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COMPREHENSIVE E-CIGARETTE FLAVOR BANS AND TOBACCO USE AMONG YOUTH, YOUNG ADULTS, AND ADULTS

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After this paper was completed, we learned of a closely related paper by Charles Courtemanche, Chad Cotti, Catherine Maclean, Erik Nesson, Joseph Sabia, and Yang Liang. Their paper is entitled "The Effect of E-Cigarette Flavor Bans on Tobacco Use" and reaches similar conclusions to our study. We are grateful to the National Institute of Drug Abuse (5 R01 DA055976), which provided funding support for this research. We thank Ege Aksu for excellent research assistance and comments on an earlier draft of this study. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Comprehensive E-cigarette Flavor Bans and Tobacco Use among Youth, Young Adults, and Adults
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ABSTRACT

The vast majority of youth e-cigarette users consume flavored e-cigarettes, raising concerns from public health advocates that flavors may drive youth initiation and continued use of e-cigarettes. Flavors drew further notice from the public health community following the sudden outbreak of lung injury among vapers in 2019, prompting several states to enact sweeping bans on flavored e-cigarettes. In this study, we examine the effects of these comprehensive bans on e-cigarette use and potential spillovers into other tobacco use by youth, young adults, and adults. We utilize both standard difference-in-differences (DID) and synthetic DID methods, in conjunction with four national data sets. We find evidence that young adults decrease their use of the banned flavored e-cigarettes as well as their overall e-cigarette use, by about two percentage points, while increasing cigarette use. For youth, there is some suggestive evidence of increasing cigarette use, though these results are contaminated by pre-trend differences between treatment and control units. The bans have no effect on e-cigarette and smoking participation among older adults (ages 25+). Our findings suggest that statewide comprehensive flavor bans may have generated an unintended consequence by encouraging substitution towards traditional smoking in some populations.

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A data appendix is available at http://www.nber.org/data-appendix/w32534

1. Introduction

The past decade has seen a major disruption to the tobacco market with the advent of electronic cigarettes (e-cigarettes) or more broadly electronic nicotine delivery systems (ENDS). Entering the U.S. market in 2007, e-cigarettes have surged in popularity among youth, surpassing cigarettes in 2014 and becoming the most widely used form of tobacco among youth. After witnessing an almost doubling in the prevalence of e-cigarette use among high school students (from 11.7% to 20.8% over 2017-2018) and about a 50 percent increase among middle school students (from 3.3% to 4.9%) in a single year (over 2017-2018), the U.S. Surgeon General declared youth vaping a national epidemic (U.S. Department of Health and Human Services – DHHS, 2018).[1]

No form of tobacco is deemed safe especially for youth and young adults for whom nicotine exposure can present adverse developmental consequences. Adolescence, in particular, is a key period for brain development, and the prefrontal cortex, which regulates executive function, rational decision making, and higher order cognitive abilities, continues to develop until about the age of 24 (López-Ojeda and Hurley, 2024; Arain et al., 2013). E-cigarette use among young adults has also been linked to respiratory symptoms (Tackett et al., 2024). While not completely safe, e-cigarettes are considered to be a safer alternative to combustible cigarette use, though there exists a degree of uncertainty with respect to the relative risk of these tobacco products. The Office of Health Improvement and Disparities in the U.K. (McNeill et al., 2022) recently reiterated its prior conclusion that nicotine vaping poses only a small fraction of the risk relative to smoking (about 5%), whereas a recent survey of 137 tobacco control experts reported a 37% relative health risk, on average, for e-cigarette use compared to smoking (Allcott and Rafkin, 2022).

The heavy toll of smoking, responsible for over 480,000 deaths annually (U.S. DHHS, 2014), in conjunction with the significantly lower relative risk profile of e-cigarettes, have presented a key regulatory challenge. Policymakers at the federal, state, and local levels have grappled with how best to regulate access

[1] Based on the National Youth Tobacco Surveys, prevalence of past 30-day e-cigarette use among high school students increased further to 27.5% in 2019 before declining over the pandemic period (19.6% in 2020 and 11.3% in 2021). Among youth and young adults who reduced their use of e-cigarettes over the pandemic, the most commonly cited reasons related to fewer social interactions, health concerns, and reduced access (Bennett et al., 2023).

to e-cigarette products such that their harm reduction potential is maximized (i.e. for adults who want to use these smoking alternatives to quit the habit or reduce their combustible cigarette consumption) while constraining uptake and use among youth. This uncertainty surrounding the optimal regulatory approach is reflected in the variance in the policy landscape across the country. For instance, e-cigarette taxes – an increasingly popular policy lever deployed by states and localities to curb e-cigarette use – are currently levied in only 32 states and in D.C., along with a handful of local jurisdictions. In contrast to cigarettes, there is no federal tax on e-cigarettes.[2] And, even among states and localities that have adopted these taxes, they vary widely in their structure (i.e. ad valorem vs. excise tax vs. specific sales tax) and in the amount of the tax (Dave et al., 2022). Moreover, several studies have shown that while higher e-cigarette taxes are effective in reducing vaping, especially among youth and young adults, they generate an unintended consequence in the form of increasing cigarette sales and smoking participation and deterring smoking cessation (Abouk et al., 2023; Cotti et al., 2022; Saffer et al., 2020).

In pronouncing youth e-cigarette use a public health epidemic, the U.S. Surgeon General further placed a spotlight on the popularity of flavored e-cigarettes among youth and the importance of reducing access to flavored tobacco products for young people (U.S. DHHS, 2018).[3] Advocates contended that flavored e-cigarettes were very appealing to youth and that restrictions on flavors could decrease tobacco use by youth (Chen et al., 2017). Among high school students who currently use e-cigarettes, the vast majority (~85%) use flavored ones (Wang, 2020). Flavors have been linked to youth initiation of e-cigarette use (Zare et al., 2018; Villanti et al., 2017) and drew further notice from the public health community following the sudden outbreak of lung injury and deaths among vapers in 2019. This "vaping associated pulmonary injury" was later linked to vapers using their vaping devices to consume tetrahydrocannabinol (THC) e-liquids that had contained harmful additives. The 2009 Family Smoking and Tobacco Prevention

[2] In 2019, Senator Ron Wyden (Oregon) introduced a bill (E-cigarette Tax Parity Act) that would have expanded the definition of federally taxable tobacco products to include ENDS, and which would establish an excise tax on these alternative nicotine products at a rate per-milligram of nicotine content that would be commensurate with the current federal excise tax of $1.01 per pack of cigarettes.

[3] Evidence from a discrete choice experiment of adults also indicated that participants exhibited the strongest preference for non-tobacco and non-menthol flavors (Yang et al., 2023b).

Act had banned the sale of flavored cigarettes, though menthol and tobacco flavors were exempted, and other flavored tobacco products – notably flavored e-cigarettes – remained on the market. This was partially remedied when the Food and Drug Administration (FDA) extended the ban to cover cartridge-based e-cigarettes in February of 2020. However, menthol and tobacco-flavored cartridge-based e-cigarettes were allowed to remain on the market, and the FDA ban also permitted all flavors to continue to be sold in disposable e-cigarettes and in tank-based vaping devices.[4] Because of these exemptions and substitution possibilities, the federal ban could be easily circumvented rendering its potential impact on flavored e-cigarette use and overall e-cigarette use to be minimal (Romm et al., 2022).

Largely in response to the sudden outbreak of severe lung injury among vapers in 2019/2020 and in recognition of the federal exemptions, several states enacted more sweeping restrictions aimed at flavored e-cigarettes by banning all flavors and/or extending the federal ban to all e-cigarette devices. The key regulatory dilemma of balancing harm reduction while constraining youth access also applies to these more stringent statewide restrictions on the sale of flavored e-cigarettes. Even if these bans are effective in reducing flavored and overall e-cigarette use among youth and young adults, they could generate unintended consequences in the form of substitution to cigarettes. The effectiveness of these bans remains uncertain since the restrictions could still be circumvented through cross-border purchases, online purchases, purchases at exempted retailers, or users adding their own flavors. These possibilities were reported by Romm et al. (2022) in a survey of young adult e-cigarette users just following the 2020 federal ban, who reported how they would respond to comprehensive flavor restrictions. Some participants reported they would quit vaping or have ways to circumvent the restrictions and not be impacted or would substitute to cigarettes.

This study directly informs each of these scenarios across youth, young adults and adults, and presents some of the most comprehensive evidence to date on how the statewide flavor restrictions have impacted e-cigarette use and smoking. We separately explore impacts for youth, young adults, and adults,

[4] In April 2021 the FDA announced that it will issue product standards within the next year to ban menthol in cigarettes and ban all flavors including menthol in cigars.

leveraging information from four national datasets: pooled state Youth Risk Behavior Surveys (YRBS), Monitoring the Future (MTF), Behavioral Risk Factor Surveillance System (BRFSS), and Population Assessment of Tobacco and Health (PATH). The main analyses rely on a generalized difference-in-differences approach in conjunction with the synthetic difference-in-differences estimator (Arkhangelsky et al., 2021; Clarke et al., 2023), and we draw conclusions from the weight of the evidence across multiple data sources in combination with the validity of the counterfactual assumptions.

We document several key findings in support of each of the three scenarios noted above – albeit operating differentially across the different age groups. First, for youth (ages 14-17), while there is some indication of a small decrease in their use of the banned flavored e-cigarettes, we find little evidence to suggest that the statewide flavor bans reduced their overall e-cigarette participation. Models that support parallel trends also do not indicate any meaningful spillovers into smoking participation for youth. Second, for young adults (ages 18-24), we find some evidence that the comprehensive restrictions on flavored e-cigarettes lowered their use of the banned flavored e-cigarettes and reduced their overall e-cigarette participation, by about one to two percentage points. For young adults, the bans appear to have generated an unintended consequence by raising their smoking participation. Finally, for older adults (ages 25+), the statewide bans have no discernible impact on either their e-cigarette or cigarette use.

The remainder of the paper proceeds as follows. Section 2 provides background on the statewide restrictions on e-cigarette flavors and discusses some of the relevant literature. The multiple data sets are outlined in Section 3, and Section 4 describes our methods. Our main results, robustness checks, and extensions are reported in Section 5. Finally, Section 6 concludes by offering further context for our findings with respect to limitations and policy implications.

2. Background

2a. Statewide e-cigarette flavor bans

Between October 2019 and July 2020, eight states had enacted far more sweeping restrictions on flavored e-cigarettes in relation to the federal ban. Table 1 presents a timeline of the enactment of these restrictions. In addition to these statewide bans, some localities in states without more comprehensive statewide restrictions enacted their own localized e-cigarette flavor bans. Local bans created confusion for retailers on what is legal to sell in their location and places the burden of enforcement on local authorities who may not have the requisite resources. Moreover, as these local bans are fairly easily circumvented through cross-border purchases or other means, we do not include them (Yang et al., 2022; Rich, 2022; Dove et al., 2023).

The enactment of more comprehensive restrictions on e-cigarette flavors was largely driven by concerns regarding the health effects of vaping as they unfolded over 2019-2020 in the form of an outbreak of lung injury among vapers. Most of the states that enacted permanent bans on flavors also enacted, or attempted to enact, emergency flavor bans as a result of this nation-wide outbreak of severe lung disease linked to e-cigarettes and other vaping devices in 2019.[5]

Eight states (Table 1) issued emergency rules to temporarily ban the sale of flavored e-cigarettes. As a result of legal challenges, these orders were blocked in four states. Temporary bans adopted in Rhode Island (RI) and Massachusetts (MA) became permanent in March and June of 2020, respectively. New York (NY) and Utah (UT), where bans were initially blocked by legal challenges, were able to enact permanent bans. New Jersey (NJ) and Maryland (MD) also enacted permanent bans. Montana (MT) and Washington (WA) implemented temporary restrictions on flavored e-cigarette sales in October 2019, which did not convert into a permanent ban and expired in January of 2020. We exclude these states from the analysis since the bans were very short-lived; we also exclude these states from the control group given they have been previously treated, albeit for a short period of time.

[5] The first case of vaping-related lung injury was reported to the Centers for Disease Control and Prevention (CDC) in August 2019. Cases quickly rose and peaked in September. By February 2020, over 2800 cases and 68 related deaths were recorded. See: Krishnasamy et al., (2020) and Lancet Respiratory Medicine (2020).

