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DISCUSSION PAPER SERIES

IZA DP No. 14751

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Michael F. Pesko
Georgia State University and IZA

Casey Warman
Dalhousie University

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Re-Exploring the Early Relationship between Teenage Cigarette and E-Cigarette Use Using Price and Tax Changes*

In 2016, the Surgeon General used longitudinal cohort studies to conclude that youth e-cigarette use is strongly associated with cigarette use. We re-evaluate data from the period of time before the writing of the Surgeon General report, using quasi-experimental methods, and reach the opposite conclusion. We study contemporaneous and intertemporal effects of e-cigarette and cigarette price and tax changes. Our price variation comes from 35,000 retailers participating in the Nielsen Retail Scanner data system. We match price and tax variation to survey data on current use of e-cigarettes and cigarettes for over 94,000 students between grades 6 to 12 in the National Youth Tobacco Survey (NYTS) for years 2011 to 2015. We find evidence that e-cigarettes and cigarettes are same-period economic substitutes. Coefficient estimates (while imprecisely estimated) also suggest potentially large positive effects of past e-cigarette prices on current cigarette use, indicating inter-temporal economic substitution. Our findings raise doubts about the conclusion of government-sponsored reports that e-cigarettes and cigarettes are strongly positively associated. We recommend revisiting and possibly amending this conclusion.

JEL Classification: I18, H71

Keywords: tobacco control, cigarette use, e-cigarette use, tax policy

Corresponding author:
Michael F. Pesko
Department of Economics
Georgia State University
55 Park Place Suite 657
Atlanta, GA 30303
USA

E-mail: mpesko@gsu.edu

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1 Introduction

In 2009, public health officials in the United States established Healthy People 2020 goals that among other things called for reducing youth cigarette use from 19.5% to 16.0% by 2019 (Office of Disease Prevention and Health Promotion, 2020). By 2019, the youth cigarette use rate was at a remarkable 6.0%, thus beating Healthy People 2020's ambitious goal of a 3.5 percentage point reduction (from 19.5% to 16.0%) over the decade by 386%. What caused the decline in youth cigarette use to be so under-estimated? One candidate is the introduction of e-cigarettes. E-cigarettes were first imported into the United States in August 2006 (Consumer Advocates for Smoke-free Alternatives Association, 2021) and overtook cigarette use as the most commonly used tobacco product among youth in 2014 (Miech et al., 2014). In 2019, 32.9% of youth used an e-cigarette over the past 30 days, but only 10.7% used e-cigarettes frequently (20 or more days over the past 30 days) (Centers for Disease Control and Prevention, 2020).

While the relative risks of e-cigarettes versus cigarettes are not known with certainty, a survey of individuals that have published on e-cigarettes (e.g., 'experts') finds that e-cigarette use has 37% of the negative effect of cigarettes on quality-adjusted life years (Allcott and Rafkin, 2020). The National Academies of Sciences, Engineering, and Medicine say in a 2018 report that e-cigarettes are not risk-free, but current evidence suggests that they are likely to be far less harmful than combustible tobacco cigarettes (National Academies of Sciences et al., 2018). One England government report, last updated in 2018, set this number at 5% for non-pregnant adults, though specifically for e-cigarettes sold in England that are regulated differently (Royal College of Physicians in England, 2018).

While it seems likely that e-cigarettes had a lot to do with the remarkable decline in youth cigarette use over the last decade, the Surgeon General issued a report in 2016 claiming that e-cigarette use is strongly associated with the use of other tobacco products among youth and young adults (U.S. DHHS, 2016). To support this claim, the report cites longitudinal cohort studies exploring the effect of current e-cigarette use on future cigarette use. As pointed out previously in the case of cigarettes being linked to illicit drugs (Beenstock and

Rahav, 2002), a plausibly exogenous source of variation for the use of e-cigarettes is needed to causally study the effect on downstream cigarette use. In the absence of an exogenous source of variation in initial e-cigarette use, estimates from longitudinal cohort studies are likely biased by omitted variables affecting youth's propensity to use both cigarettes and e-cigarettes. For example, teenagers that are susceptible to smoking may first use e-cigarettes to mitigate risk before deciding to transition fully into smoking, which would cause a spurious positive association between e-cigarette use and subsequent cigarette use assuming that the propensity to engage in risky behaviors cannot be perfectly controlled for in the regression model.

In our study, we re-visit data from before the Surgeon General report was issued in December 2016, and re-examine if there is evidence supporting a different conclusion that e-cigarettes reduced cigarette use, which appears to be ex-post validated based on observational data (e.g., the decrease in youth cigarette use far exceeding Healthy People 2020 goals). For this, we exploit plausibly exogenous changes in the availability of both e-cigarettes and cigarettes by using state-level price and tax variation. We study effects both in the current period (contemporaneous effects) and in future period (intertemporal effects).

Similar to the current study, two other studies evaluate the effect of Nielsen Retail Scanner (NRS) e-cigarette prices on youth in particular. One study used two years (2014 and 2015) of Monitoring the Future data to estimate an e-cigarette elasticity of youth participation of -0.6 for disposables and -0.4 for replaceables (controlling for market fixed effects), but perhaps because of small sample sizes and little price variation, these results, as well as cigarette cross-price elasticities, were statistically insignificant (Pesko et al., 2018). In comparison to this earlier study, our current study uses five years of data and roughly 3.5 times the sample size to estimate own- and cross-price elasticities of youth demand, thus increasing our power. More recently, Cantrell et al. (2019) used national longitudinal cohort data on a sample of approximately 11,500 15 to 21 year olds from 2014 to 2016 and found no effect of e-cigarette prices, but a cross-cigarette-price elasticity of 0.9. In contrast to this study, in our current study we estimate a statistically-significant negative effect of e-cigarette cartridge prices on

e-cigarette use. We are also the first study examining the effect of an e-cigarette tax on youth cigarette use.

Though the e-cigarette industry has undergone significant upheaval since the writing of the Surgeon General report, both disposables and cartridge-based systems remain on the market today and are used by youth. Cartridge-based Juul products had 72% of all market-based retail sales in September 2018 (Levy et al., 2020), but Juul market share declined in the following years potentially in part due to an FDA clampdown on flavored e-cigarette pods (culminating with a ban on non-mentholated flavored cartridges in February 2020). The flavor ban led to the ascendency of companies like Puff Bar that make disposable devices that look like Juul and are sold in many flavors. The FDA forced the removal of Puff Bar from store shelves in July 2020, likely because of high use among youth. However, Puff Bar recently returned to the market in February 2021 with a synthetic nicotine disposable product, which they believe exempts them from FDA regulation. In the absence of new legislation from Congress, the issue will likely be decided in court. In any case, both disposables and cartridge based e-cigarette products continue to be regularly used by youth.

Several studies evaluate the relationship between market-level prices and market-level sales using NRS data, and all of these studies offer evidence that e-cigarettes and cigarettes are economic substitutes (Cotti et al., 2020; Allcott and Rafkin, 2020; Huang et al., 2018; Zheng et al., 2017; Stoklosa et al., 2016).[1] However, unlike our current study, these studies use legal sales of cigarettes as outcomes, which are not specific to youth. Other studies use tax variation to find substitution among adults using survey data (Pesko et al., 2020; Saffer et al., 2020) and pregnant women using administrative data (Abouk et al., 2019).

Additionally, several studies use e-cigarette minimum legal sale age (MLSA) laws. Three studies use difference-in-difference models and find that e-cigarette MLSA laws increase teen smoking by approximately 0.8 to 1.0 percentage points (Friedman, 2015; Pesko et al., 2016b; Dave et al., 2019). One study finds that these laws increase teen prenatal smoking within

[1]Evidence from Allcott and Rafkin (2020) is mixed, though models without time trends provide evidence of economic substitution.

a given trimester by 0.6 percentage points (Pesko and Currie, 2019). In contrast, a fifth study also uses a difference-in-difference model and Monitoring the Future data to find that e-cigarette MLSAs decreased high school senior smoking participation by 2.0 percentage points (Abouk and Adams, 2017). Of note, both the Friedman (2015) and Pesko et al. (2016b) studies were published before the publication of the Surgeon General report in December 2016, but were not mentioned in the report.

