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The effects of traditional cigarette and e-cigarette tax rates on adult tobacco product use

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Abstract

We study the effects of traditional cigarette and e-cigarette taxes on use of these products among adults in the United States. Data are drawn from the Behavioral Risk Factor Surveillance System and National Health Interview Survey over the period 2011 to 2018. Using two-way fixed effects models, we find evidence that higher traditional cigarette tax rates reduce adult traditional cigarette use and increase adult e-cigarette use. Similarly, we find that higher e-cigarette tax rates increase traditional cigarette use and reduce e-cigarette use. Cross-tax effects imply that the products are economic substitutes. Our results suggest that a proposed national e-cigarette tax of $1.65 per milliliter of vaping liquid would raise the proportion of adults who smoke cigarettes daily by approximately one percentage point, translating to 2.5 million extra adult daily smokers compared to the counterfactual of not having the tax.

Keywords

smoking; e-cigarettes; taxation; elasticity

JEL Classifications:

H2; I12; I18

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1. Introduction

As of 2018, 34.2 million adults (13.7%) in the United States smoked traditional cigarettes and 8.1 million (3.2%) ‘vaped’ electronic cigarettes (‘e-cigarettes’) (Creamer et al. 2019; Dai and Leventhal 2019).[1] Because e-cigarettes deliver nicotine (the addictive ingredient in tobacco products) without carcinogens and most other toxicants found in traditional cigarettes, they may be a less harmful alternative to traditional cigarettes for smokers who cannot quit. Indeed, the United States Surgeon General has concluded that, while e-cigarettes are not harmless, these products contain fewer toxicants than traditional cigarettes (U.S. Department of Health and Human Services 2016). However, a recent outbreak of e-cigarette, or vaping, product use-associated lung injury (EVALI) has raised fresh concerns in many people’s minds regarding the safety of e-cigarettes. However, this outbreak has been strongly linked to tetrahydrocannabinol (‘THC’)-containing products and does not appear to involve commercially-available nicotine e-cigarettes (Centers for Disease Control and Prevention 2020), thus recent elevated concerns regarding the safety of nicotine e-cigarettes attributable to the EVALI outbreak may be unwarranted (Viscusi 2020; Dave et al. 2020).

Regulating e-cigarettes could have both intended and unintended effects. On one hand, taxing and restricting access to e-cigarettes may help to reduce overall nicotine intake within the population. On the other hand, such measures may in fact harm the health of smokers by discouraging them from switching to arguably safer sources of nicotine (i.e., e-cigarettes) or from using e-cigarettes as a cessation device (Hajek et al. 2019). Faced with this challenge, U.S. governments have taken a variety of e-cigarette regulation approaches. Early regulations in the U.S. generally focused on youth access and curtailing e-cigarette use in specific public places, for instance, bars, restaurants, and private worksites. The most recent wave of regulations includes greater emphasis on the taxation of e-cigarettes. As of December 2019, 22 states have enacted e-cigarette taxes (Public Health Law Center 2019).

In this study, we leverage cross-state, over-time variation in traditional cigarette excise tax rate increases that occurred in 21 states and five counties between 2011 and 2018, as well as the implementation of e-cigarette taxes in ten states and two counties, to examine own- and cross-product tax responsiveness. We utilize two national large-scale health survey data sources—the Behavioral Risk Factor Surveillance System (BRFSS) and the National Health Interview Survey (NHIS)—that include information on smoking and vaping. For both traditional cigarettes and e-cigarettes, we find negative own-product tax responsiveness and positive cross-product tax responsiveness. Our findings appear to be driven by younger adults—defined as those less than 40 years of age—the age group most likely to vape.

The paper proceeds as follows. Section 2 reviews the related literature. Data and variables are described in Section 3, and our methods are discussed in Section 4. Results are reported in Section 5. Section 6 concludes.

[1]Throughout the paper, we refer to the act of smoking as exclusive to traditional cigarette use. We refer to the act of vaping as consuming nicotine-containing e-cigarettes. E-cigarettes are also referred to as e-cigs, e-hookahs, electronic nicotine delivery systems (ENDS), vape pens, and vapes. There are (broadly) three types of e-cigarettes: (1) disposable single-use products, (2) kits that include a rechargeable device and cartridges containing liquid nicotine, and (3) tank or pod systems used to vaporize liquid nicotine. In this paper, we follow the U.S. Surgeon General’s convention in referring to all of these products as e-cigarettes (U.S. Department of Health and Human Services 2016).

2. Related literature

Our paper builds on the existing bodies of work on the own- and cross-price elasticities of traditional cigarettes and e-cigarettes among U.S adults.[2] Below, we discuss the existing literature on these topics as well as our specific contributions.

2.1 Own-price elasticity of traditional cigarettes

A voluminous economics literature estimates the price elasticity of demand for traditional cigarettes across various countries and periods. Chaloupka and Warner (2000) review studies conducted prior to 2000, concluding that smoking is responsive to price but is relatively inelastic, with most estimated price elasticities of total demand falling in the −0.3 to −0.5 range for adults. A more recent review by the Community Preventive Services Task Force (2014) estimates a traditional cigarette total demand price elasticity of −0.37 for adults, which is approximately equally split by effects on the extensive and intensive smoking margins.

The potential endogeneity of traditional cigarette prices is a concern with these estimated elasticities. Prices are determined by demand and supply factors that are generally difficult to measure and fully control for in regression models, which could lead to omitted variable bias in coefficient estimates and associated elasticity calculations (Gruber and Köszegi 2001; Gruber and Frakes 2006). A large number of more recent economic studies use traditional cigarette *taxes* rather than *prices* to reduce these endogeneity concerns.[3] In 2018, state taxes represented 22% of the weighted retail price for traditional cigarettes (Orzechowski and Walker 2018), suggesting that an adult price elasticity of demand of −0.40 converts to a state-level tax elasticity of demand of −0.10.

Our contribution to the literature on the own-price elasticity of demand for traditional cigarettes is to calculate an adult smoking tax elasticity during a period when e-cigarettes were widely available. Given this objective, benchmarking adult traditional cigarette tax-rate responsiveness for comparison with our findings is important.[4] We identify several studies that estimate traditional cigarette tax-rate responsiveness for adults using nationally representative data just prior to the period in which e-cigarettes became widely available in U.S. tobacco markets. We contend that these studies are the most relevant to our work while acknowledging that they do not reflect the universe of studies estimating traditional cigarette demand equations.

Cotti, Nesson, and Tefft (2016) use household scanner data from 2004 to 2012 to calculate a tax elasticity of −0.16. Similarly, Nesson (2017) finds an elasticity of −0.15 using the 1988 to 2012 National Health and Nutrition Examination Surveys; Bishop (2018) documents an

[2]There is also a literature on the effects of various e-cigarette policies—particularly minimum age laws—on youth smoking (Dave, Feng, and Pesko 2019; Friedman 2015; Pesko and Currie 2019; Pesko, Hughes, and Faisal 2016).

[3]While tax rates are arguably not as directly determined by demand as prices, they are nonetheless established within the state's political economy and thus not purely exogenous (Besley and Case 2000).

[4]Though our focus here is on prime age adults, we note that there is also a literature using quasi-experimental methods to estimate the tax elasticity of demand for traditional cigarettes among youth (DeCicca, Kenkel, and Mathios 2002; Carpenter and Cook 2008; Hansen, Sabia, and Rees 2017; Courtemanche and Feng 2018) and older adults (DeCicca and McLeod 2008; Maclean, Kessler, and Kenkel 2016).

elasticity of −0.18 using 1999 to 2012 BRFSS data; and Callison and Kaestner (2014) estimate an elasticity range from −0.06 to −0.03 using the 1995 to 2007 Current Population Survey Tobacco Use Supplements (TUS).

By examining more recent data, we explore whether the introduction of e-cigarettes into U.S. tobacco product markets may have altered traditional cigarette tax responsiveness. That is, e-cigarettes may enable some smokers to quit or to switch to a less harmful nicotine source as traditional cigarette taxes rise.

2.2 Own-price elasticity of e-cigarettes, and cross-price elasticity between traditional cigarettes and e-cigarettes

Several recent studies estimate the own-price elasticity of e-cigarettes along with the cross-price elasticity between traditional cigarettes and e-cigarettes. Most studies use e-cigarette prices generated from retail scanner data; that is researchers construct aggregated, area-level price measures based on prices that retailers in that area scan at purchase.[5] As we discuss later in this paper, U.S. localities have only recently implemented e-cigarette taxes. Thus, these earlier studies could not exploit this source of plausibly exogenous variation. Therefore, they instead rely on prices, which are likely vulnerable to similar endogeneity concerns noted by Gruber and Köszegi (2001) and Gruber and Frakes (2006) in the context of traditional cigarette prices.