2b. Use of flavored e-cigarettes

Table 2 presents descriptive information, based on the PATH, on the percentage of nicotine vapers who use banned flavors across the three age groups. In all treatment states other than MA, all flavors were banned in all e-cigarette devices except for tobacco and menthol flavors. MA further banned menthol flavors in e-cigarette products as well. These estimates underscore two key points. First, banned flavors were most popular among youth, with the majority of youth who currently use e-cigarettes reporting use of the (banned) flavored e-cigarettes, both before and after the bans. There is a steep age gradient in the use of the banned flavors among current users, with the popularity of these flavors waning for younger and older adults. This gradient appears to flatten post-treatment, particularly between youth and young adults. Second, interestingly, post-treatment, conditional on e-cigarette use, consumption of the banned flavors increases for all age groups, for treatment states as well as the control states. The last column presents the unconditional difference-in-differences estimates, which indicate that the largest decline in the use of flavors out of all age groups occurred for young adults (by 7.2 percentage points) in the ban states relative to the states without these bans. Declines in the use of the banned flavors for youth and older adults are much smaller (3.4 and 1.8 percentage points, respectively).

The relatively high use of flavors in the treatment states, even after the bans go into effect, may be in part due to exemptions for certain store types. MA exempts stores that primarily sell tobacco, e-cigarette establishments, tobacco/smoking bars, adult-only retailers, and liquor stores from all flavor bans. UT also exempts tobacco retail specialty businesses from flavor bans (Public Health Law Center, 2023). Users are also able to add their own flavors to the e-liquid mix by opening the e-cigarette cartridge or tank device. Because it is not difficult to make these modifications, a flavor ban could also result in a black market for flavored e-cigarettes. This essentially is what happened during the 2019 outbreak of lung injuries, which were linked to vape devices that had been modified and sold by black market operators. Hence, users may still be able to obtain flavored e-cigarettes through online purchases or illegally on the black market or through establishments due to lack of enforcement.[6]

2c. Prior studies

Restrictions on flavored e-cigarettes have been motivated by the popularity of flavors among youth users, and with the stated rationale of preventing youth initiation and continued use of these products. Given the recency of the more comprehensive sub-national flavor bans, the literature on the direct and broader impacts of these restrictions is still emerging.

Ali et al. (2022) study the effects of flavor restrictions on e-cigarette sales in three states with a permanent ban (MA, NY, RI) and one state with a short-lived ban (WA) using early data through 2020, and thus essentially identifying very short-term effects for up to a year post-treatment. They find substantial reductions in sales (on the order of 25-31%), largely driven by a reduction in the sale of non-tobacco flavored e-cigarettes. Xu et al. (2022), using a similar post-ban window extending through early 2020, widen the lens to study effects on cigarette sales. They focus on bans in three states (MA, RI, WA) and find significant increases in cigarette sales in the short term on the order of 5-8%. Expanding on the number of treated localities (to include seven statewide bans as well as various sub-state local bans) and extending the post-treatment window through early 2023, Friedman et al. (2023) also find a significant reduction in ENDS sales, driven by a decrease in the sale of flavored products, and a substitution into cigarette sales, both overall and for brands disproportionately preferred by youth.

All of these studies rely on commercial sales data from Circana (formally known as Information Resources, Inc.), which cover sales from national chain convenience stores, large food stores, drug stores, mass merchandiser outlets, and military sales. This work identifies compelling effects on e-cigarette sales and potential substitution into cigarettes, but the use of these commercial sales introduces three main

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[6] Anecdotal evidence on seizures from the MA Department of Revenue points to a thriving illicit market in the state. There was a substantial increase in seizures of untaxed ENDS and other tobacco products entering the state from surrounding states, and unlicensed distributors continuing to operate and sell banned flavored tobacco products within MA (Grier, 2023).

limitations to any analysis. First, sales from online retailers, independent convenience stores, independent food stores, other independent stores (excluding drug stores), and tobacco specialty stores such as vape shops are excluded. These exclusions omit a large share of tobacco sales. For instance, Selya et al. (2023) conclude that about 50% of the e-cigarette market is not recorded by Circana. Data from the PATH show that about 60% of youth purchases of vaping products occur through tobacco specialty stores; the corresponding shares for young adults and adults are 70% and 67%, respectively. In addition to capturing only a limited fraction of tobacco sales, estimates using the Circana data may further present a distorted picture of the impact of bans since many of the retailers not represented in the data (i.e. vape dispensaries, specialty tobacco retailers) were also exempted by the flavor bans in certain states. If the bans shifted sales away from traditional retailers to these specialty retailers, either because they were exempted or less vigorously enforced, then the identified treatment effects in studies using the Circana data may be overstated. Second, sales do not equate to use. A reduction in sales in the banned states could be offset by an increase in cross-border sales or through illicit purchases. Indeed, recent work with the Circana data (Chen et al., 2023), even over a short post-treatment window (through February 2020) uncovered strong evidence of spatial spillovers; bans implemented in four states (MA, WA, RI, and MT) resulted in significant increases in ENDS sales in neighboring counties. One other concern is that these aggregate sales data cannot uncover separate effects on use across youth vs. adults or across other sub-populations of interest.

There are only a few quasi-experimental studies of comprehensive flavor bans that have gone beyond effects on sales, and they have largely focused on a single state or locality prior to the 2020 federal ban. Several studies have explored the effects of restrictions on flavored tobacco that were adopted in the San Francisco Bay Area over 2018-2019. In their analysis of the impact of these bans among high school students, using the California Healthy Kids Survey, Dove et al. (2023) find no effects on current or ever use of e-cigarettes over a post-policy window of one year.[7] They attribute this finding to potential substitution from the banned to the non-banned flavors and/or cross-border purchases. Friedman (2021), utilizing data on high-school students from the district YRBS, finds robust evidence that San Francisco's ban also resulted in youth substituting into cigarette use, even over the study's short post-policy window.[8] Hawkins et al. (2022) study how local restrictions on flavored tobacco products in Massachusetts counties, which predated the federal flavor ban, affect youth use of e-cigarettes and cigarettes. Using biennial data from the 2011-2017 Massachusetts Health Surveys, they find significant reductions in both e-cigarette and cigarette use among youth in the treated counties after the adoption of the ban relative to counties that did not enact these restrictions.

Based on an online survey of 1624 adult e-cigarette users, a recent study (Yang et al., 2023a) explores pre-post changes in e-cigarette use and flavored e-cigarette use associated with flavor restrictions in three states (WA, NJ, NY). Following the ban, 8.1% of e-cigarette users stopped using e-cigarettes, and overall, the use of non-flavored e-cigarettes increased from 5.4% to 25.4%. Descriptive evidence indicated that e-cigarette users were able to obtain the banned flavors, post-restrictions, through various means: in-state retailers, cross-state purchases, online purchases, black market, mixing the flavors themselves, and stocking up on e-cigarettes prior to the ban. Their finding that 45% of e-cigarette users continued to be able to purchase the banned flavors from in-state retailers suggests that compliance and enforcement were not high.

Another study, which is concurrent with our study is Cotti et al. (2024). They examine the effects of flavor bans on tobacco outcomes using two of the datasets employed in this study. While their findings are similar to ours, our study differs in several ways. First, we provide evidence using two additional

[7] Similarly, evidence from outside the U.S. context – based on a pre-post comparison surrounding the Finnish Tobacco Act, which in 2016 banned flavors in tobacco products excluding tobacco flavor – found essentially no change in e-cigarette use (Ruokolainen et al., 2022).
[8] A descriptive study (Yang et al., 2020), presenting pre-post comparisons among a small sample of previous tobacco users in San Francisco, finds a similar pattern of result for flavored tobacco and e-cigarette use among adults (ages 18-34). These decreases, however, are counteracted by increases in cigarette use, with this substitution being particularly pronounced among younger adults (ages 18-24).

datasets, the MTF (for youth), and the longitudinal PATH (for youth and adults). As shown in Table 2, a key strength of the PATH is that it contains information on the specific e-cigarette products that were used including the banned flavors. Second, our analyses are based on a synthetic difference-in-differences (SDID) estimation strategy. This estimator has several advantages compared to the standard two-way fixed effects and synthetic control methods, which are discussed in Section 3e.

2d. Contributions

Our study makes several key contributions to this nascent literature. First, we focus on reported use (as opposed to aggregates sales) and provide some of the first and most comprehensive evidence to date on the impact of major statewide restrictions on flavors on both e-cigarette use and cigarette use. Second, we provide effects of these restrictions on three age groups, including youth, young adults, and adults, thereby informing some of the key issues that present a challenge for policymakers – how to regulate e-cigarettes so as to reduce uptake and use among youth without generating unintended consequences across the life-course (i.e. increasing the update of smoking or deterring smoking cessation). Third, we draw on information from four national individual-level data sets – with three of these data sets containing information on youth, and two containing information on adults – allowing us to cross-validate findings across independent surveys and settings. Fourth, we are able to extend the post-policy window beyond the very short-term to encompass effects up to three years following the bans. Other than studies utilizing sales data, most of the prior work on reported use (with the exception of Cotti et al. 2024), which also has been confined to only a single state or locality, has peered into very short-term windows (up to one-year post-treatment). Finally, we also bring to bear recent innovations in the two-way fixed effects (TWFE) difference-in-differences (DID) literature in our analyses, paying careful attention to the validity of counterfactual assumptions and drawing conclusions from the weight of the evidence across the multiple datasets and estimation methods.

3. Data

To obtain a comprehensive view on the effects of flavor ban policies on smoking and e-cigarette use, we capitalize on information from several different datasets for both youth and adults, each offering complementary strengths. Specifically, we use the pooled state Youth Risk Behavior Survey (YRBS), Monitoring the Future (MTF), Population Assessment of Tobacco and Health (PATH), and the Behavior Risk Factor Surveillance Survey (BRFSS). The outcomes we assess in each dataset are past 30-day use of cigarettes or e-cigarettes.[9] A summary of all datasets with descriptive statistics on key variables is presented in Appendix Tables A1-A3. Figure 1 documents trends in e-cigarette and cigarette use separately for youth, young adults, and older adults across the four datasets.[10]

3a. Youth Risk Behavior Survey

The state YRBS is a biennial representative sample of youth for each state that participates and collects information on a set of topics that the CDC has determined is of critical importance for mortality and morbidity. The pandemic year 2020 was not a data collection year. It is a self-administered survey that takes place in schools for grades 9-12. The YRBS is opt-in, and not every state samples in every sample period. For models that require a balanced panel, we drop states that are not available in all waves of the survey. Information on e-cigarette use is available from 2015 onwards. The YRBS offers several important advantages. With approximately 150,000 students surveyed in a given year, pooling the states yields very large sample sizes for assessing heterogeneity and improving precision of the estimates. The YRBS is also one of the few national datasets that is state-representative, which helps to minimize bias in identifying the effects of a statewide intervention (such as the ones we study here) that may arise due to potential shifts in the composition of state-specific samples.[11]

[9] In supplementary analyses, we also assess spillover effects on other tobacco products (smokeless tobacco, cigars) when available.
[10] While there are some differences in the prevalence rates across data sources, likely driven by differences in the underlying sampling, the trends largely track similarly across the datasets.
[11] Pooling the state YRBS data and generating national estimates requires standardized person-specific sampling weights, which we generate by following the literature (see for instance: Dave et al., 2024; Abouk et al., 2023).

3b. Monitoring the Future

As with the YRBS, the MTF is also a school-based survey; it is nationally representative of middle school and high school students in the 8^{th}, 10^{th}, and 12^{th} grades. We exclude students under 14 years of age and utilize the restricted version of the MTF with geographic identifiers. Approximately 45,000 students are sampled each year. We measure e-cigarette and cigarette use in the MTF from 2014-2022. Due to the difficulty with in-school sampling during the school closures and lockdowns during the pandemic, data for 2020 are excluded from the analyses.