A later report by the National Academies of Science, Engineering, and Medicine (NASEM) did cite e-cigarette quasi-experimental studies published by the time the report was issued in 2018 (National Academies of Sciences et al., 2018), two finding that e-cigarette MLSA laws increase cigarette use (Friedman, 2015; Pesko et al., 2016b) and one finding the opposite among high school seniors (Abouk and Adams, 2017). Despite the inclusion of additional studies in the NASEM report, it reaches the same conclusion as the Surgeon General 2016 report, noting that 'Overall, the small and inconsistent evidence base on this topic fails to provide confirmatory evidence for or against individual-level associations found in the principal epidemiological data.' Based on these longitudinal cohort studies, NASEM concludes that, 'there is substantial evidence that e-cigarette use increases risk of ever using combustible tobacco cigarettes among youth and young adults.' Again, this conclusion seems at odds with cigarette use falling to record lows and far surpassing Healthy People 2020 goals.

2 Methods

Our primary data source is the National Youth Tobacco Survey (NYTS) data, a nationally-representative school-based survey data source for students in grades 6 to 12, for years 2011 to 2015. Additionally, the NYTS was also collected in 2006 and earlier years. We use year 2009 in a sensitivity analysis in which we use tax variation rather than price variation; however, we do not include the 2006 or prior waves in our analysis since it is collected in the spring of each year and e-cigarettes were not imported into the United States until August 2006 (Consumer Advocates for Smoke-free Alternatives Association, 2021).

The NYTS was the first nationally-representative survey data source to add e-cigarette use questions in 2011. Other comparable school-based survey data sources, such as the Youth Risk Behavior Surveillance System and Monitoring the Future, did not begin asking e-cigarette questions until 2015 and 2014 respectively. This makes the NYTS uniquely suited for understanding the early effects of e-cigarettes on youth smoking behavior, by leveraging price variation across five years and e-cigarette tax changes in one state. The NYTS data is also collected by the Centers for Disease Control and Prevention's Office on Smoking and Health, who were heavily involved in the production of the 2016 Surgeon General report.

In the NYTS, all students are asked if they have used cigarettes or e-cigarettes over the past 30 days. Cigarette users are also asked the number of days that they used cigarettes over the past 30 days and the number of cigarettes smoked on smoking days, which we use to create a past 30-day cigarette consumption variable. Starting in 2014, e-cigarette users are asked the number of days using e-cigarettes over the past 30 days, which we also use to create a measure of e-cigarette use frequency.

Similar to Pesko and Robarts (2017) and Feng and Pesko (2019), we use school geocode information to merge on state-level cigarette and e-cigarette prices from NRS (available from the Kilts Center at the University of Chicago). Data from approximately 35,000 participating grocery, drug, mass merchandiser, and other stores are included in the NRS, and each individual store reports weekly data for every UPC code that has any sales volume during the week. From this data, we construct annual, state-level cigarette and e-cigarette prices for cartridges and disposables for between February through June of each year to match the time period over which the NYTS data was collected. We estimate separate price responsiveness for these products since these products may be used along different stages of the e-cigarette initiation trajectory, with more established e-cigarette users likely using refill cartridges that require the previous investment of a rechargeable e-cigarette device. Liquid nicotine only appeared in NRS starting in year 2014 and there was substantial variation in the content of e-cigarette starter kits; therefore, we do not use these prices in our analysis.

Additional details on the data can be found in a data appendix.

We estimate a traditional demand equation for cigarettes and e-cigarettes using regression analysis. We evaluate four separate dependent variables: 1) any e-cigarette use over the past 30 days, 2) any cigarette use over the past 30 days, 3) days of e-cigarette use over the past 30 days (setting this zero for non-e-cigarette users),[2] and 4) total cigarettes consumed over the past 30 days (setting this equal to 0 for non-cigarette users). We also estimate the effect on conditional e-cigarette use days and conditional number of cigarettes smoked. E-cigarette past 30 day use was first available in the NYTS in 2011. E-cigarette days is available starting in 2014, therefore we only have two years of data for this outcome.

We estimate variants of the following regression model:

$$\text{tobacco use}_{isct} = \alpha_0 + \alpha_1 \text{cig price}_{st} + \alpha_2 \text{ecig price}_{st} + \Theta \text{environment}_{sct} + \beta X_{isct} + \gamma_s + \upsilon_t + \varepsilon_{isct} \quad (1)$$

where subscripts denote individual i living in county c of state s at year t. The vector $\mathbf{X}_{isct}$ includes individual-level controls for gender, age dummies, and race/ethnicity dummies (White non-Hispanic (default category), Black non-Hispanic, Hispanic, other race non-Hispanic, and missing). State fixed effects (γ_s) removes confounding from time-invariant state-specific sources (e.g., anti-smoking sentiment that does not change over time within a given state) and year fixed effects (υ_t) removes confounding from time-varying, national changes (e.g., changes in the national marketplace for e-cigarettes over time).

$Environment_{sct}$ is a vector of time-varying policy and other environmental controls that could be correlated with both tobacco prices and tobacco use; therefore representing potential sources of omitted variable bias unless controlled for. At the county-level, we control for urban/rural classification scheme (large central metro, large fringe metro, medium metro, small metro, micropolitan, and noncore),[3] percent of the population living in poverty,[4] median household income,[5] the unemployment rate,[6] indoor smoking restrictions, indoor vaping

[2] This is the only measure of e-cigarette use frequency available in the NYTS.
[3] Ingram and Franco (2014)
[4] United States Census Bureau (2018)
[5] United States Census Bureau (2018)
[6] Bureau of Labor Statistics (2018)

restrictions,[7] e-cigarette minimum legal sale age laws,[8] and percent of the population covered by a Tobacco 21 law banning the sale of tobacco to individuals under 21 years of age.[9] At the state-level, we control for beer taxes,[10] medical marijuana laws, medical decriminalization laws,[11] and the minimum wage.[12]

Cigarette and e-cigarette prices vary at the state level and across time. E-cigarette prices are either the prices for one disposable e-cigarette unit or the price for one refill cartridge. With state and year fixed effects controlled for, the model's identifying price variation comes from within-state changes in prices that deviate from the national average in prices for that year. Additionally, we eliminate sources of within-state, time-varying omitted variable bias by including a rich set of policy and environmental controls. Our preferred specification includes these extra controls. Uncontrolled time-varying, within-state variables remain potential sources of bias.

We also estimate a model replacing prices with taxes. Minnesota enacted a first-in-the-nation e-cigarette tax in August 2010, which was set at 35% of the wholesale price. Minnesota increased this tax rate to 95% of the wholesale price in 2013. No other states adopted an e-cigarette tax during the time period of our study. We explore this tax increase in the following way. Minnesota participates in the NYTS survey in 2009, 2012, and 2014; therefore, we have a period of time without an e-cigarette tax, a period of time with a 35% ad valorem e-cigarette tax, and a period of time with a 95% ad valorem e-cigarette tax. Since we do not have e-cigarette questions for 2009, we present results for only cigarettes. We can use this limited variation to study Minnesota's cross-tax responsiveness similar in spirit to

[7] The American Nonsmokers Rights Foundation tracks when municipalities, counties, and states pass indoor air laws for vaping or smoking in different venues. 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. We also consider laws applying to only part of the establishment (but not the full establishment) with 1/2 weight.

[8] Used in Pesko and Currie (2019). These laws use the same purchasing age as for cigarettes, which itself did not vary in our data source except from some local-level Tobacco 21 laws that we control for separately.

[9] Using data received from Tobacco21.org.

[10] Urban Institute & Brookings Institution (2021)

[11] Marijuana laws provided by the Marijuana Policy Project (Marijuana Policy Project, 2021; Smart and Pacula, 2019).