There are four recent studies that leverage variation in e-cigarette taxes to estimate elasticities of tobacco product demand; these studies are arguably most relevant to our own work as they exploit the same source of tax variation.[6] Cotti et al. (2020) use Nielsen retail scanner data over the period 2011 to 2017 to estimate tax pass-through rates for e-cigarettes. The authors document a pass-through rate of 1.55, which suggests that taxes are over-shifted to consumers. Cotti and colleagues estimate that traditional cigarette price increases (instrumented with taxes) reduce traditional cigarette sales (own-price elasticity −0.6) and increase e-cigarette sales (cross-price elasticity of 1.0). In addition, the authors document that e-cigarette price increases (also instrumented with taxes) reduce e-cigarette sales (own-price elasticity of −1.5). Saffer et al. (2020) use synthetic control methods to conduct a case-study analysis of Minnesota's e-cigarette tax, comparing adult smoking outcomes in this state to a 'synthetic' composite of other U.S. states. Minnesota was the first state in the U.S. to adopt an e-cigarette tax in 2010. The authors show that Minnesota's e-cigarette tax increased smoking and reduced cessation among adults. In particular, the authors document a cross-price elasticity of 0.13. Abouk et al. (2019) use the universe of birth records data in the U.S. over the period 2013 to 2018 to show that a $1.00 increase in the e-cigarette tax leads to a 7.7% increase in prenatal smoking, which suggests that traditional cigarettes and e-cigarettes are economic substitutes among pregnant women. Finally, Allcott and Rafkin

[5]These prices include excise taxes but do not include sales taxes.

[6]Additionally, several studies evaluate the effect of e-cigarette price variation on sales or use of e-cigarettes and/or traditional cigarettes (Huang et al. 2018; Zheng et al. 2017; Stoklosa, Drope, and Chaloupka 2016; Pesko and Warman 2017; Pesko et al. 2018; Cantrell et al. 2019; Saffer et al. 2018; Marti et al. 2019; Pesko et al. 2016). All of these studies, with the exception of Cantrell et al. (2019), show that e-cigarette sales or use declines following a price or tax increase. Several studies provide evidence that traditional cigarettes and e-cigarettes are economic substitutes (Zheng et al. 2017; Stoklosa, Drope, and Chaloupka 2016; Pesko and Warman 2017; Cantrell et al. 2019), with none finding evidence to support the hypothesis that the two products are economic complements.

(2020) find little evidence of complementarity or substitution using Nielsen sales data or through a shift-share strategy using pre-2013 smoking propensities for different demographic groups.

One study explores the effects of traditional cigarette taxes on adult e-cigarette use. Cotti, Nesson, and Tefft (2018) use Nielson household scanner data to show that traditional cigarette tax increases lead to a decline in purchases of both products. This finding implies that the products are economic complements, which contrasts with the results from the majority of studies discussed above that suggest substitutability across the two products.

A novel contribution of our study is being the first to study the effect of e-cigarette taxes across adults in multiple states (instead of just pregnant women as in Abouk et al. (2019) or a single state, Minnesota, as in Saffer et al. (2020)) on e-cigarette use (rather than sales, as in Cotti et al. (2020) and Allcott and Rafkin (2020)).[7] Examining use instead of sales is potentially of particular importance, as the time and location of tobacco products being sold does not necessarily correspond to when and where they are consumed. For instance, Gruber and Köszegi (2001) note the possibility of traditional cigarette stockpiling in anticipation of a pending traditional cigarette tax increase. In the presence of stockpiling, the tax taking effect would lead to a large decline in sales that is not accompanied by a similar reduction in use, therefore overstating the public health benefit of the tax hike and the tax elasticity. Additionally, smuggling of tobacco products from a low to high tax locality is a widely documented phenomenon that could lead to estimated effects of taxes on sales that exceed their actual effects on tobacco product use (United States General Accounting Office 2004).

3. Data

3.1 Survey data

We use data for the period 2011 to 2018 from the BRFSS and the NHIS.[8] The U.S. federal government and economists use these data sources to track health behaviors such as smoking and vaping (Barbaresco, Courtemanche, and Qi 2015; Miller and Wherry 2017; Horn, Maclean, and Strain 2017; Pesko 2014). We use geocoded versions of the BRFSS and the NHIS available through federal statistical research data centers. Thus, we have access to granular geographic information that is not available in the public use files. In particular, through the use of the restricted data, we can accurately study sub-state taxes.[9]

We combine these two data sources to maximize data on e-cigarette use, which have only recently been added to national surveys. Combing datasets in this manner is not uncommon

[7]Two other studies find a negative association between e-cigarette tax adoption and e-cigarette use using at most two waves of BRFSS data (Jun and Kim 2020; Du et al. 2020). However, these studies do not control for locality or time fixed effects and hence omitted variable bias is likely.

[8]We begin our study period in 2011 due to a change in the BRFSS survey frame. Prior to 2011, the BRFSS, a telephone survey, conducted surveys using landlines. Beginning in 2011, cellphones were added to the survey frame to better capture a sample that represented the U.S. population. This change in survey frame led to a compositional shift in survey respondents, and thus we follow CDC recommendations and do not combine pre- and post-2011 data. In addition, the focus on relatively recent years enables us to isolate the period in which e-cigarettes were widely available in U.S. tobacco product markets, which is our main contribution to the traditional cigarette tax elasticity literature.

[9]The public use BRFSS includes geographic information on states but not sub-state localities. The finest geographic area recorded in the public use NHIS is the region.

within economics (Maclean, Tello-Trillo, and Webber 2019; Webber 2016; Farber et al. 2018; Altonji, Kahn, and Speer 2016; Miller 2012). The BRFSS surveys over 400,000 adults each year, and the NHIS surveys approximately 33,000 adults annually as part of its adult sample, where e-cigarette information is queried. Both data sources record information on traditional and e-cigarette use. To measure traditional cigarette use, surveyors first ask respondents if they have smoked at least 100 traditional cigarettes in their lifetime. Respondents who indicate that they have smoked this number of traditional cigarettes are then asked if they now smoke daily, some days, or not at all. The BRFSS added e-cigarette questions in 2016 and the NHIS did so in 2014. Both surveys ask respondents if they have ever used e-cigarettes and, if so, if they now use e-cigarettes daily, some days, or not at all. We combine answers to questions on any traditional cigarette use and any e-cigarette use (in years when both are available) to create two additional measures: any use of both products (‘dual use’) and any use of either product (‘any use’).

We make two sample restrictions. First, we drop individuals from Alaska because of limited sub-state geographical information for Alaska, even in the restricted versions of the data files that we use. Second, we remove any period between the enactment of a new tax and its effective data, a period of time that averages 1.4 months for the 14 states adopting traditional cigarette taxes of ≥ $0.50 and 4.2 months for the ten localities adopting e-cigarette taxes by the end of 2018. The years of data differ across our smoking and vaping outcomes based on data availability in the BRFSS and the NHIS. We use 2011 to 2018 for our smoking outcomes in both data sources. For our vaping outcomes, we use 2016 to 2018 in the BRFSS and 2014 to 2018 in the NHIS; these are the years for which we have vaping information in each survey.

We create harmonized demographic variables, which we include in our empirical models, across the two data sources. We include the following individual-level control variables in our regressions: sex (female, male, and missing/other), education (less than high school, high school or GED, some college, college or more, and missing), race/ethnicity (non-Hispanic white, non-Hispanic African American, non-Hispanic Asian, non-Hispanic Native American/Alaskan Native, non-Hispanic other, Hispanic, and missing race/ethnicity), marital status (married, divorced, widowed, separated, never married, and missing), age in years, health insurance status (insured, not insured, and missing), employment (currently employed, not currently employed, and missing), income, and an indicator for data source.[10]

While most variables in the two data sources are similar, an exception is income. The BRFSS collects household income while the NHIS collects personal income. We account for this difference in the income variable as follows. Separately for each data source, we convert the categories into a pseudo-continuous variable and then impute missing values using state-year means. We control for the differences in income across data source by interacting the harmonized income variable with the indicator for data source. We also control for separate indicators for the top income category, the amounts of which vary across the data sources.

[10]This variable is included to control for differences in survey design. For instance, the BRFSS is a telephone survey while the NHIS is a face-to-face survey.

We later discuss how results are insensitive to including/excluding income as a control variable.

3.2 Traditional cigarette and e-cigarette policies

We obtain dates of state traditional cigarette excise tax changes from the Centers for Disease Control and Prevention (2019). We also obtain sub-state traditional cigarette excise tax changes affecting localities with 100,000 people or more using proprietary data obtained from the American Non-Smokers Rights Foundation. The CDC State System (2019) and the Public Health Law Center (2019) are used to determine the dates and timing of state-level e-cigarette tax changes, and the Vapor Products Tax (2019) is used to determine dates for sub-state changes.

While traditional cigarette excise tax units are common across localities (i.e., a dollar value per pack of 20 traditional cigarettes), e-cigarette taxes are levied in different ways. Of the 13 localities levying an e-cigarette tax by the end of 2018, five use an ad valorem tax on the wholesaler and eight use an excise tax per milliliter (ml) of vaping liquid.[11] Washington DC's tax is unique in that the e-cigarette ad valorem tax is set to match the traditional cigarette tax amount, suggesting that each one percent of ad valorem tax is 4.4 cents. Following Cotti et al. (2020), we use this relationship to convert e-cigarette ad valorem taxes into excise tax equivalents for each relevant locality. Please see the online appendix for a detailed discussion of our conversion process, which utilizes Nielsen Retail Scanner data. Our primary e-cigarette tax measure is therefore a continuous tax variable representing the actual excise tax rate, or the excise tax rate equivalency for an ad valorem tax. We refer to the converted tax as the 'standardized' e-cigarette tax.

