Estimates of the Relationship between Cigarettes and Electronic Cigarettes: Evidence from Household Panel Data

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PRELIMINARY WORK

Abstract

Understanding the relationship between electronic cigarettes and traditional cigarettes is crucial to identifying the appropriate public policy response to the increasing popularity of electronic cigarettes. However, good data on electronic cigarette purchases has been challenging to obtain, limiting the research on the relationship between these two products. In this paper we analyze the impact of cigarette excise taxes, smoke-free air laws, and smoke-free air laws applicable to electronic cigarettes on household purchases of electronic cigarettes to examine the effectiveness of these laws and, importantly, the nature of the relationship between e-cigarettes and traditional cigarettes. We use the Nielsen Consumer Panel (NCP) between 2011 and 2015, which contain detailed information about daily purchases of a panel of more than 60,000 households. We categorize the product type and nicotine content of approximately 85 percent of electronic cigarette product purchases and the nicotine, tar, and carbon monoxide contents of approximately 90 percent of traditional cigarette purchases in the NCP. We estimate the effects of these tobacco control policies on the number of traditional and electronic cigarette purchases, the types of products purchased, and the estimated nicotine purchased via electronic cigarettes and traditional cigarettes. We find consistent evidence that cigarettes and electronic cigarettes are complementary goods, as cigarette excise tax increases decrease both cigarette purchases and electronic cigarette purchases. Importantly, we also find that cigarette excise tax increases reduce the amount of nicotine purchased from both cigarettes and electronic cigarettes.

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1. Introduction

Use of electronic cigarettes (e-cigarettes) has rapidly increased in the past few years. According to the CDC, in 2014 12.6 percent of adults had ever tried an e-cigarette and 3.7 percent of adults currently use e-cigarettes. Compared to traditional cigarettes, e-cigarettes release lower doses of carcinogens and nicotine, leading to a debate as to whether increased e-cigarette use will reduce the harms from traditional cigarettes (Goniewicz et al. 2014, Goniewicz et al. 2012, Cahn and Siegel 2011). Concern over potential harms in e-cigarettes has led to a number of restrictions on the purchase and use of e-cigarettes. However, depending on the relationship between e-cigarettes and traditional cigarettes, these restrictions could either increase or decrease traditional cigarette use.

Indeed, recent evidence among adolescents has been mixed. Notably, both Friedman (2015) and Pesko et al. (2016a) find that states which passed restrictions on e-cigarette purchases saw increases in smoking among adolescents, which suggest that cigarettes and e-cigarettes are substitutes. Conversely, Adams and Abouk (2017) find that e-cigarette bans decrease smoking; suggesting a complementary relationship between the two goods. However, limitations in data availability on purchases and consumption of e-cigarettes has caused previous work to focus on the effects of policies targeting e-cigarettes on the use of traditional cigarettes to infer the nature of the relationship. No research to date has had the ability to comprehensively examine the impacts of more traditional tobacco control policies (such as cigarette taxes) on actual e-cigarette consumption. Moreover, there has been no meaningful research that measures the impact of these policies on the purchases or consumption of the harmful ingredients in electronic cigarettes (e.g. nicotine) or any studies that estimate the nature of the relationship between cigarettes and e-cigarettes among adults.

Using the Nielsen Consumer Panel (NCP) between the years of 2011 and 2015, we provide the first evidence of how e-cigarette purchases respond to increases in cigarette excise taxes and smoke-free air laws (SFA laws) restricting both traditional cigarettes and e-cigarettes. The use of the NCP allows for a comprehensive evaluation of *within* household purchases *across* time in response to policy changes. Moreover, we match over 85% of e-cigarette purchases to product characteristics, including the product type, liquid volume, and nicotine content, and we match over 90% of cigarette purchases to nicotine contents of each product by UPC code. These additional characteristics allow for a detailed investigation of not just the product and cross-product effects on purchase quantity, but also a detailed understanding of the impacts across product type and on harmful ingredients, both for cigarettes and e-cigarettes separately, and together. Additionally, we examine how these emerging e-cigarette SFA laws affect both traditional cigarette purchases and smoking cessation product purchases.

We find that increases in cigarette excise taxes reduce cigarette purchases and e-cigarette purchases, measured both by the counts of purchases and by the total amount of nicotine or volume of liquid purchased. Traditional SFA laws decrease cigarette purchases. Finally, we do not find that e-cigarette SFA laws lead to statistically significant changes in tobacco purchases among adults. Broadly, our results provide causal evidence that a complementary relationship exists between traditional cigarettes and e-cigarettes among adults.

This study contributes to the literature in several ways. We offer the first estimates of how purchases of e-cigarettes respond to tobacco control policies, and the first evidence of how e-cigarette SFA laws affect purchases of cigarettes, e-cigarettes, and smoking cessation products. Moreover, we leverage the detailed product information (including UPC codes) in the NCP to match cigarette purchases to the nicotine contents of the cigarettes using data from the National

Health and Nutrition Examination Surveys (NHANES) and electronic cigarette purchases to the product type, volume of liquid, and nicotine content, using internet searches, correspondence/conversations with companies, and visits to retailers. The NCP household panel data also offers advantages over traditional self-reported measures of tobacco use. Since we examine changes in smoking behavior within households across time in response to changes in tobacco control policies, and using household fixed effects, we are able to determine whether estimated changes in the number of cigarettes, electronic cigarettes, or smoking cessation products purchases represent changes in behavior or changes in the pool of purchasers. Finally, since our data represent scanned purchases, it likely suffers from less measurement error than backward-looking self-reported measures of consumption.

The rest of this paper is organized as follows. Section 2 provides a review of the literature surrounding electronic cigarette use, Section 3 summarizes our data sources, Section 4 describes our methodology, Section 5 reviews the results, and Section 6 concludes.

2. Background

Electronic cigarettes are handheld devices which heat a liquid solution containing nicotine into an aerosol that can be inhaled. In addition to nicotine, the solution contains flavorings, propylene glycol or glycerin, and other additives (U.S. Food & Drug Administration 2017). Most electronic cigarettes consist of a battery, a vaporizer which heats the liquid solution, and a cartridge which holds the liquid solution. Electronic cigarettes may be disposable devices, which are marketed to last about as long as a pack of traditional cigarettes, or more permanent devices consisting of a battery and vaporizer and a replaceable or reusable cartridge (Glasser et al. 2016).

Currently, the contents and labeling of electronic cigarettes are not regulated by the U.S. Food & Drug Administration, and the labeling of electronic cigarette packages varies across brands and manufacturers. Specifically, brands label the nicotine concentration of their liquids, often in terms of percent of nicotine per milliliter of liquid (e.g. 1.7% nicotine/ml) or in the total amount of nicotine in the liquid (e.g. 18 mg of nicotine). Laboratory tests suggest that the actual content of nicotine varies somewhat but is often consistent with product labels (Etter, Zäther, and Svensson 2013, Goniewicz et al. 2012). The amount of nicotine ingested by electronic cigarette users is often less than would be ingested using traditional cigarettes, however, the amount of nicotine ingested by the user may vary greatly, depending on the experience of the user (Farsalinos et al. 2014, Vansickel and Eissenberg 2013, Etter 2014).

