mass. | 67,656 | 15.72 | 26,603 | 41,053 | 128,592 | 7,973 |
| Michigan | 51,826 | 6.22 | 22,895 | 28,930 | 249,500 | 14,469 |
| Nebraska | 5,830 | 9.17 | 1,549 | 4,281 | 50,647 | 3,140 |
| New Jersey | 71,794 | 10.72 | 41,340 | 30,453 | 150,328 | 9,320 |
| New Mexico | 1,410 | 3.52 | 680 | 730 | 21,153 | 487 |
| New York | 79,451 | 8.13 | 53,738 | 25,713 | 263,873 | 16,360 |
| Ohio | 22,456 | 4.20 | 2,072 | 20,385 | 456,928 | 10,509 |
| Penn. | 31,773 | 3.56 | 13,133 | 18,640 | 184,282 | 11,425 |
| S. Dakota | 310 | 1.33 | 78 | 233 | 21,993 | 506 |
| Utah | 2,715 | 5.28 | 573 | 2,142 | 39,636 | 912 |
| Washington | 40,539 | 12.27 | 13,466 | 27,073 | 624,955 | 14,374 |
| W. Virginia | 7,711 | 10.95 | 516 | 7,195 | 153,000 | 3,519 |
| Wisconsin | 5,874 | 2.01 | 2,746 | 3,128 | 113,416 | 2,609 |
| Total | 585,654 | — | 247,586 | 338,065 | 4,215,215 | 166,329 |