The Effects of Tobacco Control Policies on Tobacco Products, Tar, and Nicotine Consumption: Evidence from Household Panel Data

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Abstract

We use the Nielsen Homescan Consumer Panel (NHCP) to estimate the effects of tobacco control policies on purchases of tobacco-related products using within-household variation. We also match 91% of cigarette product purchases in the NHCP to tar, nicotine, and carbon monoxide contents from the National Health and Nutritional Examination Surveys. Higher cigarette taxes reduce the number of cigarettes households purchase, but households also purchase cigarettes with higher tar, nicotine, and carbon monoxide contents. Contrary to previous findings, this effect is overwhelmed by the reduction in cigarettes purchased. Neither smokefree air laws nor smokeless tobacco taxes affect tobacco product purchases.

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I. Introduction

Cigarette smoking causes many adverse health outcomes including cancers of the mouth, pharynx, larynx, esophagus, stomach, pancreas, bladder, kidney, cervix, and stomach; stroke; coronary heart disease; chronic obstructive pulmonary disease; asthma; and low birth weight (U.S. Department of Health and Human Services, 2004). Additionally, smokeless tobacco (SLT) carries its own risks, including cancers of the mouth, tooth loss, and oral lesions (National Cancer Institute, 1992). In *The Handbook of Health Economics,* Chaloupka and Warner (2000) lay out a strong case for the importance of economic research into the impact of tobacco control policies on consumption and other outcomes. They state:

> "Economic analysis of the markets for tobacco products, particularly cigarettes, has contributed considerable insight to debates about the importance of the industry and the appropriate roles of public policy in grappling with the health consequences of tobacco. Certainly the most significant example of this phenomenon has been the rapidly expanding and increasingly sophisticated body of research on the effects of price increases on cigarette consumption. Because excise tax comprises an important component of price, the resultant literature has played a prominent role in legislative debates about using taxation as a principal tool to discourage smoking. In addition to informing legislative debates, this literature has contributed both theory and empirical evidence to the growing interest in modeling the demand for addictive products."

Indeed, the body of economic research suggests that tobacco consumption responds to policy levers such as cigarette taxes, although some important aspects of consumer responses to tobacco control policies remain relatively unexplored. For example, more detailed research examining

whether cigarettes and other tobacco-related products are economic substitutes or complements is needed, e.g., for predicting whether raising cigarette taxes will have the unintended consequence of raising SLT use. Little research examines whether cigarette smokers respond to tobacco control policies by switching to cigarette brands with higher nicotine contents, and relatively small sample sizes and limited time variation hinder the ability of many of these studies to reach consistent conclusions. Lastly, much of the economic research examining responses to tobacco control policies is based on repeated cross-section data, raising concerns about endogeneity arising from unobserved determinants of smoking levels.

This paper aims to address these existing issues in the literature. Using the Nielsen Homescan Consumer Panel (NHCP) between the years of 2004 and 2012, we examine a panel of households to estimate the effects of tobacco control policy changes on household purchases of cigarettes, smoking-cessation products, and chewing tobacco. Additionally, we use UPC codes and product names to match 91% of cigarette product purchases in the NHCP to cigarette characteristics from the National Health and Nutrition Examination Surveys (NHANES). This allows us to examine whether households respond to changes in tobacco control policies by changing the tar, nicotine, and carbon monoxide contents of the cigarettes they purchase, and moreover, whether tobacco control policies lead to changes in households' estimated intakes of these substances.

In a preview of our results, we confirm that cigarette taxes meaningfully reduce cigarette consumption, even when examining within-household variation. Results do not, however, provide strong evidence that smokefree air laws or SLT taxes lead to statistically significant changes in tobacco product purchases. We find some evidence that cigarette taxes lead to substitution toward the purchase of smoking-cessation products, but cigarette taxes do not lead to

statistically significant changes in SLT consumption. Lastly, and importantly, we find that cigarette taxes reduce estimated tar, nicotine, and carbon monoxide consumption, and we do not find consistent evidence of the compensatory behavior previously suggested by cross-sectional studies (Adda & Cornaglia, 2006; Evans & Farrelly, 1998; Farrelly, Nimsch, Hyland, & Cummings, 2004). These estimates are robust to the inclusion of controls for household-level demographic characteristics, geographic area controls expected to affect individual tobacco consumption, and time period, household, and geographic fixed effects.

The findings presented here therefore contribute to the literature in several ways. We present a comprehensive investigation of the impact of several principal tobacco control policies on household consumption habits across range of tobacco-related products. This includes investigating impacts on the consumption of smoking cessation products (e.g. electronic cigarettes, nicotine patches/gum, etc.), which, due to their relatively new and expanding presence in the marketplace, have not been studied in conjunction with tobacco control polies in a comprehensive way. Second, by matching detailed cigarette characteristics information on tar, nicotine, and carbon monoxide content, as well as cigarette length and type, from the NHANES back to the NHCP, we are able to more definitively understand the degree to which smokers alter their smoking behavior to compensate for changes in tobacco control policies. Lastly, our analysis leverages detailed household panel data to examine changes in smoking behavior within households across time in response to changes in tobacco control policies. This setup is ideal for addressing concerns that a changing pool of smokers may affect the estimation of conditional cigarette demand or smokers' compensatory behavior.

We view the findings in this paper as further demonstrating the effectiveness of cigarette excise taxes as a policy lever to reduce smoking levels, for a number of reasons. We find that

cigarette taxes lead to statistically and economically significant reductions in cigarette smoking, even when including household level fixed effects. Moreover, although previous literature utilizing cross sectional data has suggested that substitution to other tobacco products or cigarettes with higher tar and nicotine contents may offset the impact of cigarette taxes, our results suggest that this substitution is overwhelmed by the reduction in total cigarette purchases. Lastly, we find evidence suggesting that other tobacco control policies, such as smokefree air laws, have heterogeneous impacts on smoking outcomes.

The rest of this paper is organized as follows. Section II summarizes the previous economic literature estimating the effects of tobacco control policies, Section III describes the NHCP and other data sources, Section IV overviews our empirical strategy, Section V describes our results, and Section VI concludes.

II. Literature Review and Background

a) *Research on Tobacco Control Policies*

Literature on the impacts of tobacco control policies is vast and covers decades of research. Beginning in the 1970s, economists began to examine the link between cigarette prices and consumption. While elasticity estimates varied depending on timeframe, dataset, age group, etc., a general consensus about the effectiveness of cigarette taxes on reducing cigarette consumption has formed, with own-price elasticity estimates of between -0.2 and -0.6 for adults and -1.0 to -1.3 for youth (see Chaloupka & Warner (2000) for an extensive summary of the literature) . The evidence of the impact of taxes on cigarette demand is so well established that the Surgeon General's Report (2000) concluded "*raising tobacco excise taxes is widely regarded as one of the most effective tobacco prevention and control strategies."* Nevertheless, these conclusions

spurred even more research into the effects of other tobacco control policies, such as smoking bans and SLT taxes, and investigation into potential substitution across tobacco-related products.

For example, Ohsfeldt and Boyle (1994) conducted the first such study on SLT taxes and cigarette taxes using the Current Population Survey from 1985. They find a large own-price elasticity of approximately -0.5, as well as a strong positive cross-price elasticity with cigarettes of just under 0.5, suggesting (at least for adults) that substitution between cigarettes and SLT is present. Similarly, Ohsfeldt et al. (1997) follow up with a look at individual-level data (1997) from the 1995 Current Population Survey data, and conclude that the negative own-price elasticity is much smaller (about -0.15) and the cross-price elasticity is also smaller (only about 0.10). Chaloupka et al. (1997) revisit the question of SLT use after the Comprehensive Smokeless Tobacco Act of 1986 and other anti-smoking developments in the early 1990s. They find a large own-price elasticity for SLT. Among users, however, the price elasticity of the intensity of use is low. Tauras et al. (2007) revisit the SLT demand question, using the 1995, 1997, 1999, and 2001 National School-Based Youth Risk Behavior Survey, and find price elasticity estimates in the range of -0.1 to -0.2. Moreover, the contemporary and related literature of the impacts of smoking restrictions (smoking bans) is also prominent, with a number of recent studies showing a substantial reduction in cigarette sales and smoking prevalence following the implementation of smoking bans (Gallus et al., 2006; Levy, Chaloupka, & Gitchell, 2004). In an attempt to relate the SLT and smoking ban findings, Adams at al. (2013) utilize several waves of the Behavioral Risk Factor Surveillance System data to test for compensatory behavior across tobacco products. They find a meaningful increase in SLT use among smokers, particularly those who drink and are of typical bar-going age.