In addition to nicotine, electronic cigarette vapor contains other compounds including particulate matter and some of the same toxic chemicals in tobacco smoke. According to laboratory tests, the particulate matter similar in size as particles released from traditional cigarettes, but studies have not reached a consensus as to the amount of particulate matter released (Fuoco et al. 2014, Ingebrethsen, Cole, and Alderman 2012, Long 2014). Most studies have found that the toxic chemical concentrations are much less that traditional cigarettes (Farsalinos, Gillman, Poulas, et al. 2015, Goniewicz et al. 2014, Farsalinos, Gillman, Melvin, et al. 2015). There is a debate regarding the overall safety of electronic cigarettes relative to traditional cigarettes. Researchers who view electronic cigarettes favorably point to the smaller amounts of toxins in electronic cigarettes, while researchers who are more skeptical of electronic cigarettes express concerns regarding a ‘re-normalization’ of smoking, a lack of regulation in the electronic cigarette market, and the rapid take-up of electronic cigarettes by adolescents (Etter

2012, Wagener, Siegel, and Borrelli 2012b, Wagener, Siegel, and Borrelli 2012a, Cobb et al. 2010, Fairchild, Bayer, and Colgrove 2014, Dutra and Glantz 2014).

Electronic cigarette use among both adolescents and adults has markedly increased over the past five years (Centers for Disease Control and Prevention 2016, Regan et al. 2013). A growing literature examines the relationship between electronic cigarette use and traditional cigarettes, usually finding positive correlations between the two products. As an example, Dutra and Glantz (2014) examine the National Youth Tobacco Surveys and find that electronic cigarette use is positively correlated with different measures of cigarette use among adolescents. Coleman et al. (2014) examine young adults who are not established smokers and find that use of electronic cigarettes is correlated with openness to cigarette smoking. However, these studies do not use identification strategies which support a causal interpretation.

As a result of a lack of good data sources, early papers in the economics literature have focused on experiments to analyze the market for electronic cigarettes. Marti et al. (2016) conduct an online experiment examining how various e-cigarette attributes affected demand for e-cigarettes. The authors find that adult smokers in general have a strong preference for traditional cigarettes over e-cigarettes. Smokers value e-cigarettes as cessation devices, a *relatively* healthy alternative to traditional cigarettes, and the ability to smoke e-cigarettes in public places. Pesko et al. (2016b) also conduct an experiment to analyze the effects of electronic cigarette regulations on the demand for electronic cigarettes. They found that proposed taxes on electronic cigarettes, warning labels, and restrictions on electronic cigarette flavors would likely reduce the number of adult smokers who would switch to electronic cigarettes.

Friedman (2015) examines the effects of adolescent electronic cigarette restrictions on state-level smoking rates among adolescents, using the National Survey on Drug Use and Health.

She finds that states which pass electronic cigarette restrictions see increases in smoking rates as measured by cigarette smoking in the past 30 days, suggesting that traditional cigarettes and e-cigarettes are substitutes among adolescents. Similarly, Pesko et al. (2016a) uses the Youth Risk Behavior Surveillance System for teens in high school to also study the effect of restrictions on e-cigarette use on the smoking behavior of minors. Their findings also suggest e-cigarettes and traditional cigarettes are substitutes, as e-cigarette restriction increase usage of rates of cigarettes. However, counter to these findings, Adams and Abouk (2017), use individual-data from Monitoring the Future to assess the impact of policy restriction on the use of e-cigarettes and conclude that the relationship between electronic cigarette and traditional cigarette among adolescents in complementary in nature.

The aforementioned studies identify the relationship between e-cigarettes and traditional cigarettes by measuring the effect of state-level variation in restrictions on e-cigarette use on the consumption of traditional cigarettes, with mixed results. However, these studies have a few notable limitations, which we hope to improve on. First, with the exception of one year of data analyzed by Adams and Abouk (2017), these studies are unable to evaluate the impact of policies on e-cigarette consumption directly. Specifically, the impact of cigarette taxes, which have been shown repeatedly to be the most relevant and effective policy at reducing cigarette and nicotine consumption (for example, Cotti, Nesson, and Tefft 2016), are not studied. Hence, there are no estimates of the impact of exogenous price changes on cigarettes on purchases of electronic cigarettes, which would provide an estimate of cross-price elasticity or semi-elasticity and are the most straight-forward and classic measures of the relationship between two products. Moreover, by matching the NCP data on purchases of both cigarettes and e-cigarettes (at the UPC level) to information on the product type and size, we can analyze the impact of these policies on more

finely recorded measures of quantity (e.g. milliliters of fluid or milligrams of nicotine) than simple unit counts would provide. Second, much of the economic research examining responses to policies is based on repeated cross-section data, raising concerns about endogeneity between these policies and unobserved determinants of smoking levels. Moreover, repeated cross sectional data is especially problematic when examining changes in product characteristics aside from product counts. Repeated cross-section data do not permit identification of whether changes in nicotine intake after cigarette tax increases result from changes on the intensive margin or from changes in the pool of e-cigarette users or smokers of traditional cigarettes after some quit smoking altogether. By focusing on within-household variation in purchases, we can alleviate any concerns that measured changes in behavior are the result of unobserved compositional differences in the sample. Lastly, the research to date has focused on adolescents. Since adolescence is where many smokers' form their smoking habit, this is a group worthy of researchers' focus. However, the NCP allows for an understanding of the behavioral response of adults to these policies, a population that has not been in this context at all. Since the vast majority of smokers are adults and much of the harm from smoking occurs over the course of decades of smoking while an adult, we believe adults are an important group worthy of study as well. Additionally, as previous research finds that adults and adolescents may react vary differently to changes in tobacco control policies, it is plausible that the relationship between traditional cigarettes and e-cigarettes may be different between adults and adolescents.

3. Data

We use data from the NCP dataset for the years 2011 through 2015.[1] The Nielsen Corporation recruits a sample of American households and provides each NCP household with a device to scan the UPC 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 panelist is asked to provide the price. Each unique UPC code purchase is treated as a separate item in the data. The sample includes respondents from all states and major metropolitan areas, and allows for calculations of national, regional, and market area projections. The dataset annually contains approximately 60,000 households, and respondents are provided incentives in the form of "points" which may be redeemed for products to encourage continued participation, but are designed to not influence purchasing habits. Approximately 80% of households each year continue participation in the following year.

We collect data on three categories of tobacco-related products: cigarettes, electronic cigarettes, and nonsmoking-cessation products other than e-cigarettes (e.g. nicotine patches/gum, etc.). For each product category, we first create an indicator variable for whether a household purchased that product in a given quarter. We also create variables for the number of products in each category a household purchased over each quarter. Cigarettes are measured in the number cigarettes purchased in a quarter, and e-cigarettes and smoking cessation products are initially measured in the number of products purchased in a quarter.[2] For cigarettes and electronic cigarettes, we also examine characteristics of the products purchased. We match cigarette characteristics contained in the National Health and Nutrition Examination Survey (NHANES)

[1] There were virtually no e-cigarette purchases before 2011 in the NCP.
[2] The e-cigarettes product categories include e-cigarettes and related accessories, such as the e-cigarettes themselves and liquid refills.

to measure the nicotine content of each cigarette purchased.[3] We then create an average amount of nicotine purchased per cigarette and a total estimated amount of nicotine purchased. For electronic cigarettes, we use internet searches, correspondence/conversations with electronic cigarette companies, and visits to retailers to match about 85% of the electronic cigarette products in the NCP to product characteristics based on UPC codes. We first record the type of electronic cigarette product for each UPC, classifying products into disposable electronic cigarettes, "starter kits," which include a reusable battery and atomizer along with a selection of disposable cartridges, and cartridge refills.