3c. Population Assessment of Tobacco and Health

The PATH is a panel study that longitudinally resamples youth ages 12-17 and adults of all ages in multiple waves. It is a household sample and takes place in-home and therefore provides an alternate sample to the school-based MTF and YRBS. The included waves cover 2014-2021 where both cigarette and e-cigarette use are measured throughout. We again drop 2020 from the analyses due to challenges with in-home sampling during this pandemic period. An advantage of the PATH is its detailed information on the use of flavored ENDS products, which is important for assessing the popularity of these flavors among youth and adults and how e-cigarette users shifted their consumption across banned and non-banned flavors following the restrictions (Table 2). Another advantage of the PATH is its sampling of both youth as well as adults. There are approximately 13,000 youth, 8,000 young adults (ages 18-24), and 16,900 older adults (ages 25+). The samples are refreshed from a shadow sample to maintain sample sizes and representativeness. They also include new sets of youth as they age into the sample, and youth who age out are then included in the adult sample. To be consistent with the other datasets, our analyses treat the PATH as repeated cross-sections.

3d. Behavioral Risk Factor Surveillance System

The BRFSS is a state representative phone survey of adults conducted on a yearly basis. It covers approximately 24,000 younger adults (ages 18-24) and 410,000 older adults (ages 25+) sampled independently each year. One disadvantage of the BRFSS is that e-cigarette use was only included in an optional module that each state could opt into or out of in 2018, and it was not measured at all in 2019, and included again as an optional module in 2020. This limits the consistency of this measure across time and we can include only the years 2016, 2017, 2021, and 2022 in our analyses of e-cigarette use in the BRFSS. Past 30-day cigarette use is measured consistently from 2014-2022.

3e. Additional policy measures and control variables

We account for various additional confounding tobacco control measures, including cigarette taxes, indicators for the adoption of an e-cigarette tax, and indicators for the adoption of internet sales bans. We match these to the survey data based on residential state and survey year. Appendix Table A4 presents descriptive data on these state-year level covariates. All analyses further control for socio-demographics (age, sex, race, and ethnicity).

4. Methods

We leverage the quasi-natural experiment provided by the enactment of comprehensive flavor bans in six states to provide plausibly causal estimates of the effects of these bans. We start with the following standard difference-in-differences (DID) model:

$$E_{ist} = \beta * FBAN_{st} + X_{ist} * \theta + \gamma_s + \tau_t + \varepsilon_{ist} \quad (1)$$

Here, E_{ist} denotes various tobacco use outcomes for person i in state s at time t, and $FBAN_{st}$ is an indicator for when, and which states, enacted the comprehensive e-cigarette flavor ban. The six states with permanent e-cigarette flavor bans adopted these bans between late 2019 and mid-2020. These adoption dates are reasonably proximate and minimally staggered such that 2020 can be defined as the treatment initiation year. The issues associated with potential biases due to staggered adoption periods are thus not empirically relevant. The vector X_{ist} includes tobacco policy measures, individual characteristics including age, sex, race, and Hispanic ethnicity, and COVID-19 death rates by state and year.[12] All models include fixed effects for each state (γ_s), which accounts for any stable unmeasured heterogeneity across these areas (for instance, differences resulting from unmeasured cultural factors or sentiment towards tobacco use) and fixed effects for each period (τ_t), which captures unobserved secular trends in tobacco use outcomes impacting the full sample. The parameter of interest, β, summarizes the average causal effect of the flavor bans on tobacco use realized over the post-treatment period. We estimate the effects of flavor bans for the three age groups, and for e-cigarette use and cigarette use in the past month. As noted above, the three age groups studied are youth aged 14-17, young adults ages 18-24, and adults ages 25+. We estimate equation (1) at the individual level but cluster bootstrap standard errors at the state level.

To draw a more explicit focus on the validity of the control states and the counterfactual design, we apply the synthetic difference-in-differences (SDID) estimator (Arkhangelsky et al., 2021; Clarke et al., 2023). The SDID estimator bridges strengths from both panel data DID and synthetic control (SC) methods, while providing various additional strengths and modeling flexibility.

Specifically, in its basic form, a consistent causal effect of the flavor restrictions on a given tobacco use outcome (Y_{st}, in a given state s at time t) can be derived by estimating:

$$\left(\hat{\beta}^{SDID}, \hat{\mu}, \hat{\gamma}, \hat{\tau}\right) = \underset{\beta, \mu, \gamma, \tau}{arg\ min} \left\{ \sum_{s=1}^{n} \sum_{t=1}^{t} (Y_{st} - \mu - \gamma_s - \tau_t - FBAN_{st}\beta)^2 \widehat{\omega}_i^{SDID} \hat{\lambda}_t^{SDID} \right\} \tag{2}$$

In the above equation, the causal effect of the treatment, that is the average treatment effect on the treated (ATT; represented above by $\hat{\beta}^{SDID}$), is estimated from a two-way fixed effects (TWFE) model with optimally-chosen weights $\widehat{\omega}_i^{SDID}$ and $\hat{\lambda}_t^{SDID}$. In contrast to the standard TWFE DID estimation, however, which relies on the "parallel trends" assumption, SDID more flexibly reweights and matches pre-treatment *trends* by selecting a weighted set of control units that minimizes the trend differences in the pre-exposure

[12] Data from Centers for Disease Control and Prevention (CDC), National Center for Health Statistics. (2022). Retrieved from https://www.cdc.gov/nchs/pressroom/sosmap/covid19_mortality_final/COVID19.htm.

periods. Specifically, optimal unit-specific weights $\widehat{\omega}_i^{SDID}$ are chosen to align pre-treatment trends across outcomes in the untreated vs. treated states, subject to a regularization parameter that prevents overfitting while increasing the variance and uniqueness of the weights. SDID also introduces and optimally chooses time-specific weights $\hat{\lambda}_t^{SDID}$ to further remove bias from unobserved shocks and improve precision. These considerations serve to improve the robustness and precision of the SDID estimator, in addition to making the model more flexible in generating credible counterfactual comparisons (Arkhangelsky et al., 2021). As with our estimates of the ATT based on the TWFE DID (equation (1)), we construct standard errors for the SDID estimates by cluster bootstrapping at the state level.

SDID estimation requires a balanced panel that, given the state-level policy variation and the data we are using, requires aggregation to the state and year level. This necessitates dropping some states in datasets that do not appear in every year. SDID has been shown in some contexts to outperform two-way fixed effects models based on having superior power and insensitivity in power to selection of the pre-treatment period by the analyst (Dench et al., 2024). In this case this advantage may be balanced against the need to drop some states from some analytic samples.

In order to assess pre-policy parallel trends between the treatment and control states, we generate event studies that in this circumstance are the average conditional difference between the treatment and control group in each year relative to some reference period. In the context of DID analysis, we use the reference period included in that dataset that is closest to the treatment, and control groups are all weighted equally. The SDID event studies are time series plots of the difference between the treatment group and the control group. Because the average pre-period differential between the treatment group and control group is subtracted from each period's differential, the "reference group" is the average over the entire pre-policy period. All confidence intervals are based on state-level cluster bootstrap inference and reported at the 95% confidence level.

Because we rely on a set of studies and alternate samples, we further construct and report an aggregate of the separately estimated treatment effects using a fixed effects method of aggregation (Hedges, 1998). We do so in order to provide a convenient summary of our estimates and to draw out patterns across alternate data sets. This "meta-analysis" involves taking a weighted average of the estimates across the alternate data sets, where the weights are the inverse of the squared standard error of each estimate, normalized to add up to one. The standard error of this estimate is the inverse of the square root of the sum of all these weights. In this aggregation method, we assume that each dataset is estimating the same target parameter from an underlying population (i.e. youth, young adults, adults) but with different samples. Assuming homogeneity of effects across samples and time periods is required for this assumption to be met.

5. Results

5a. Main analyses of e-cigarette use and cigarette use

We report our main findings in Tables 3 and 4, and in Figures 2 through 4. Supplemental analyses and robustness checks are reported in the Appendix. Table 3 presents estimated treatment effects of the statewide flavor bans on our key outcomes – e-cigarette and cigarette use – across the three age-defined sub-populations, across the four datasets, for both the DID and SDID estimation. We emphasize and discuss results based on our preferred SDID estimation, though our conclusions and overall pattern of findings are not materially changed with the standard TWFE DID estimates. We summarize the average treatment effect on the treated (ATT) across the alternate datasets for each age group in Table 4 through the meta-analytic aggregation method.

Turning to youth (Table 3, Panel A), we do not find any statistically significant effects of the bans on e-cigarette participation for any of our datasets, using either the DID or SDID estimator. Estimated effects based on the MTF are somewhat more suggestive of a potentially meaningful decline in overall e-cigarette use, between 1.9 to 3.6 percentage points (13.9 ~ 26.3% relative to the mean). While these estimates in the MTF are credibly supported by parallel trends in the SDID event study analyses (Figure 2), they are imprecise and are not statistically significant. Moreover, the aggregated treatment effect (Table 4, Panel A) of the bans on youth e-cigarette use across all datasets is smaller (decrease of 1.2 percentage points) and not statistically distinguishable from zero.[13]

Interestingly, the aggregated average treatment effect on youth in the treated states (Table 4, Panel A) indicates evidence of spillovers into the cigarette market – a statistically significant increase in cigarette use at the extensive margin (on the order of 1.6 to 2.1 percentage points). This suggests that the flavor bans generate an unintended consequence by raising smoking participation among youth. Given the small and imprecise effects on e-cigarette participation, one interpretation is that any such potential substitution effects into cigarette use may operate through shifts at the intensive margins of e-cigarette use and/or the composition of e-cigarette use (types of devices and flavors uses). However, on closer scrutiny, it is notable that the significant and positive aggregated ATT (for the SDID estimation) on cigarette use among youth (Table 4, Panel A) is driven by positive and significant effects in the YRBS and the PATH (Table 3, Panel A). SDID event study analyses (Figure 2) show that the apparent increase in cigarette use in the YRBS, and the PATH may be a continuation of a pre-existing trend differential and therefore not supportive of a causal interpretation. For the MTF analyses, where there is stronger evidence of parallel pre-treatment trends between the treated and control states, and thus more supportive of causal inference, there is no indication of any statistically significant or meaningful change in cigarette use. We interpret the sum of these results for youth to suggest that the state flavor bans had little to no impact on their use of e-cigarettes or cigarettes at the extensive margin.

Next, we explore effects for young adults (ages 18-24) using data from the BRFSS and the PATH. Estimates of the ATT presented separately across the two datasets (Table 3, Panel B) show a significant decrease in e-cigarette use and a substitution into cigarette use, based on analyses with the BRFSS. The SDID estimates indicate effect magnitudes on the order of about 3.0 to 3.8 percentage points (25.0% decrease in e-cigarette use, 27% increase in cigarette use relative to the mean). A causal interpretation of these estimates is strongly supported by the balanced trends in both the SDID (Figure 3) and DID (Appendix

[13] We present the DID event study plots for youth in Appendix Figure A1.

Figure A2.a and A2.b) event study analyses. Estimated SDID effects, based on the PATH, show a similar pattern (suggesting a 1.2 percentage point decrease in e-cigarette use and a consequent 1.0 percentage point increase in cigarette use) but are not statistically significant. Combining the treatment effects across both samples (Table 4, Panel B), summarizes our key findings for young adults. Comprehensive flavor bans were effective in reducing overall e-cigarette use among 18-24 year olds by about 3.5 percentage points, and a corresponding increase in their smoking participation (3.0 percentage points). In contrast to these shifts for young adults, we do not find any discernible extensive margin effects of the bans on either e-cigarette or cigarette use for older adults (ages 25 and up) in Tables 3 and 4, Panel C. While the event study analyses for older adults (Figure 4 and Appendix Figure A3) are noisy, they also do not uncover any consistent or meaningful effects over a post-policy window of two to three years.