While very impactful, these studies have important shortcomings. They typically do not study tobacco control policies concurrently, nor are they able to leverage panel data, which presents identification challenges. In particular, much of the economic research examining responses to tobacco control policies is based on repeated cross-section data, raising concerns about endogeneity between tobacco control policies and unobserved determinants of smoking levels. By utilizing panel data in purchases from the NHCP for several years, on thousands of households, and across several tobacco-related products (including cessation/anti-tobacco products), this paper adds to the literature by addressing previous shortcoming and expanding the comprehensiveness of the studied policies and products.

b) Within-product Substitution and Compensation

In addition to reductions in consumption and substitution to other related products in response to tobacco control policies, there is also great interest in understanding the compensating behaviors among tobacco users in terms of within-product substitution. Economic theory suggests that if cigarette taxes are levied on each cigarette regardless of nicotine content, smokers may switch to brands with higher nicotine content or change the way which they smoke each cigarette (Adda & Cornaglia, 2006; Harris, 1980). From a policy perspective, if smokers reduce the number of cigarettes they smoke but do not change their intake of carcinogens in response to tobacco control policies, then the policies may not be effective at combating smoking-related disease. Evans and Farrelly (1998) and Farrelly et al. (2004) examine whether cigarette tax or price increases lead smokers to purchase cigarettes with higher tar and nicotine contents. Both studies find that smokers facing higher cigarette taxes decrease the self-reported number of cigarettes smoked but that these taxes are associated with increased tar and nicotine contents of the cigarettes smoked. This increase in tar and nicotine content offsets the reduced

number of cigarettes smoked, leaving daily estimated nicotine intake unchanged. However, these papers are both limited by only having access to data sources with only two time periods, which reduces the ability of the authors to control for state-level unobservable characteristics without generating large standard errors. Evans and Farrelly (1998) use the 1979 Smoking Supplement and 1987 Cancer Control Supplements to the National Health Interview Survey, a repeated cross section dataset. While they find statistically significant increases in tar and nicotine contents in response to cigarette tax changes in pooled-OLS models, including state-fixed effects renders very large standard errors and statistically insignificant coefficients. Farrelly et al. (2004) use two waves of the Community Intervention Trial for Smoking Cessation (COMMIT) project, which follows smokers through a randomly-assigned smoking cessation program.[1] Here again, limitations in the time period variation contribute to the authors choosing a random-effects, rather than a fixed effects, framework.

Some more recent studies measure smoking behavior through biomarkers of recent nicotine intake, although these papers arrive at differing conclusions. Adda and Cornaglia (2006) find that while increased cigarette taxes decrease the number of cigarettes smoked, cigarette taxes do not change the average levels of serum cotinine, a biomarker of recent nicotine exposure, found in smokers. However, Abrevaya and Puzzello (2012), a comment, find that Adda and Cornaglia's results are unstable when the sample is increased to all respondents in the NHANES III data. In a reply Adda and Cornaglia (2013) extend the NHANES III data set through 2006 and find that their initial results largely hold. Most recently, Nesson (2015) extends the NHANES dataset further to include data through 2012 and finds that cigarette taxes lead to statistically significant reductions in serum cotinine levels.

[1] Please see Farrelly et al. (2004) for more information regarding the COMMIT project.

However, in addition to sharing problems associated with utilizing cross-sectional data discussed above, these studies leave other issues unresolved as well. Most importantly, small sample sizes and limited time variation cause these papers to arrive at differing conclusions regarding whether compensating behavior exists and, if so, how much it offsets reductions in cigarette consumption. Second, measuring changes in smokers' behavior using the self-reported number of cigarettes smoked and information from cigarette packs may introduce measurement error. The self-reported number of cigarettes smoked per day shows evidence of misreporting, as most responses are for round numbers of cigarettes smoked per day such as five, 10, or 20 cigarettes smoked per day. However, the actual number of purchases per month in the NHCP display no such discontinuities. Relatedly, previous studies which examine changes in smokers' cigarette brand purchases such as Evans and Farrelly (1998) and Farrelly et al. (2004), determine cigarette characteristics by asking survey respondents to provide a pack of cigarettes that they usually smoke.[2] This may omit information if smokers purchase more than one brand of cigarette, and if multi-product purchases are correlated with tobacco control policies, this may lead to biased estimates of smokers' responses to tobacco control policies. Using biomarkers of smoking intake to measure smokers' behavior offers an advantage over using the self-reported number of cigarettes smoked in that there is less measurement error introduced by misreports. However, the use of biomarkers introduces its own concerns. First, the collection of biomarkers is a time and money-intensive process, so surveys containing biomarkers such as NHANES contain much smaller sample sizes than other health surveys such as the Behavioral Risk Factor Surveillance System or National Health Interview Survey. Second, as biomarkers of nicotine are metabolized and removed from the body, smokers consuming the same amount of nicotine on

[2] For example, in NHANES survey respondents are asked, "May I please see the pack for the brand of cigarettes you usually smoke?" See the NHANES documentation for the smoking module for the 2011/2012 waves, available at http://wwwn.cdc.gov/nchs/nhanes/2011-2012/SMQ_G.htm (accessed February 2015).

average may have very different levels of these biomarkers, depending on the time of day or day of the week they were interviewed.

III. Data

To study the comprehensive impact of state-level policies on household purchases of tobacco and anti-tobacco products, we use data from the NHCP between 2004 and 2012. The Nielsen Corporation recruits a sample of American households that continually provide information on their purchasing behavior, including when and where they shop, what food and non-food items they purchase, and how much they pay for each item. Specifically, Nielsen provides each NHCP household with a device to scan the UPC code of each item they purchase on a shopping trip and report where they bought the item. If the store participates in Nielsen's point-of-sale (POS) data collection program, the item is assigned the average weekly price of that good at that store. If the store is not a POS participant, the Homescan panelist is asked to provide the price. Each unique UPC code is treated as a separate item.

The sample includes respondents from all states and major metropolitan areas, and allows for calculations of national, regional, and market area projections. The dataset contains approximately 40,000 households between 2004 and 2006, and 60,000 households between 2007 and 2012. Respondents are provided incentives to encourage continued participation, but these are designed to not influence purchasing habits. Approximately 80% of households each year continue participation in the following year.

The NHCP does not include purchases made outside of retail stores, which may underestimate total household purchases and, importantly for this project, bias estimates of policy responses. A primary concern is Internet purchases. Although online purchases cannot

directly be measured, the potential for bias in elasticity estimates will be addressed by including a measure of household Internet use from the NHCP.

While the NHCP is a rich data source of all retail purchases, it does not provide details about the characteristics of cigarettes purchased. To complement the data on household purchases, we merge in cigarette characteristics collected from the National Health and Nutrition Examination Surveys (NHANES). NHANES is a cross-sectional survey of health and nutritional information conducted by the CDC which combines surveys, physical examinations, and laboratory measurements. NHANES releases waves every two years, and each wave is nationally representative and contains about 10,000 individuals. Since the 2001-2002 wave, NHANES has collected cigarette UPC codes and characteristics including tar, nicotine, and carbon monoxide contents as measured by the Federal Trade Commission. We created a database of all the unique UPC codes with cigarette characteristics and NHANES survey wave combinations. We then merged the cigarette characteristics using the survey wave and UPC code. Using our match algorithm, we match 91% of cigarette brands and 90% of cigarette purchases.[3] We use this information to construct two types of measures of cigarette characteristics. First, we examine the average characteristic levels that households consume per month, aggregating characteristics for each cigarette pack to the household-month level. For example, here we construct a measure of the average nicotine content of the cigarettes a household consumes using the average nicotine content of each unique brand purchased by each household-month cell weighted by the number

[3] When merging based on complete survey year and UPC matches, approximately 35% of cigarette purchases were for a brand that was successfully assigned NHANES characteristics. In order to increase the match rate we successively stepped backward through NHANES years until a purchase matched a UPC (or until the NHANES years were exhausted). This additional step increased the cigarette purchase match rate to approximately 43% of recorded cigarette purchases. Finally, since unique UPC codes are generated for each packaging variation of a cigarette brand (i.e. single packs vs. 3-packs vs. cartons), we standardized cigarette product names in the NHCP to match cigarette products for which a package variety was matched to NHANES. This additional step increased our match rate to 91%. This additional step assumes that cigarette brand characteristics are identical across packaging, i.e. 84mm Marlboro Light Non-Menthol cigarettes have identical nicotine, tar, and carbon monoxide characteristics whether sold in single packs or cartons.

of cigarettes purchased of each brand. We also construct measures of the estimated tar, nicotine, and carbon monoxide consumption by multiplying the tar, nicotine, and carbon monoxide contents of each cigarette brand by the number of purchases of that brand and then summing across all brands consumed by each household-month cell.

Data on cigarette tax rates are available in the Tax Burden on Tobacco (TBOT) historical compilation, produced by Orzechowski and Walker (2012). The TBOT is an annual compendium of tobacco revenues and industry statistics that provides information on cigarette taxes for all 50 states and the District of Columbia, as well as information on the month and year in which tax changes occurred. We use this information to assign real (denominated in Q4 2012 dollars) cigarette tax rates for every household in the NHCP. A few cities, such as Chicago and New York, levy municipal-level cigarette taxes. In these rare cases, and when the household-level data allow for the identification of municipality, we use historical information on local cigarette tax rates drawn from municipal tax administrators. We also include an indicator variable for whether a state levies a SLT tax using data from the Centers for Disease Control and Prevention and the Office on Smoking and Health. Lastly, we include a measure of the percent of each household's county that lives under a smoking ban in bars derived from Americans for Nonsmokers' Rights Foundation (ANR) Tobacco Control Laws Database. The ANR Tobacco Control Laws Database is a repository of nearly 8,500 state, county, and municipal laws, with detailed information about the day, month, and year of implementation by legislative type (e.g. clean indoor air laws/smoking bans, youth access, advertising, conditional use permits). Using the ANR database, we calculate the percent of each county living under a smoking ban in bars in each quarter.