Next, we record the amounts of liquid in milliliters and nicotine in milligrams in each purchase. As stated earlier, there are no regulations regarding the labeling of nicotine on electronic cigarette packages, and while nearly all the products we identified labeled the nicotine content of their electronic cigarettes, it was labeled in different manners. Some brands directly labeled the nicotine content in milligrams, while other brands labeled the nicotine content in terms of a percent of the total volume of liquid. For these brands, the milligrams of nicotine may be calculated as $nicotine\ (mg) = \%nic * 10\ * volume$. For example, if a cartridge is labeled as 1.5% nicotine by volume and contains two milliliters of fluid, then that cartridge contains 1.5*10*2 = 30 milligrams of nicotine. In this way, nearly all purchased units were converted to both milliliters of nicotine liquid purchased and milligrams of nicotine purchased by each household in each quarter.

A potential concern with the NCP is that the sample is not nationally representative. However, previous studies using the NCP find very similar cigarette price elasticity estimates to previous studies using nationally-representative survey data, and our estimated elasticities are

[3] See Cotti, Nesson, and Tefft (2016) for more information on the matching process between the NCP and NHANES.

very similar to those previously estimated elasticities as well (Harding, Leibtag, & Lovenheim, 2012). Additionally, we utilize survey weights provided with the NCP data and control for many demographic characteristics in our regressions to account for variation in the demographic composition of the NCP compared the nation as a whole. Another potential concern with the NCP, especially relating to e-cigarettes, is internet purchases. The NCP tracks whether purchases are made with an online retailer, and only 0.5 percent of cigarettes purchased are from an online retailer. That said, to further account for internet purchases, we include an indicator of household internet use in all models.

We collect data on cigarette excise taxes from the Tax Burden on Tobacco output by Orzechowski & Walker (Orzechowski and Walker 2015) and transform these into the cigarette excise tax measured in real 2015 dollars in each state and quarter. Additionally, we collect data on SFA laws from the American Non-Smokers' Rights Foundation (ANR). ANR tracks when municipalities, counties and states pass smoke-free air laws in a number of different venues, and we use these to create two measures. First, we measure the percent of the population in each county living under a SFA law restricting traditional cigarette use in either private workplaces, restaurants, or bars. Second, we measure the percent of the population in each county living under a SFA law restricting e-cigarette use in either private workplaces, restaurants, or bars. We match this data to households based on their county of residence and quarter of purchase.

Figure 1 displays variation in the prevalence of SFA laws. There has been substantial variation in the coverage of SFA laws and SFA laws which apply to e-cigarette laws. The percent of the U.S. population living under an SFA law has increased from 79 to almost 81.5 percent over our time period, while the percent of the U.S. population living under an SFA law applying to e-cigarettes has increased from 3 to over 20 percent over our time period.

4. Methodology

We utilize an identification strategy that connects variation in households' tobacco-related purchases to changes in tobacco control policies. We first estimate the probability that a household buys a specific tobacco product with a linear probability model as follows:

$$\boldsymbol{P(T_{hcsyq} > 0) = \beta_0 + Z_{syq}\beta_Z + W_{csyq}\beta_w + X_{hcsyq}\beta_X + \delta_h + \tau_y + \mu_q + \sigma\tau_{sy} + \varepsilon_{hcsyq}} \quad (1)$$

where $P(T_{hcsyq} > 0)$ is the probability that household h at year y and quarter q purchases the tobacco product in question, Z_{syq} is state-level cigarette taxes expressed in dollars, W_{csyq} is a vector of smoke-free laws (measured as the percent of the household's county living under a traditional SFA law, and separately as the percent of the household's county living under an e-cigarette SFA law), and X_{hsyq} contains household-level demographic characteristics. We also include household and time period (year and quarter) fixed effects, given by δ_h, τ_y and μ_q, respectively, as well as state-specific linear time trends, given by $\sigma\tau_{sy}$. We cluster standard errors at the state level (Bertrand et al., 2004). Next, we estimate the effects of tobacco control policies on the quantity of tobacco products purchased using a similar fixed effects model:

$$\boldsymbol{T_{hcsyq} = \alpha_0 + Z_{syq}\alpha_Z + W_{csyq}\alpha_W + X_{hcsyq}\alpha_X + \delta_h + \tau_y + \mu_q + \sigma\tau_{sy} + \varepsilon_{hcsyq}} \quad (2)$$

where T_{hcsyq} represents the amount of the tobacco product purchased each quarter and all other variables are defined as above. We estimate Equation (2) over the population of all observed households and then again for all households which purchase each good at least once in the whole sample.

Finally, we modify equation (2) to estimate how tobacco control policies affect the characteristics of cigarettes and electronic cigarettes, described earlier, purchased by households. For cigarettes, we estimate the total amounts of nicotine tar, and carbon monoxide purchased by

households. We multiply the amount contained within each type of cigarette a household purchases by the number of cigarettes of that type purchased. For electronic cigarettes, we examine the type of products purchased, disaggregating electronic cigarettes into the numbers of disposables, starter kits, and refills purchased. Finally, we calculate the total volume of liquid purchased and total amount of nicotine purchased in a similar fashion to cigarettes. We multiply the amount of liquid or nicotine in each purchase by the number of electronic cigarettes of that type purchased.

5. Results

a) *Analysis of Extensive and Intensive Purchase Habits*

Table 1 shows summary statistics from samples used in our baseline estimation. Specifically, our overall sample represents over 1.2 million household quarter observations from over 99,000 households, and we estimate our extensive margin results over this sample. For our intensive margin analyses, we use two samples. The full "all-household" sample, also used to investigate the extensive margin, as well as an "ever- purchasers" sample, which only includes households that purchase the relevant product at least once while observed. In the latter cases, our analysis sample is 285,609 observations from 22,042 households for cigarettes, 35,166 observations from 2,404 households for electronic cigarettes, and 45,793 observations from 3,127 households for smoking cessation products (e.g. nicotine gum, nicotine patches, etc.). In a quarter, approximately 11 percent of households purchase cigarettes on average, while 0.4 percent purchase e-cigarettes. Cigarettes are a strong predictor of e-cigarette purchases, and vice versa. Approximately 55 percent of households that have ever purchased e-cigarettes purchase

cigarettes each quarter, and the average number of cigarettes purchased among households that have ever purchase e-cigarettes is about two times the number among households that have ever purchased cigarettes.