5b. Extensions

In supplementary analyses (results reported in the Appendix), we address specific issues and sensitivity of our main estimates. First, we explore whether the bans had any impacts on other forms of tobacco (other than e-cigarettes and cigarettes) or at the margin of dual use of both e-cigarettes and cigarettes (Appendix Table A5, Appendix Figures A5-A9). We do find a significant increase in co-use of both e-cigarettes and cigarettes for youth, based on the YRBS estimates, which are supported by strong parallel trends (Appendix Figure A4.b) and thus suggestive of a causal interpretation. Given the weak to nil effects on e-cigarette participation that we reported earlier, this suggestive increase in dual use would imply an increase in cigarette use among current e-cigarette users, operating through pathways related to shifts in the intensive margin of e-cigarette use or through changes in the composition of e-cigarette products being used. The MTF analyses also point to an increase in other nicotine use among youth, which is consistent with a causal interpretation based on the event-study analyses (Appendix Figure A4.e), though we do not find such effects with the other youth datasets. Among young adults, for whom we found a significant decrease in their e-cigarette use and increase in cigarette use, we also find some evidence of substitution into other tobacco use based on both the BRFSS and PATH analyses, though the latter are imprecisely estimated. For older adults, we continue to find no impacts on other forms or margins of tobacco use that are supported by parallel trends and a credible causal interpretation from the event study analyses.

Second, we present estimates without controlling for any covariates in Appendix Table A6. Our findings for youth and adults are not sensitive to models that exclude the additional policy controls and covariates. Finally, we assess heterogeneity in the estimated treatment effects across sex and race/ethnicity (Appendix Tables A7-A8). Among youth, it is difficult to discern heterogeneity that is consistent or credibly supported across datasets. For young adults, there is more consistent evidence of stronger effects on e-cigarette use and substitution effects into smoking among whites and Hispanics, and effects are largely similar across sexes. Among older adults, where we had overall found no impact on their use of e-cigarettes or cigarettes in relation to the flavor bans, unpacking the estimates by sex and race/ethnicity continues to show no economically or statistically significant impacts on their tobacco use. Estimating heterogeneous treatment effects across these sub-populations is a noisy endeavor, and we view these patterns as suggestive.

6. Discussion

When a sample of current e-cigarette users was asked how they may respond to comprehensive flavor restrictions in nicotine vaping products (Romm et al., 2022), three modal responses emerged: 1) quit e-cigarette use; 2) not change their use of e-cigarettes; 3) substitute into cigarette use. Each of these scenarios has important implications for public health. We provide some of the first and most comprehensive evidence to date, informing these scenarios and assessing how the statewide flavor bans affected youth, young adults, and adults with respect to their actual use of e-cigarettes and cigarettes.

We find evidence of a meaningful decline in e-cigarette participation, on the order of about three to four percentage points, among young adults ages 18-24; however, this decrease was offset by substitution into smoking. For youth, some of our analyses, especially with the MTF data, seem to suggest a similar pattern including potential substitution into other tobacco use as well. However, pre-existing trends and sensitivity of these estimates across data sets and samples make us cautious in attributing a causal interpretation. We therefore cannot rule out that the bans had little to no effect on adolescents' cigarette or e-cigarette use. Turning to adults ages 25+, we do not find any discernible impacts associated with the bans.

One implication of these results is that the statewide restrictions – even if more comprehensive in scope compared to the federal ban – are still being circumvented. Support for this interpretation of the findings comes from the PATH, which shows that a substantial fraction of youth and young adult e-cigarette users continue to report using banned flavors even after the bans. Survey and anecdotal evidence point to various ways that e-cigarette users are able to bypass the restrictions, through online purchases, purchases from illicit sources, cross-border purchases, purchases from non-compliant retailers in the state, and users adding their own flavors to the e-liquid in vaping devices (Romm et al., 2022; Chen et al., 2023; Yang et al., 2023a; Rich, 2022). A more comprehensive federal ban on flavored e-cigarettes could be more effective in reducing flavored and overall e-cigarette use by shutting down some of these circumvention channels, for instance by deterring cross-border purchases or by enforcing retailer compliance. However, other sources of flavored e-cigarettes may remain (black market, self-made flavorings) and may continue to moderate the effectiveness of further nationwide restrictions unless directly addressed.

A key challenge for any analysis of the recent statewide flavor bans, adopted over late 2019-mid 2020, is that these bans coincided with the advent of the COVID-19 pandemic. While we were cautious in drawing causal interpretations in conjunction with evidence of balanced trends pre-policy adoption or pre-pandemic and we controlled for COVID-19 deaths (as a proxy for the intensity of the pandemic), we cannot rule out potential confounding bias arising from more complex interactions between the bans and the pandemic and from any heterogeneous impact of the pandemic-related shocks (economic, health, social distancing, school and business closures) across the various treated and control states. Given the recency of the statewide bans, the treatment effects we estimate capture changes over a post-policy window of two to three years. Observing effects as additional years of data become available would be fruitful for assessing behavioral changes in tobacco use that may take further time to materialize; extending the post-policy window can also help further disentangle the confounding effects of the pandemic (which would be expected to fade over time) from any persistent direct effects of the bans.

These caveats notwithstanding, we note that even the moderately sized substitution effects into smoking, which we find among the young adult population, can generate substantial costs. Our finding that the comprehensive flavor bans increased smoking participation by about 2.4 percentage points among young adults would add about $5.1 billion total lifetime societal costs for the average treatment state.[14] Such unintended consequences serve to moderate the public health benefits of sub-national restrictions on flavored e-cigarettes. They underscore the need to account for not only outcomes directly targeted by such restrictions but also potential spillovers into non-targeted outcomes for a more complete calculus of the potential costs and benefits of such policies.

[14] We monetize the increase in smoking participation using the population for the average treated state (7.76 million in 2022), the share of the population that is ages 18-24 (~ 9.4%), and estimates for the total social cost of smoking over one's lifetime from Sloan et al. (2006). The study reports total costs in the amount of $106,000 for a female smoker and $220,000 for a male smoker. We take the average and deflate to 2022 dollars, resulting in a lifetime cost estimate of $292,700 per average smoker.

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Table 1.
Timeline of state e-cigarette flavor bans

Date		**10/19**	**11/19**	**12/19**	**1/20**	**2/20***	**3/20**	**4/20**	**5/20**	**6/20**	**7/20**
State	**EVALI**										
Maryland	12.10				P	P	P	P	P	P	P
Massachusetts	17.86		T	T	T	T	T	T	T	P	P
New Jersey	13.59							P	P	P	P
New York**	8.75								P	P	P
Rhode Island	5.00	T	T	T	T	T	P	P	P	P	P
Utah**	39.06										P
Montana	5.00	T	T	T	T						
Washington	3.25	T	T	T	T						
United States	6.67										

Note: EVALI represents the approximate number of E-cigarette or Vaping Use-Associated Lung Injury (EVALI) hospitalizations or deaths reported to the Centers for Disease Control and Prevention (CDC), as of 2/2020, per million population. T and P represent temporary ban based on EVALI concerns and permanent ban on flavored vapes, respectively. The state flavor bans are for e-cigarettes only. No state bans tobacco flavor. Only Massachusetts bans menthol in all tobacco products. Maryland prohibits only the sale of cartridge-based and disposable e-cigarettes with flavors. Montana and Washington are excluded from the analyses presented in this paper due to implementing only temporary bans, if present. Ban data are obtained from Tobacco Free Kids. See https://www.tobaccofreekids.org/assets/factsheets/0398.pdf.
*Federal ban on cartridge based flavored e-cigarettes goes into effect. **Temporary bans blocked by legal challenges.

Table 2.
Weighted descriptive data on the percentage of e-cigarette users that report using a banned flavor

Treated states pre-period	Treated states post-period	Difference	Control states pre-period	Control states post-period	Difference	Difference-in-difference
			Youth			
60.58%	74.42%	13.84	51.52%	68.78%	17.26	-3.42
			Young Adults 18-24			
38.14%	59.40%	21.26	35.11%	63.55%	28.43	-7.17
			Adults 25+			
22.69%	45.19%	22.50	23.47%	47.73%	24.26	-1.76

Note: Authors' calculation using 2014-2021 PATH (excluding 2020 due to COVID-19). Table presents the percentage of e-cigarette users who reported using banned flavors. Difference columns are calculated by subtracting the pre-period from the post-period and represent percentage point difference. Difference-in-difference column is calculated by subtracting the control state difference from the treated state difference and represent percentage point difference. Treatment states are Maryland, Massachusetts, New Jersey, New York, Rhode Island, and Utah. Banned flavors are candy, fruit, chocolate, clove/spice, alcoholic drink, non-alcoholic drink, or other flavors. Unbanned flavors are tobacco and menthol, except for Massachusetts where tobacco is the only unbanned flavor. Data were adjusted for sample weights.

Table 3.
Results by dataset: Dichotomous e-cigarette and cigarette use in the past 30 days

	Panel A: Youth		*Panel B: Young Adults 18-24*		*Panel C: Adults 25 +*	
	YRBS		**BRFSS**		**BRFSS**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.004	0.007	**-0.032***	**-0.038*****	-0.003	0.000
SE	(0.018)	(0.036)	(0.017)	(0.012)	(0.005)	(0.004)
p-value	0.810	0.849	0.054	0.002	0.544	0.919
N	606,405	100	89,551	188	1,460,245	188
Mean Y	0.180	0.207	0.137	0.152	0.045	0.047
Cigarette	**0.014***	**0.031*****	**0.020*****	**0.030*****	-0.002	-0.002
SE	(0.008)	(0.011)	(0.007)	(0.007)	(0.004)	(0.003)
p-value	0.083	0.004	0.005	0.000	0.688	0.650
N	902,482	132	201,137	432	3,292,178	423
Mean Y	0.069	0.102	0.099	0.111	0.156	0.165
	PATH		**PATH**		**PATH**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.008	-0.008	-0.011	-0.012	0.016	0.011
SE	(0.013)	(0.022)	(0.019)	(0.032)	(0.011)	(0.012)
p-value	0.538	0.713	0.587	0.701	0.145	0.341
N	41,766	266	51,959	266	111,744	266
Mean Y	0.065	0.080	0.174	0.195	0.056	0.057
Cigarette	**0.017***	0.019	0.011	0.010	-0.004	-0.009
SE	(0.009)	(0.012)	(0.029)	(0.050)	(0.008)	(0.013)
p-value	0.070	0.106	0.703	0.833	0.642	0.495
N	41,861	266	52,142	266	112,433	266
Mean Y	0.038	0.042	0.219	0.226	0.201	0.205
	MTF					
	DID	SDID				
E-cigarette	-0.019	-0.036				
SE	(0.029)	(0.032)				
p-value	0.499	0.254				
N	111,988	296				
Mean Y	0.137	0.137				
Cigarette	**0.016****	-0.009				
SE	(0.008)	(0.021)				
p-value	0.036	0.679				
N	203,641	296				
Mean Y	0.053	0.053				