[12] University of Kentucky Center for Poverty Research (2021)

Saffer et al. (2020), who estimates a cross-tax elasticity of adult smoking with respect to e-cigarette prices of 0.13.[13] Additionally, we replace cigarette prices with state and county cigarette tax changes.[14]

$$\text{cigarette use}_{isct} = \alpha_0 + \alpha_1 \text{cig tax}_{st} + \alpha_2 \text{ecig tax}_{st} + \Theta \text{environment}_{sct} + \beta X_{isct} + \gamma_s + \upsilon_t + \varepsilon_{isct} \quad (2)$$

We estimate the equations using linear models. However, in the appendix results, we explore the sensitivity of our results to estimating probit models for extensive margin measures.

We cluster standard errors at the state level and use self-response weights in all regression analyses to assist in making the results representative of the population of public and private school students in grades 6-12. In all regressions, we exclude observations without complete information for our two cigarette consumption and e-cigarette use dependent variables and three price variables.[15] This provides a consistent sample that makes comparing effect sizes easier.

3 Results

In Table 1, we present the summary statistics. Across our sample, 5.3% of youth use e-cigarettes over the past 30 days, 7.9% of youth smoke cigarettes over the past 30 days, and 2.3% currently dual-use both tobacco products. A pack of cigarettes is more expensive than a refill cartridge ($5.90 versus $3.36 in 2014 dollars), but is less expensive than a disposable e-cigarette ($8.65).[16] 81% of respondents live in a county banning smoking in bars, private workplaces, and restaurants, and 8.4% of respondents live in a county banning vaping in

[13] Our estimate is specific to youth and we unfortunately are unable to do a synthetic control group analysis like Saffer et al. (2020) because of limited data availability.

[14] State cigarette taxes are from Centers for Disease Control and Prevention (2018) and local cigarette taxes are from the American Nonsmokers Rights Foundation.

[15] We lose around 5,700 observations due to missing responses to the dependent variables and 1,300 observations due to price information not being available for select states in year 2011 (see Data Appendix).

[16] One cartridge is thought to be equivalent to between one to two packs of cigarettes.

the same locations. E-cigarette MLSA laws apply to 43.9% of respondents. The average respondent is 14.6 years of age, and attends school in a diverse set of urban/rural counties.

In Figure 1, we present rates of ever and current e-cigarette and cigarette use. In 2011, around 10.7% of youth smoked cigarettes in the past month, 1.2% used e-cigarettes in the past month, and 3.3% had used e-cigarettes in their lifetime.[17] Over the next 3 years, cigarette smoking rates declined while e-cigarette use rates increased sharply. By 2014, more youth currently use e-cigarettes than cigarettes (9.1% versus 6.2%). Ever use of these products followed similar patterns to current use, although at levels roughly 2.5 times higher in 2015.

In Table 2, when controlling for demographics, year fixed effects, and state fixed effects (column 1), we estimate that a $1 increase in e-cigarette cartridge prices reduces youth current e-cigarette use by 3.4 percentage points ($p<0.05$). This translates into an own-price elasticity of demand for cartridges of -2.2 (e.g., a 10% increase in cartridge prices reduces current e-cigarette use by 22%). A $1 increase in e-cigarette disposable prices meanwhile has no statistically or economically significant effect on e-cigarette use.[18] Estimates remains virtually identical in our preferred specification after adding state/local environment controls. The cross-price elasticity of demand relating cigarette prices to e-cigarette extensive margin demand is statistically significant in the first two columns and suggests a substitution relationship (cross-price elasticities ranging from 3.4 to 3.5).

In columns 3 and 4, we use two waves of data with questions on days of e-cigarette use to explore if price variation affects number of days using e-cigarettes, setting this equal to 0 for non-e-cigarette users. Without state/local environment controls, we see evidence that cartridge prices reduce e-cigarette days and cigarette prices increase e-cigarette days, suggesting economic substitution. However, the coefficients are attenuated when adding state/local environment controls and are no longer statistically significant.

[17] These e-cigarette use rates suggest that e-cigarettes may have already been affecting use of cigarettes as early as 2011.

[18] One meta-analysis has found that only 15% of teenagers use disposable e-cigarettes (Barrington-Trimis et al., 2017). The lack of statistical significance for disposable e-cigarettes, but the finding that youth are price responsive to cartridges, may suggest greater price responsiveness for regular users rather than experimenters.

In columns 5 and 6, we estimate own- and cross-price elasticities of demand for past 30-day cigarette use. We do not find statistically-significant evidence that cigarette prices or e-cigarette prices influence youth past-30 day smoking participation.[19] However, in columns 7 and 8, we turn to estimating own- and cross-price elasticities of demand for the number of cigarettes smoked, setting this to 0 for non-smokers. This dependent variable captures both extensive and intensive margin cigarette use. While cigarette prices remain statistically insignificant predictors of number of cigarettes used, a $1 increase in e-cigarette cartridge prices increases cigarette consumption among both smokers and non-smokers by between 3.8 to 4.6 cigarettes monthly, which is similar to results from columns 1 to 4 suggesting that e-cigarettes and cigarettes are substitute products. We again find little evidence of a consistent relationship when using disposable e-cigarette prices.

In online material, we present estimates where we include each e-cigarette price individually and derive very similar results to when we include both in the analysis at the same time.

In Table 3, we redo columns 3, 4, 7 and 8 from Table 2 dropping non-participants. In models with state/local environment controls, a $1 increase in cigarette prices increases e-cigarette days by 17 days among users ($p<0.05$). Meanwhile, a $1 increase in cartridge prices increases cigarettes smoked by 3 packs over the past 30 days among users ($p<0.01$).

In Table 4, we include 1-year price lags in our model to explore whether prices in one period affect use in the subsequent period, which permits exploring the gateway relationship by using a plausibly exogenous source of variation in initial period e-cigarette use, instead of relying on self-selection that may be correlated with unobserved risk preferences (Beenstock and Rahav, 2002). We find in column 2 that a $1 increase in cigarette prices increases subsequent-period e-cigarette use (conditional on current prices) by 3.5 pp ($p<0.10$), which is consistent with the idea that individuals may intertemporally substitute e-cigarettes for

[19]We also calculate a model without either e-cigarette price measure, and the estimate of the own-price elasticity of demand was substantially similar to models including either e-cigarette price. This evidence in our paper of low or no cigarette price responsiveness is similar to another recent study finding little cigarette tax responsiveness among youth in Youth Risk Behavior Surveillance System data from 2007-2013 (Hansen et al., 2017).

cigarettes to try to quit smoking. We do not observe any statistically significant effect of e-cigarette prices affecting subsequent cigarette use, through coefficient estimates suggest potentially large diversion effects (e.g., point estimates suggest a $1 increase in current-period e-cigarette cartridge prices raises subsequent cigarette use by 2.9 pp (column 6) and by 4.0 cigarettes per 30 days (column 8)). We certainly do not find evidence supporting "strong" associations between current e-cigarette use and subsequent cigarette use as documented in both scientific reports (U.S. DHHS, 2016; National Academies of Sciences et al., 2018); if anything, our point estimates suggest strong effects in the opposite direction.

In Table 5, we show results from equation 2 using data from 2009-2015 for only cigarette use outcomes available in all waves. The Minnesota e-cigarette tax rate was established at 35% in 2010 and increased to 95% in 2013.[20] We see mixed evidence that the e-cigarette taxes increase cigarette use and cigarettes smoked. Coefficient estimates show that a 100% ad valorem tax on e-cigarettes would increase cigarettes smoked among youth by 5 cigarettes per 30 days (p=0.053), averaged across smokers and non-smokers.

In Appendix Table A1, we stratify models separately for males and females. We find evidence that female e-cigarette use is more responsive to price (cartridge own-price elasticity of -3.1, cross-price elasticity of 4.6) than for males (cartridge own-price elasticity of -1.5, cross-price elasticity of 2.7). Females also appear more responsive to cigarette prices on the intensive + extensive margin than males. Otherwise we notice little observably different between these group's responses to price changes.

In Appendix Table A2, we re-estimate our extensive margin outcomes using a probit model (coefficients are displayed as marginal effects). Elasticities in this case appear substantially similar to those reported in Table 2.