Online Table A1 lists the localities that changed their traditional cigarette tax rate over the period 2011 to 2018, and Online Table A2 lists localities that levied an e-cigarette tax by the end of 2018. The last column of Online Table A2 shows that the standardized e-cigarette tax magnitudes vary widely from $0.05 per ml in Kansas and Louisiana to $1.82 per ml in Minnesota at the end of our study period. A standard JUUL (at the time of writing JUUL is the leading e-cigarette manufacturer in the U.S.) pod containing 0.7 ml of fluid would therefore be assessed a tax of less than $0.04 for Kansas and Louisiana and $1.27 for Minnesota. For comparison, in 2018 the weighted federal and state traditional cigarette excise tax was $2.51 per pack (Orzechowski and Walker 2018).

Figures 1 and 2 depict these taxes geographically, and Figures 3 and 4 report the number of tax changes in each year of our study period. While there is some clustering of higher traditional cigarette tax increases from 2011 to 2018 in the West and the Northeast regions, we have reasonable variation in these tax increases across the country. In terms of e-cigarette tax changes, there is no obvious clustering in specific geographic areas and we observe adopting localities in all four regions of the country. Traditional cigarette tax changes are relatively homogenous across years, while e-cigarette tax adoptions and changes are more

[11]Both Chicago and Cook County have adopted an e-cigarette tax. We assume that the earlier tax in Chicago affects all of Cook County, since we cannot separate Chicago residents from residents of the rest of Cook County in our data.

concentrated in the latter half of the study period which is as expected given that e-cigarette taxes are recent policies.

3.3 Locality-level control variables

We also control for several time-varying locality-level factors in our regression models, we include these variables to account for differences that may be correlated with both tobacco product taxes and our outcomes, and thus we reduce omitted variable bias. In particular, we include the county-level share of the population covered by indoor vaping restrictions and indoor smoking restrictions in bars, restaurants, and private workplaces;[12] and state-level e-cigarette minimum legal purchase age laws (Centers for Disease Control and Prevention 2019); Tobacco 21 laws (Centers for Disease Control and Prevention 2019); beer taxes per gallon (National Institute on Alcohol Abuse and Alcoholism 2019); medical marijuana laws (Sabia and Nguyen 2018); marijuana decriminalization laws (Pacula, Chriqui, and King 2003);[13] prescription drug monitoring programs (Ali et al. 2017); Affordable Care Act Medicaid expansion status (Maclean, Pesko, and Hill 2019; Kaiser Family Foundation 2020); and the unemployment rate (University of Kentucky Center for Poverty Research 2019). All monetary values are consumer price index-adjusted to 2010 dollars. We link all locality-level variables to the combined BRFSS and NHIS dataset using year/quarter and county/state information available in both data sources.

3.4 Summary statistics

Descriptive statistics for both data sources combined are presented in Table 1, and separately for the BRFSS and the NHIS in online appendix Tables A3 and A4, respectively. For each table, variable means are presented separately for all respondents, for respondents residing in localities that had not levied an e-cigarette tax by the end of 2018, and for respondents residing in localities that had levied such a tax by the end of 2018. Overall, 15.6% of respondents use traditional cigarettes, 11.2% of respondents use traditional cigarettes daily, 3.4% of respondents use e-cigarettes, 1.2% use e-cigarettes daily, 1.9% use both products (dual use), and 16.5% use either product (any use). The share of respondents residing in a locality that had adopted an e-cigarette tax by 2018 is 7.6%. All measures of tobacco product use are slightly lower and tobacco control policy strengths are higher for localities that had adopted an e-cigarette tax by 2018. While there are some differences in other policies and demographics across groups, they do not appear to be substantial. Moreover, we control for these variables in regression models.

4. Methods

We estimate two-way fixed effects regression models. Specifically, we estimate the regression model outlined in equation (1):

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[12]The American Non-Smokers Rights Foundation tracks when municipalities, counties, and states pass indoor air laws for vaping or smoking in different venues. These comprehensive data have been used in several papers (McGeary et al. 2020; Abouk and Adams 2017; Cotti, Nesson, and Tefft 2018). We use this information to create two separate measures for the share of the population in each county covered by indoor smoking and indoor vaping restrictions for private workplaces, restaurants, or bars. We weight laws applying to bars, restaurants, and private workplaces equally. For indoor smoking restrictions, we also consider laws applying to only part of the establishment (but not the full establishment) with ½ weight. Partial laws are uncommon for indoor vaping restrictions.

[13]We thank Rosalie Pacula for sharing an updated version of the marijuana decriminalization variable with us.

$$Y_{i,\,c,\,s,\,t} = a + \beta Ttax_{c,\,s,\,t} + \partial Etax_{c,\,s,\,t} + Z_{c,\,s,\,t}\phi + X_{i,\,c,\,s,\,t}\theta + \gamma_{c,\,s} + \tau_t + \varepsilon_{i,\,c,\,s,\,t} \quad (1)$$

In this equation, i indexes an individual interviewed in year-quarter t, who resides in county c of state s. $Y_{i,c,s,t}$ is an indicator for whether the individual smokes, smokes daily, vapes, vapes daily, uses both products (dual use), or uses either traditional cigarettes and/or e-cigarettes (any use). $Z_{c,s,t}$ includes the time-varying locality- (state- or county-) level policies. $X_{i,c,s,t}$ includes demographics, an indicator for whether the observation was surveyed in the BRFSS or the NHIS, and an interaction between data source and income.

We control for county fixed effects ($\gamma_{c,s}$), which mitigate potential bias from time-invariant, county-specific factors. Note that county fixed effects incorporate state fixed effects as counties are nested within states. Including these fixed effects allows us to leverage within-locality (county or state) variation in traditional cigarette and e-cigarette taxes for identification of treatment effects. We also control for year-by-quarter fixed effects (τ_t) that account for time varying factors affecting the nation as a whole.

β and ∂ are our primary coefficients of interest; they capture the effect of traditional cigarette and e-cigarette taxes on our outcomes. We expect own taxes will reduce current use of these products, but the cross-tax effects are *a priori* ambiguous. Cross-tax effects will be positive if the goods are substitutes, negative if the goods are complements, and zero if the goods are unrelated. As discussed in Section 2, the literature has not yet reached consensus on whether these products are complements or substitutes among adults, although most studies to date suggest that they are economic substitutes.

A necessary assumption for two-way fixed effects models to recover causal estimates is that the treatment group (i.e., localities changing traditional cigarette taxes or adopting e-cigarette taxes) and the comparison group (i.e., localities not changing traditional cigarette taxes or adopting e-cigarette taxes) would have followed the same trend in the post-treatment period had the treatment localities not been treated (i.e., had they not changed the traditional cigarette tax or adopted an e-cigarette tax). This assumption is referred to as ‘parallel trends.’ Clearly this assumption is untestable as treated localities are treated in the post-period, preventing us from observing counterfactual trends. Instead, we follow the economics literature and provide suggestive evidence on whether the parallel trends assumption is satisfied in our data by modifying equation (1) to conduct an event study (Autor 2003).

To implement the event study, we replace the traditional cigarette tax rate with an indicator variable for if the traditional cigarette tax increased by $0.50 or more at any point during the study period following; we refer to such a change as a large traditional cigarette tax increase (Callison and Kaestner 2014).[14] For the e-cigarette tax, we construct an indicator that divides the study period into a pre- and post-tax effective period for adopting localities, non-adopting localities are coded zero. For both the large traditional cigarette tax increase and e-

[14]Fourteen states passed a cigarette excise tax increase of ≥ $0.50 during the study period, and no states passed more than two such increases. Due to local taxes, both Cook County and Philadelphia County had more than one $0.50 excise tax increase. In those cases, we use the first large tax increase to define the ‘event’ in our event study.

cigarette tax effective date variables, we create five mutually exclusive policy time periods: >2 years in advance of the tax, [2–1) years in advance of the tax, [1–0) years in advance of the tax, (0 to 1] years after the tax, and >2 years after the tax. In creating these event-time groups we use effective dates through the end of 2019 for both traditional cigarettes and e-cigarettes following Ghimire and Maclean (2020), and Schmidheiny and Siegloch (2019).

The omitted category is >2 years prior to the tax effective date. We code all non-adopting localities as zero for all event-time indicators (Lovenheim 2009). All other variables are as defined in equation (1). If the policy lead coefficient estimates (i.e., in advance of the tax) are small in magnitude and statistically indistinguishable from zero, this pattern of results suggests that there were no changes in smoking or vaping before the policy's adoption. Such results can be interpreted as providing suggestive evidence that a covariate-adjusted version of the parallel trends assumption is met and that our two-way fixed effects models can recover causal estimates.