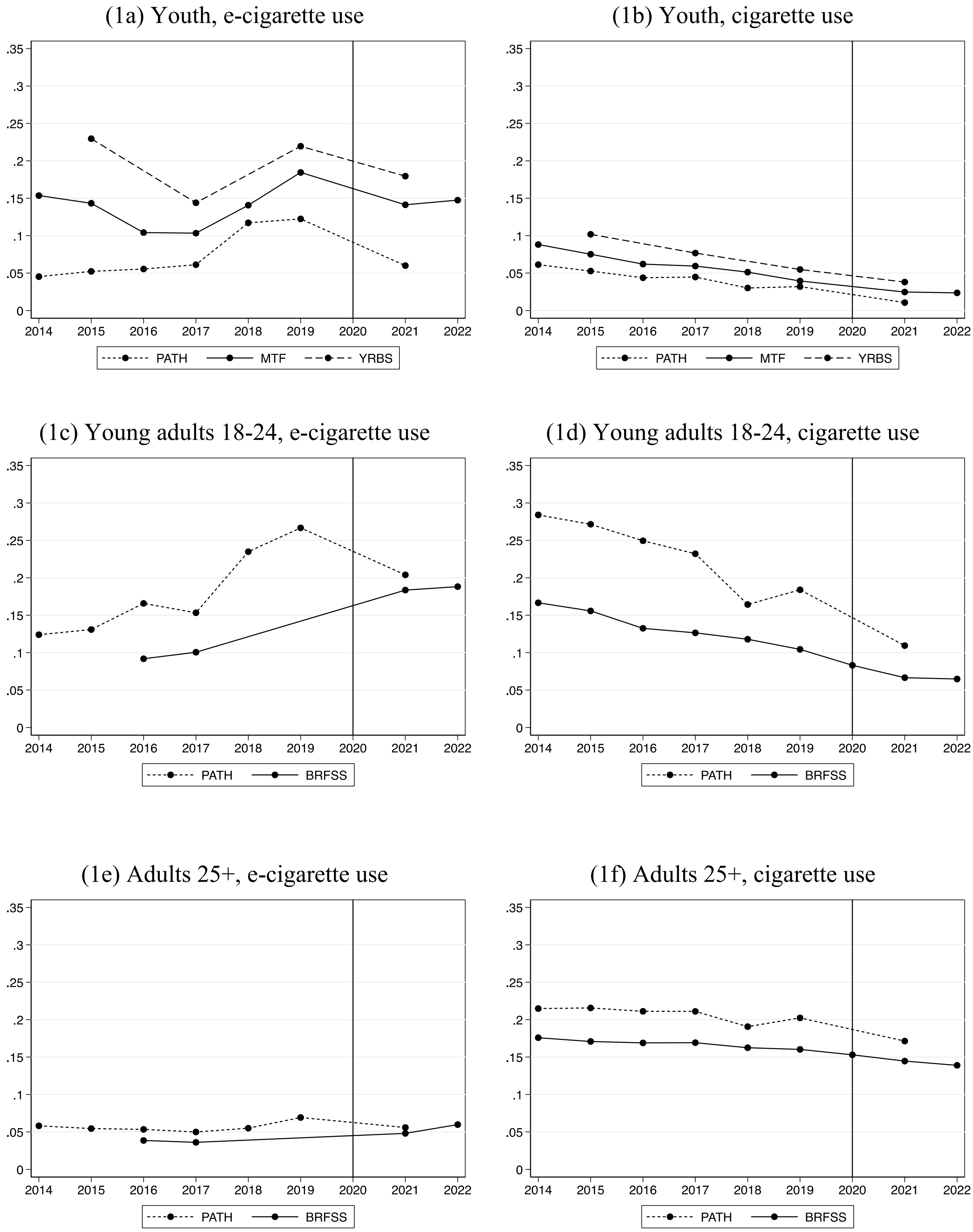
Note: Authors' analyses of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana if present due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Table presents difference-in-differences (DID) and synthetic difference-in-differences (SDID) estimates of each outcome, bootstrapped standard errors that are clustered at the state level, p-values, sample sizes and weighted means of the dependent variables. DID models use individual-level data. BRFSS and PATH DID models include all six treatment states. YRBS DID models exclude MA because that state is not in the YRBS in our sample period. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in DID MTF models. SDID models require balanced, aggregate state-level data. BRFSS SDID models include all six treatment states. PATH SDID models include all treatment states except RI. YRBS SDID models include MD, NY, and RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Table 4.
Meta-analysis estimates of the effects of flavor bans on e-cigarette use and cigarette use across youth, young adults and adults

	Panel A: Youth		*Panel B: Young Adults 18-24*		*Panel C: Adults 25 +*	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.004	-0.012	**-0.023***	**-0.035*****	0.000	0.001
SE	0.010	0.016	0.013	0.011	0.005	0.004
Cigarette	**0.016*****	**0.021*****	**0.020*****	**0.030*****	-0.002	-0.002
SE	0.005	0.008	0.007	0.007	0.004	0.003

Note: The outcome variables are dichotomous indicators of use in the last 30 days. We used the fixed effect method of meta-analysis to combine estimates from Table 3. We take the weighted average of the estimates for each population for each outcome. The weights are equal to the inverse of the standard errors squared, normalized to add up to one. The standard errors for each estimate are computed as the inverse of the square root of the sum of the non-normalized weights. ***p < 0.01; **p < 0.05; *p < 0.10.

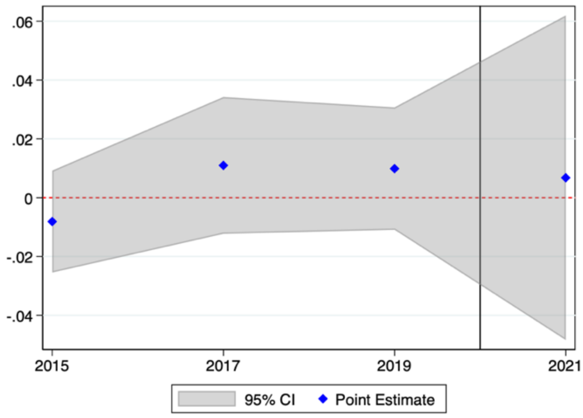
Figure 1.
Trends in e-cigarette and cigarette use



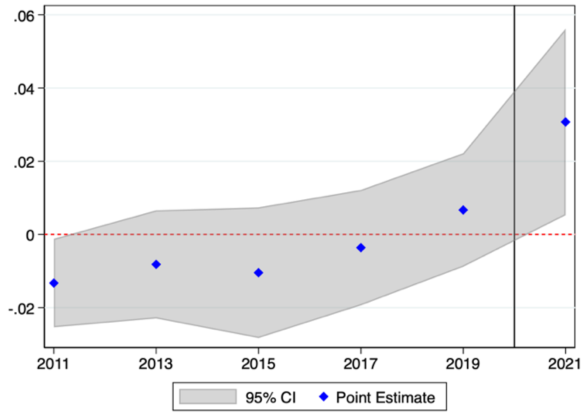
Note: All samples exclude Washington and Montana if present due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Data were adjusted for sample weights.

Figure 2.
Synthetic difference-in-differences event study plots for youth

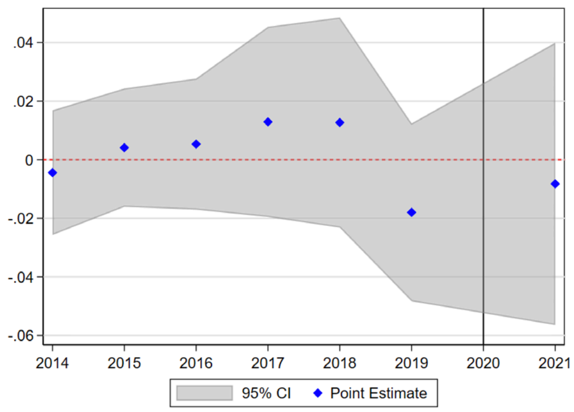
(2a) YRBS, e-cigarette use



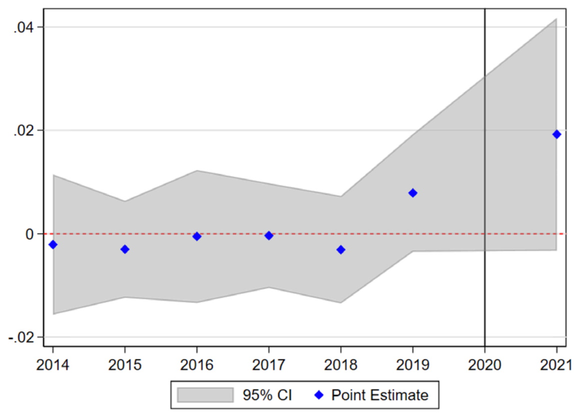
(2b) YRBS, cigarette use



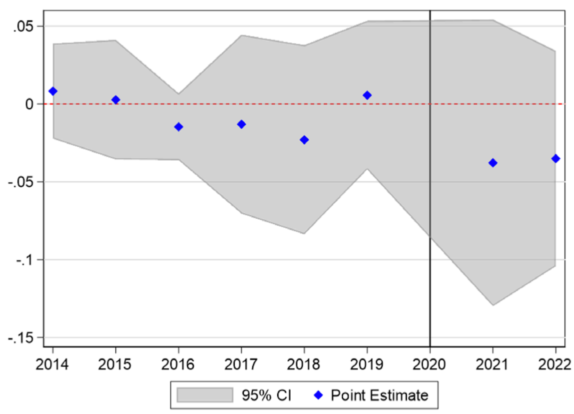
(2c) PATH, e-cigarette use



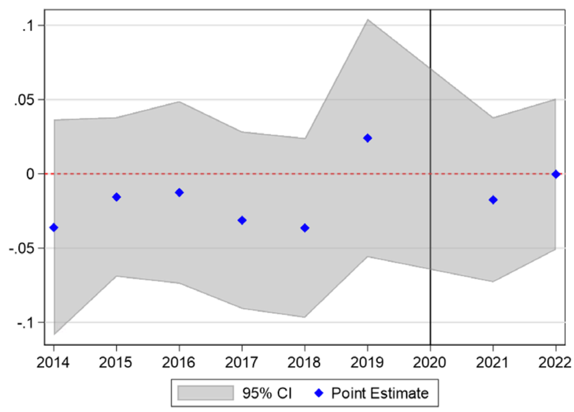
(2d) PATH, cigarette use



(2e) MTF, e-cigarette use

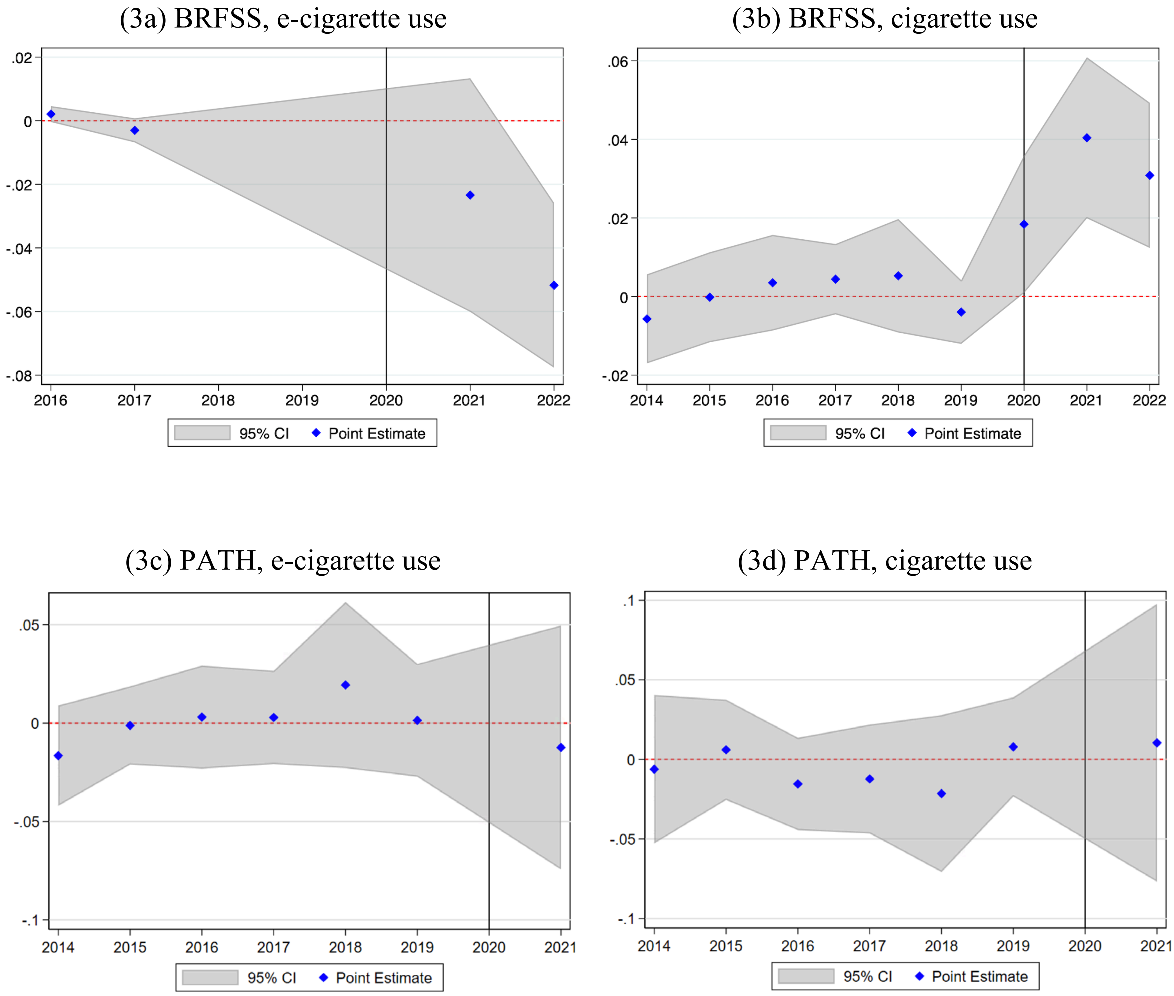


(2f) MTF, cigarette use



Note: Authors' analyses of the YRBS, PATH, and MTF. All samples exclude Washington and Montana if present due to temporary flavor bans in these states. Sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table 3. Shaded area represents 95% confidence interval around the point estimates based on the bootstrapping method. YRBS SDID models include MD, NY, and RI. PATH SDID models include all treatment states except RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.