[20] We do not show elasticity calculations in this table because the baseline level of e-cigarette tax is 0.

4 Discussion

Our study contributes some evidence that e-cigarettes and cigarettes are economic substitutes for youth. Our own- and cross-price elasticity estimates for e-cigarette cartridges and cigarettes are generally larger than those found in studies using market-level sales data (Huang et al., 2018; Zheng et al., 2017; Cotti et al., 2020; Allcott and Rafkin, 2020), potentially because youth are more price responsive than adults. The cartridge price elasticity for extensive margin e-cigarette use of -2.2 (Table 2, column 2) is also larger in absolute magnitude than the consensus cigarette extensive margin price elasticity estimate for youth of -0.4 (The Community Preventive Services Task Force, 2014), which could be explained by more flexible preferences among youth for the new tobacco product, or larger peer effects for e-cigarettes that cause multiplier effects.

Only Minnesota had an e-cigarette tax during our study period, but as of December 15, 2020, 28 states had passed e-cigarette taxes (Public Health Law Center, 2020). Additionally, as of Sept. 30, 2020, 39 jurisdictions and 3 tribes have banned the sale of all e-cigarettes (Truth Initiative, 2020), which is analogous to an infinite e-cigarette price increase absent (likely) black market activity. Policymakers passing e-cigarette taxes and bans may believe that they are protecting the well-being of youth, but our results provide some evidence they may cause youth to smoke cigarettes more, which may be doing more harm than good for youth if e-cigarettes are a substantially safer product. A $1 increase in e-cigarette cartridge prices, for example, causes teenagers to smoke 4.6 extra cigarettes per month (3 extra packs among teenager smokers). A 100% ad valorem tax causes teenagers to smoke 5.0 extra cigarettes per month, though the latter is only significant at p=0.053 in a fully-specified model. While the purpose of this paper is to only use data available prior to the 2016 Surgeon General report, further research is needed on the effect of e-cigarette taxes on youth using the larger number of states with e-cigarette taxes today, which should help provide more precise estimates.

Congress is currently considering doubling the federal cigarette tax rate to $2.01 per pack and adopting an e-cigarette tax and setting this to parity with the higher federal

cigarette tax; therefore, increasing the e-cigarette tax twice as much as the cigarette tax (117th Congress, 2021). Assuming a cigarette wholesale price of $5.00 as determined by California and Washington DC tax authorities, "parity" would be approximately a 40% ad valorem tax. Using Table 5 coefficient estimates, a proposed $1 cigarette tax increase, and a proposed 40% e-cigarette ad valorem tax, this bill would be predicted to raise cigarette use by 0.2 pp (= -0.03 x 1.00 + 0.58 x .40) and cigarettes monthly by 1.5 among all youth (= -0.521 x 1.00 + 0.4 x 5.017), or approximately an extra pack monthly assuming a mean smoking rate of 7.9%.

This paper applies quasi-experimental methods to data from before the Surgeon General's 2016 report concluding that e-cigarette use is strongly associated with the use of combustible cigarettes (U.S. DHHS, 2016). In contrast to the Surgeon General's 2016 conclusion, our results provide weak evidence of substitution, which is in the opposite direction to the Surgeon General report finding. We find evidence that e-cigarettes are immediately displacing cigarette use, and generally imprecise estimates that e-cigarettes displace cigarette use intertemporally. Our quasi-experimental approach offering weak evidence on substitution is ex-post supported by real-world data, as teenage cigarette use ended far lower than Healthy People 2020 goals (6.0% versus 16.5%) (Office of Disease Prevention and Health Promotion, 2020).

The belief that the previously documented positive association between e-cigarette use and cigarette use is a causal effect continues to be used today as justification for aggressive e-cigarette regulation that many studies suggest raise combustible cigarette use (Pesko and Currie, 2019; Dave et al., 2019; Friedman, 2015; Pesko et al., 2016a; Cotti et al., 2020; Abouk et al., 2019; Saffer et al., 2020; Pesko et al., 2020; Friedman, 2021). These recommendations are in need of revision to help avoid costly mistakes in policy-making. We therefore encourage the Surgeon General and NASEM to update their evaluation of the relationship between e-cigarettes and cigarettes using findings from quasi-experimental studies.

The future sale of e-cigarettes in the United States is uncertain. The FDA has to determine that e-cigarettes are appropriate for public health for them to be approved as new

tobacco products. The FDA is currently allowing the sale of e-cigarettes through enforcement discretion while they undergo review for public health benefit. Policy evaluation research is particularly well-suited to studying public health benefit of e-cigarettes by answering what effect does reducing accessibility or appeal of e-cigarettes have on combustible tobacco product use, a more dangerous product. If reducing e-cigarette accessibility increases combustible cigarette use, this provides evidence of a public health benefit of allowing e-cigarettes to be legally sold: reduced cigarette use. This study contributes weak "early" evidence towards this effect, which joins other quasi-experimental studies using more recent data (Pesko and Currie, 2019; Dave et al., 2019; Friedman, 2015; Pesko et al., 2016a; Cotti et al., 2020; Abouk et al., 2019; Saffer et al., 2020; Pesko et al., 2020) to collectively provide strong evidence suggesting e-cigarette accessibility has some public health benefit by reducing cigarette use.

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Figure 1: Cigarette and E-cigarette use from 2011 to 2015