Figures 2 and 3 show the evolution of electronic cigarette and cigarette purchases in the NCP. Figure 2 plots counts of cigarette and electronic cigarette purchases among NCP households by quarter and shows a steady decrease in cigarette purchase and a rapid rise in electronic cigarette purchases. Figure 3 plots the evolution in nicotine within purchases in cigarette and electronic cigarettes. Beginning in 2011, electronic cigarettes comprise less than two hundredths of a percent (0.013%) of all nicotine purchased in the NCP from cigarette or e-cigarette sources. However, over the five year sample, the share of nicotine acquired from the purchase of traditional cigarettes declines steadily and notably. This is driven both by a decline nicotine through cigarettes channels and a rise in nicotine acquisition through e-cigarette channels. By the fourth quarter of 2015, nicotine from electronic cigarettes comprises over five percent (5.28%) of all nicotine purchased in the NCP from cigarette or e-cigarette sources.

Table 2 shows results from our baseline regressions. The three columns correspond to different dependent variables, cigarette purchases, e-cigarette purchases, and non-e-cigarette smoking cessation product purchases. Panel A shows models estimating Equation (1), the probability that a household purchases the product in a quarter, while the bottom two panels show models estimating Equation (2), the total amount purchased by household each quarter. Consistent with other research, all panels show clear evidence that cigarette excise taxes negatively impact cigarette purchases. We also find some evidence that cigarette taxes impact smoking cessation products on the extensive margin (p-value = 0.076), suggesting that higher cigarette prices may induce a great likelihood of purchase of cession products.

Importantly, however, we find that cigarette excise taxes negatively impact the probability that a household purchases e-cigarettes and the amount of e-cigarette product purchased by ever users, indicating that cigarettes and e-cigarettes are economic complements. Specifically, results indicate that a $1.00 increase in cigarette taxes reduces the probability that a household will purchase electronic cigarettes in a quarter by approximately 0.1 percentage points (p-value=0.09), or, transformed into a semi-elasticity, by about 22 percent. Similarly, when turning to an examination of the total quantities of e-cigarette products purchased among ever users (found in Panels B and C), we find that cigarette taxes also meaningfully reduce the quantity of e-cigarette purchases. Collectively, both extensive and intensive margin analysis suggest a complementary relationship exists between cigarettes and e-cigarettes.

In addition to our primary covariate of interest (cigarette taxes), we also investigate the impact of smoke-free air laws for cigarettes and e-cigarettes on purchases. While we find little impact of these laws on the extensive margin that is both statistically and/or economically significant, we do find evidence that SFA cigarette laws decrease the quantity of cigarette purchased slightly among households in both the all-household and ever-purchaser samples, and that they marginally increase the number of smoking cessation purchases as well. Even though not large, both sensible and intuitive results. Lastly, we find that electronic cigarette SFA laws have no notable effect on traditional or electronic cigarette usage, but do find very small estimated negative effects on smoking cessation products as well.

b) *Analysis of Electronic Cigarette Characteristics*

One concern with estimating the impact of tobacco control policies on electronic cigarette purchases, that is not as great of a concern with cigarette purchases, is the aggregation and interpretation of purchase counts. Specifically, cigarette sales are sold as cartons and packs, with

standardized numbers of cigarettes in each. Hence, purchases can easily be counted and standardized by the number of cigarettes per purchase. With e-cigarette products, no such consistent "unit-of-measurement" exists across purchases. First, e-cigarette purchases come in a wide variety of product types. Principally, these break down into three categories: disposable e-cigarettes, starter kits, and refill cartridges. The NCP lacks identifiable separation between these product types. Moreover, the quantity of product (e.g. milliliters of nicotine solution or even number of cartridges in a refill pack) can vary a great deal even within products of the same type. For example, Nicotek Metro brand e-cigarette starter kits come with as many as 10 one ml cartridges to as few as 1 one ml cartridge, but both are listed as one e-cigarette purchase in the NCP data, even though one provides 10 times the milliliters of nicotine solution as the other. To complicate this aspect even further, cartridge size also fluctuates across UPC products. Furthermore, the true "essential" product being purchased in both e-cigarettes and traditional cigarettes is the nicotine itself, and the concentration of the nicotine fluid also varies across e-cigarette UPCs. This latter problem (concentration across UPC by brand) is, of course, also an issue with traditional cigarettes, but all the other concerns (e.g. number of cartridges, size of cartridges, etc.) are all unique to e-cigarette purchases.

In order to be able to more cleanly estimate the impact cigarette tax and smoke-free air laws on e-cigarette quantities, we needed to be able to 1) separate all the e-cigarette product purchase counts in the NCP by product type (e.g. disposable e-cigarettes, starter kits, and refill cartridges), 2) account for differences in the number of disposable e-cigarettes and refill cartridges by UPC, as well as the difference in the cartridge tank size of these products, so that a standardized milliliters of fluid per UPC can be calculated for each purchase, and 3) subsequently determine the concentration of nicotine per milliliter for each UPC so that the total

milligrams of nicotine per UPC can be ascertained. Collectively, these measures will allow for estimation of the effects of these tobacco control policies on specific product types, the amount of nicotine solution purchased (in ml), and the total amount of nicotine purchased (in mg) within households over time. This detailed level of measurement will improve our understanding of the relationship between e-cigarettes and traditional cigarettes notably and give us a much greater deal of interpretation and clarity about the estimates.

As mentioned above, we leverage the product-code level detail provided in the NCP data (e.g. UPCs) to match our sample of NCP e-cigarette product purchases to e-cigarette characteristics using internet searches, direct correspondence/conversations with companies, and visits to retailers to gather information directly from packaging. We also match information on traditional cigarettes from the National Health and Nutrition Examination Surveys (NHANES). Table 3 shows summary statistics from the matched sample of cigarette and e-cigarettes purchases, which contains all households where at least one product could be matched.

Table 4 presents estimates analogous to the bottom two panels of Table 2, and offers a very similar overall story. In particular, estimates again show that the quarterly quantity of e-cigarette cartridge refills and starter kits purchased is negatively impacted by increases in traditional cigarette taxes. No meaningful relationship is detected for disposable e-cigarettes, however.

Table 5 shows estimates from the models estimating the effects of tobacco control policies on cigarette purchases measured by total quarterly household purchases of nicotine, tar, and carbon monoxide, as well as the analogous measures of total e-cigarette solution and nicotine from the purchase of e-cigarette products for the all-household and ever-purchasers samples. The first section of Table 5 displays evidence consistent with the result in Cotti,

Nesson, and Tefft (2016) that cigarette taxes and smoke-free cigarette air laws reduce total household purchases of nicotine, tar, and carbon monoxide (measured in milligrams purchased quarterly). The center "Electronic Cigarettes" section, however, provides statistically significant evidence that, when measured in total fluid millimeters of solution of nicotine, increases in cigarette taxes negatively impact total quantity purchased. While not statistically significant for either the all-households sample (p-value=0.232) or the ever-purchasers sample (p-value=0.212), the point estimates of the impact of cigarette excise taxes on total milligrams of nicotine purchased are large and consistent with those measuring volume and simple purchase count. Specifically, we find that a $1.00 cigarette tax increase would decrease the total amount of nicotine purchased by 23 milligrams in the ever-purchasers sample, which is a semi-elasticity indicative of approximately a 50% decline. Taken as a whole, the overarching story provided across the different measures of electronic cigarette purchases suggests a complementary relationship with respect to traditional cigarettes, and provides no evidence that a substitute relationship exists among adults.