IV. Methods

We utilize a quasi-natural experiment design, connecting policy changes within counties and states, over time, to within-household variation in tobacco-related purchases. We first estimate the effects of tobacco control policies on the purchase of a comprehensive set of tobacco products, including cigarettes, SLT, and smoking-cessation products. Thus, we are able to study potential substitution responses when the scope of a policy is limited to only specific tobacco products. We utilize household fixed effects regression models to estimate the total effect of tobacco control policies on each tobacco product. We first estimate a linear probability model to estimate the probability that a household purchases a specific tobacco product as follows:

$$(1) \qquad \mathrm{P}(T_{hst} > 0) = \beta_0 + Z_{st}\beta_Z + X_{hst}\beta_X + \tau_t + \delta_h + \varepsilon_{hst},$$

where $\mathrm{P}(T_{hst} > 0)$ is the probability that household *h* at time *t* purchases the tobacco product of interest, Z_{st} includes tobacco control policies such as cigarette taxes expressed in dollars or an indicator variable for whether a smoking ban is in effect, and X_{hst} contains household-level demographic characteristics. We also include time period (year and month) and household fixed effects, given by τ_t and δ_h, respectively. As we include household fixed effects, we only include households in these models which contain variation in whether they purchase cigarettes. In these instances, a dichotomous measure at the household level can be a reasonable proxy for cessation, although in multi-person households it is only an indirect measure. We will also vary our model specification to include geographic fixed effects and time trends to demonstrate the robust of the results to these alternative approaches.

Next we estimate the effects of tobacco control policies on the amount of tobacco products purchased using a similar fixed effects model:

$$(2) \qquad T_{hst} = \alpha_0 + Z_{st}\alpha_Z + X_{hst}\alpha_X + \tau_t + \delta_h + \varepsilon_{hst},$$

where T_{hst} represents the amount of the tobacco product purchased each month and all other variables are defined as above. By estimating the effects of each policy on each tobacco product category within this framework we will identify the comprehensive, causal policy effects across all tobacco product sub-categories. We also use the merged cigarette characteristics from the NHANES to explore whether tobacco control policies induce smokers to substitute to cigarettes that have higher tar, nicotine, and carbon monoxide contents. To estimate these effects, we examine all purchases which can be matched to cigarette characteristics and examine household-month observations where at least one purchase is matched to cigarette characteristics. We also ran models where we restrict our sample to households where all purchases can be matched to cigarette purchases, and the results from these regressions are very similar. We modify Equation (2) to run two additional models. First, we replace the dependent variable with cigarette characteristics. Specifically, we look at the tar, nicotine, and carbon monoxide contents of each cigarette, measured in milligrams.[4] If a household purchases more than one cigarette brand per month, we weight the different product characteristics by the amount of each specific cigarette brand purchased. Second, we multiply the tar, nicotine, and carbon monoxide contents of each cigarette by the number of cigarettes purchased to arrive at an estimated monthly consumption level for these different compounds. We cluster our standard errors at the household level in all regressions (Bertrand, Duflo, & Mullainathan, 2004).

[4] We also examined whether the cigarettes purchased were filtered and cigarette length as measured by an ordinal variable: 1 (68-72mm), 2 (79-88mm), 3 (94-101mm), and 4 (110-121mm). We do not report these results in our main tables. With respect to filtered cigarettes, this variable did not have meaningful variation, as 99 percent of cigarettes in our sample are filtered. As cigarette length is only measured on an ordinal scale, we do not have as much variation in this variable either. Additionally, longer cigarettes would be most relevant for policy makers as all else equal they contain more tar, nicotine, and carbon monoxide. However, we already have direct measures of these substances. We did run regressions using filtered cigarette purchases or cigarette length as dependent variables and not find that tobacco control policies had statistically or economically significant effects on either.

V. Results

a) Analysis of Extensive and Intensive Purchase Habits and Tobacco Product Substitution

Table 1 shows summary statistics. Our total sample includes just over 5.6 million observations, although we only include households which use the relevant tobacco product at least once during our sample. Thus our analysis sample is 1,750,752 observations from 36,988 households for cigarettes, 335,649 observations from 6,081 households for smoking-cessation products, and 396,589 observations from 7,048 households for chewing tobacco products. In a month, the probability that a household purchases cigarettes is just about 9%, and the average number of cigarettes purchased among ever-purchase households is 139 cigarettes per month, or about 5 cigarettes per day per household.

Table 2 shows results estimating the effects of tobacco control policies on tobacco-related purchases using the models outlined in Equations (1) and (2). We find that a $1.00 increase in cigarette taxes reduces the probability that a household will purchase cigarettes in a quarter by 2.2 percentage points, statistically significant at the one percent level. This coefficient suggests a reduction of roughly 8 percent off the mean of 0.29 and translates to a participation tax elasticity of around 9 percent, slightly smaller than most participation elasticities in the literature (Evans & Farrelly, 1998; Nesson, 2015; J. A. Tauras, 2004, 2006). We also find some evidence that increases in cigarette taxes also increase the probability that households will purchase smoking-cessation products. Specifically, results suggest that a $1.00 increase in cigarette taxes increases the probability that a household purchases smoking-cessation products by roughly 7 percent off the mean, although this coefficient is only statistically significant at the 10 percent level. We do not find statistically significant changes in consumers' likelihood to make tobacco-related purchases in response to SLT taxes or bar smokefree air laws when looking at this sample.

However, when turning to an examination of the total quantities of tobacco products purchased, we find that a $1.00 increase in cigarette taxes reduces the quantity of cigarettes that ever-purchase households purchase by about 16 cigarettes a month, corresponding to about a 12 percent decrease off the mean of 139 cigarettes a month and a tax elasticity of about -0.13. These results are comparable to those in the literature (Adda & Cornaglia, 2013; Evans & Farrelly, 1998; Farrelly et al., 2004; Harding, Leibtag, & Lovenheim, 2012; Nesson, 2015; J. A. Tauras, 2006).[5] Additionally, we find some evidence that if a state imposes a SLT tax, households will purchase about 21 fewer cigarettes per month, although this coefficient is only significant at the 10 percent level.

Next, we investigate whether there is heterogeneity along a few dimensions in the estimated effects of tobacco control policies on tobacco-related purchases as suggested by previous analysis of repeated cross section data. First, previous research suggests that heavy and light smokers may respond differently to tobacco control policies (Maclean, Webber, & Marti, 2014; Nesson, 2015), and second, research also suggests that inter-tobacco product substitution may be concentrated among younger every-day smokers (Adams et al., 2013). To examine these sources of heterogeneity, we estimate separate models for households who purchase an average of 300 cigarettes per month or less (occasional smoker households) versus an average of 600 cigarettes per month or more (pack-a-day smoker households), and we also estimate models where we restrict our sample to single person households. Table 3 displays results from these additional models. Comparing the results from occasional smokers versus pack-a-day smokers in the top two sets of regression results, we see that heavier smokers respond more strongly to

[5] We tested the robustness of our results to including state fixed effects and state-specific time trends, and these results are very similar in terms of coefficient size and statistical significance. Appendices A and B show results from these regressions. We also tested the effects of examining our data set in a repeated cross-section context by removing household fixed effects and instead including state fixed effects. These results are contained in Appendix C and are again comparable to our main results.

cigarette taxes in terms of the number of cigarettes smoked. However, in terms of tax elasticities, lighter smoking households are much more responsive with an estimated conditional tax elasticity of around -0.22 compared to -0.11. In our main specification, we no longer find evidence that cigarette taxes impact the likelihood of purchasing smoking cession products among either type of smoker.[6] Examining single households, we see very similar participation and conditional demand cigarette tax elasticities for the number of cigarettes smoked per day. Additionally, similar to Adams et al. (2013), we find that single households are more likely to substitute chewing tobacco for cigarettes in response to bar smoking bans, and every percentage point increase in the percent of the county population under a bar smoking ban increases the ounces of chewing tobacco purchased by 0.44 percent.

b) Analysis of Compensatory Behavior; Cigarette Characteristics

In addition to reductions in consumption and substitution to other related products in responses to tobacco control policies, there is also great interest in understanding the compensating behaviors among tobacco users in terms of within-product substitution. In this regard, we leverage the product-code level detail provided in the NHCP data to match our sample of NHCP tobacco purchases to cigarette characteristics in the NHANES in order to estimate whether tobacco control policies induce smokers to switch to cigarettes with different characteristics and whether tobacco control policies lead to reductions in estimated tar, nicotine, and carbon monoxide intake. Table 4 shows summary statistics from the matched sample of cigarette purchases, which contains all households where at least one product could be matched

[6] These results are somewhat sensitive to model specifications. When we include both state fixed effects and state specific time trends, we find that cigarette taxes increase the probability that occasional smoker households purchase smoking cessation products and reduce the probability that occasional smoker households purchase chewing tobacco.

to NHANES. Nearly all cigarettes purchased in this sample are filtered. The average tar, nicotine, and carbon monoxide contents are just under 12mg, 1mg, and 12mg, respectively. As a basis for comparison, Winston Filtered 100mm cigarettes have 16mg of tar, 1.3mg of nicotine, and 15mg of carbon monoxide. On the lower end of tar, nicotine, and carbon monoxide contents, Marlboro Ultra-Light 83mm cigarettes have 6mg of tar, 0.5mg of nicotine, and 8mg of carbon monoxide.