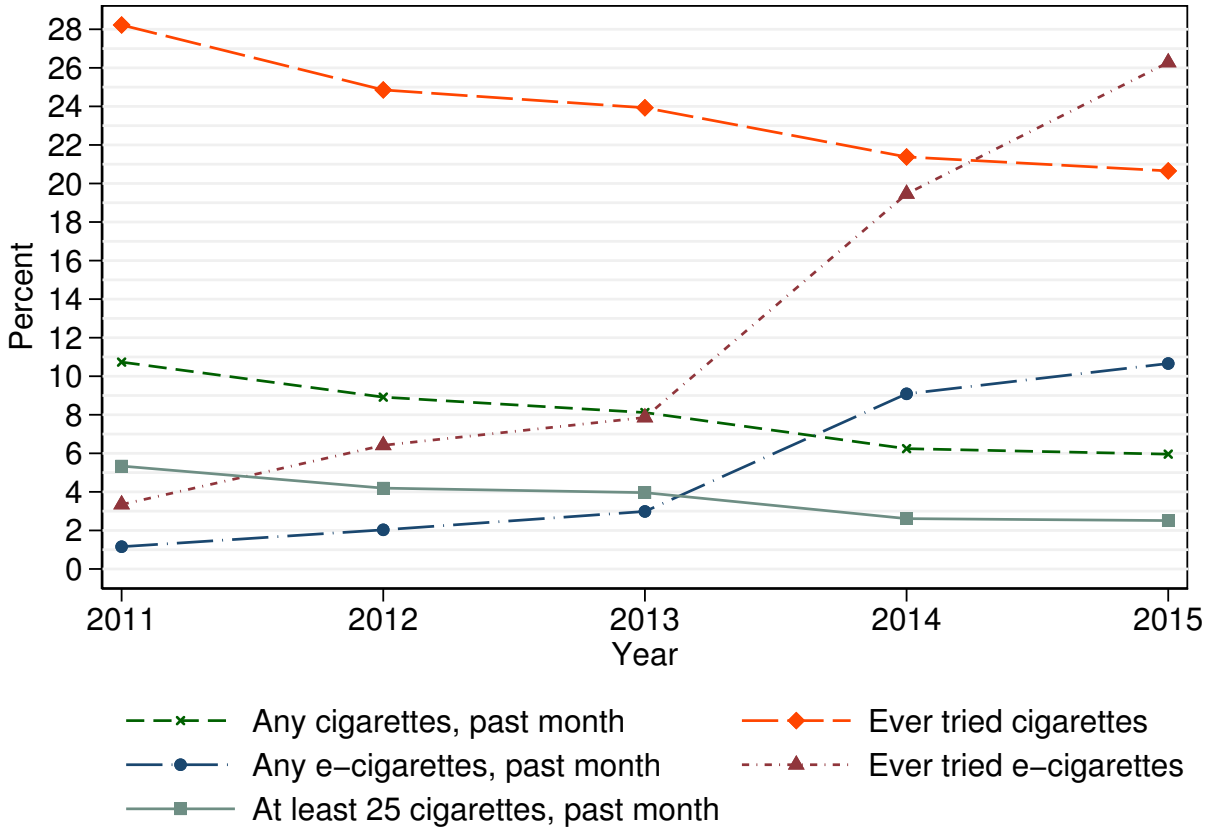


Table 1: Summary Statistics

	Mean	Standard Deviation
Outcomes:		
E-cigarette 30-day participation	0.053	
Cigarette 30-day participation	0.079	
Both e-cigarette and cigarette 30-day participation	0.023	
Number of days using e-cigarettes over the past 30 days	0.769	(3.714)
Number of days using e-cigarettes over the past 30 days, users[1]	7.787	(9.228)
Number of cigarettes past month	7.411	(55.253)
Number of cigarettes past month, smokers[2]	93.448	(174.528)
Individual demographic controls:		
Female	0.495	
Sex missing	0.004	
Age	14.618	(2.047)
Age missing	0.003	
Race		
White	0.524	
Black	0.136	
Hispanic	0.208	
Other	0.096	
Missing	0.035	
State controls:		
Cigarette state prices	5.904	(1.364)
E-cigarette cartridge state price	3.355	(0.454)
E-cigarette disposable state price	8.652	(1.394)
Cigarette tax (state + federal + local)	2.725	(1.215)
E-cigarette minimum legal purchase age law	0.439	
Marijuana decriminalization law	0.374	
Medical marijuana law	0.385	
County controls:		
Cigarette indoor smoking restrictions	0.810	(0.226)
E-cigarette indoor vaping restrictions	0.084	(0.249)
Tobacco 21	0.007	(0.082)
Urban classification		
Centre of metro	0.275	
Fringe of metro	0.287	
Medium metro	0.200	
Small metro	0.106	
Micropolitan	0.085	
Non core	0.047	
County poverty rate	0.156	(0.005)
County median household income	55704	(14244)
County unemployment rate	7.391	(2.458)
Minimum wage	7.887	(0.558)
Year		
2011	0.185	
2012	0.201	
2013	0.201	
2014	0.208	
2015	0.205	
Observations	94,651	

Estimates weighted. All monetary values in real 2014 dollars. 1. Sample size: 3,726 ; 2. Sample size: 7,537

Table 2: The effect of current state cigarette and e-cigarette prices on youth tobacco use in past 30 days

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E-cigarette use		E-cigarette days		Cigarette use		Cigarettes smoked	
Cigarette state prices	0.0307**	0.0316*	3.687+	1.827	0.0094	0.0052	0.424	-0.0885
	(0.0107)	(0.0149)	(2.074)	(1.742)	(0.0110)	(0.0112)	(1.123)	(1.244)
E-cigarette prices								
Cartridge state price	-0.0341*	-0.0353**	-1.574*	-0.568	-0.0116	-0.0036	3.800+	4.618*
	(0.0147)	(0.0130)	(0.688)	(0.573)	(0.0182)	(0.0185)	(1.911)	(2.129)
Disposable state price	0.0003	-0.0041	-0.397	0.264	-0.0021	0.0019	-0.632	-0.353
	(0.0079)	(0.0066)	(0.286)	(0.280)	(0.0068)	(0.0066)	(1.369)	(1.248)
Price elasticities								
Cigarette state prices	3.416**	3.526*	28.78+	14.26	0.700	0.385	0.338	-0.0710
	(1.196)	(1.664)	(16.19)	(13.60)	(0.820)	(0.833)	(0.895)	(0.991)
E-cigarette prices								
Cartridge state price	-2.161*	-2.236**	-6.604*	-2.382	-0.490	-0.151	1.720+	2.090*
	(0.928)	(0.826)	(2.885)	(2.402)	(0.772)	(0.783)	(0.865)	(0.964)
Disposable state price	0.0520	-0.666	-4.360	2.902	-0.226	0.209	-0.738	-0.412
	(1.295)	(1.083)	(3.146)	(3.073)	(0.744)	(0.724)	(1.598)	(1.457)
Additional controls								
Demographics?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes	No	Yes	No	Yes
Mean of dependent variable	0.053	0.053	0.769	0.769	0.079	0.079	7.41	7.41
# of clusters	46	46	40	40	46	46	46	46
Observations	94,651	94,651	38,033	38,033	94,651	94,651	94,651	94,651
R-squared	0.059	0.061	0.043	0.045	0.062	0.064	0.067	0.068

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Other outcomes from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. + Significant at the 10%; * Significant at 5%; ** Significant at 1%

Table 3: The effect of state cigarette and e-cigarette prices on youth overall e-cigarette days (conditional on e-cigarette use) and cigarettes smoked (conditional on cigarette use) in past 30 days

	(1)	(2)	(3)	(4)
	E-cigarette days		Cigarettes smoked	
Cigarette state prices	19.68*	17.06*	-1.598	-4.779
	(8.506)	(6.846)	(9.418)	(10.71)
E-cigarette prices				
Cartridge state price	-7.289*	-3.073	56.66**	58.96**
	(3.226)	(2.319)	(16.10)	(16.15)
Disposable state price	-2.708*	-0.474	0.270	0.952
	(1.194)	(0.857)	(12.79)	(11.17)
Price elasticities				
Cigarette state prices	15.08*	13.07*	-0.0980	-0.294
	(6.517)	(5.245)	(0.579)	(0.659)
E-cigarette prices				
Cartridge state price	-3.039*	-1.281	2.066**	2.150**
	(1.345)	(0.967)	(0.587)	(0.589)
Disposable state price	-2.961*	-0.519	0.0250	0.0870
	(1.306)	(0.937)	(1.170)	(1.022)
Additional controls				
Demographics?	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes
Mean of dependent variable	7.787	7.787	93.45	93.45
# of clusters	40	40	46	46
Observations	3,726	3,726	7,537	7,537
R-squared	0.067	0.075	0.103	0.107

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Cigarettes smoked results from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. $^{+}$ Significant at the 10%; * Significant at 5%; ** Significant at 1%

Table 4: The effect of current and lagged state cigarette and e-cigarette prices on youth tobacco use in past 30 days