Lastly, in the right-most section of Table 5, we investigate the overall impact of cigarette excises taxes on nicotine purchased as measured by the summation of the total amount of nicotine purchased (in milligrams) in each household each month. This is an important measure, as these two products make up a large share of nicotine consumption and estimates will provide a good overall picture of the net effects of cigarette taxes on nicotine purchases. Results are consistent and show that the overall impact of cigarette excises taxes on nicotine purchases from these two sources is negative and highly statistically significant. Transformed into a semi-elasticity, these estimates suggest that a $1.00 increase in cigarette excise taxes reduces the amount of nicotine that a household purchases between 18 and 25 percent. These results strongly

indicate that, at least among adults, increases in cigarette tax should reduce overall consumption of nicotine in the population.

c) *Robustness*

[Forthcoming]

d) *Heterogeneous Effects*

[Forthcoming]

e) *Dynamic Effects*

[Forthcoming]

6. Conclusion

In this paper, we utilize detailed household panel data to examine the relationship between tobacco control policies and cigarette, e-cigarette, and smoking cessation purchases among adults. We use panel data on the quarterly purchases of a large number of households from the NCP, and we further leverage the detailed product information contained in the NCP to match cigarette UPCs to nicotine, tar, and carbon monoxide contents and e-cigarette purchases to the product type, volume of liquid and amount of nicotine. The panel nature of the NCP allows us 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.

We confirm many previous papers that find that cigarette excise taxes and SFA laws reduce smoking. We also, importantly, find evidence of a complementary relationship between cigarettes and e-cigarettes, which is consistent across the variety of increasingly detailed measures of e-cigarette purchase amounts. Specifically, we find that a $1.00 increase in cigarette

excise taxes reduces the probability that a household purchases e-cigarette products by about 22 percent and reduces the number of e-cigarette purchases among ever-purchasers by a further 42 percent. Similarly, we find that cigarette taxes likely reduce the quantity of e-cigarette fluid and overall total nicotine as well. Moreover, we find some evidence that cigarettes and smoking cessation products are substitutes, with a $1.00 increase in cigarette taxes leading to an 18 percent increase in the probability that households purchase smoking cessation products. Finally, we find that cigarette SFA laws decrease cigarette purchases on both the extensive and intensive margins.

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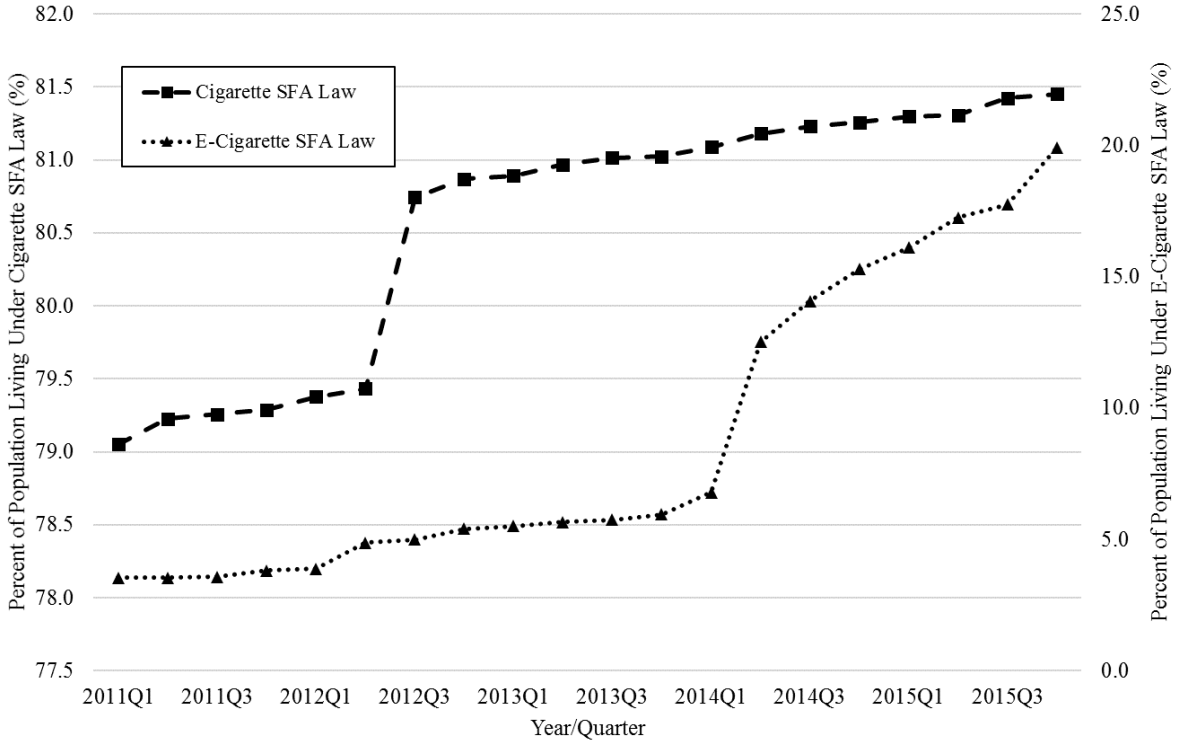
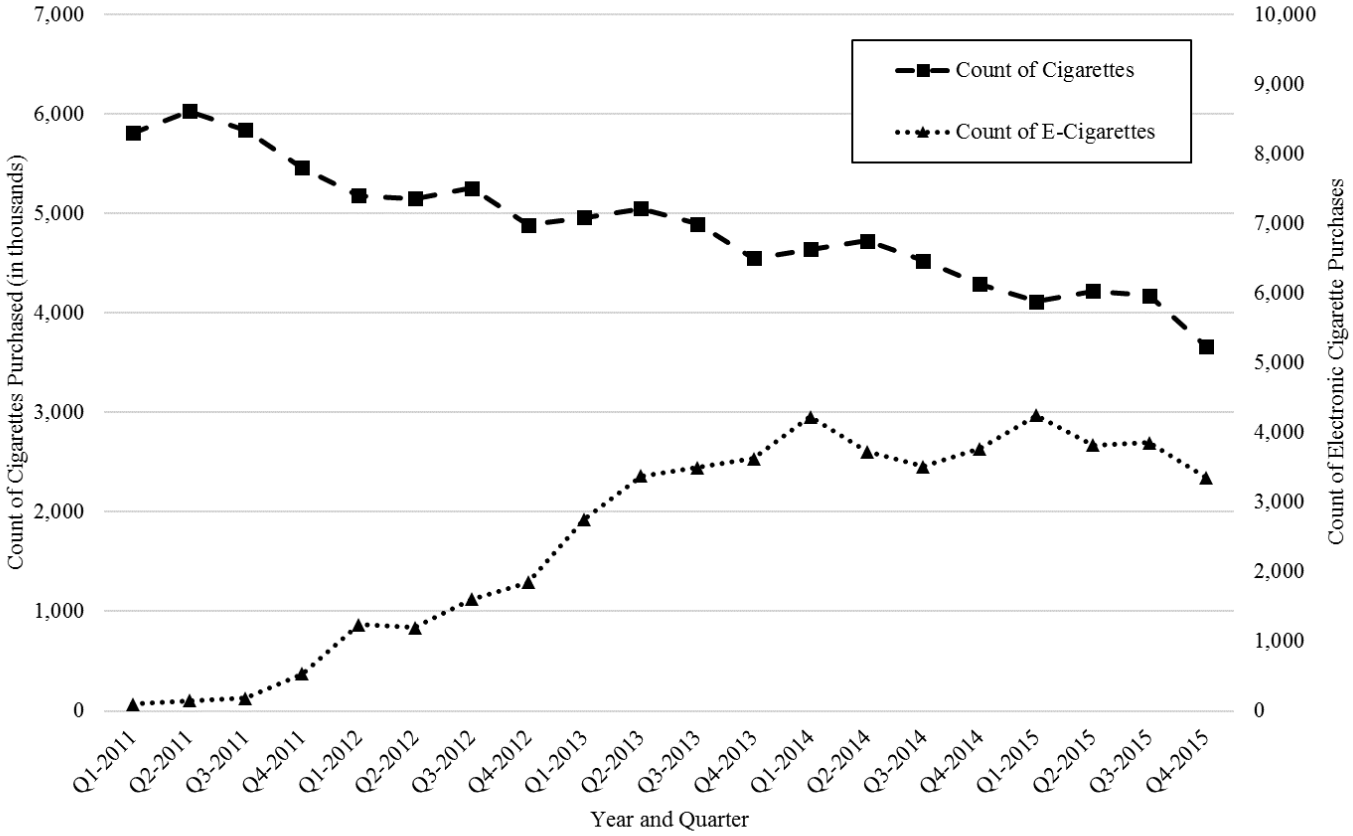
Figure 1
Percent of Population Living Under Cigarette and E-Cigarette SFA Laws