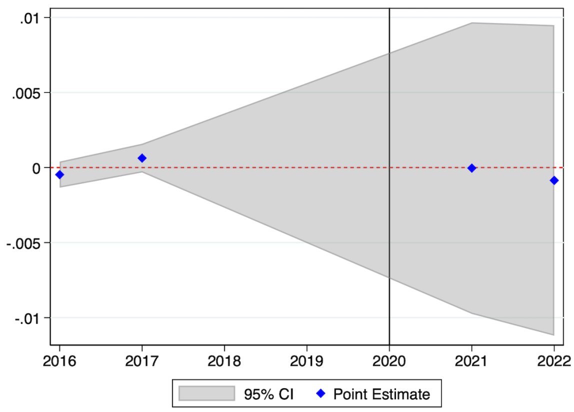
Figure 3.
Synthetic difference-in-differences event study plots for young adults 18-24



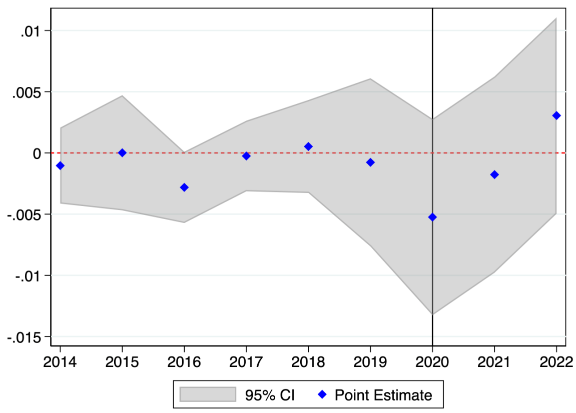
Note: Authors' analyses of the PATH and BRFSS. All samples exclude Washington and Montana due to temporary flavor bans in these states. Sample is restricted to ages 18-24 in all datasets. Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table 3. Shaded area represents 95% confidence interval around the point estimates based on the bootstrapping method. PATH SDID models include all treatment states except for Rhode Island. BRFSS SDID models include all treatment states. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.

Figure 4.
Synthetic difference-in-difference event study plots for adults 25+

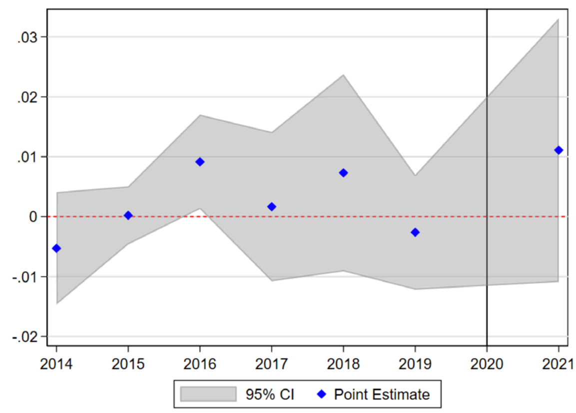
(4a) BRFSS, e-cigarette use



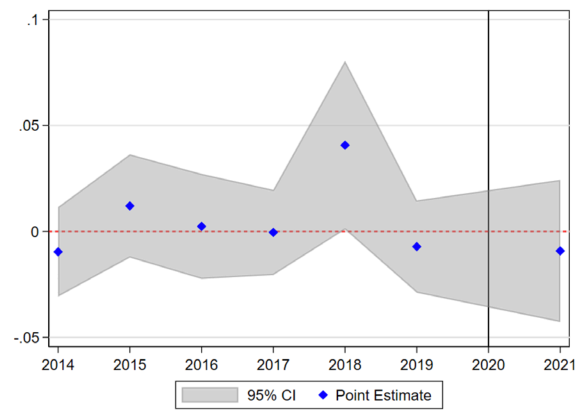
(4b) BRFSS, cigarette use



(4c) PATH, e-cigarette use



(4d) PATH, cigarette use



Note: Authors' analyses of the PATH and BRFSS. All samples exclude Washington and Montana due to temporary flavor bans in these states. Sample is restricted to ages 25+ in all datasets. Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table 3. Shaded area represent 95% confidence interval around the point estimates. PATH SDID models include all treatment states except for Rhode Island. BRFSS SDID models include all treatment states. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.

Appendix

Table A1.
Datasets

Data/Type	Sample Population	Approximate Sample Size	Time Period
YRBS/ In school survey	Youth 14+, 9th through 12th grade	150,000 per year, with state representative samples	E-cigarette and dual: biennial 2015- 2021. Cigarette and other nicotine: biennial 2011-2021.
MTF*/ In school survey	Youth 14+ 8th, 10th, and 12th grade	45,000 per year	All outcomes for 2014 – 2022, 2020 was dropped, 50% of the students were not asked about e-cigarettes.
PATH*/ At home survey	Youths 12-17, Young Adults 18-24, Adults 25+	13,000 youths per year 8,000 young adults 16,900 adults per year	All outcomes for 2014 – 2021, 2020 was dropped.
BRFSS/ Telephone survey	Young Adults 18-24, Adults 25+	24,000 young adults per year 410,000 adults per year state representative samples	E-cigarette and dual: 2016, 2017, 2021, 2022. Cigarette and other nicotine: 2014-2022.

Note: All outcomes include dichotomous indicators of e-cigarettes, cigarettes, other nicotine, and dual use in the past 30 days. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. 2020 was dropped because of disruptions in data collection due to the COVID-19 pandemic.
*Restricted version, including state of residence.

Table A2.
Weighted descriptive data on tobacco use in all included states

	2015	*2021*
	Youth	
	YRBS	
E-cigarette	0.230	0.180
Cigarette	0.102	0.038
Other nicotine	0.096	0.033
Dual	0.070	0.033
	PATH	
E-cigarette	0.051	0.060
Cigarette	0.049	0.010
Other nicotine	0.048	0.010
Dual	0.019	0.008
	MTF	
E-cigarette	0.142	0.132
Cigarette	0.070	0.020
Other nicotine	0.091	0.022
Dual	0.041	0.016
	Young Adults 18-24	
	BRFSS*	
E-cigarette	0.091	0.182
Cigarette	0.132	0.065
Other nicotine	0.050	0.033
Dual	0.035	0.034
	PATH	
E-cigarette	0.131	0.209
Cigarette	0.269	0.111
Other nicotine	0.260	0.100
Dual	0.084	0.066
	Adults 25+	
	BRFSS*	
E-cigarette	0.039	0.048
Cigarette	0.169	0.145
Other nicotine	0.034	0.032
Dual	0.022	0.018
	PATH	
E-cigarette	0.056	0.056
Cigarette	0.207	0.171
Other nicotine	0.098	0.076
Dual	0.042	0.029

Note: Authors' calculation of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana, if present due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. Data were adjusted for sample weights.
* BRFSS data are from 2016 instead of 2015.

Table A3.
Weighted descriptive data on covariates in all included states

	Panel A: Youth		*Panel B: Young Adults 18-24*		*Panel C: Adults 25 +*	
	YRBS		**BRFSS**		**BRFSS**	
	2015	*2021*	*2015*	*2021*	*2015*	*2021*
White	0.521	0.494	0.524	0.518	0.650	0.626
Black	0.152	0.164	0.138	0.112	0.115	0.116
Hispanic	0.225	0.243	0.213	0.230	0.144	0.153
Asian	0.048	0.040	0.076	0.090	0.045	0.053
Male	0.508	0.507	0.514	0.513	0.483	0.483
Age	15.983	15.786	20.940	20.877	51.117	51.749
	PATH		**PATH**		**PATH**	
	2015	*2021*	*2015*	*2021*	*2015*	*2021*
White	0.704	0.673	0.699	0.698	0.792	0.777
Black	0.152	0.153	0.151	0.155	0.118	0.122
Hispanic	0.192	0.226	0.180	0.197	0.130	0.142
Asian	0.049	0.057	0.074	0.055	0.052	0.057
Male	0.517	0.513	0.497	0.504	0.475	0.473
Age	15.474	15.485	21.064	21.032	51.032	51.926
	MTF					
	2015	*2021*				
White	0.653	0.664				
Black	0.155	0.146				
Hispanic	0.207	0.211				
Asian	0.003	0.005				
Male	0.477	0.494				
Age	16.374	15.970				

Note: Authors' calculation of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana if present due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Data were adjusted for sample weights. * BRFSS data are from 2016 instead of 2015.

Table A4.
Descriptive data on state-year level covariates

	Treatment States		**All Other States**	
	2015	*2021*	*2015*	*2021*
State tobacco tax	3.437	3.589	1.232	1.811
Percent of states with an e-cigarette tax	0.000	0.949	0.051	0.628
Percent of states with an internet sales ban	0.000	0.489	0.003	0.023
Covid death rate (per 100,000 population)	0.000	74.417	0.000	110.592

Note: Treatment states are Maryland, Massachusetts, New Jersey, New York, Rhode Island, and Utah.

Table A5.
Results for dichotomous tobacco use in the past 30 days models with covariates

	Panel A: Youth		*Panel B: Young Adults 18-24*		*Panel C: Adults 25 +*	
	YRBS		**BRFSS**		**BRFSS**	
	DID	SDID	DID	SDID	DID	SDID
Other nicotine	-0.002	0.007	**0.009*****	**0.012****	0.000	**-0.002***
SE	(0.010)	(0.019)	(0.003)	(0.005)	(0.001)	(0.001)
p-value	0.874	0.714	0.007	0.018	0.786	0.099
N	790,870	96	201,965	432	3,314,041	423
Mean Y	0.059	0.088	0.042	0.048	0.033	0.040
Dual	**0.017*****	**0.018***	-0.003	-0.003	0.001	0.001
SE	(0.006)	(0.011)	(0.005)	(0.006)	(0.002)	(0.002)
p-value	0.002	0.093	0.586	0.671	0.699	0.503
N	580,544	96	89,207	188	1,450,777	188
Mean Y	0.052	0.058	0.035	0.039	0.020	0.021
	PATH		**PATH**		**PATH**	
	DID	SDID	DID	SDID	DID	SDID
Other nicotine	0.001	0.003	0.010	0.014	-0.007	-0.007
SE	(0.007)	(0.011)	(0.019)	(0.038)	(0.006)	(0.008)
p-value	0.867	0.798	0.587	0.714	0.263	0.381
N	41,014	266	51,895	266	111,252	266
Mean Y	0.035	0.037	0.203	0.199	0.090	0.090
Dual	0.009	0.006	0.008	0.006	0.003	-0.002
SE	(0.006)	(0.009)	(0.013)	(0.026)	(0.007)	(0.007)
p-value	0.123	0.488	0.559	0.808	0.664	0.745
N	41,718	266	51,949	266	111,713	266
Mean Y	0.016	0.019	0.087	0.095	0.038	0.038
	MTF					
	DID	SDID				
Other nicotine	**0.027***	**0.038****				
SE	(0.016)	(0.018)				
p-value	0.085	0.031				
N	60,424	296				
Mean Y	0.066	0.066				
Dual	0.006	0.000				
SE	(0.009)	(0.020)				
p-value	0.492	0.985				
N	110,536	296				
Mean Y	0.032	0.032				

Note: Authors' analyses of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana if present due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Table presents difference-in-differences (DID) and synthetic difference-in-differences (SDID) estimates of each outcome, bootstrapped standard errors that are clustered at the state level, p-values, sample sizes and weighted means of the dependent variables. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. DID models use individual-level data. BRFSS and PATH DID models include all six treatment states. YRBS DID models exclude MA because that state is not in the YRBS in our sample period. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in DID MTF models. SDID models require balanced, aggregate state-level data. BRFSS SDID models include all six treatment states. PATH SDID models include all treatment states except RI. YRBS SDID models include MD, NY, and RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.
***p < 0.01; **p < 0.05; *p < 0.1.