In regression analysis, we use weights that we construct from the National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER) data to ensure that the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort is proportionate to its national population share (i.e., we create weights reflective of each locality's population across these characteristics).[15] We base our weighting scheme on two papers that pool national, state, and local versions of the Youth Risk Behavior Surveillance System (Anderson, Hansen, and Rees 2015; Dave, Feng, and Pesko 2019).

We leverage both state and county tax variation to identify treatment effects. The correct level at which to cluster standard errors is thus unclear. In our main analysis, we cluster standard errors at the level of the state (Bertrand, Duflo, and Mullainathan 2004), but we also explore the sensitivity of our analysis to clustering at the county level as well.

5. Results

5.1 Effects of traditional cigarette and e-cigarette tax rates on adult tobacco product use

Our main two-way fixed effects results are reported in Table 2. A $1.00 increase in the traditional cigarette tax reduces current traditional cigarette use by 0.1 percentage points (ppts) (p>0.10, i.e., statistically insignificant) and everyday traditional cigarette use by 0.6 ppts (p<0.01), which represents a 0.8% and 5.3% reduction compared to the mean smoking rates in the sample (all relative comparisons are calculated in this manner). Given a mean traditional cigarette state excise tax rate of $1.54, these estimates imply a modest own-tax elasticity of demand of −0.01 for current smoking and −0.09 for daily smoking.[16] We note that our traditional cigarette tax elasticity estimates are reasonably close to Callison and Kaestner (2014), who report elasticities in the range of −0.03 to −0.06. However, our

[15]Data is only available through 2017 as of the writing of this paper; therefore, we use 2017 SEER values for 2018 weights. Details available on request.

[16]For current smoking, we use the traditional cigarette tax coefficient estimated listed in the first column of Table 2 (−0.0012), multiply this number by the average traditional cigarette tax for adopting localities ($1.51 from Table 1), and then divide this product by the average traditional cigarette use for adopting localities (0.156 from Table 1). Thus, the exact calculation is as follows: −0.0012 * (1.54/0.155) = −0.012. For daily smoking, we follow a similar procedure and the exact calculation is as follows: −0.0062 * (1.54/0.112) = −0.085.

estimates are somewhat lower than other more recent estimates ranging from −0.15 to −0.18 documented by Cotti, Nesson, and Tefft (2016), Nesson (2017), and Bishop (2018). In sum, we do not find evidence that traditional cigarette tax responsiveness increases in the era in which e-cigarettes are more available.

A $1.00 traditional cigarette excise tax increase increases current vaping by 0.3 ppts (p>0.10), or 7.4%, and everyday vaping by 0.2 ppts (p<0.05), or 14.2%, suggesting that the two products are economic substitutes. Traditional cigarette taxes also increase dual use of both tobacco products by 0.3 ppts (p<0.05), or 17.2%, and any use of either product by 0.2 ppts (p>0.10), or 1.3%. These results suggest that smokers use e-cigarettes when traditional cigarette taxes rise, either to continue to consume some portion of their regular nicotine at a lower relative price or as a means to quit smoking.

We note that a recent, large-scale randomized control trial in England documents that individuals given e-cigarettes to quit smoking have a one-year cigarette abstinence rate of 18% compared to a 10% rate for other forms of nicotine replacement therapy (Hajek et al. 2019). While e-cigarettes are more effective than nicotine replacement therapies, the authors find that the average smoker will require up to five cessation attempts using e-cigarettes before they are able to fully quit smoking. The high quitting failure probability could account for our finding that traditional cigarette tax hikes increase dual use.

We find that a $1.00 increase in tax per fluid ml of vaping liquid increases daily smoking propensity by 0.6 ppts (p<0.05) or 5.3%. A $1.00 increase in tax per fluid ml of vaping liquid reduces the probability of current vaping by 0.5 ppts (p<0.10) or 15.3% and the probability of daily vaping by 0.2 ppts (p>0.10) or 14.2%.[17] Finally, we observe that a $1.00 increase in tax per fluid ml of vaping liquid reduces the probability of dual use by 0.4 ppts (p<0.10), or 24.4%. Collectively, these findings further suggest that traditional cigarettes and e-cigarettes are economic substitutes. E-cigarette taxes may reduce dual use rates by discouraging adult smokers from trying to use e-cigarettes to quit.

In Online Table A5, we explore the effect of any e-cigarette tax rather than the standardized e-cigarette tax rate. More specifically, we replace the continuous e-cigarette tax measure with an indicator variable for the presence of any e-cigarette tax. We note that none of the coefficient estimates are statistically distinguishable from zero. However, while imprecise in this specification, we document that the adoption of an e-cigarette tax reduces current vaping by 0.6 ppts, or 16.2%, and daily vaping by 0.2 ppts, or 15.0%. However, these coefficient estimates are not statistically different from zero. These findings suggest that considering the magnitude of the tax, rather than just the presence of a tax, provides important variation that allows for more precise estimation of treatment effects.

5.2 Internal validity of the research design

In Table 3, we report coefficient estimates and associated standard errors for our tobacco and e-cigarette use outcomes generated using our event study. The reference period is >2 years

[17]Given that the vast majority of our e-cigarette tax variation primarily comes from tax introductions rather than tax increases, we are unable to calculate an e-cigarette tax elasticity because the percent change in the tax is undefined.

prior to the enactment of a large traditional cigarette tax increase or adoption of an e-cigarette tax. Overall, of the 24 policy lead coefficients for a large traditional cigarette tax increase or an e-cigarette tax adoption, only two are statistically significant at the 10% level or better (one cross-tax policy lead for both smoking and vaping). This pattern of results is within the window of random chance. However, we note that some of the coefficients in the pre-period are large in magnitude relative to coefficients in the post-period. Taken together, we interpret our findings as providing suggestive evidence that our data can support a covariate-adjusted version of the parallel trends assumption.

5.3 Heterogeneity in tax effects on adult tobacco product use

Given differences in use of these products (Wang et al. 2018) and perceptions regarding their health harms (Glasser et al. 2017), tax responsiveness may vary across subgroups. In Tables 4 through 7, we empirically explore this possibility.

We find evidence that most of the own- and cross-tax responsiveness that we documented among the full sample is potentially being driven by younger adults, defined as those under 40 years of age (Table 4). This finding is reasonable as younger adults are much more likely to use e-cigarettes than other groups of adults. For these younger adults, a $1.00 increase in the traditional cigarette tax rate reduces daily smoking by 0.7 ppts ($p<0.05$), or 5.4%; increases current vaping by 0.8 ppts ($p<0.05$), or 11.4%; and increases daily vaping by 0.5 ppts ($p<0.01$), or 19.2%. Similarly, this magnitude of an increase in the traditional cigarette tax rate increases dual use by 0.9 ppts ($p<0.01$), or 27.6%, and increases use of either tobacco product by 2.4 ppts ($p<0.01$), or 10.6%. A $1.00 increase in the standardized e-cigarette tax increases daily smoking by 1.2 ppts ($p<0.01$) or 8.8%, reduces current vaping by 1.8 ppts ($p<0.01$), or 26.0%, and reduces daily vaping by 0.6 ppts ($p<0.01$), or 24.8%. The probability of dual use declines by 1.6 ppts ($p<0.01$), or 47.0%, and the probability of any use declines by 3.7 ppts ($p<0.05$), or 16.3%, following a $1.00 increase in the standardized e-cigarette tax.

Among older adults (Table 5), defined as those 40 years and above, we find that current and daily smoking are responsive to traditional cigarette tax rate changes, but otherwise we find little in the way of tax responsiveness. Observed changes in the probability of any use for older adults is primarily attributable to changes in smoking. The coefficient estimates for the e-cigarette outcomes may be particularly small due to baseline e-cigarette use rates for older adults being approximately one-third of the younger adult rate in our data. Among women overall (Table 6), we find evidence traditional cigarette taxes reduce daily smoking and increase daily vaping while e-cigarette taxes reduce daily vaping and increase daily smoking. For men (Table 7), we find limited evidence of own- or cross-tax responsiveness.

5.4 Robustness

In Figures 5 and 6, we re-evaluate findings from Table 2 by sequentially dropping treatment localities that adopted a large traditional cigarette excise tax and an e-cigarette tax respectively during our study period (i.e., a ‘leave one out’ analysis). The purpose of this exercise is to examine whether any single treated locality has an outsized impact on our coefficient estimates. We report results for daily smoking and vaping since all but one of these coefficient estimates is statistically significant in our full model (Table 2). These figures suggest that our results are stable when removing individual treatment localities. The 95% confidence intervals when removing California from the e-cigarette models noticeably increase, which is likely due to the disproportionate size of this state and the magnitude of its tax among e-cigarette adopting states.

In Online Table A6, we re-estimate equation (1) using an alternative e-cigarette tax rate measure that accounts for possible endogeneity in the standardization process (see online appendix for further details). In Online Table A7, we drop income as a control variable since income information is collected differently across the BRFSS (household income) and NHIS (personal income) data sources. Our results are substantially similar to Table 2 regardless of these changes. In Online Table A8, we drop all time varying variables besides traditional cigarette and e-cigarette taxes. Doing so causes our coefficient estimates for e-cigarette use to attenuate somewhat and the associated confidence intervals to widen, although the signs remain the same as in Table 2. This attenuation is perhaps unsurprising because some states passed e-cigarette indoor vaping restrictions at the same time as taxes, for example, so not controlling for these policies may be causing omitted variable bias.