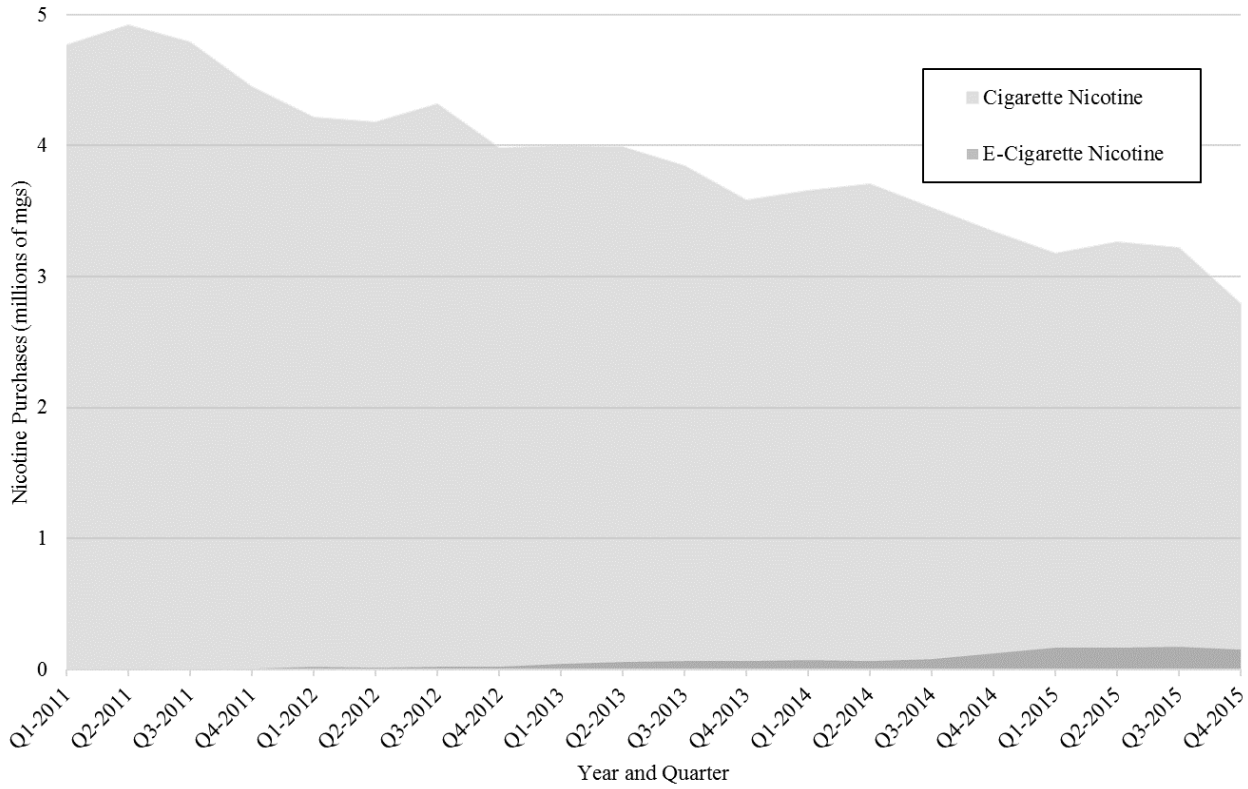
Notes:
Data from the Americans for Non-Smokers' Rights Foundation.

Figure 2
Purchases of Cigarettes and Electronic Cigarettes



Notes:
Data from the Nielsen Consumer Panel dataset.

Figure 3.
Purchases of Nicotine from Cigarettes and Electronic Cigarettes



Notes:
Data from the Nielsen Consumer Panel dataset.

Table 1: Summary Statistics

	Entire Sample (N=1,226,568)		Ever Purchased Sample: Cigarettes (N=285,609)		E-Cigarettes (N=35,166)		Smoking Cessation Products (N=45,793)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Dependent Variables								
Any Cigarettes	0.111	0.314	0.430	0.495				
Any E-Cigarettes	0.004	0.064			0.126	0.332		
Any Anti-Smoking Products	0.007	0.083					0.190	0.392
Number of Cigarettes	83.999	438.508	325.295	816.190				
Number of E-Cigarettes	0.055	2.208			1.656	12.061		
Number of Anti-Smoking Products	2.058	49.371					56.377	252.437
Policy Variables								
Cigarette Excise Taxes	2.568	1.068	2.465	1.004	2.469	0.985	2.508	1.004
% Pop Under Cigarette SFA Law	80.759	36.689	77.833	38.886	76.792	39.886	78.695	38.120
% Pop Under E-Cigarette SFA Law	8.459	25.055	7.368	23.438	6.818	22.757	7.155	23.016

Notes:

Individual data from the Nielsen Consumer Panel Dataset spanning 2011 to 2015. Tobacco policy data are from the Tax Burden on Tobacco and the Americans for Non-Smokers' Rights Foundation.