Table 5 and Figure 1 show estimates from the models estimating the effects of tobacco control policies on cigarette characteristics and estimated tar, nicotine, and carbon monoxide consumption. The left panel of Table 5 displays results estimating whether tobacco control policies affect the average tar, nicotine and carbon monoxide contents of the cigarettes consumers purchase, all measured in milligrams. We find some evidence that cigarette taxes lead to statistically significant changes in tar, nicotine, and carbon monoxide content. For example, in our preferred specifications, a $1.00 increase in cigarette taxes leads to a statistically significant increases of 0.0877mg, 0.0057mg and 0.0058mg in the average tar, nicotine, and carbon monoxide contents of cigarettes smoked. However, these point estimates translate to very small tax elasticities of 0.0075, 0.0060, and 0.0004 in the average tar, nicotine, and carbon monoxide contents, respectively. The small magnitudes of these elasticities are visually apparent in Figure 1. Furthermore, these results for tar, nicotine, and carbon monoxide are not robust to changing the sample or to the inclusion of additional geographic controls.[7]

[7]While these results are robust to the inclusion of state fixed effects, they are not robust to the additional inclusion of state-specific time trends. These results can be seen in Appendix Tables A3 and B3. We also tested whether our results were robust to only examining households where *all* purchases, rather than *at least one purchase*, are matched to cigarette characteristics, and these results are shown in Appendix D. As these households are less likely to change brands, we not surprisingly find that the coefficients on the average tar, nicotine, and carbon monoxide contents are not statistically significant at conventional levels and are roughly half the size of the coefficients in our preferred specification.

The right panel displays results estimating whether tobacco control policies affect estimated household monthly tar, nicotine, and carbon monoxide consumption. For comparison, we also include results for monthly cigarette purchases among this subsample. Here, our coefficients are all negative and statistically significant at the 1 percent level. We find that cigarette excise taxes lead to a reduction in cigarette purchases of about 31 cigarettes a month, a tax elasticity of about -0.07. We find very similar and negative elasticities with respect to tar, nicotine, and carbon monoxide consumption, all around -0.07 and statistically significant at the one percent level. Figure 1 visually shows the similarity in tax elasticities between cigarette purchases and estimated tar, nicotine, and carbon monoxide consumption. These outcomes indicate that, while some compensatory behavior exists with regard to tax increases, these effects are overwhelmed by households purchasing fewer cigarettes.

Finally, we compare our results to previous studies by transforming our coefficients into tax elasticities and comparing them to tax elasticities from previous literature. A summary of the tax elasticities in this literature estimating smokers' compensatory behavior, and how our results compare, is provided in Table 6.[8] Notably, our results (presented in row 1) intersect the confidence intervals of all of the other papers presented. However, the precision of the estimates presented in this paper is much higher in all cases but one.[9] This suggests that a strong degree of confidence can be attributed to our estimates, as they build on the previous literature but are able to improve on identification and precision with the use of household panel data from the NHCP and merged cigarette characteristics from the NHANES. In many ways these results tie together conflicting estimates of smokers' compensatory responses to cigarette taxes. Like Evans and Farrelly (1998) and Farrelly et al. (2004), which use self-reported cigarette consumption and

[8] Appendix D summarizes our calculation of tax elasticity estimates in the previous literature.
[9] In Farrelly et al. (2004) the confidence interval for their estimates of tax elasticity of cigarettes is comparable, but their estimates are not statistically significant, except for the youngest age group of 25-34.

cigarette characteristics, we find evidence that smokers increase the tar and nicotine contents of the cigarettes they smoke in response to cigarette taxes. However, given our more extensive data source, we are able to identify these effects even when accounting for household fixed effects. Similar to more recent estimates of smokers' compensatory behavior using biomarkers of nicotine intake, we find that smokers' compensatory responses are not large enough to meaningfully offset reductions in the number of cigarettes smoked (Nesson, 2015).

VI. Conclusion

This paper utilizes household panel data to estimate the effects of tobacco control policies on a range of tobacco-related outcomes, including purchases of cigarettes, SLT, and smoking-cessation products. Using panel data on the monthly purchases of a large number of households, we are able to control for household-level fixed effects, which provides much clearer evidence of detailed changes in purchasing habits in response to different tobacco control policies. Moreover, we are able to circumvent the many potential issues arising from the use of self-reported smoking data. Lastly, we are able to look at within-household changes in cigarette characteristics, including the tar, nicotine, and carbon monoxide contents of the cigarettes smoked, and estimate the total household intake of these substances.

Our results provide convincing evidence that cigarette taxes are an effective policy lever with which to reduce cigarette smoking. We find that, even when examining cigarette purchases within households over time, cigarette taxes both induce households to stop purchasing cigarettes and reduce the number of cigarettes that they purchase. Additionally, we find some evidence that increased cigarette taxes increase the probability that households purchase smoking cessation products. When we stratify our sample into light vs. heavy smoking households and

single households, we find that cigarette taxes reduce cigarette smoking in all subgroups. We do find some evidence that bar smoking bans reduce cigarette purchases in single households, but we also find that these bans increase chewing tobacco purchases. Lastly, we find some, albeit weak, evidence that households respond to cigarette taxes by switching to cigarettes with higher tar, nicotine, and carbon monoxide contents. However, these changes are too small to be economically significant, and we find that the reduction in the number of cigarettes smoked per day overwhelms these small increases in the tar, nicotine, and carbon monoxide contents of cigarettes. When we run models estimating how households' total estimated tar, nicotine, and carbon monoxide consumption is affected by tobacco control policies, we find tax elasticities of total tar, nicotine, and carbon monoxide consumption that are very close to the tax elasticity of cigarettes purchased.

Our methodology and dataset lend themselves to a number of extensions. First, although our results are in line with previous estimates of smokers' responses to tobacco control policies, little research has addressed the relationship between self-reported measures of consumption and scanner-data measures of purchases. In particular, future research could estimate whether taxes and other policies affect purchase venues and thus the probability that households scan certain items. Additionally, the literature on consumers' responses to taxes and prices has also recently examined the effect of salience on purchasing behavior, and our data are well positioned to add to the literature examining whether smokers respond differently to more salient taxes, included in the price of the cigarettes, or less-visible sales taxes, incorporated only at the register.

References

Abrevaya, J., & Puzzello, L. (2012). Taxes, Cigarette Consumption, and Smoking Intensity: Comment. *American Economic Review*, *102*(4), 1751–1763. Retrieved from http://www.aeaweb.org/articles.php?doi=10.1257/aer.102.4.1751

Adams, S., Cotti, C., & Fuhrmann, D. M. (2013). Smokeless Tobacco Use Following Smoking Bans in Bars. *Southern Economic Journal*, *80*(1), 147–161. Retrieved from http://econpapers.repec.org/RePEc:sej:ancoec:v:80:1:y:2013:p:147-161

Adda, J., & Cornaglia, F. (2006). Taxes, Cigarette Consumption, and Smoking Intensity. *The American Economic Review*, *96*(4), 1013–1028. doi:doi:10.1257/000282806779468553

Adda, J., & Cornaglia, F. (2013). Taxes, Cigarette Consumption, and Smoking Intensity: Reply. *American Economic Review*, *103*(7), 3102–3114. Retrieved from http://www.aeaweb.org/articles.php?doi=10.1257/aer.103.7.3102

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How Much Should We Trust Differences-In-Differences Estimates? . *The Quarterly Journal of Economics* , *119* (1), 249–275. doi:10.1162/003355304772839588

Chaloupka, F. J., Tauras, J. A., & Grossman, M. (1997). Public Policy and Youth Smokeless Tobacco Use. *Southern Economic Journal*, *64*(2), 503–516. doi:10.2307/1060863

Chaloupka, F. J., & Warner, K. E. (2000). Chapter 29 The economics of smoking. *Handbook of Health Economics*, *1*, 1539–1627. doi:10.1016/S1574-0064(00)80042-6

Evans, W. N., & Farrelly, M. C. (1998). The Compensating Behavior of Smokers: Taxes, Tar, and Nicotine. *The RAND Journal of Economics*, *29*(3), 578–595. doi:10.2307/2556105

Farrelly, M. C., Nimsch, C. T., Hyland, A., & Cummings, M. (2004). The effects of higher cigarette prices on tar and nicotine consumption in a cohort of adult smokers. *Health Economics*, *13*(1), 49–58. doi:10.1002/hec.820

Gallus, S., Zuccaro, P., Colombo, P., Apolone, G., Pacifici, R., Garattini, S., & La Vecchia, C. (2006). Effects of new smoking regulations in Italy. *Annals of Oncology* , *17* (2), 346–347. doi:10.1093/annonc/mdj070

Harding, M., Leibtag, E., & Lovenheim, M. F. (2012). The Heterogeneous Geographic and Socioeconomic Incidence of Cigarette Taxes: Evidence from Nielsen Homescan Data. *American Economic Journal: Economic Policy*. Retrieved from http://www.aeaweb.org/articles_detail.php?doi=10.1257/pol.4.4.169

Harris, J. E. (1980). Taxing tar and nicotine. *The American Economic Review*, 300–311.

Levy, D., Chaloupka, F. J., & Gitchell, J. (2004). The Effects of Tobacco Control Policies on Smoking Rates: A Tobacco Control Scorecard. *Journal of Public Health Management and Practice*, *10*(4), 338–353.

Maclean, J. C., Webber, D. A., & Marti, J. (2014). An Application of Unconditional Quantile Regression to Cigarette Taxes. *Journal of Policy Analysis and Management*, *33*(1), 188–210. doi:10.1002/pam.21724

National Cancer Institute. (1992). *Smokeless Tobacco or Health: An International Perspective. Tobacco Control Monograph No. 2*. Bethesda, MD.