Finally, in Online Table A9, we cluster standard errors at the level of county instead of state. Standard errors are very similar for our traditional cigarette use outcomes. However, we note that we lose precision on our outcomes for which we only have data starting in 2014 (i.e., e-cigarette use, dual use, and any use).

6. Discussion

In this paper, we provide evidence on the effects of traditional cigarette taxes on traditional cigarette use and e-cigarette use in a period when e-cigarettes were widely available in tobacco markets, and the effects of e-cigarette taxes on these outcomes. To do so, we combine data from two large-scale health surveys administered by the U.S. federal government to track health outcomes among Americans, the BRFSS and the NHIS, and detailed information on state and county traditional cigarette and e-cigarette taxes with a two-way fixed effects design. Overall, we observe that, as previous studies estimating traditional cigarette demand equations have documented, smoking declines when traditional cigarette tax rates increase. We also find evidence that adults are more likely to use e-cigarettes when traditional cigarette taxes rise, which mirrors evidence from retail sales data (Zheng et al. 2017; Stoklosa, Drope, and Chaloupka 2016; Cotti et al. 2020; Allcott and Rafkin 2020).

Our study has limitations. First, because e-cigarette questions have only recently been added to large-scale U.S. health surveys, we have limited data on e-cigarette use. Second, while we can measure daily smoking and vaping, we cannot, with the information collected in our data sources, fully examine effects on the intensive margin of tobacco product use. As noted earlier, this data feature likely leads us to understate tax effects. Third, we rely on self-reported traditional cigarette and e-cigarette use, which may be measured with some error.

We suspect that our focus on (primarily) the extensive margins of traditional cigarette and e-cigarette use likely leads us to understate tax effects. That is, following a traditional cigarette tax hike or the adoption/increase of an e-cigarette tax, some individuals may reduce the quantity demanded on the intensive margin (e.g., the number of traditional cigarettes smoked or e-cigarettes vaped per day) but not quit completely. While we do examine the intensive margin in part by exploring daily smoking and vaping, we are unable to fully capture this margin given limited information available in both data sources.

Our findings depart from those of a recent and related study. Whereas we document that traditional cigarettes and e-cigarettes are substitutes, Cotti, Nesson, and Tefft (2018) provide evidence of complementarity between the two products. One possible explanation is that our dataset encompasses more recent changes. Cotti, Nesson, and Tefft (2018) use data from 2011 to 2015. Our dataset includes the years 2016 through 2018, when twelve additional localities—California, Connecticut, Washington, DC, Delaware, Kentucky, Louisiana, Minnesota, Oklahoma, Oregon, Pennsylvania, Rhode Island, and West Virginia—increased their traditional cigarette excise taxes. These localities are different in terms of geography, population, tobacco product use, and so forth from the localities that passed such taxes from 2011 to 2015. In particular, California is a treatment state in our study because it enacted a traditional cigarette tax increase in April 2017. This populous state with a historically strong tobacco-control program was a control locality during the period investigated by Cotti, Nesson, and Tefft (2018).

Ten states and two localities had adopted e-cigarette taxes by the end of our study period in 2018. However, in 2019 and in the first days of 2020, e-cigarette taxes came into effect in 11 additional states (Connecticut, Illinois, Maine, Nevada, New Hampshire, New Mexico, New York, Ohio, Vermont, Washington, and Wisconsin) (Public Health Law Center 2019). In February 2020, the U.S. House of Representatives approved a national e-cigarette tax proportional to the federal traditional cigarette tax (116th Congress of the United States 2020). The bill specifies a tax rate of $50.33 per 1,810 milligrams of nicotine (or $0.028 per milligram). For comparison, JUUL pods at the time of writing contain 59 milligrams/ml (at 5% nicotine volume). Assuming this conversion, the proposed federal e-cigarette tax per fluid ml would be $1.65 ($0.028 * 59). Therefore, using our findings, we predict that the House bill could raise adult daily traditional cigarette use by approximately 1.0 ppt ($1.65 × 0.0059 from Table 2). Given that there are roughly 254.7 million adults in the U.S. (United States Census Bureau 2020), the proposed federal e-cigarette tax could increase the number of daily adult smokers by 2.5 million, likely by reducing smoking cessation that would otherwise occur. The tax would also reduce the number of adults using e-cigarettes by roughly the same number. Under this simulation, if e-cigarettes are a substantially safer product than traditional cigarettes for adults (Royal College of Physicians 2019; U.S. Department of Health and Human Services 2016), then an e-cigarette tax is predicted to overall harm public health for adults.

7. Conclusion

We document an inverse relationship between e-cigarette tax rates and e-cigarette use. Two other working papers identify a negative relationship between e-cigarette taxes and sales

(Cotti et al. 2020; Allcott and Rafkin 2020). However, our study is the first to specifically examine the effect of these taxes on adult e-cigarette use. Additionally, we are also able to show that e-cigarette taxes *increase* traditional cigarette use, echoing results from studies using price variation matched to sales data (Zheng et al. 2017; Cotti et al. 2020) and tax variation matched to prenatal smoking data (Abouk et al. 2019).

Our research contributes further evidence (from quasi-experimental two-way fixed effects methods) that regulating e-cigarettes has the unintended consequence of raising traditional cigarette use. While neither product is harmless, the clinical literature strongly suggests that e-cigarettes are the less harmful product (U.S. Department of Health and Human Services 2016). With few exceptions (Abouk and Adams 2017; Cotti, Nesson, and Tefft 2018), this finding has been documented for youth (Dave, Feng, and Pesko 2019; Pesko, Hughes, and Faisal 2016; Pesko and Currie 2019; Friedman 2015), pregnant women (Cooper and Pesko 2017; Pesko and Currie 2019; Abouk et al. 2019), and now, for the first time, for adults. These results suggest caution in regulating e-cigarettes because e-cigarette regulations may have a harmful, unintended consequence: increased smoking of traditional cigarettes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Researcher(s) own analyses calculated (or derived) based in part on data from The Nielsen Company (U.S.), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the Nielsen data are those of the researcher(s) and do not reflect the views of Nielsen. Nielsen is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

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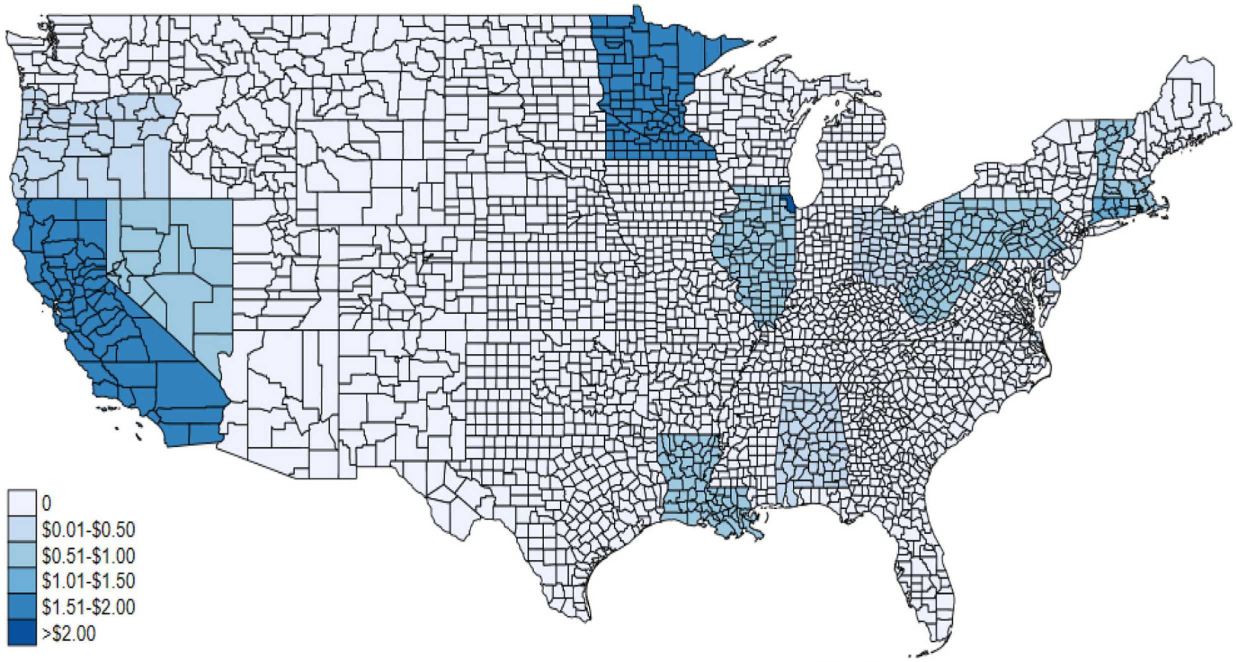


Figure 1.
Geographic variation in traditional cigarette tax increases 2011–2018
Note: See text for details.