Table A6.
Results without covariates for dichotomous tobacco use in the past 30 days

	Panel A: Youth		*Panel B: Young Adults 18-24*		*Panel C: Adults 25 +*	
	YRBS		**BRFSS**		**BRFSS**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	**-0.020***	-0.005	**-0.033*****	**-0.046*****	-0.002	-0.004
SE	(0.012)	(0.010)	(0.012)	(0.012)	(0.004)	(0.003)
p-value	0.094	0.610	0.006	0.000	0.512	0.147
N	627,596	100	89,672	188	1,463,370	188
Mean Y	0.180	0.207	0.137	0.152	0.045	0.047
Cigarette	**0.033*****	**0.029*****	**0.018****	**0.032*****	-0.001	-0.002
SE	(0.008)	(0.009)	(0.007)	(0.007)	(0.004)	(0.003)
p-value	0.000	0.001	0.014	0.000	0.846	0.540
N	932,314	132	201,469	432	3,300,290	423
Mean Y	0.069	0.102	0.099	0.111	0.156	0.165
Other nicotine	0.016	0.008	**0.011*****	**0.013*****	**-0.002****	**-0.003*****
SE	(0.011)	(0.007)	(0.002)	(0.004)	(0.001)	(0.001)
p-value	0.145	0.286	0.000	0.000	0.044	0.002
N	817,880	96	202,298	432	3,322,260	423
Mean Y	0.059	0.088	0.042	0.048	0.033	0.040
Dual	**0.018*****	**0.020*****	-0.003	-0.005	0.001	0.001
SE	(0.003)	(0.004)	(0.0042)	(0.005)	(0.002)	(0.001)
p-value	0.000	0.000	0.510	0.353	0.516	0.651
N	600,027	96	89,328	188	1,453,868	188
Mean Y	0.052	0.058	0.035	0.039	0.020	0.021
	PATH		**PATH**		**PATH**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.007	-0.004	-0.004	0.001	0.005	0.001
SE	(0.013)	(0.018)	(0.022)	(0.023)	(0.008)	(0.007)
p-value	0.587	0.821	0.868	0.961	0.550	0.843
N	45,542	266	55,238	266	115,894	266
Mean Y	0.065	0.080	0.174	0.195	0.056	0.057
Cigarette	**0.013****	**0.016****	0.017	0.029	-0.003	-0.001
SE	(0.006)	(0.006)	(0.030)	(0.026)	(0.006)	(0.009)
p-value	0.021	0.011	0.575	0.268	0.609	0.906
N	45,650	266	55,434	266	116,624	266
Mean Y	0.038	0.042	0.219	0.226	0.201	0.205
Other nicotine	-0.009	-0.001	0.021	0.014	0.001	0.001
SE	(0.008)	(0.006)	(0.020)	(0.018)	(0.005)	(0.007)
p-value	0.246	0.882	0.306	0.436	0.762	0.898
N	44,713	266	55,168	266	115,387	266
Mean Y	0.035	0.037	0.203	0.199	0.090	0.090
Dual	0.002	0.000	0.014	0.013	0.002	0.000
SE	(0.005)	(0.005)	(0.009)	(0.012)	(0.005)	(0.004)
p-value	0.739	0.950	0.137	0.280	0.615	0.977
N	45,483	266	55,225	266	115,859	266
Mean Y	0.016	0.019	0.087	0.095	0.038	0.038
	MTF					
	DID	SDID				
E-cigarette	-0.005	-0.037				
SE	(0.025)	(0.028)				
p-value	0.855	0.181				
N	144,148	296				
Mean Y	0.137	0.137				
Cigarette	**0.013****	-0.020				
SE	(0.006)	(0.027)				
p-value	0.030	0.465				
N	264,851	296				
Mean Y	0.053	0.053				
Other nicotine	**0.028***	**0.038*****				
SE	(0.014)	(0.014)				
p-value	0.050	0.005				
N	77,338	296				
Mean Y	0.066	0.066				
Dual	**0.009***	-0.010				
SE	(0.005)	(0.019)				
p-value	0.093	0.612				
N	142,105	296				
Mean Y	0.032	0.032				

Note: Authors' analyses of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Table presents difference-in-differences (DID) and synthetic difference-in-differences (SDID) estimates of each outcome, bootstrapped standard errors that are clustered at the state level, p-values, sample sizes and weighted means of the dependent variables. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. DID models use individual-level data. BRFSS and PATH DID models include all six treatment states. YRBS DID models exclude MA because that state is not in the YRBS in our sample period. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in DID MTF models. SDID models require balanced, aggregate state-level data. BRFSS SDID models include all six treatment states. PATH SDID models include all treatment states except RI. YRBS SDID models include MD, NY, and RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. Data were adjusted for sample weights. ***p < 0.01; **p < 0.05; *p < 0.1.

Table A7.
Results with covariates by sex, dichotomous tobacco use in the past 30 days

Panel A: Youth

	YRBS, male		YRBS, female	
	DID	SDID	DID	SDID
E-cigarette	0.005	0.013	0.001	-0.013
SE	(0.018)	(0.032)	(0.025)	(0.045)
p-value	0.790	0.678	0.975	0.777
N	297,678	100	308,727	100
Mean Y	0.181	0.209	0.178	0.203
Cigarette	**0.017***	**0.047*****	0.011	**0.028*****
SE	(0.009)	(0.012)	(0.009)	(0.010)
p-value	0.062	0.000	0.219	0.006
N	439,808	132	462,674	132
Mean Y	0.076	0.112	0.061	0.090
Other nicotine	0.008	0.012	-0.011	-0.003
SE	(0.012)	(0.020)	(0.010)	(0.021)
p-value	0.506	0.543	0.306	0.879
N	387,806	96	403,064	96
Mean Y	0.076	0.117	0.040	0.056
Dual	**0.021****	**0.022****	**0.012****	0.016
SE	(0.008)	(0.010)	(0.006)	(0.013)
p-value	0.011	0.035	0.036	0.199
N	283,482	96	297,062	96
Mean Y	0.059	0.065	0.044	0.050
	PATH, male		**PATH, female**	
	DID	SDID	DID	SDID
E-cigarette	0.005	-0.002	0.013	0.029
SE	(0.020)	(0.037)	(0.018)	(0.025)
p-value	0.792	0.950	0.494	0.240
N	21,589	259	20,177	259
Mean Y	0.067	0.085	0.063	0.074
Cigarette	0.006	0.014	**0.031*****	**0.025***
SE	(0.017)	(0.022)	(0.008)	(0.014)
p-value	0.701	0.519	0.000	0.059
N	21,629	259	20,232	259
Mean Y	0.038	0.040	0.039	0.042
Other nicotine	0.007	-0.023	-0.004	-0.004
SE	(0.013)	(0.024)	(0.010)	(0.016)
p-value	0.604	0.331	0.729	0.778
N	21,113	259	19,901	259
Mean Y	0.045	0.049	0.024	0.023
Dual	0.003	0.006	**0.017*****	0.016
SE	(0.010)	(0.014)	(0.006)	(0.010)
p-value	0.748	0.662	0.004	0.118
N	21,555	259	20,163	259
Mean Y	0.017	0.018	0.016	0.019
	MTF, male		**MTF, female**	
	DID	SDID	DID	SDID
E-cigarette	-0.001	-0.014	-0.034	-0.034
SE	(0.031)	(0.029)	(0.033)	(0.033)
p-value	0.978	0.635	0.308	0.296
N	55,206	296	56,782	296
Mean Y	0.147	0.158	0.126	0.130
Cigarette	**0.028*****	0.012	0.006	-0.016
SE	(0.010)	(0.019)	(0.010)	(0.020)
p-value	0.003	0.534	0.541	0.435
N	101,608	296	102,033	296
Mean Y	0.056	0.061	0.047	0.052
Other nicotine	**0.059***	0.035	0.004	**0.025***
SE	(0.031)	(0.034)	(0.009)	(0.014)
p-value	0.056	0.304	0.691	0.074
N	29,682	280	30,742	296
Mean Y	0.082	0.083	0.048	0.046
Dual	0.010	0.026	0.004	-0.008
SE	(0.010)	(0.020)	(0.011)	(0.024)
p-value	0.328	0.191	0.715	0.730
N	54,464	280	56,072	296
Mean Y	0.036	0.040	0.027	0.027

	Panel B: Young Adults 18-24				*Panel C: Adults 25 +*			
	BRFSS, male		**BRFSS, female**		**BRFSS, male**		**BRFSS, female**	
	DID	SDID	DID	SDID	DID	SDID	DID	SDID
E-cigarette	**-0.050****	**-0.029***	-0.014	**-0.044****	-0.002	-0.002	-0.004	-0.003
SE	(0.019)	(0.017)	(0.022)	(0.020)	(0.007)	(0.004)	(0.004)	(0.006)
p-value	0.010	0.089	0.517	0.030	0.728	0.576	0.413	0.660
N	48,974	188	40,577	188	649,818	188	810,427	188
Mean Y	0.169	0.179	0.104	0.125	0.052	0.053	0.039	0.041
Cigarette	0.018	**0.030*****	**0.021****	**0.028*****	0.001	-0.006	-0.004	-0.001
SE	(0.012)	(0.011)	(0.010)	(0.009)	(0.006)	(0.004)	(0.004)	(0.005)
p-value	0.128	0.004	0.032	0.002	0.862	0.159	0.347	0.867
N	108,430	432	92,707	432	1,444,180	423	1,847,998	423
Mean Y	0.119	0.128	0.077	0.094	0.175	0.181	0.138	0.150
Other nicotine	**0.013****	0.005	0.004	**0.017****	0.001	-0.003	-0.001	-0.002
SE	(0.005)	(0.004)	(0.005)	(0.008)	(0.003)	(0.002)	(0.001)	(0.003)
p-value	0.018	0.163	0.359	0.037	0.773	0.252	0.165	0.369
N	108,957	432	93,008	432	1,454,204	423	1,859,837	423
Mean Y	0.069	0.079	0.013	0.015	0.059	0.071	0.009	0.010
Dual	**-0.011***	0.003	0.006	-0.010	0.001	0.002	0.001	-0.001
SE	(0.006)	(0.009)	(0.008)	(0.012)	(0.003)	(0.002)	(0.003)	(0.003)
p-value	0.055	0.727	0.427	0.379	0.758	0.282	0.747	0.682
N	48,756	188	40,451	188	645,470	188	805,307	188
Mean Y	0.046	0.049	0.023	0.029	0.023	0.023	0.018	0.020
	PATH, male		**PATH, female**		**PATH, male**		**PATH, female**	
	DID	SDID	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.011	0.008	-0.036	-0.012	0.013	0.004	0.019	0.008
SE	(0.024)	(0.041)	(0.029)	(0.050)	(0.012)	(0.013)	(0.012)	(0.012)
p-value	0.639	0.852	0.219	0.813	0.266	0.768	0.118	0.527
N	25,729	266	26,230	266	54,045	266	57,699	266
Mean Y	0.205	0.232	0.141	0.165	0.063	0.062	0.051	0.053
Cigarette	0.017	-0.007	-0.003	0.020	0.001	-0.006	-0.009	-0.007
SE	(0.029)	(0.045)	(0.037)	(0.054)	(0.012)	(0.020)	(0.008)	(0.015)
p-value	0.567	0.883	0.942	0.706	0.910	0.780	0.290	0.641
N	25,826	266	26,316	266	54,352	266	58,081	266
Mean Y	0.254	0.261	0.183	0.193	0.228	0.229	0.177	0.186
Other nicotine	0.040	0.038	-0.028*	-0.022	-0.021	-0.013	0.006	-0.003
SE	(0.027)	(0.039)	(0.016)	(0.029)	(0.014)	(0.022)	(0.005)	(0.008)
p-value	0.140	0.338	0.073	0.440	0.133	0.556	0.219	0.669
N	25,674	266	26,221	266	53,733	266	57,519	266
Mean Y	0.262	0.261	0.144	0.139	0.145	0.148	0.040	0.038
Dual	0.025	-0.004	-0.013	0.001	-0.000	-0.006	0.007	0.002
SE	(0.024)	(0.034)	(0.015)	(0.027)	(0.009)	(0.011)	(0.007)	(0.008)
p-value	0.295	0.902	0.403	0.974	0.976	0.586	0.323	0.836
N	25,723	266	26,226	266	54,025	266	57,688	266
Mean Y	0.108	0.117	0.067	0.073	0.041	0.041	0.035	0.036

Note: Authors' analyses of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Table presents difference-in-differences (DID) and synthetic difference-in-differences (SDID) estimates of each outcome by sex, bootstrapped standard errors that are clustered at the state level, p-values, sample sizes and weighted means of the dependent variables. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. DID models use individual-level data. BRFSS and PATH DID models include all six treatment states. YRBS DID models exclude MA because that state is not in the YRBS in our sample period. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in DID MTF models. SDID models require balanced, aggregate state-level data. BRFSS SDID models include all six treatment states. PATH SDID models include all treatment states except RI. YRBS SDID models include MD, NY, and RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. All models control for age, race/ethnicity (White/Black/Asian/Hispanic), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.
***p < 0.01; **p < 0.05; *p < 0.1.