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E-cigarette use		E-cigarette days		Cigarette use		Cigarettes smoked	
Cigarette state prices	0.0272	0.0244	2.518	0.779	0.0127	0.0231	-2.117	0.206
	(0.0281)	(0.0299)	(1.825)	(1.599)	(0.0160)	(0.0153)	(2.401)	(2.612)
Cigarette state prices, 1 year lag	0.0173	0.0345^{+}	0.314	1.250	-0.00816	-0.0194	1.076	-1.783
	(0.0135)	(0.0182)	(0.893)	(0.989)	(0.0129)	(0.0168)	(2.516)	(2.643)
E-cigarette prices								
Cartridge state price	-0.0621**	-0.0497**	-1.546*	-0.750	-0.0076	-0.0127	5.888*	5.311^{+}
	(0.0177)	(0.0161)	(0.716)	(0.604)	(0.0204)	(0.0160)	(2.907)	(2.924)
Cartridge state price, 1 year lag	0.0079	-0.0040	0.0872	-1.530	0.0186	0.0292	1.740	3.954
	(0.0246)	(0.0152)	(2.367)	(2.153)	(0.0178)	(0.0186)	(4.629)	(5.547)
Disposable state price	-0.0022	-0.0033	0.137	0.367	-0.0013	-0.0032	0.590	0.628
	(0.0135)	(0.0128)	(0.309)	(0.350)	(0.0107)	(0.0111)	(1.324)	(1.401)
Disposable state price, 1 year lag	0.0125	0.0026	0.647	0.335	-0.0053	0.0014	-0.0546	-0.910
	(0.0086)	(0.0124)	(0.477)	(0.388)	(0.0101)	(0.0134)	(1.344)	(2.221)
Price elasticities								
Cigarette state prices	2.556	2.298	19.66	6.080	1.032	1.884	-1.890	0.184
	(2.642)	(2.814)	(14.25)	(12.49)	(1.307)	(1.246)	(2.144)	(2.332)
Cigarette state prices, 1 year lag	1.586	3.159^{+}	2.371	9.442	-0.648	-1.541	0.935	-1.550
	(1.233)	(1.668)	(6.742)	(7.472)	(1.021)	(1.329)	(2.187)	(2.297)
E-cigarette prices								
Cartridge state price	-3.118**	-2.495**	-6.484*	-3.146	-0.331	-0.554	2.805*	2.530^{+}
	(0.891)	(0.810)	(3.005)	(2.534)	(0.888)	(0.696)	(1.385)	(1.393)
Cartridge state price, 1 year lag	0.412	-0.206	0.336	-5.903	0.838	1.312	0.858	1.949
	(1.281)	(0.791)	(9.131)	(8.307)	(0.802)	(0.837)	(2.282)	(2.734)
Disposable state price	-0.325	-0.476	1.503	4.038	-0.163	-0.399	0.814	0.867
	(1.971)	(1.858)	(3.394)	(3.852)	(1.346)	(1.396)	(1.827)	(1.934)
Disposable state price, 1 year lag	1.688	0.352	7.330	3.791	-0.614	0.160	-0.0700	-1.162
	(1.157)	(1.665)	(5.406)	(4.397)	(1.179)	(1.562)	(1.716)	(2.837)
Additional controls								
Demographics?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes	No	Yes	No	Yes
Mean of dependent variable	0.063	0.063	0.769	0.769	0.073	0.073	6.634	6.634
# of clusters	44	44	40	40	44	44	44	44
Observations	77,105	77,105	38,033	38,033	77,105	77,105	77,105	77,105
R-squared	0.059	0.060	0.043	0.046	0.060	0.062	0.072	0.073

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Other outcomes from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. $^{+}$ Significant at the 10%; * Significant at 5%; ** Significant at 1%

Table 5: The effect of state cigarette and e-cigarette taxes on cigarette use measures in past 30 days

	(1)	(2)	(3)	(4)
	Cigarette use		Cigarettes smoked	
Total cigarette tax	-0.0019	-0.0003	-0.691*	-0.521
	(0.0017)	(0.0024)	(0.316)	(0.433)
Minnesota e-cigarette tax	0.0121+	0.0058	8.617**	5.017+
	(0.0066)	(0.0158)	(0.932)	(2.529)
Price elasticities				
Total cigarette tax	-0.0590	-0.0100	-0.211*	-0.159
	(0.0520)	(0.0730)	(0.0970)	(0.133)
Minnesota e-cigarette tax	0.001+	0.000	0.007**	0.004+
	(0.001)	(0.001)	(0.001)	(0.002)
Additional controls				
Demographics?	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes
Mean of dependent variable	0.088	0.088	8.791	8.791
of clusters	49	49	49	49
Observations	120,280	120,280	120,280	120,280
R-squared	0.068	0.070	0.078	0.079

Notes: Marginal effects are presented first and elasticities second. NYTS for years 2009 and 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. + Significant at the 10%; * Significant at 5%; ** Significant at 1%