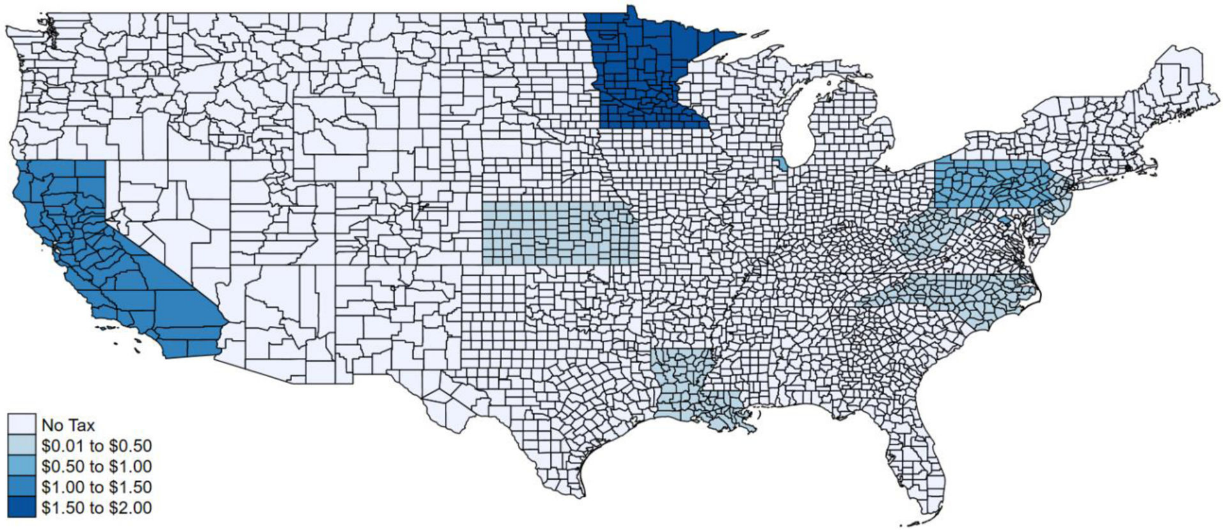


Figure 2.
Geographic variation in e-cigarette taxes, as of 4Q 2018
Note: See text for details.

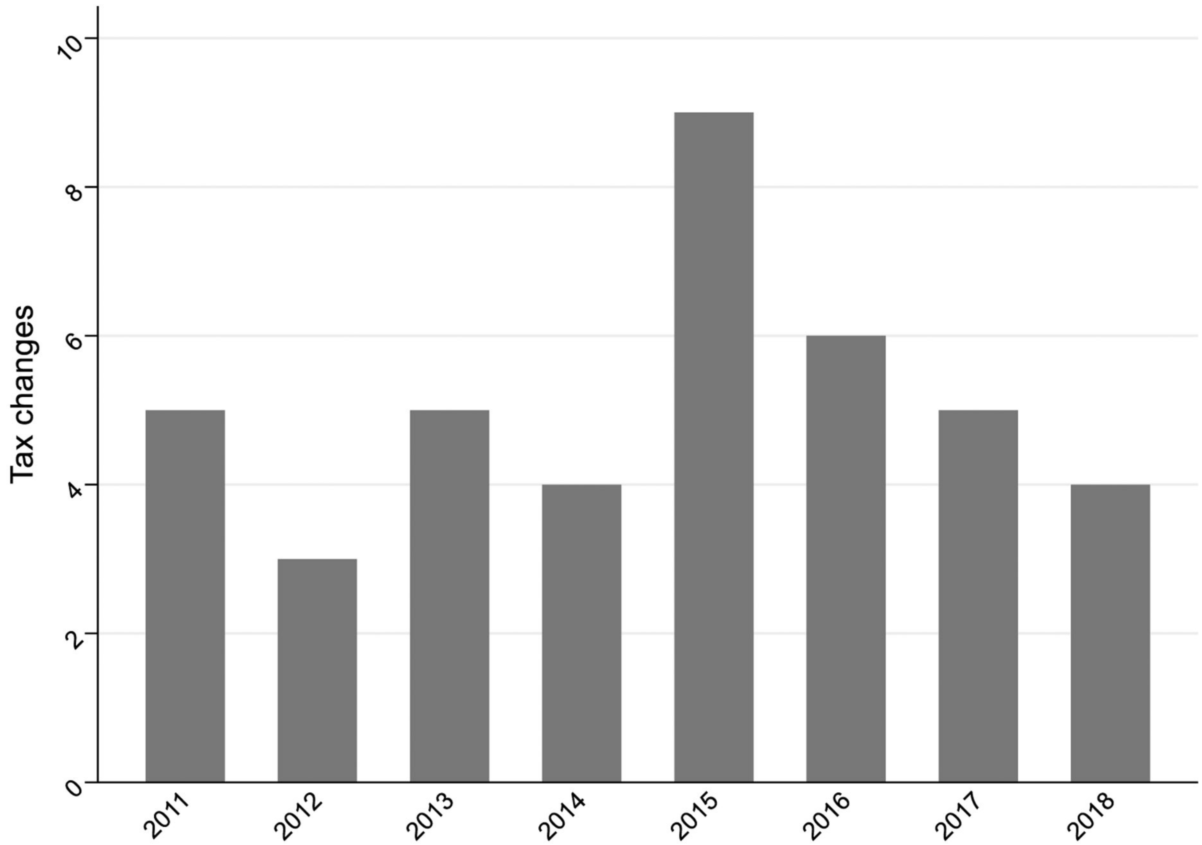


Figure 3.
Traditional cigarette tax changes in each year, 2011–2018
Notes: See text for details.

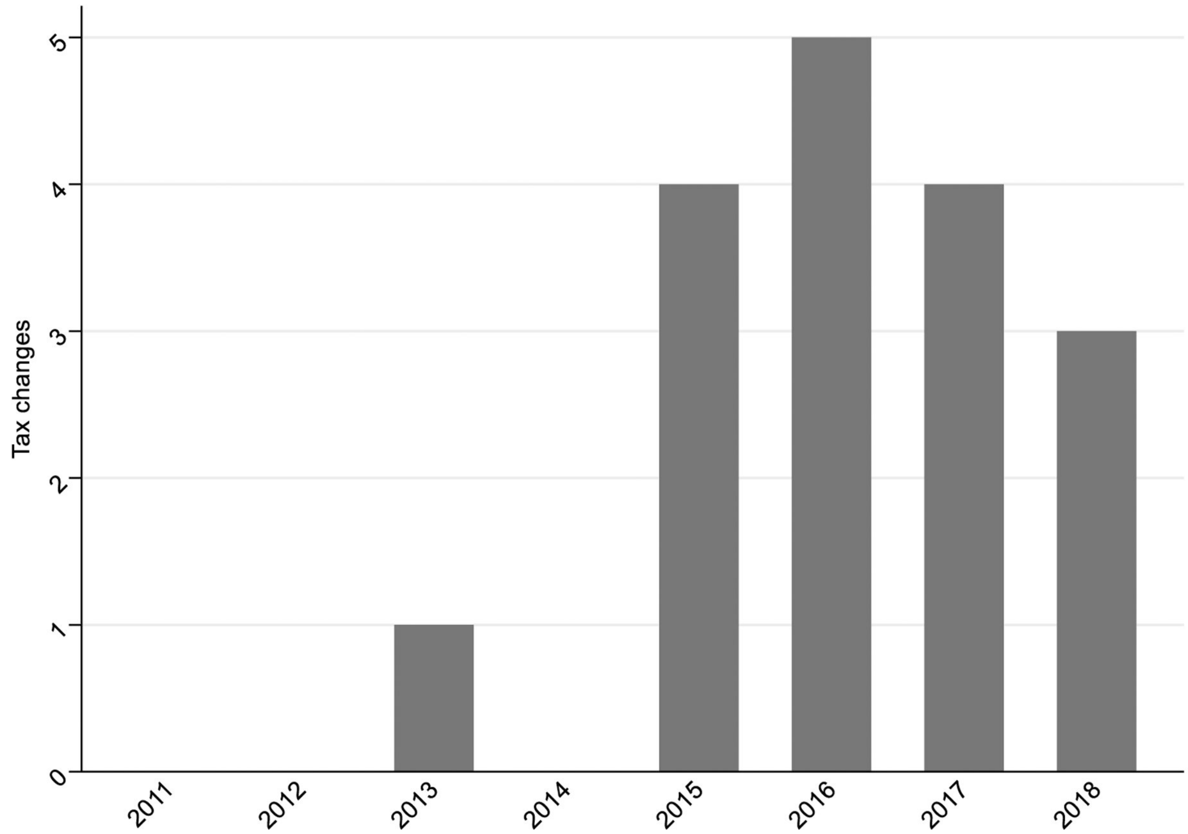
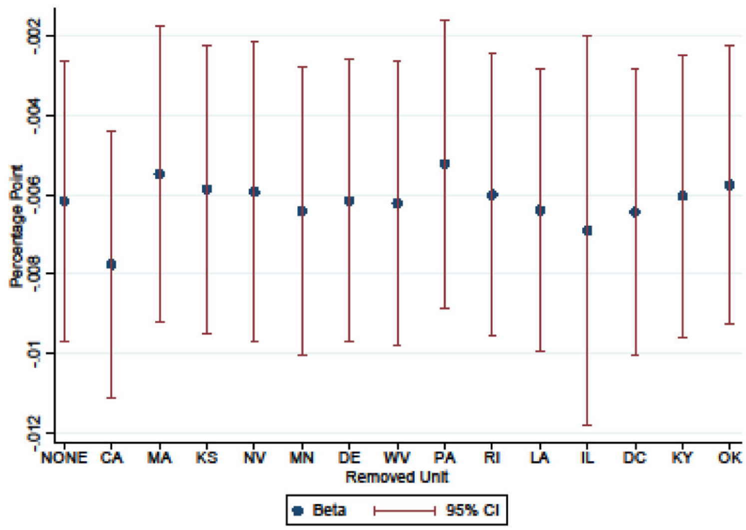


Figure 4.
E-cigarette tax changes in each year, 2011 to 2018
Note: See text for details.