Nesson, E. (2015). *Heterogeneity in Smokers' Responses to Tobacco Control Policies*. Retrieved from http://ssrn.com/abstract=2558140

Ohsfeldt, R. L., & Boyle, R. G. (1994). Tobacco Excise Taxes and Rates of Smokeless Tobacco Use in the US: An Exploratory Ecological Analysis. *Tobacco Control*, *3*(4), 316–323. doi:10.2307/20207099

Ohsfeldt, R. L., Boyle, R. G., & Capilouto, E. (1997). Letter: Effects of tobacco excise taxes on the use of smokeless tobacco products in the USA. *Health Economics*, *6*(5), 525–531. doi:10.1002/(SICI)1099-1050(199709)6:5<525::AID-HEC300>3.0.CO;2-Y

Orzechowski, W., & Walker, R. C. (2012). *The tax burden on tobacco, historical compilation*. Arlington, VA.

Tauras, J. A. (2004). PUBLIC POLICY AND SOME-DAY SMOKING AMONG ADULTS. *Journal of Applied Economics*, *7*(1).

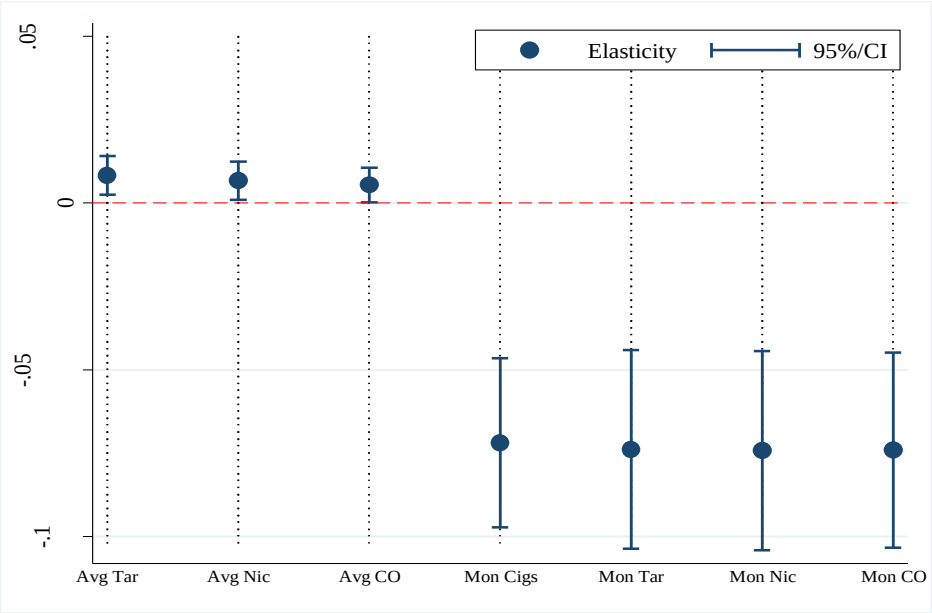
Tauras, J. A. (2006). SMOKE-FREE AIR LAWS, CIGARETTE PRICES, AND ADULT CIGARETTE DEMAND. *Economic Inquiry*, *44*(2), 333–342. doi:10.1093/ei/cbj028

Tauras, J., Powell, L., Chaloupka, F., & Ross, H. (2007). The demand for smokeless tobacco among male high school students in the United States: the impact of taxes, prices and policies. *Applied Economics*, *39*(1), 31–41. doi:10.1080/00036840500427940

U.S. Department of Health and Human Services. (2000). *Reducing Tobacco Use: A Report of the Surgeon General*. Atlanta, Georgia.

U.S. Department of Health and Human Services. (2004). *The Health Consequences of Smoking, A Report of the Surgeon General.* Rockville, MD.

Figure 1. Estimated tax elasticities
Average cigarette characteristics and monthly purchases



Notes: Each dot and bar show estimated tax elasticities and corresponding 95% confidence intervals for the effects of cigarette taxes on cigarette characteristics and monthly consumption of cigarettes, tar, nicotine, and carbon monoxide. These elasticities are calculated from regression coefficients in Table 5. The samples are restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for smokeless tobacco taxes, bar smoking bans, the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include household, year and month fixed-effects. The confidence intervals are calculated from robust standard errors clustered by household are in parentheses.

Table 1. Summary Statistics

	Entire Sample (N=5,610,416)		Ever Purchased: Cigarettes (N=1,750,752)		Ever Purchased: Smoking Cessation Products (N=335,649)		Ever Purchased: Chewing Tobacco (N=396,589)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Dependent Variables								
Any Cigarettes	0.090	0.287	0.290	0.454	0.309	0.462	0.170	0.375
Any Smoking Cessation Products	0.004	0.066	0.010	0.098	0.074	0.262	0.008	0.088
Any Chewing Tobacco	0.008	0.086	0.013	0.113	0.014	0.117	0.107	0.310
Number of Cigarettes	43.236	211.553	138.554	360.852	158.888	373.663	87.820	304.318
Number Smoking Cessation Products	0.699	17.556	1.121	19.217	11.678	70.879	1.206	20.746
Chewing Tobacco (Oz.)	0.139	2.919	0.234	3.775	0.248	3.656	1.967	10.813
Policy Variables								
Cigarette Excise Taxes	1.177	0.812	1.125	0.782	1.147	0.786	1.029	0.743
Smokeless Tobacco Tax Indicator	0.952	0.214	0.949	0.220	0.954	0.209	0.948	0.222
% Pop Under Bar Ban	0.538	0.497	0.504	0.507	0.509	0.489	0.435	0.494

Table 2: Analysis of tobacco control policies and products

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Cigarette Excise Tax ($)	-0.0222***	-16.1500***	0.0049*	0.5569	0.0013	0.1294
	(0.0023)	(2.1702)	(0.0027)	(0.6393)	(0.0026)	(0.0904)
Smokeless Tobacco Tax	-0.0072	-20.8142*	0.0054	1.9832	-0.0181	-0.3113
	(0.0112)	(12.2292)	(0.0135)	(1.8182)	(0.0156)	(0.5666)
% Pop Under Bar Smoking Ban	-0.0004	-0.9836	-0.0018	-0.3420	-0.0005	0.1256
	(0.0024)	(2.1102)	(0.0032)	(0.9379)	(0.0033)	(0.1327)
Observations	1,750,752	1,750,752	335,649	335,649	396,589	396,589
Households	36,988	36,988	6,081	6,081	7,048	7,048
R-Squared (Within)	0.020	0.022	0.020	0.001	0.004	0.003
Mean Value: Dep Variable	0.290	138.554	0.074	11.678	0.107	1.967

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Analysis of tobacco control policies and products: Occasional and pack-a-day smokers

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Occasional Smokers						
Cigarette Excise Tax ($)	-0.0172***	-8.0720***	0.0007	0.0395	0.0003	0.0296*
	(0.0022)	(1.0858)	(0.0005)	(0.1061)	(0.0005)	(0.0153)
Smokeless Tobacco Tax	-0.0088	-9.2398	0.0007	0.2918	0.0013	0.1159
	(0.0121)	-8.101	(0.0024)	(0.3675)	(0.0034)	(0.1218)
% Pop Under Bar Smoking Ban	-0.0001	-1.7165	-0.0004	-0.1537	0.0003	0.0214
	(0.0023)	(1.1508)	(0.0004)	(0.1012)	(0.0005)	(0.0219)
Observations	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608
Households	30,482	30,482	30,482	30,482	30,482	30,482
R-Squared (Within)	0.015	0.017	0.000	0.000	0.001	0.001
Mean Value: Dep Variable	0.190	41.911	0.009	1.166	0.013	0.200
Pack-a-Day Smokers						
Cigarette Excise Tax ($)	-0.0449***	-97.7241***	0.0023	0.0548	0.0013	0.0274
	(0.0123)	(26.2719)	(0.0024)	(0.1148)	(0.0029)	(0.0360)
Smokeless Tobacco Tax	-0.0076	-162.7555	-0.0032	-0.0858	-0.0014	0.0515
	(0.0349)	(107.7571)	(0.0059)	(0.3241)	(0.0053)	(0.0579)
% Pop Under Bar Smoking Ban	-0.0029	14.6625	-0.0004	-0.0875	0.0052	0.0432
	(0.0136)	(30.4506)	(0.0022)	(0.1465)	(0.0037)	(0.0860)
Observations	115,285	115,285	115,285	115,285	115,285	115,285
Households	2,783	2,783	2,783	2,783	2,783	2,783
R-Squared (Within)	0.049	0.074	0.002	0.001	0.002	0.002
Mean Value: Dep Variable	0.905	986.851	0.010	0.733	0.020	0.446
Single Households						
Cigarette Excise Tax ($)	-0.0255***	-18.7958***	0.0106	2.8285	0.0009	0.2621
	(0.0048)	(3.6469)	(0.0072)	(1.7695)	(0.0042)	(0.1890)
Smokeless Tobacco Tax	-0.0154	-18.0108	-0.0082	0.9419	-0.0216	-0.4269
	(0.0262)	(20.7260)	(0.0398)	(5.5761)	(0.0368)	(1.1412)
% Pop Under Bar Smoking Ban	-0.0099*	-7.1494*	-0.0022	1.5426	0.0064	0.5428**
	(0.0052)	(3.7832)	(0.0069)	(2.6754)	(0.0062)	(0.2605)
Observations	411,713	411,713	76,278	76,278	77,351	77,351
Households	9,399	9,399	1,605	1,605	1,504	1,504
R-Squared (Within)	0.021	0.024	0.003	0.004	0.004	0.005
Mean Value: Dep Variable	0.305	134.071	0.078	13.081	0.077	1.216

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 4. Summary statistics: Cigarette characteristics - households ever purchase cigarettes -NHANES match sample

	Mean	Std. Dev.	N
Average Cigarette Tar Content	11.762	3.775	455,766
Average Cigarette Nicotine Content	0.950	0.278	455,766
Average Cigarette Carbon Monoxide Content	11.970	3.144	455,766
Average Monthly Cigarette Purchases	481.5	536.6	455,766
Total Monthly Cigarette Tar Content	5304.7	6408.2	455,766
Total Monthly Cigarette Nicotine Content	427.7	505.5	455,766
Total Monthly Cigarette Carbon Monoxide Content	5430.8	6446.7	455,766

Notes: The sample is restricted to household-month observations with a positive cigarette purchase which could be matched to cigarette characteristics from NHANES.