Appendix Figure 1: Real price changes from 2012 to 2015

Figure A1a: Cigarette price changes from 2012 to 2015

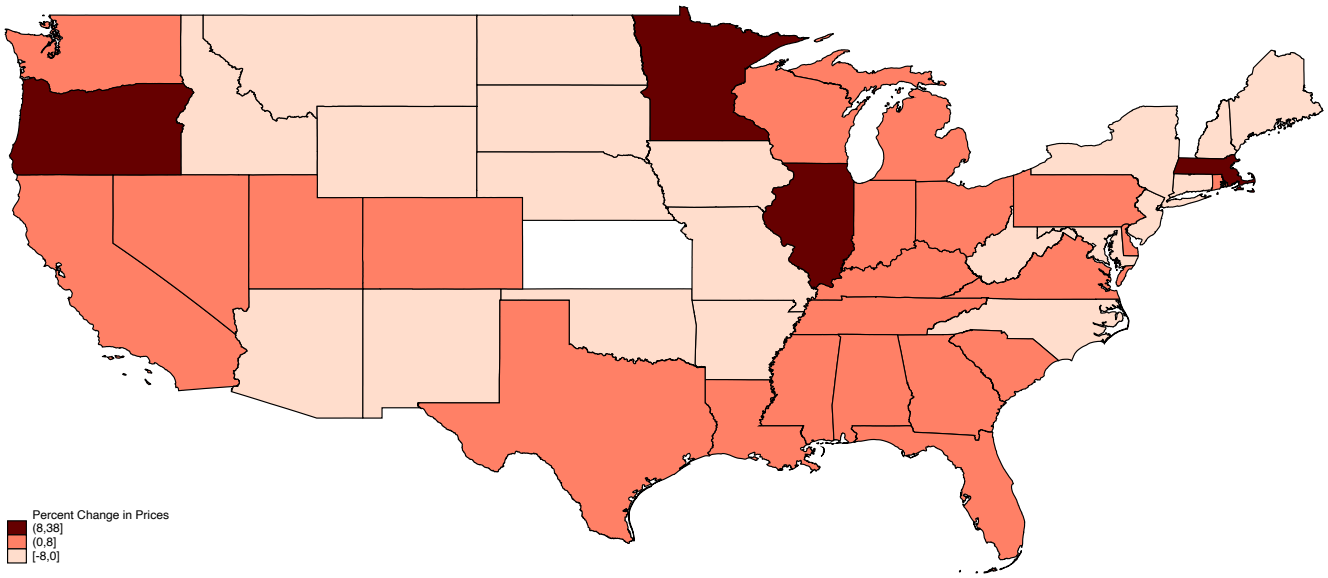


Figure A1b: Cartridge E-cigarette price changes from 2012 to 2015

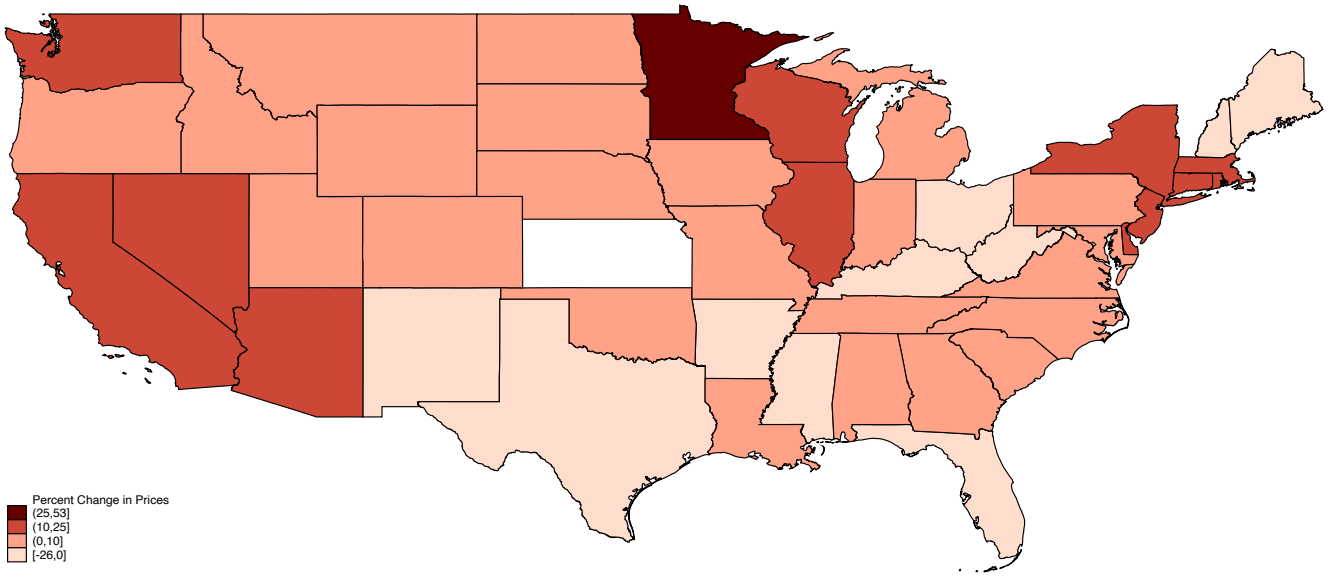
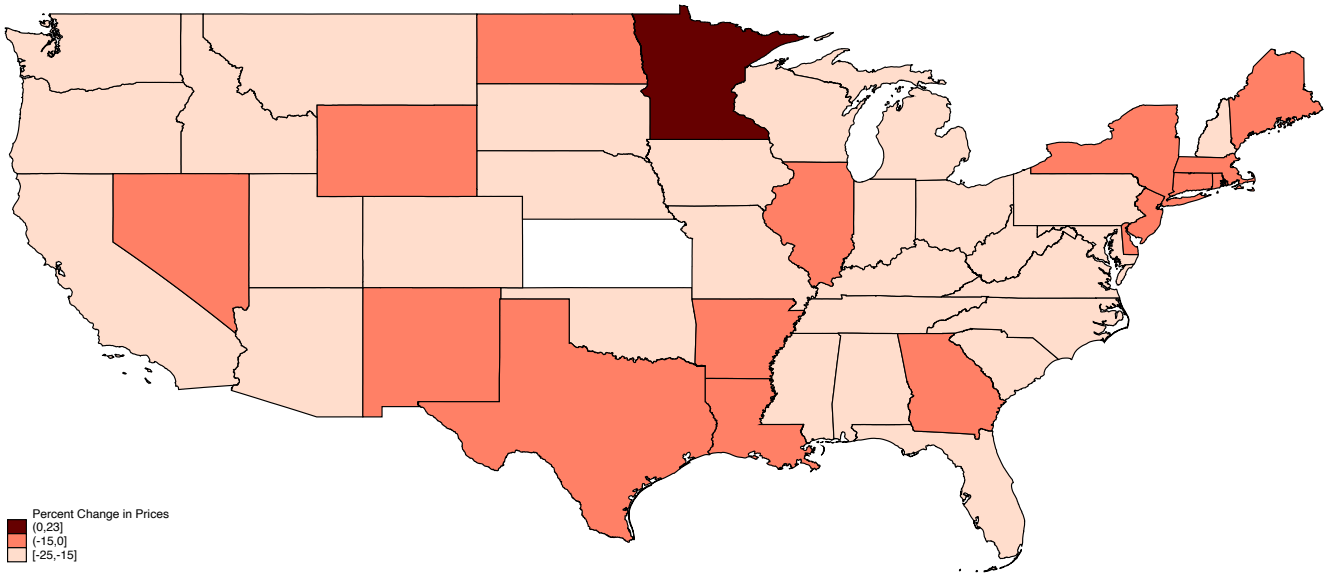


Figure A1c: Disposable E-cigarette price changes from 2012 to 2015



Notes: E-cigarette prices are available for six additional states by using 2012 as the baseline rather than 2011. Kansas, Vermont, and Washington D.C. are excluded due to not being sampled in the NYTS. Hawaii and Alaska are excluded due to not being included in the NRS through 2015.

Table A1: The effect of state cigarette and e-cigarette prices on youth tobacco use in past 30 days, by gender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E-cigarette use		E-cigarette days		Cigarette use		Cigarettes smoked	
Females								
Cigarette state prices	0.0298**	0.0339**	3.219+	2.289	0.0075	0.0083	-1.882	-2.181+
	(0.0082)	(0.0096)	(1.764)	(2.110)	(0.0146)	(0.0133)	(1.242)	(1.169)
E-cigarette prices								
Cartridge state price	-0.0369*	-0.0405*	-1.414*	-0.995	-0.0134	-0.0100	2.441	2.500
	(0.0178)	(0.0168)	(0.568)	(0.607)	(0.0192)	(0.0166)	(2.053)	(1.814)
Disposable state price	0.0025	0.0005	-0.0554	0.276	0.0078	0.0120+	-0.0937	0.264
	(0.0076)	(0.0060)	(0.243)	(0.259)	(0.0070)	(0.0062)	(1.562)	(1.143)
Price elasticities								
Cigarette state prices	4.044**	4.607**	33.58+	23.88	0.638	0.714	-2.128	-2.466+
	(1.117)	(1.305)	(18.41)	(22.01)	(1.248)	(1.140)	(1.404)	(1.322)
E-cigarette prices								
Cartridge state price	-2.844*	-3.121*	-7.909*	-5.566	-0.652	-0.485	1.566	1.604
	(1.375)	(1.298)	(3.178)	(3.395)	(0.934)	(0.805)	(1.317)	(1.164)
Disposable state price	0.497	0.105	-0.811	4.047	0.984	1.505+	-0.155	0.437
	(1.508)	(1.198)	(3.558)	(3.788)	(0.877)	(0.773)	(2.586)	(1.892)
Mean of dependent variable	0.044	0.044	0.576	0.576	0.069	0.069	5.227	5.227
# of clusters	46	46	40	40	46	46	46	46
Observations	47,329	47,329	18,656	18,656	47,329	47,329	47,329	47,329
R-squared	0.053	0.055	0.037	0.039	0.053	0.056	0.087	0.089
Male								
Cigarette state prices	0.0314*	0.0285	4.131	1.619	0.0106	0.0019	2.498+	1.457
	(0.0133)	(0.0203)	(3.987)	(3.468)	(0.0113)	(0.0134)	(1.295)	(1.613)
E-cigarette prices								
Cartridge state price	-0.0302+	-0.0279+	-1.529	-0.0685	-0.0073	0.0061	4.850+	6.996+
	(0.0162)	(0.0155)	(1.152)	(0.777)	(0.0275)	(0.0320)	(2.787)	(3.556)
Disposable state price	-0.0025	-0.0087	-0.738	0.243	-0.0112	-0.0077	-1.001	-0.708
	(0.0090)	(0.0084)	(0.469)	(0.467)	(0.0077)	(0.0082)	(1.353)	(1.468)
Price elasticities								
Cigarette state prices	2.976*	2.700	25.92	10.16	0.701	0.122	1.547+	0.902
	(1.264)	(1.930)	(25.02)	(21.76)	(0.743)	(0.888)	(0.802)	(0.999)
E-cigarette prices								
Cartridge state price	-1.626+	-1.505+	-5.163	-0.231	-0.274	0.230	1.706+	2.462+
	(0.876)	(0.838)	(3.889)	(2.623)	(1.033)	(1.202)	(0.981)	(1.251)
Disposable state price	-0.344	-1.213	-6.535	2.151	-1.084	-0.744	-0.910	-0.643
	(1.250)	(1.176)	(4.152)	(4.135)	(0.746)	(0.795)	(1.229)	(1.334)
Mean of dependent variable	0.062	0.062	0.955	0.955	0.089	0.089	9.531	9.531
# of clusters	46	46	40	40	46	46	46	46
Observations	46,971	46,971	19,158	19,158	46,971	46,971	46,971	46,971
R-squared	0.065	0.068	0.048	0.054	0.072	0.075	0.060	0.061
Additional controls								
Demographics?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Other outcomes from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. + Significant at the 10%; * Significant at 5%; ** Significant at 1%

Table A2: The effect of state cigarette and e-cigarette prices on e-cigarette and cigarette use measures, alternative functional forms

	(1)	(2)	(3)	(4)
	E-cigarette use		Cigarette use	
Cigarette state prices	0.0152^{+}	0.0186^{+}	0.0119	0.0061
	(0.0086)	(0.0104)	(0.0093)	(0.0089)
E-cigarette prices				
Cartridge state price	-0.0236*	-0.0221**	-0.0121	-0.0052
	(0.0098)	(0.0071)	(0.0141)	(0.0131)
Disposable state price	-0.0033	-0.0063	-0.0033	0.0019
	(0.0058)	(0.0053)	(0.0059)	(0.0048)
Price elasticities				
Cigarette state prices	3.015^{+}	3.704^{+}	1.255	0.652
	(1.694)	(2.060)	(0.991)	(0.958)
E-cigarette prices				
Cartridge state price	-2.658*	-2.500**	-0.729	-0.315
	(1.079)	(0.803)	(0.851)	(0.794)
Disposable state price	-0.955	-1.854	-0.507	0.293
	(1.688)	(1.540)	(0.922)	(0.752)
Additional controls				
Demographics?	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes
Mean of dependent variable	0.053	0.053	0.079	0.079
# of clusters	46	46	46	46
Observations	94,651	94,651	94,651	94,651