Panel A: Daily traditional cigarette use



Panel B: Daily e-cigarette use

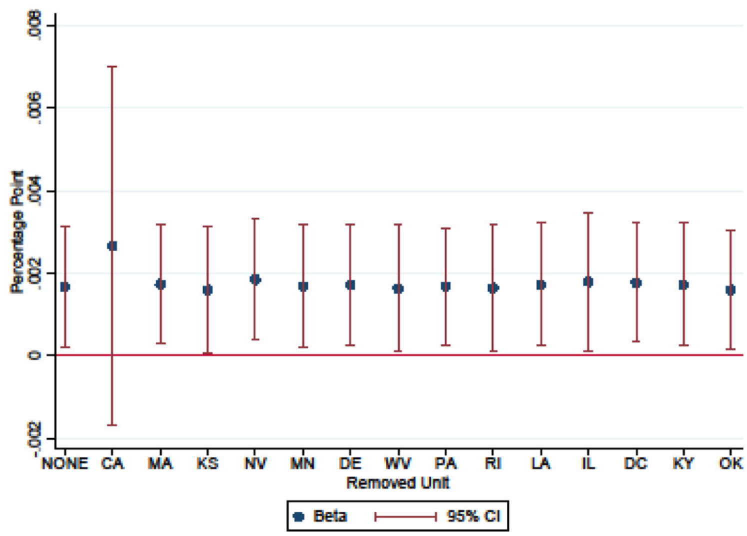


Figure 5.

Effects of traditional cigarette rates on smoking and vaping outcomes among adults using a two-way fixed effects removing one large traditional cigarette tax increase (≥$0.50) locality at a time: Combined BRFSS and NHIS data, 2011–2018

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. Blue circles represent coefficient estimates. 95% confidence intervals account for within-state correlations.

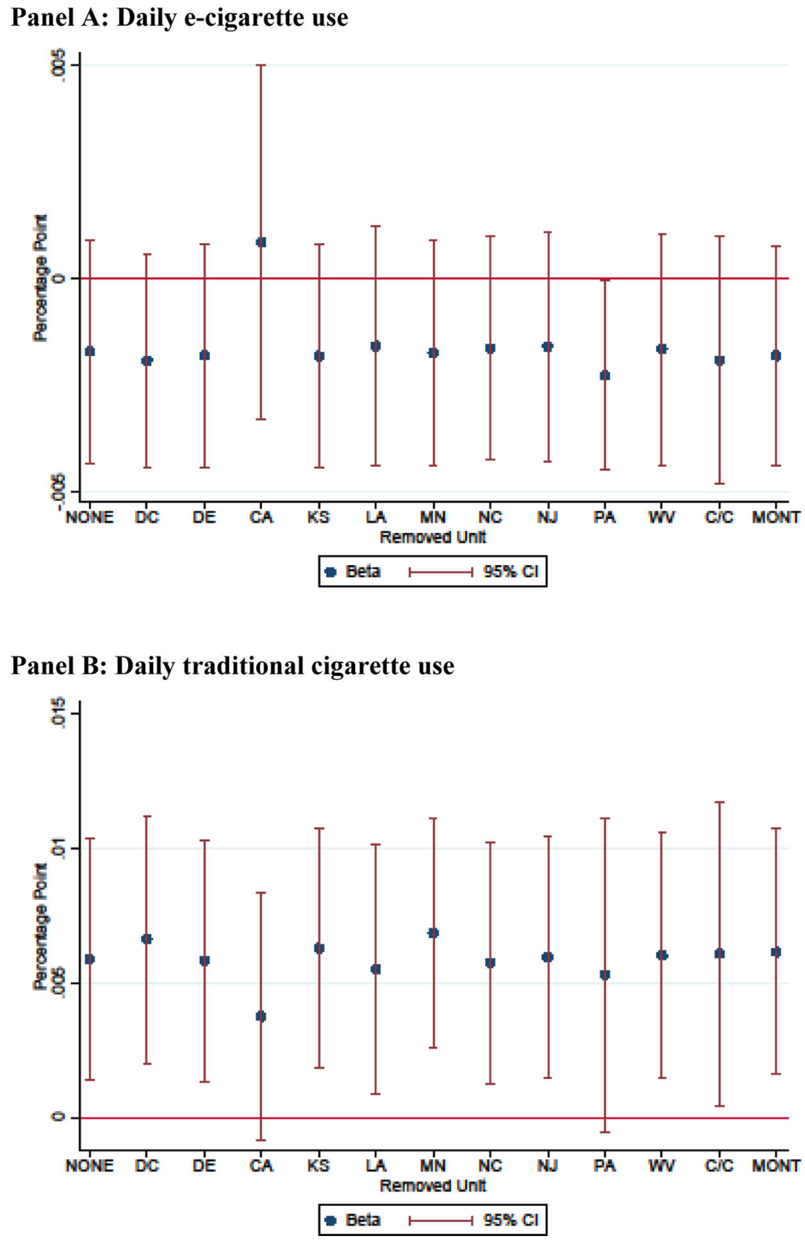


Figure 6.

Effects of e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects removing one e-cigarette adoption locality at a time: Combined BRFSS and NHIS data, 2011–2018

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. Blue circles represent coefficient estimates. 95% confidence intervals account for within-state correlations.

Table 1.

Summary statistics among respondents in all localities, and localities that did and did not adopt an e-cigarette tax by 2018: Combined BRFSS and NHIS data, 2011–2018

Sample:	All localities	Non-adopting localities	Adopting localities
Outcomes			
Current traditional cigarette use	0.156	0.156	0.155
Daily traditional cigarette use	0.112	0.112	0.110
Current e-cigarette use	0.034	0.035	0.032
Daily e-cigarette use	0.012	0.012	0.011
Current dual use	0.019	0.019	0.017
Current any use	0.165	0.166	0.161
Traditional cigarette and e-cigarette taxes			
Traditional cigarette tax rate ($ per pack)	1.539 (0.991)	1.547 (1.017)	1.514 (0.897)
Any tax on e-cigarettes	0.076	0	0.339
Standardized e-cigarette tax rate ($ per ml of nicotine)	0.058 (0.262)	0	0.256 (0.501)
Locality-level controls			
Indoor smoking restrictions (% population)	0.738 (0.359)	0.707 (0.384)	0.846 (0.226)
Indoor vaping restrictions (% population)	0.176 (0.357)	0.145 (0.327)	0.282 (0.428)
Minimum legal purchase age of 21	0.026	0.014	0.071
E-cigarette minimum legal purchase age law	0.632	0.603	0.735
Beer tax ($ per gallon)	0.262 (0.221)	0.282 (0.237)	0.194 (0.131)
Medical marijuana law	0.439	0.421	0.503
Marijuana decriminalized	0.336	0.369	0.226
Prescription drug monitoring program	0.953	0.95	0.965
Unemployment rate (%)	5.737 (2.064)	5.578 (2.009)	6.278 (2.156)
ACA-Medicaid expansion	0.353	0.338	0.406
Individual-level controls			
Women	0.561	0.563	0.556
Men	0.420	0.417	0.430
Sex missing/other gender	0.018	0.020	0.014
Less than high school	0.087	0.085	0.094
High school or GED	0.276	0.280	0.262
Some college	0.271	0.274	0.261
College degree or more	0.342	0.336	0.361
Education missing	0.342	0.336	0.361
White, non-Hispanic	0.744	0.757	0.699
African American, non-Hispanic	0.088	0.081	0.110
Asian, non-Hispanic	0.027	0.023	0.038
Native American or Alaskan, non-Hispanic	0.015	0.016	0.009
Other race, non-Hispanic	0.013	0.013	0.011
Hispanic	0.082	0.075	0.109
Race or ethnicity missing	0.032	0.034	0.025

Sample:	All localities	Non-adopting localities	Adopting localities
Married	0.516	0.518	0.509
Divorced	0.132	0.134	0.125
Widowed	0.118	0.122	0.107
Separated	0.021	0.02	0.023
Never married	0.188	0.18	0.216
Marital status missing	0.024	0.026	0.020
Age (years)	55.012 (18.287)	55.506 (18.273)	53.314 (18.229)
Uninsured	0.096	0.095	0.101
Insured	0.881	0.881	0.881
Insurance missing	0.023	0.024	0.019
Income ($; missing values imputed)	44,051 (26,523)	43,983 (26,263)	44,282 (27,391)
Unemployed or not in labor force	0.474	0.481	0.450
Employed	0.500	0.492	0.528
Employment missing	0.026	0.027	0.022
Observation	4,322,183	3,347,320	974,799

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Data are unweighted. The unit of observation is an individual in a county in a year. Standard deviations for continuous variables are reported in parentheses.