Table 5: Cigarette characteristics among households purchasing matched cigarettes (excluding zero purchases)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average CO Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0877***	0.0057**	0.0579**	-30.7679***	-348.5236***	-28.2174***	-357.7535***
	(0.0310)	(0.0025)	(0.0282)	(5.5513)	(71.6863)	(5.7913)	(71.9361)
Smokeless Tobacco Tax	0.0455	0.0052	0.0661	-49.5549	-417.5570	-36.9884	-346.1202
	(0.1003)	(0.0083)	(0.0914)	(30.3142)	(366.9285)	(28.7689)	(382.5079)
% Pop Under Bar Smoking Ban	0.0666*	0.0052*	0.0338	4.6787	81.7315	5.5227	82.4293
	(0.0365)	(0.0029)	(0.0302)	(5.9281)	(76.0270)	(5.9644)	(76.5938)
Observations	455,766	455,766	455,766	455,766	455,766	455,766	455,766
Households	32,134	32,134	32,134	32,134	32,134	32,134	32,134
Mean Value: Dep Variable	11.762	0.950	11.970	481.5	5304.7	427.7	5430.8

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 6: Estimated tax elasticities for cigarette, nicotine per cigarette, and nicotine demand among studies estimating smokers' compensatory behavior

	Cigarettes			Nicotine			Total Nicotine		
Paper	Tax Elasticity	Lower Bound	Upper Bound	Tax Elasticity	Lower Bound	Upper Bound	Tax Elasticity	Lower Bound	Upper Bound
Cotti, Nesson, Tefft (2015)	-0.072	-0.097	-0.046	0.007	0.001	0.012	-0.074	-0.104	-0.044
Evans & Farrelly (1998)	0.031	-0.105	0.167	0.061	-0.038	0.159	0.054	-0.122	0.230
Farrelly et al. (2004): Age 25-34	-0.035	-0.063	-0.008	0.046	0.024	0.068	na	na	na
Farrelly et al. (2004): Age 35-44	-0.017	-0.045	0.011	0.005	-0.017	0.028	na	na	na
Farrelly et al. (2004): Age 45-64	-0.017	-0.043	0.010	0.037	0.013	0.061	na	na	na
Adda and Cornaglia (2006)	-0.190	-1.152	0.772	0.461	0.136	0.786	0.270	-0.397	0.937
Abrevaya and Puzzello (2012)	0.009	-0.358	0.377	0.078	-0.161	0.317	0.087	-0.192	0.366
Adda and Cornaglia (2013)	-0.089	-0.175	-0.003	0.069	0.012	0.126	-0.020	-0.094	0.054
Nesson (2015)	-0.149	-0.210	-0.088	0.022	-0.115	0.158	-0.095	-0.172	-0.017

Notes: Each dot and bar show estimated tax elasticities and corresponding 95% confidence intervals for the effects of cigarette taxes on cigarette consumption from various studies. From left to right, these studies are the current study, Evans and Farrelly (1998), Farrelly et al. (2004) including three age break downs, Abrevaya and Puzzello (2012), Adda and Cornaglia (2013), and Nesson (2015). Nicotine content per cigarette is measured by cigarette nicotine contents in the current study, Evans and Farrelly (1998), and Farrelly et al. (2004). Nicotine demand is estimated from the logged ratio of serum cotinine levels and cigarette consumption in Abrevaya and Puzzello (2012), Adda and Cornaglia (2013), and Nesson (2015).

APPENDIX A:
RESULTS INCLUDING HOUSEHOLD AND STATE FIXED EFFECTS

Appendix Table A1: Analysis of tobacco control policies and products (including state fixed effects)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Cigarette Excise Tax ($)	-0.0215***	-14.2995***	0.0056*	0.5740	0.0040	0.2302**
	(0.0025)	(2.4009)	(0.0030)	(0.6925)	(0.0029)	(0.1066)
Smokeless Tobacco Tax	-0.0085	-15.9666	0.0063	0.5977	-0.0228	-0.4594
	(0.0125)	(12.9569)	(0.0138)	(1.8386)	(0.0174)	(0.6781)
% Pop Under Bar Smoking Ban	0.0007	0.4016	-0.0005	-0.2014	0.0000	0.1041
	(0.0024)	(2.1151)	(0.0033)	(0.9793)	(0.0033)	(0.1342)
Observations	1,750,752	1,750,752	335,649	335,649	396,589	396,589
Households	36,988	36,988	6,081	6,081	7,048	7,048
Mean Value: Dep Variable	0.290	138.554	0.074	11.678	0.107	1.967

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table A2: Analysis of tobacco control policies and products: Occasional and pack-a-day smokers (including state fixed effects)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Occasional Smokers						
Cigarette Excise Tax ($)	-0.0166***	-7.5739***	0.0008	0.0525	0.0003	0.0338**
	(0.0023)	(1.1133)	(0.0005)	(0.1130)	(0.0005)	(0.0166)
Smokeless Tobacco Tax	-0.0104	-10.0494	0.0008	0.1105	0.0013	0.1199
	(0.0134)	(9.4115)	(0.0025)	(0.4058)	(0.0033)	(0.1444)
% Pop Under Bar Smoking Ban	0.0006	-1.3244	-0.0004	-0.1711	0.0004	0.0246
	(0.0024)	(1.1655)	(0.0004)	(0.1045)	(0.0005)	(0.0227)
Observations	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608
Households	30,482	30,482	30,482	30,482	30,482	30,482
R-Squared (Within)	0.016	0.018	0.000	0.000	0.001	0.001
Mean Value: Dep Variable	0.190	41.911	0.009	1.166	0.013	0.200
Pack-a-Day Smokers						
Cigarette Excise Tax ($)	-0.0411***	-89.1089***	0.0025	0.0316	0.0015	0.0351
	(0.0131)	(27.9266)	(0.0026)	(0.1228)	(0.0032)	(0.0423)
Smokeless Tobacco Tax	0.0328	-15.5049	0.0045	-0.1019	-0.0013	0.0707
	(0.0425)	(117.6991)	(0.0049)	(0.4309)	(0.0060)	(0.0872)
% Pop Under Bar Smoking Ban	0.0004	26.1436	0.0003	-0.0762	0.0053	0.0430
	(0.0139)	(30.9844)	(0.0022)	(0.1516)	(0.0038)	(0.0904)
Observations	115,285	115,285	115,285	115,285	115,285	115,285
Households	2,783	2,783	2,783	2,783	2,783	2,783
R-Squared (Within)	0.053	0.077	0.002	0.001	0.002	0.002
Mean Value: Dep Variable	0.905	986.851	0.010	0.733	0.020	0.446

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. Occasional smokers are housholds purchasing less than 300 cigarettes per month on average and pack-a-day smokers are those households purchasing at least 600 cigarettes per month on average. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table A3: Cigarette characteristics among households purchasing matched cigarettes (including state fixed effects)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0875***	0.0052**	0.0531*	-29.6895***	-339.1081***	-27.5320***	-355.4258***
	(0.0325)	(0.0026)	(0.0295)	(5.7199)	(74.9918)	(6.0576)	(75.1521)
Smokeless Tobacco Tax	-0.0628	-0.0070	0.0413	-16.6567	-5.2478	-5.8047	100.4196
	(0.1005)	(0.0074)	(0.1022)	(24.8770)	(324.6631)	(24.7962)	(348.3689)
% Pop Under Bar Smoking Ba	0.0610*	0.0048*	0.0275	6.0561	92.5149	6.6293	86.9657
	(0.0368)	(0.0029)	(0.0305)	(6.0580)	(77.3798)	(6.0795)	(77.8376)
Observations	455,766	455,766	455,766	455,766	455,766	455,766	455,766
Households	32,134	32,134	32,134	32,134	32,134	32,134	32,134
Mean Value: Dep Variable	11.762	0.950	11.970	481.5	5304.7	427.7	5430.8