Notes: Marginal effects (from a probit model) are presented first and elasticities second. NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. $^{+}$ Significant at the 10%; * Significant at 5%; ** Significant at 1%

A Data Appendix

The NRS reports e-cigarette sales from 66 different companies, and per year the number of companies is 16 in 2011, 29 in 2012, 45 in 2013, 52 in 2014, 56 in 2015. According to Nielsen documentation, as of year-end 2011, the amount of commodity volume captured by each store type was 53% for food stores, 55% for drug stores, 32% for mass merchandise, 1% for liquor stores, and 2% for convenience stores. Excise taxes and retailer coupons are factored into the price, but manufacturer coupons are not.

We create e-cigarette prices by first searching online for all e-cigarette UPC codes available in Nielsen data to identify if the product was a disposable, cartridge, liquid nicotine, or a starter kit. We then calculate a year-by-state volume and revenue for each product class, using Nielsen-provided UPC code descriptors of how many goods appear in a given pack and the numeric quantity of the good in individual packaging. We divide the revenue by volume for each product class/year/state combination to create state-level, annual prices.

In Figures A1a through A1c, we show how Nielsen prices for cigarettes and e-cigarettes changed across states over time, comparing state-level real prices in 2012 to real prices in 2015.[21] We use 2012 as our baseline measure of prices in these maps (despite using 2011-2015 prices in our analysis) because e-cigarette prices for either disposables, cartridges, or both were missing for six states[22] in 2011 for which price data was available starting in 2012.[23]

In panel A, we show that cigarette prices increased from 2012 to 2015 by up to 38% (likely due to tax changes) or declined by as much as 8% (likely due to inflation eroding the real value of cigarettes). The states with significant (>8%) cigarette excise tax increases between June, 2012 to June, 2015 are Illinois, Minnesota, Massachusetts, and Oregon (Campaign for

[21] We group obvious brands produced by the same company together. For example, BLU is listed as BLU CIGS, BLU ECIGS, BLU ECIGS PLUS+, etc.

[22] The six states without e-cigarette price data in 2011 are Delaware, Maine, Montana, New Hampshire, Oregon, and Rhode Island. The NYTS collected data in all of these state except Montana and New Hampshire in 2011; therefore, respondents from these states in year 2011 are excluded from our study.

[23] Nielsen does not collect retail price data in Alaska or Hawaii through 2015, and the states of Kansas, Vermont, and Washington D.C. were not surveyed by the NYTS during any of the five years of data collection.

Tobacco Free Kids, 2018), which are also the states with the highest price increases in the maps. Therefore, cigarette prices appear to correlate strongly with cigarette taxes.

In panel B, we see that disposable e-cigarette prices for all states except Minnesota have fallen over the same time period. Minnesota increased its e-cigarette excise tax in July 2013 (Centers for Disease Control and Prevention, 2018), from 35% of the wholesale cost to 95% of the wholesale cost. This was the only e-cigarette tax during our data collection period.

In panel C, we see that e-cigarette cartridge prices rose in most states, but especially in Minnesota due to the excise tax increase. This pattern of e-cigarette disposable prices falling and e-cigarette cartridge prices rising has been documented elsewhere (U.S. DHHS, 2016).

Our two-way fixed effect modelling approach compensates for national changes in disposable and refill prices, and across-state time-invariant differences in prices. We are only exploiting deviations in these prices within-state, and differing from the national trend.

B Online Appendix

Table A3: The effect of current state cigarette and e-cigarette prices on youth tobacco use in past 30 days

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E-cigarette use		E-cigarette days		Cigarette use		Cigarettes smoked	
Cigarette state prices	0.0308**	0.0291*	4.202+	1.730	0.0083	0.0064	0.0918	-0.309
	(0.0083)	(0.0116)	(2.255)	(1.860)	(0.0092)	(0.0098)	(0.975)	(0.963)
E-cigarette prices								
Cartridge state price	-0.0339*	-0.0378**	-1.736*	-0.555	-0.0132	-0.0024	3.320+	4.405*
	(0.0138)	(0.0129)	(0.735)	(0.597)	(0.0186)	(0.0185)	(1.756)	(1.984)
Price elasticities								
Cigarette state prices	3.435**	3.242*	32.81+	13.51	0.620	0.474	0.0730	-0.246
	(0.920)	(1.298)	(17.61)	(14.52)	(0.687)	(0.727)	(0.776)	(0.767)
E-cigarette prices								
Cartridge state price	-2.146*	-2.392**	-7.281*	-2.329	-0.556	-0.103	1.503+	1.994*
	(0.876)	(0.817)	(3.083)	(2.502)	(0.786)	(0.782)	(0.795)	(0.898)
Additional controls								
Demographics?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes	No	Yes	No	Yes
Mean of dependent variable	0.053	0.053	0.769	0.769	0.079	0.079	7.41	7.41
# of clusters	46	46	40	40	46	46	46	46
Observations	94,651	94,651	38,033	38,033	94,651	94,651	94,651	94,651
R-squared	0.059	0.061	0.042	0.045	0.062	0.064	0.067	0.068

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Other outcomes from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. + Significant at the 10%; * Significant at 5%; ** Significant at 1%

Table A4: The effect of current state cigarette and e-cigarette prices on youth tobacco use in past 30 days

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E-cigarette use		E-cigarette days		Cigarette use		Cigarettes smoked	
Cigarette state prices	0.0250*	0.0250^{+}	2.455	1.347	0.0075	0.0045	1.056	0.776
	(0.0100)	(0.0134)	(1.869)	(1.796)	(0.0094)	(0.0099)	(1.090)	(1.339)
E-cigarette prices								
Disposable state price	-0.0039	-0.0077	-0.558	0.255	-0.0035	0.0016	-0.166	0.117
	(0.0075)	(0.0064)	(0.371)	(0.291)	(0.0070)	(0.0066)	(1.278)	(1.188)
Price elasticities								
Cigarette state prices	2.784*	2.789^{+}	19.17	10.52	0.557	0.335	0.841	0.618
	(1.115)	(1.497)	(14.59)	(14.02)	(0.700)	(0.735)	(0.868)	(1.067)
E-cigarette prices								
Disposable state price	-0.633	-1.253	-6.135	2.804	-0.381	0.169	-0.193	0.137
	(1.231)	(1.046)	(4.082)	(3.199)	(0.768)	(0.719)	(1.492)	(1.387)
Additional controls								
Demographics?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State/local environment?	No	Yes	No	Yes	No	Yes	No	Yes
Mean of dependent variable	0.053	0.053	0.769	0.769	0.079	0.079	7.41	7.41
# of clusters	46	46	40	40	46	46	46	46
Observations	94,651	94,651	38,033	38,033	94,651	94,651	94,651	94,651
R-squared	0.059	0.061	0.042	0.045	0.062	0.064	0.067	0.068

Notes: Marginal effects are presented first and elasticities second. E-cigarette days results from NYTS for years 2014 and 2015. Other outcomes from NYTS for years 2011 to 2015. Demographic controls include: age indicators, race indicators, and a female indicator (including missing categories). State/local environment controls include: urban classification, cigarette indoor smoking restrictions, e-cigarette indoor vaping restrictions, Tobacco 21, e-cigarette minimum legal purchase age law, medical marijuana law and decriminalization law, county unemployment rate, poverty rate, and median household income. Robust standard errors in parentheses clustered at the state level. $^{+}$ Significant at the 10%; * Significant at 5%; ** Significant at 1%