Table 2: Baseline Results

	Cigarettes	E-Cigarettes	Smoking Cessation Products
Panel A: Probability of any purchase			
Cigarette Excise Tax	-0.0093***	-0.0009*	0.0012*
	(0.0027)	(0.0005)	(0.0007)
Cigarette SFA Law	-0.0002*	0.0000	0.0000
	(0.0001)	(0.0000)	(0.0000)
E-Cigarette SFA Law	0.0000	-0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Mean of Dependent Variable	0.111	0.004	0.007
Observations	1,226,568	1,226,568	1,226,568
Panel B: Purchase amount (all HHs)			
Cigarette Excise Tax	-11.809***	-0.024**	-0.157
	(4.378)	(0.011)	(0.319)
Cigarette SFA Law	-0.532***	0.000	0.006*
	(0.191)	(0.000)	(0.004)
E-Cigarette SFA Law	0.024	0.000	-0.006*
	(0.065)	(0.000)	(0.004)
Mean of Dependent Variable	83.999	0.055	2.058
Observations	1,226,568	1,226,568	1,226,568
Panel C: Purchase amount (ever-users)			
Cigarette Excise Tax	-42.009**	-0.692*	1.042
	(16.340)	(0.396)	(6.887)
Cigarette SFA Law	-1.653***	-0.007	0.258*
	(0.496)	(0.007)	(0.130)
E-Cigarette SFA Law	0.028	0.007	-0.158**
	(0.253)	(0.007)	(0.071)
Mean of Dependent Variable	325.295	1.656	56.377
Observations	285,609	35,166	45,793

Notes:

Data from the Nielsen Consumer Panel dataset, the Tax Burden on Tobacco, and the Americans for Non-Smokers' Rights Foundation. The top panel is estimated on all households, and the bottom panel is estimated on households which purchase the product at least once. All models include controls for the gender, race, ethnicity and marital status of the head of household, household size, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, employment, and household access to the internet. Additionally, all models include household, year and quarter fixed-effects and state-specific linear time trends. Robust standard errors clustered by state are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Summary Statistics for Cigarette and Electronic Cigarette Characteristics

Panel A: All Households	**Mean**	**Std. Dev.**	**N**
Cigarette Variables			
Total Nicotine (mg)	61.253	359.835	1,198,663
Total Tar (mg)	745.956	4371.952	1,198,663
Total CO (mg)	748.505	4369.754	1,198,663
Electronic Cigarette Variables			
Disposable E-Cigarette	0.006	0.552	1,225,650
Refill	0.040	2.184	1,225,650
Starter Kit	0.002	0.120	1,225,650
Volume Purchased (ml)	0.056	2.493	1,226,568
Total Nicotine (mg)	1.259	81.182	1,225,337

Panel B: Ever -Purchasers	**Mean**	**Std. Dev.**	**N**
Cigarette Variables			
Total Nicotine (mg)	255.920	700.834	257,704
Total Tar (mg)	3116.672	8513.010	257,704
Total CO (mg)	3127.320	8505.323	257,704
Electronic Cigarette Variables			
Disposable E-Cigarette	0.228	3.335	29,096
Refill	1.466	13.139	29,096
Starter Kit	0.085	0.724	29,096
Volume Purchased (ml)	2.036	14.831	29,562
Total Nicotine (mg)	46.616	491.748	28,822

Notes:

Individual data from the Nielsen Consumer Panel Dataset spanning 2011 to 2015.

Table 4: Quantity Purchased by Electronic Cigarette Product Type

Panel A: All Households	Disposable E-Cigarette	Refill	Starter Kit
Cigarette Excise Tax	0.001	-0.030**	-0.002**
	(0.003)	(0.014)	(0.001)
Cigarette SFA Law	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
E-Cigarette SFA Law	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mean of Dependent Variable	0.006	0.040	0.002
Observations	1,225,650	1,225,650	1,225,650

Panel B: Ever-Purchasers	Disposable E-Cigarette	Refill	Starter Kit
Cigarette Excise Tax	0.065	-1.293*	-0.073
	(0.103)	(0.694)	(0.045)
Cigarette SFA Law	0.007	-0.016*	-0.001**
	(0.005)	(0.008)	(0.001)
E-Cigarette SFA Law	0.002	-0.007	0.000
	(0.002)	(0.008)	(0.001)
Mean of Dependent Variable	0.228	1.466	0.085
Observations	29,096	29,096	29,096

Notes:

Data from the Nielsen Consumer Panel dataset, the Tax Burden on Tobacco, and the Americans for Non-Smokers' Rights Foundation. The top panel is estimated on all households, and the bottom panel is estimated on households which purchase the product at least once. All models include controls for the gender, race, ethnicity and marital status of the head of household, household size, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, employment, and household access to the internet. Additionally, all models include household, year and quarter fixed-effects and state-specific linear time trends. Robust standard errors clustered by state are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 5: Purchases of Nicotine and Electronic Cigarette Liquid

	Cigarettes			Electronic Cigarettes		Cigs + ECigs
Panel A: All Households	**Total Nicotine (mg)**	**Total Tar (mg)**	**Total CO (mg)**	**Volume Purchased (ml)**	**Total Nicotine (mg)**	**Total Nicotine (mg)**
Cigarette Excise Tax	-11.045***	-132.954***	-139.936***	-0.037**	-0.570	-11.368***
	(3.896)	(48.408)	(47.118)	(0.016)	(0.471)	(4.103)
Cigarette SFA Law	-0.384***	-4.445***	-4.477***	0.000	0.000	-0.387***
	(0.056)	(0.737)	(0.821)	(0.000)	(0.006)	(0.054)
E-Cigarette SFA Law	0.022	0.185	0.263	0.000	-0.014**	0.009
	(0.051)	(0.642)	(0.706)	(0.000)	(0.007)	(0.050)
Mean of Dependent Variable	61.253	745.956	748.505	0.056	1.259	62.029
Observations	1,198,663	1,198,663	1,198,663	1,226,568	1,225,337	1,197,653

	Cigarettes			Electronic Cigarettes		Cigs + ECigs
Panel B: Ever -Purchasers	**Total Nicotine (mg)**	**Total Tar (mg)**	**Total CO (mg)**	**Volume Purchased (ml)**	**Total Nicotine (mg)**	**Total Nicotine (mg)**
Cigarette Excise Tax	-41.611**	-498.378**	-525.963**	-1.573*	-23.481	-139.802***
	(17.184)	(211.079)	(202.011)	(0.796)	(18.537)	(24.885)
Cigarette SFA Law	-1.369***	-15.880***	-16.146***	-0.009	-0.142	-1.082
	(0.175)	(2.220)	(2.581)	(0.010)	(0.257)	(1.266)
E-Cigarette SFA Law	0.055	0.289	0.667	-0.003	-0.361	0.072
	(0.213)	(2.705)	(2.988)	(0.009)	(0.224)	(1.387)
Mean of Dependent Variable	255.920	3116.672	3127.320	2.036	46.616	549.578
Observations	257,704	257,704	257,704	29,562	28,822	24,477

Notes:

Data from the Nielsen Consumer Panel, the Tax Burden on Tobacco, and the Americans for Non-Smokers' Rights Foundation. Regressions are estimated on all households. All models include controls for the gender, race, ethnicity and marital status of the head of household, household size, indicator variables for income categories, and interactions between head of household gender and indicators for age categories, education categories, employment, and household access to the internet. Additionally, all models include household, year and quarter fixed-effects and state-specific linear time trends. Robust standard errors clustered by state are in parentheses. Stars denote statistical significance: *** p<0.01, ** p<0.05, * p<0.10.