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

APPENDIX B:
RESULTS INCLUDING HOUSEHOLD AND STATE FIXED EFFECTS AND STATE-SPECIFIC TIME TRENDS

Appendix Table B1: Analysis of tobacco control policies and products (including state fixed effects and state-specific time trends)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Cigarette Excise Tax ($)	-0.0228***	-16.7323***	0.0059*	0.0284	-0.0047	-0.1465
	(0.0026)	(2.2543)	(0.0030)	(0.6719)	(0.0033)	(0.1850)
Smokeless Tobacco Tax	0.0093	1.3487	0.0165	2.8379	-0.0061	-0.3674
	(0.0125)	(13.7660)	(0.0148)	(2.4276)	(0.0164)	(0.4829)
% Pop Under Bar Smoking Ban	-0.0004	-1.6307	-0.0037	-1.2920	0.0027	-0.3809
	(0.0021)	(1.7600)	(0.0036)	(0.8294)	(0.0033)	(0.2529)
Observations	1,750,752	1,750,752	335,649	335,649	396,589	396,589
Households	36,988	36,988	6,081	6,081	7,048	7,048
Mean Value: Dep Variable	0.290	138.554	0.074	11.678	0.107	1.967

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects, and state-specific linear time trends. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table B2: Analysis of tobacco control policies and products: Occasional and pack-a-day smokers (including state fixed effects and state-specific time trends)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any	**Quantity**	**Any**	**Quantity**	**Any**	**Quantity**
Occasional Smokers						
Cigarette Excise Tax ($)	-0.0184***	-8.8384***	0.0011**	0.0357	-0.0011**	-0.0162
	(0.0027)	(1.3507)	(0.0006)	(0.1102)	(0.0005)	(0.0181)
Smokeless Tobacco Tax	-0.0016	-8.4078	0.0040	0.7409	0.0046*	-0.1050
	(0.0135)	(9.3266)	(0.0033)	(0.4908)	(0.0028)	(0.1295)
% Pop Under Bar Smoking Ban	0.0012	0.4798	-0.0005	-0.2125**	0.0007	0.0234
	(0.0021)	(0.9911)	(0.0004)	(0.0979)	(0.0005)	(0.0166)
Observations	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608
Households	30,482	30,482	30,482	30,482	30,482	30,482
Mean Value: Dep Variable	0.190	41.911	0.009	1.166	0.013	0.200
Pack-a-Day Smokers						
Cigarette Excise Tax ($)	-0.0349***	-80.4368***	0.0005	-0.0144	0.0021	0.0225
	(0.0124)	(25.7576)	(0.0022)	(0.2405)	(0.0034)	(0.0912)
Smokeless Tobacco Tax	0.0756**	70.2897	0.0009	-0.4355	-0.0071	-0.1808
	(0.0356)	(122.5991)	(0.0081)	(0.6210)	(0.0094)	(0.1405)
% Pop Under Bar Smoking Ban	0.0088	-1.5042	-0.0002	-0.0717	0.0042	0.1679
	(0.0123)	(29.1114)	(0.0024)	(0.1636)	(0.0039)	(0.1077)
Observations	115,285	115,285	115,285	115,285	115,285	115,285
Households	2,783	2,783	2,783	2,783	2,783	2,783
Mean Value: Dep Variable	0.905	986.851	0.010	0.733	0.020	0.446

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. Occasional smokers are housholds purchasing less than 300 cigarettes per month on average and pack-a-day smokers are those households purchasing at least 600 cigarettes per month on average. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects, and state-specific linear time trends. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table B3: Cigarette characteristics among households purchasing matched cigarettes (including state fixed effects and state-specific time trends)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0738**	0.0037	0.0553*	-36.7885***	-405.3401***	-33.8319***	-409.9689***
	(0.0334)	(0.0025)	(0.0290)	(5.8030)	(71.0277)	(5.7169)	(72.3178)
Smokeless Tobacco Tax	-0.1194	-0.0168**	0.1075	-2.8252	-1.2751	-10.5080	119.6042
	(0.1133)	(0.0084)	(0.0974)	(31.3390)	(427.9156)	(30.8120)	(467.6931)
% Pop Under Bar Smoking Ba	0.0346	0.0040	-0.0148	-1.3388	15.3790	1.6804	-3.6462
	(0.0324)	(0.0025)	(0.0271)	(5.2069)	(65.9195)	(5.2031)	(65.3604)
Observations	455,766	455,766	455,766	455,766	455,766	455,766	455,766
Households	32,134	32,134	32,134	32,134	32,134	32,134	32,134
Mean Value: Dep Variable	11.769	0.951	11.974	481.5	5304.7	427.7	5430.8

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects, and state-specific linear time trends. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

APPENDIX C:
RESULTS INCLUDING STATE FIXED EFFECTS

Appendix Table C1: Analysis of tobacco control policies and products (without household fixed effects and including state fixed effects)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased	Any Purchase	Quantity Purchased
Cigarette Excise Tax ($)	-0.0248***	-15.3602***	0.0031	1.2250	-0.0050	0.0369
	(0.0046)	(4.1249)	(0.0039)	(0.7437)	(0.0065)	(0.1429)
Smokeless Tobacco Tax	0.0204	-9.6469	0.0001	-2.6352	0.0091	-0.0330
	(0.0182)	(11.5971)	(0.0139)	(3.3800)	(0.0111)	(0.6395)
% Pop Under Bar Smoking Ban	-0.0002	-0.8784	-0.0028	-1.5336	-0.0026	-0.2775
	(0.0047)	(4.1621)	(0.0045)	(1.6438)	(0.0071)	(0.2898)
Observations	1,750,752	1,750,752	335,649	335,649	396,589	396,589
R-Squared	0.036	0.030	0.010	0.014	0.043	0.028
Mean Value: Dep Variable	0.290	138.554	0.074	11.678	0.107	1.967

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table C2: Analysis of tobacco control policies and products: Occasional and pack-a-day smokers (without household fixed effects and including state fixed effects)

	Cigarettes (count)		Smoking Cessation Products (count)		Chewing Tobacco (oz)	
	Any	**Quantity**	**Any**	**Quantity**	**Any**	**Quantity**
Occasional Smokers						
Cigarette Excise Tax ($)	-0.0184***	-8.8384***	0.0011**	0.0357	-0.0011**	-0.0162
	(0.0027)	(1.3507)	(0.0006)	(0.1102)	(0.0005)	(0.0181)
Smokeless Tobacco Tax	-0.0016	-8.4078	0.0040	0.7409	0.0046*	-0.1050
	(0.0135)	(9.3266)	(0.0033)	(0.4908)	(0.0028)	(0.1295)
% Pop Under Bar Smoking Ban	0.0012	0.4798	-0.0005	-0.2125**	0.0007	0.0234
	(0.0021)	(0.9911)	(0.0004)	(0.0979)	(0.0005)	(0.0166)
Observations	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608	1,478,608
Households	30,482	30,482	30,482	30,482	30,482	30,482
Mean Value: Dep Variable	0.190	41.911	0.009	1.166	0.013	0.200
Pack-a-Day Smokers						
Cigarette Excise Tax ($)	-0.0349***	-80.4368***	0.0005	-0.0144	0.0021	0.0225
	(0.0124)	(25.7576)	(0.0022)	(0.2405)	(0.0034)	(0.0912)
Smokeless Tobacco Tax	0.0756**	70.2897	0.0009	-0.4355	-0.0071	-0.1808
	(0.0356)	(122.5991)	(0.0081)	(0.6210)	(0.0094)	(0.1405)
% Pop Under Bar Smoking Ban	0.0088	-1.5042	-0.0002	-0.0717	0.0042	0.1679
	(0.0123)	(29.1114)	(0.0024)	(0.1636)	(0.0039)	(0.1077)
Observations	115,285	115,285	115,285	115,285	115,285	115,285
Households	2,783	2,783	2,783	2,783	2,783	2,783
Mean Value: Dep Variable	0.905	986.851	0.010	0.733	0.020	0.446

Notes: Samples are restricted to households who purchased the product at least once throughout the sample period. Occasional smokers are housholds purchasing less than 300 cigarettes per month on average and pack-a-day smokers are those households purchasing at least 600 cigarettes per month on average. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table C3: Cigarette characteristics among households purchasing matched cigarettes (without household fixed effects and including state fixed effects)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0929**	0.0045	0.0761**	-19.0157***	-162.3760*	-13.3794	-170.9185*
	(0.0459)	(0.0039)	(0.0328)	(6.8320)	(94.6527)	(8.1533)	(86.3747)
Smokeless Tobacco Tax	-0.2675	-0.0163*	-0.2344	-43.7155	-448.4782	-35.7300	-472.3179
	(0.1831)	(0.0082)	(0.2080)	(32.6457)	(464.1154)	(41.2168)	(472.5288)
% Pop Under Bar Smoking Ba	-0.0489	-0.0047	-0.0292	0.9075	-4.8814	-0.5033	23.6782
	(0.0704)	(0.0057)	(0.0509)	(9.4130)	(98.7061)	(8.1738)	(106.5311)
Observations	455,766	455,766	455,766	455,766	455,766	455,766	455,766
R-Squared	0.073	0.076	0.069	0.057	0.041	0.040	0.042
Mean Value: Dep Variable	11.769	0.951	11.974	481.5	5304.7	427.7	5430.8

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

APPENDIX D:

NHANES RESULTS NOT INCLUDING ZERO PURCHASES

Appendix Table D1: Cigarette characteristics among households only purchasing matched cigarettes (excluding zero purchases and any non-matched cigarettes)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0452	0.0019	0.0226	-28.7802***	-338.1325***	-27.4337***	-351.1218***
	(0.0361)	(0.0028)	(0.0311)	(6.6991)	(83.9683)	(6.6645)	(84.0745)
Smokeless Tobacco Tax	0.1542	0.0155	0.1095	-55.7082	-610.5503	-48.6475	-611.5570
	(0.0962)	(0.0098)	(0.0870)	(46.6303)	(524.4734)	(42.3800)	(533.9055)
% Pop Under Bar Smoking Ba	0.0634	0.0042	0.0324	0.9400	27.0592	1.3984	19.3071
	(0.0396)	(0.0029)	(0.0298)	(5.7221)	(71.7360)	(5.6030)	(70.1640)
Observations	264,990	264,990	264,990	264,990	264,990	264,990	264,990
Households	23,349	23,349	23,349	23,349	23,349	23,349	23,349
Mean Value: Dep Variable	11.744	0.952	11.945	420.5	4833.8	391.4	4940.2