Table 2.

Effects of traditional cigarette and e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects model: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Traditional cigarette tax rate	−0.0012 [−0.0058,0.0034]	−0.0062*** [−0.0097,−0.0026]	0.0025 [−0.0015,0.0065]	0.0017** [0.0002,0.0031]	0.0031** [0.0004,0.0058]	0.0021 [−0.0073,0.0115]
E-cigarette tax rate	−0.0027 [−0.0107,0.0054]	0.0059** [0.0014,0.0103]	−0.0052* [−0.0110,0.0006]	−0.0017 [−0.0044,0.0009]	−0.0044* [−0.0094,0.0006]	−0.0061 [−0.0232,0.0110]
Observations	3,762,311	3,759,230	1,271,453	1,270,998	1,265,442	1,265,442
Proportion of outcome variable	0.156	0.112	0.034	0.012	0.018	0.165
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets.

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Table 3.

Effects of large cigarette tax increases and any e-cigarette tax adoption on smoking and vaping outcomes among adults using an event study style model: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Large traditional cigarette tax indicators						
[2–1) years in advance of large tax increase	0.0021 [−0.0040,0.0083]	0.0016 [−0.0048,0.0080]	−0.0020 [−0.0069,0.0030]	−0.0005 [−0.0029,0.0018]	−0.0010 [−0.0068,0.0049]	−0.0030 [−0.0163,0.0103]
[1,0) years in advance of large tax increase	0.0000 [−0.0057,0.0058]	−0.0007 [−0.0064,0.0049]	−0.0055 [−0.0122,0.0012]	−0.0041*** [−0.0071,−0.0011]	−0.0013 [−0.0062,0.0037]	−0.0033 [−0.0144,0.0077]
[0,1) years after large tax increase	−0.0045 [−0.0136,0.0047]	−0.0042 [−0.0105,0.0020]	−0.0026 [−0.0111,0.0059]	−0.0005 [−0.0044,0.0034]	−0.0004 [−0.0068,0.0059]	−0.0027 [−0.0265,0.0212]
1+ years after large tax increase	−0.0021 [−0.0083,0.0040]	−0.0058** [−0.0112,−0.0004]	−0.0013 [−0.0096,0.0071]	−0.0015 [−0.0054,0.0025]	0.0038 [−0.0034,0.0110]	−0.0089 [−0.0292,0.0113]
E-cigarette tax indicators						
[2–1) years in advance of tax adoption	0.0039* [−0.0000,0.0078]	0.0027 [−0.0010,0.0064]	−0.0009 [−0.0057,0.0039]	−0.0009 [−0.0025,0.0008]	−0.0001 [−0.0029,0.0028]	0.0029 [−0.0026,0.0084]
[1,0) years in advance of tax adoption	0.0011 [−0.0038,0.0059]	0.0015 [−0.0034,0.0064]	−0.0029 [−0.0105,0.0048]	0.0023 [−0.0007,0.0054]	−0.0032 [−0.0091,0.0027]	0.0032 [−0.0030,0.0094]
[0,1) years after tax adoption	0.0045 [−0.0068,0.0158]	0.0004 [−0.0049,0.0058]	−0.0027 [−0.0127,0.0073]	0.0010 [−0.0038,0.0059]	−0.0005 [−0.0073,0.0064]	0.0060 [−0.0163,0.0283]
1+ years after tax adoption	−0.0005 [−0.0069,0.0059]	0.0013 [−0.0031,0.0057]	−0.0055 [−0.0149,0.0038]	−0.0007 [−0.0048,0.0035]	−0.0023 [−0.0094,0.0049]	0.0048 [−0.0138,0.0233]
Observations	3,762,311	3,759,230	1,271,453	1,270,998	1,265,442	1,265,442
Proportion of outcome variable	0.156	0.112	0.034	0.012	0.018	0.165
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. The dashed horizontal lines divide the study period into pre- and post-tax sub-periods. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets. The omitted category is >2 years prior to the tax policy adoption. A large traditional cigarette tax hike is defined as an increase of ≥$0.50 by the end of 2019. All non-adopting localities are coded as zero for all event-time indicators.

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Table 4.

Effects of traditional cigarette and e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects model among adults < 40 years: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Traditional cigarette tax rate	0.0045 [−0.0051,0.0140]	−0.0073 ** [−0.0141,−0.0005]	0.0080 ** [0.0012,0.0148]	0.0048 *** [0.0024,0.0073]	0.0091 *** [0.0048,0.0134]	0.0237 *** [0.0064,0.0411]
E-cigarette tax rate	−0.0105 [−0.0241,0.0031]	0.0119 *** [0.0039,0.01991	−0.0182 *** [−0.0286,−0.0078]	−0.0062 *** [−0.0106,−0.0018]	−0.0155 *** [−0.0229,−0.0081]	−0.0366 ** [−0.0676,−0.0057]
Observations	869,138	868,656	304,198	304,007	303,160	303,160
Proportion of outcome variable	0.199	0.135	0.070	0.025	0.033	0.224
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets.

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Table 5.

Effects of traditional cigarette and e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects model among adults ≥ 40 years: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Traditional cigarette tax rate	−0.0046** [−0.0083,−0.0010]	−0.0051*** [−0.0084,−0.0017]	−0.0012 [−0.0041,0.0017]	−0.0005 [−0.0024,0.0015]	−0.0012 [−0.0034,0.0010]	−0.0133*** [−0.0194,−0.0072]
E-cigarette tax rate	0.0022 [−0.0037,0.0081]	0.0017 [−0.0045,0.0080]	0.0028 [−0.0020,0.0077]	0.0013 [−0.0017,0.0044]	0.0032 [−0.0010,0.0074]	0.0150*** [0.0052,0.0248]
Observations	2,893,173	2,890,574	967,255	966,991	962,282	962,282
Proportion of outcome variable	0.143	0.105	0.023	0.008	0.014	0.147
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets.

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Table 6.

Effects of traditional cigarette and e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects model among women: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Traditional cigarette tax rate	−0.0031 [−0.0074,0.0013]	−0.0077*** [−0.0119,−0.0036]	0.0002 [−0.0045,0.0048]	0.0015* [−0.0002,0.0033]	0.0011 [−0.0031,0.0053]	−0.0032 [−0.0117,0.0053]
E-cigarette tax rate	0.0004 [−0.0075,0.0083]	0.0064* [−0.0006,0.0135]	−0.0023 [−0.0115,0.0068]	−0.0038** [−0.0077,−0.00001	−0.0027 [−0.0106,0.0052]	−0.0009 [−0.0143,0.0124]
Observations	2,173,324	2,171,782	710,064	709,875	706,693	706,693
Proportion of outcome variable	0.144	0.104	0.029	0.009	0.017	0.149
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets.

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Table 7.

Effects of traditional cigarette and e-cigarette tax rates on smoking and vaping outcomes among adults using a two-way fixed effects model among men: Combined BRFSS and NHIS data, 2011–2018

Outcome:	Current traditional cigarette use	Daily traditional cigarette use	Current e-cigarette use	Daily e-cigarette use	Current dual use	Current any use
Traditional cigarette tax rate	0.0005 [−0.0065,0.0076]	−0.0046 [−0.0104,0.0012]	0.0044 [−0.0029,0.0117]	0.0015 [−0.0010,0.0041]	0.0050** [0.0010,0.0089]	0.0062 [−0.0098,0.0222]
E-cigarette tax rate	−0.0067 [−0.0176,0.0043]	0.0054* [−0.0010,0.0118]	−0.0081 [−0.0206,0.0044]	0.0007 [−0.0032,0.0045]	−0.0062** [−0.0123,−0.0000]	−0.0103 [−0.0388,0.0182]
Observations	1,587,777	1,586,242	560,437	560,172	557,824	557,824
Proportion of outcome variable	0.172	0.123	0.041	0.015	0.021	0.185
Number of clusters	50	50	50	50	50	50

Notes: BRFSS = Behavioral Risk Factor Surveillance System. NHIS = National Health Interview Survey. Each column presents partial results from a single regression model. The unit of observation is an individual in a county in a year. Data are weighted to make the number of observations for each state, year, gender, race/ethnicity, and five-year age band cohort be proportionate to its national population share. Models are estimated with a linear probability model and control for locality-level and individual-level variables reported in Table 1, county fixed effects, and quarter-by-year fixed effects. 95% confidence intervals account for within-state correlations and are reported in square brackets.

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