Table 6: Heterogeneity Estimates (Ever Purchasers)

	Cigarettes				Electronic Cigarettes			Cessation Products
	Count	Total Tar (mg)	Total Nicotine (mg)	Total CO (mg)	Count	Volume Purchased (ml)	Total Nicotine (mg)	Count
Ages 25-54	-30.978**	-425.545*	-36.048*	-414.351*	-1.175**	-1.716*	-21.436	-9.445
	(13.975)	(227.580)	(18.765)	(210.001)	(0.537)	(0.924)	(23.546)	(7.108)
N	140,948	128,053	128,053	128,053	19,098	16,102	15,698	22,067
Ages 55+	-53.989***	-617.928***	-50.331***	-684.855***	-0.017	-0.417	-15.066	-2.885
	(18.143)	(201.384)	(16.745)	(188.184)	(0.834)	(0.767)	(20.704)	(17.674)
N	175,457	157,047	157,047	157,047	20,608	17,320	16,886	29,082
Pack-a-Day Smoking Households	192.871	1540.613	125.744	1115.802	-0.078	-0.189	-1.091	2.155
	(161.817)	(1718.731)	(146.367)	(1671.677)	(0.819)	(1.147)	(22.625)	(5.775)
N	14,884	10,427	10,427	10,427	4,196	3,472	3,382	2,396
Occasional Smoking Households	-27.316**	-288.776*	-25.599*	-283.896*	-0.166	-0.644	-13.168	-0.173
	(11.650)	(163.742)	(13.697)	(154.610)	(0.504)	(0.804)	(24.966)	(5.713)
N	249,450	231,313	231,313	231,313	20,215	17,063	16,631	23,422
Household Income At Least $30k	-41.069**	-473.156***	-38.548***	-487.621***	-0.236	-0.988	-17.690	2.062
	(18.553)	(171.823)	(13.127)	(177.706)	(0.615)	(0.614)	(10.825)	(9.054)
N	206,599	188,895	188,895	188,895	23,662	20,082	19,619	35,561
Household Income Less Than $30k	-47.294***	-540.809*	-49.691*	-605.573**	-2.363***	-3.292***	-89.806**	-27.377
	(14.671)	(295.096)	(27.151)	(271.152)	(0.759)	(1.115)	(35.928)	(21.877)
N	79,010	68,736	68,736	68,736	11,504	9,480	9,203	10,232
Before 2014	-45.962***	-586.310***	-48.455***	-612.051***	-0.728**	-1.072*	-16.703*	3.121
	(11.642)	(166.159)	(13.376)	(167.634)	(0.324)	(0.563)	(9.892)	(4.718)
N	171,234	154,371	154,371	154,371	19,788	16,364	16,066	27,552
2014 and 2015	-36.616***	-221.396	-20.359	-219.844	0.031	-0.116	-10.477	16.639
	(10.615)	(192.888)	(16.614)	(197.716)	(0.639)	(1.633)	(60.801)	(18.292)
N	114,375	103,127	103,127	103,127	15,378	13,198	12,754	18,241
States w/ High Smoking Prevalence	-46.149*	-640.246*	-49.692*	-705.452*	-0.311	-1.152	-45.416	-17.624
	(25.901)	(326.236)	(25.832)	(348.728)	(0.880)	(1.265)	(41.606)	(11.083)
N	107,506	96,297	96,297	96,297	14,083	11,699	11,424	16,322
States w/ Low Smoking Prevalence	-43.604***	-516.081***	-43.430***	-540.863***	-0.789*	-1.641*	-21.089	-0.929
	(14.270)	(186.810)	(15.452)	(177.587)	(0.435)	(0.818)	(19.014)	(12.887)
N	178,103	161,399	161,399	161,399	21,083	17,863	17,398	29,471

Table 7: Heterogeneity Estimates (All Households)

	Cigarettes				Electronic Cigarettes			Cessation Products
	Count	Total Tar (mg)	Total Nicotine (mg)	Total CO (mg)	Count	Volume Purchased (ml)	Total Nicotine (mg)	Count
Ages 25-54	-8.780**	-116.509**	-9.794**	-113.925**	-0.044***	-0.055***	-0.874**	-0.722*
	(3.863)	(50.970)	(4.153)	(47.329)	(0.016)	(0.020)	(0.336)	(0.367)
N	592,527	579,632	579,632	579,632	592,527	592,527	591,866	592,527
Ages 55+	-16.299***	-174.347***	-14.193***	-193.144***	-0.004	-0.028*	-0.940*	0.805***
	(5.531)	(54.034)	(4.326)	(54.030)	(0.025)	(0.016)	(0.546)	(0.249)
N	736,328	717,918	717,918	717,918	736,328	736,328	735,608	736,328
Pack-a-Day Smoking Households	192.871	1540.613	125.744	1115.802	-0.818	-0.871	-11.323	0.705
	(161.817)	(1718.731)	(146.367)	(1671.677)	(0.967)	(0.906)	(14.279)	(0.773)
N	14,884	10,427	10,427	10,427	14,884	14,884	14,744	14,884
Occasional Smoking Households	-27.316**	-288.776*	-25.599*	-283.896*	-0.042	-0.070	-1.345	-0.718
	(11.650)	(163.742)	(13.697)	(154.610)	(0.047)	(0.051)	(1.782)	(0.607)
N	249,450	231,313	231,313	231,313	249,450	249,450	248,718	249,450
Household Income At Least $30k	-10.237**	-109.712***	-8.911***	-113.440***	-0.011	-0.032***	-0.549***	-0.232
	(4.478)	(37.015)	(2.866)	(38.900)	(0.017)	(0.010)	(0.174)	(0.435)
N	956,366	938,662	938,662	938,662	956,366	956,366	955,593	956,366
Household Income Less Than $30k	-19.243***	-227.417***	-20.211**	-244.396***	-0.058	-0.056	-0.751	0.255
	(4.628)	(84.254)	(7.675)	(77.566)	(0.046)	(0.065)	(1.872)	(0.272)
N	270,202	259,928	259,928	259,928	270,202	270,202	269,743	270,202
Before 2014	-12.832***	-152.896***	-12.572***	-160.132***	-0.006	-0.025**	-0.375**	-0.347
	(2.740)	(35.234)	(2.808)	(36.788)	(0.015)	(0.010)	(0.176)	(0.525)
N	734,883	718,020	718,020	718,020	734,883	734,883	734,287	734,883
2014 and 2015	-8.387	-42.931	-4.051	-42.997	0.004	-0.013	-1.705*	0.415
	(5.398)	(70.961)	(6.025)	(70.676)	(0.020)	(0.035)	(1.014)	(0.631)
N	491,685	480,437	480,437	480,437	491,685	491,685	491,046	491,685
States w/ High Smoking Prevalence	-20.124	-208.482*	-16.759*	-224.044**	0.027	0.003	-0.549	-0.869
	(13.006)	(102.017)	(8.056)	(102.898)	(0.037)	(0.046)	(1.553)	(0.694)
N	417,665	406,456	406,456	406,456	417,665	417,665	417,198	417,665
States w/ Low Smoking Prevalence	-11.235***	-122.435***	-10.291***	-128.648***	-0.028**	-0.041**	-0.614	-0.071
	(3.696)	(41.482)	(3.368)	(40.429)	(0.011)	(0.016)	(0.466)	(0.334)
N	808,903	792,199	792,199	792,199	808,903	808,903	808,139	808,903