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that all purchases could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table D2: Cigarette characteristics among households only purchasing matched cigarettes (excluding zero purchases and any non-matched cigarettes and including state fixed effects)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0685*	0.0027	0.0322	-26.5861***	-313.1303***	-25.8577***	-329.4752***
	(0.0410)	(0.0031)	(0.0357)	(7.0117)	(90.9576)	(7.1743)	(90.9259)
Smokeless Tobacco Tax	0.0712	0.0011	0.1154	-4.9400	-81.4222	-5.9774	-64.6088
	(0.0953)	(0.0060)	(0.1022)	(28.5361)	(339.0089)	(27.5124)	(358.2549)
% Pop Under Bar Smoking Ba	0.0579	0.0039	0.0300	2.3561	43.5648	3.0629	35.1721
	(0.0396)	(0.0029)	(0.0300)	(5.8382)	(73.8853)	(5.8115)	(72.4014)
Observations	264,990	264,990	264,990	264,990	264,990	264,990	264,990
Households	23,349	23,349	23,349	23,349	23,349	23,349	23,349
Mean Value: Dep Variable	11.744	0.952	11.945	420.5	4833.8	391.4	4940.2

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that all purchases could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table D3: Cigarette characteristics among households purchasing matched cigarettes (excluding zero purchases and any non-matched cigarettes and including state fixed effects and state-specific time trends)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0476	0.0017	0.0512*	-32.4320***	-340.2421***	-28.7957***	-345.6948***
	(0.0367)	(0.0028)	(0.0308)	(6.6661)	(83.2070)	(6.6660)	(83.6141)
Smokeless Tobacco Tax	0.0439	-0.0037	0.1453	7.8189	-21.5282	-4.8697	43.4805
	(0.1082)	(0.0073)	(0.1123)	(27.4988)	(327.2362)	(25.4343)	(344.7698)
% Pop Under Bar Smoking Ba	0.0318	0.0021	-0.0003	-1.5347	-7.4856	-0.3154	-9.8191
	(0.0339)	(0.0026)	(0.0259)	(4.7081)	(59.5595)	(4.7167)	(59.1159)
Observations	264,990	264,990	264,990	264,990	264,990	264,990	264,990
Households	23,349	23,349	23,349	23,349	23,349	23,349	23,349
Mean Value: Dep Variable	11.744	0.952	11.945	420.5	4833.8	391.4	4940.2

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that all purchases could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects, and state-specific linear time trends. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix Table D4: Cigarette characteristics among households purchasing matched cigarettes (excluding zero purchases and any non-matched cigarettes and without household fixed effects and including state fixed effects)

	Cigarette Characteristics			Total Estimated Monthly Consumption of:			
	Average Tar Content	Average Nicotine Content	Average Carbon Monoxide Content	Cigarettes	Tar	Nicotine	Carbon Monoxide
Cigarette Excise Tax ($)	0.0494	0.0022	0.0591	-15.5293*	-139.4072	-11.3732	-132.0032
	(0.0589)	(0.0047)	(0.0430)	(7.9918)	(102.2363)	(8.0788)	(97.5212)
Smokeless Tobacco Tax	-0.2530	-0.0193*	-0.3172*	33.0796	277.6482	25.3637	150.3751
	(0.2263)	(0.0108)	(0.1799)	(22.5471)	(362.0071)	(27.4827)	(355.7704)
% Pop Under Bar Smoking Ba	-0.0549	-0.0062	-0.0293	0.1797	-53.0617	-4.6834	-7.4863
	(0.0756)	(0.0060)	(0.0577)	(10.5024)	(126.9731)	(9.9335)	(126.2242)
Observations	264,990	264,990	264,990	264,990	264,990	264,990	264,990
R-Squared	0.081	0.085	0.084	0.060	0.045	0.045	0.046
Mean Value: Dep Variable	11.744	0.952	11.945	420.5	4833.8	391.4	4940.2

Notes: The sample is restricted to household-month observations with a positive purchase for households who purchased cigarettes such that at least one purchase could be matched to cigarette characteristics. All models include controls for the gender, race, ethnicity and marital status of the head of household, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, and employment. Additionally, all models include state, household, year and month fixed-effects, and state-specific linear time trends. Robust standard errors clustered by household are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Appendix E: Calculation of Tax Elasticity Estimates in Previous Literature

1. **Evans and Farrelly (1998).**
We base our tax elasticity estimates off of the coefficients in the Fixed Effects specifications in the left panel of Table 2. The paper presents marginal effect coefficients, and we combine these with tax and cigarettes per day sample means to estimate tax elasticities. We calculate sample means from Table 1, weighting the values in 1979 and 1987 by the numbers of observations in each year.

   Our tax elasticity estimate is $\varepsilon_t = \beta\left(\frac{\bar{t}}{\bar{x}}\right)$, where β is the marginal effect coefficient of interest from Table 2, $\bar{t}$ is the sample mean tax, and $\bar{x}$ is the sample mean of the dependent variable of interest. To build a 95% confidence interval, we use the t-statistics contained in Table 2 as follows: $LB_{\varepsilon_t} = \varepsilon_t\left(1 - 1.96/t_\beta\right)$ and $UB_{\varepsilon_t} = \varepsilon_t\left(1 + 1.96/t_\beta\right)$.

2. **Farrelly et al. (2004)**
We base our tax elasticity estimates off of the price elasticities in Tables 3 and 4. Although the paper reports marginal effect coefficients, we do not have estimates of average tax rates and thus cannot estimate tax elasticities as with Evans and Farrelly (1998). Therefore, we combine the price elasticities with information regarding the relationship between taxes and prices to transform the price elasticity into a tax elasticity. Adda and Cornaglia (2006) use data over a similar time period and estimate that a one percent increase in cigarette taxes leads to a 0.15 percent increase in cigarette prices, i.e., $\frac{\partial p}{\partial t} * \frac{t}{p} = 0.15$.

   Thus, we estimate the tax elasticity as $\varepsilon_t = \varepsilon_p * 0.15$. To build a 95% confidence interval, we use the standard errors and coefficients to calculate t-statistics, then use the t-statistics as follows: $LB_{\varepsilon_t} = \varepsilon_t\left(1 - 1.96/t_\beta\right)$ and $UB_{\varepsilon_t} = \varepsilon_t\left(1 + 1.96/t_\beta\right)$.

3. **Adda and Cornaglia (2006)**
Adda and Cornaglia (2006) report tax elasticities and their respective standard errors, so we can directly compute confidence intervals using the elasticities and standard errors contained in Model (3) in Table 2. To measure nicotine consumption per cigarette, we use Adda and Cornaglia's measure of smoking intensity, or the logged ratio of cotinine concentration to the number of cigarettes smoked. To measure total nicotine consumption, we use serum cotinine concentrations.

4. **Abrevaya and Puzzello (2012)**
Abrevaya and Puzzello (2012) report tax elasticities and their respective standard errors, so we can directly compute confidence intervals using the elasticities and standard errors in Table 1 Specification 3, top panel. These results contain unweighted regressions, similar to Adda and Cornaglia (2006). The authors also report weighted regressions in the bottom panel , and these results are qualitatively similar in that no coefficients are statistically significant at conventional levels. To measure nicotine consumption per cigarette, we use Adda and Cornaglia's measure of smoking intensity, or the logged ratio of cotinine concentration to the number of cigarettes smoked. To measure total nicotine consumption, we use serum cotinine concentrations.

5. Adda and Cornaglia (2013)

Adda and Cornaglia (2013) report tax elasticities and their respective standard errors, so we can directly compute confidence intervals using the elasticities and standard errors. We use the estimates in Table 3 in the right-most column, reporting results using lagged cigarette taxes. To measure nicotine consumption per cigarette, we use Adda and Cornaglia's measure of smoking intensity, or the logged ratio of cotinine concentration to the number of cigarettes smoked. To measure total nicotine consumption, we use serum cotinine concentrations.

6. Nesson (2015)

We base our tax elasticity estimates off of the coefficients in the OLS specifications in Tables 2 and 3. The paper presents marginal effect coefficients, and we combine these with tax and cigarettes per day sample means from Table 1.

Thus our tax elasticity estimate is $\varepsilon_t = \beta\left(\frac{\bar{t}}{\bar{x}}\right)$, where these values are as defined above. To build a 95% confidence interval, we use the standard errors and coefficients contained in Tables 2 and 3 to calculate t-statistics, then use the t-statistics as follows: $LB_{\varepsilon_t} = \varepsilon_t\left(1 - 1.96/t_\beta\right)$ and $UB_{\varepsilon_t} = \varepsilon_t\left(1 + 1.96/t_\beta\right)$.

To measure nicotine consumption per cigarette, we use Adda and Cornaglia's measure of smoking intensity, or the logged ratio of cotinine concentration to the number of cigarettes smoked. To measure total nicotine consumption, we use serum cotinine concentrations.