Table A8.
Results with covariates by race/ethnicity, dichotomous tobacco use in the past 30 days

Panel A: Youth

	YRBS, White		YRBS, Black		YRBS, Hispanic	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.005	-0.023	-0.009	0.070	0.016	-0.014
SE	(0.022)	(0.031)	(0.025)	(0.074)	(0.027)	(0.047)
p-value	0.814	0.456	0.717	0.343	0.540	0.768
N	336,976	100	79,445	100	104,822	100
Mean Y	0.206	0.219	0.113	0.164	0.169	0.211
Cigarette	**0.017***	**0.034*****	-0.005	0.057	0.012	**0.035***
SE	(0.009)	(0.008)	(0.013)	(0.035)	(0.014)	(0.020)
p-value	0.054	0.000	0.701	0.105	0.396	0.080
N	491,694	132	124,602	132	162,801	132
Mean Y	0.085	0.111	0.030	0.071	0.059	0.108
Other nicotine	0.001	-0.008	-0.002	0.008	-0.013	0.008
SE	(0.013)	(0.014)	(0.026)	(0.047)	(0.014)	(0.026)
p-value	0.967	0.551	0.939	0.857	0.328	0.765
N	450,322	96	110,630	96	134,711	96
Mean Y	0.066	0.086	0.052	0.093	0.049	0.099
Dual	**0.017***	0.014	0.002	0.044	**0.032*****	0.017
SE	(0.009)	(0.013)	(0.010)	(0.037)	(0.010)	(0.015)
p-value	0.057	0.271	0.862	0.235	0.002	0.249
N	321,354	96	76,784	96	100,309	96
Mean Y	0.065	0.065	0.020	0.036	0.043	0.060
	PATH, White		**PATH, Black**		**PATH, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.012	0.021	0.001	**0.061***	-0.001	0.019
SE	(0.015)	(0.020)	(0.025)	(0.034)	(0.040)	(0.030)
p-value	0.422	0.297	0.979	0.075	0.977	0.520
N	28,888	259	7,004	175	13,460	224
Mean Y	0.077	0.090	0.030	0.045	0.048	0.068
Cigarette	0.016	**0.022***	0.013	0.016	0.018	0.013
SE	(0.010)	(0.012)	(0.020)	(0.029)	(0.017)	(0.021)
p-value	0.116	0.071	0.500	0.575	0.285	0.540
N	28,948	259	7,023	175	13,508	224
Mean Y	0.045	0.046	0.022	0.026	0.029	0.036
Other nicotine	0.003	-0.003	-0.044	0.012	-0.012	**-0.071****
SE	(0.009)	(0.010)	(0.037)	(0.037)	(0.012)	(0.034)
p-value	0.770	0.750	0.233	0.751	0.323	0.036
N	28,432	259	6,818	175	13,209	224
Mean Y	0.038	0.038	0.032	0.034	0.028	0.030
Dual	0.008	0.008	0.001	-0.003	0.002	-0.003
SE	(0.007)	(0.010)	(0.007)	(0.007)	(0.006)	(0.010)
p-value	0.231	0.451	0.853	0.687	0.703	0.766
N	28,861	259	6,991	175	13,439	224
Mean Y	0.020	0.022	0.006	0.005	0.010	0.017
	MTF, White		**MTF, Black**		**MTF, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	-0.029	-0.038	-0.016	0.041	0.023	0.008
SE	(0.023)	(0.037)	(0.052)	(0.086)	(0.022)	(0.030)
p-value	0.219	0.309	0.761	0.634	0.292	0.794
N	95,042	296	25,298	248	40,313	248
Mean Y	0.149	0.159	0.140	0.109	0.134	0.123
Cigarette	0.011	-0.016	0.007	0.042	0.025	0.037
SE	(0.009)	(0.025)	(0.014)	(0.020)	(0.010)	(0.010)
p-value	0.226	0.512	0.617	0.033	0.013	0.000
N	170,613	296	48,680	248	75,449	248
Mean Y	0.057	0.062	0.053	0.041	0.053	0.051
Other nicotine	0.030	0.039	0.036	0.054	0.017	0.016
SE	(0.020)	(0.016)	(0.024)	(0.034)	(0.021)	(0.019)
p-value	0.137	0.016	0.133	0.109	0.419	0.387
N	52,089	296	14,135	240	21,865	248
Mean Y	0.064	0.063	0.063	0.063	0.062	0.063
Dual	0.004	0.004	0.004	0.032	0.012	0.013
SE	(0.011)	(0.020)	(0.025)	(0.029)	(0.009)	(0.009)
p-value	0.696	0.846	0.855	0.273	0.222	0.159
N	93,994	296	24,773	240	39,694	248
Mean Y	0.036	0.039	0.034	0.022	0.033	0.030

Panel B: Young Adults 18-24

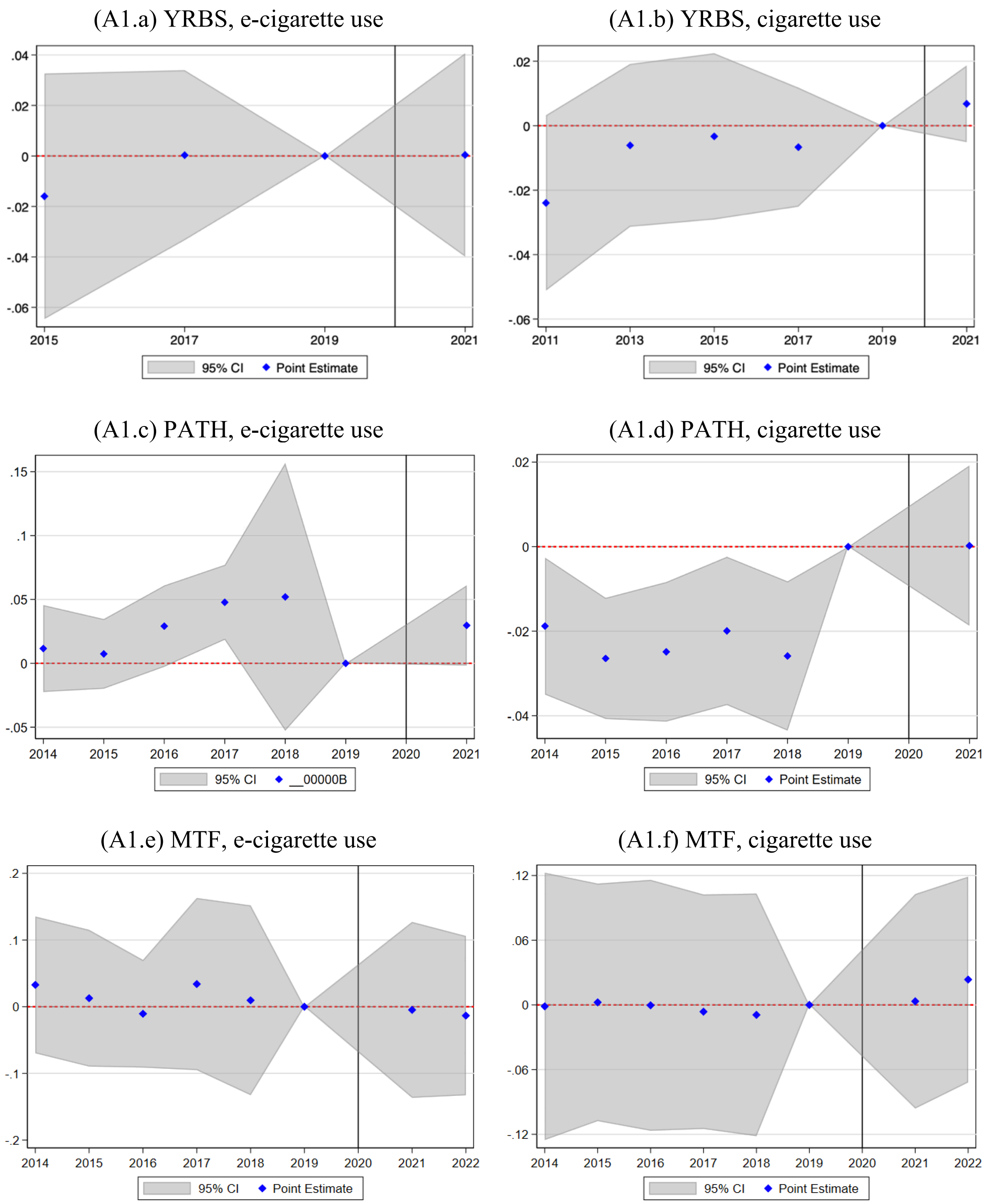
	BRFSS, White		**BRFSS, Black**		**BRFSS, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	-0.011	-0.020	**-0.078***	-0.042	-0.029	-0.052
SE	(0.026)	(0.020)	(0.044)	(0.064)	(0.029)	(0.037)
p-value	0.681	0.308	0.078	0.516	0.313	0.166
N	54,436	188	8,113	180	14,868	188
Mean Y	0.161	0.169	0.091	0.108	0.115	0.148
Cigarette	0.016	**0.021****	0.022	-0.008	0.011	0.030
SE	(0.012)	(0.011)	(0.022)	(0.029)	(0.016)	(0.019)
p-value	0.165	0.047	0.308	0.795	0.484	0.112
N	123,777	432	17,997	405	32,514	432
Mean Y	0.116	0.119	0.080	0.083	0.083	0.111
Other nicotine	**0.011****	**0.012***	0.003	-0.007	-0.001	0.010
SE	(0.005)	(0.007)	(0.014)	(0.011)	(0.009)	(0.016)
p-value	0.034	0.095	0.854	0.525	0.923	0.515
N	124,167	432	18,044	405	32,733	432
Mean Y	0.054	0.056	0.023	0.028	0.033	0.040
Dual	-0.003	-0.010	-0.014	-0.029	-0.007	0.003
SE	(0.006)	(0.008)	(0.026)	(0.024)	(0.012)	(0.026)
p-value	0.653	0.217	0.594	0.234	0.570	0.917
N	54,244	188	8,086	180	14,804	188
Mean Y	0.042	0.044	0.021	0.027	0.029	0.041
	PATH, White		**PATH, Black**		**PATH, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	-0.023	-0.024	0.028	0.053	0.010	0.073
SE	(0.022)	(0.036)	(0.049)	(0.074)	(0.063)	(0.073)
p-value	0.303	0.493	0.569	0.470	0.878	0.319
N	35,293	266	9,326	196	15,122	238
Mean Y	0.194	0.211	0.106	0.128	0.152	0.192
Cigarette	-0.007	-0.006	0.024	0.074	-0.028	-0.009
SE	(0.032)	(0.043)	(0.086)	(0.110)	(0.059)	(0.066)
p-value	0.827	0.898	0.781	0.503	0.632	0.891
N	35,413	266	9,359	196	15,190	238
Mean Y	0.237	0.243	0.178	0.170	0.196	0.220
Other nicotine	-0.004	-0.026	0.026	-0.010	-0.041	-0.072
SE	(0.019)	(0.036)	(0.039)	(0.092)	(0.033)	(0.053)
p-value	0.826	0.467	0.507	0.910	0.214	0.175
N	35,267	266	9,307	196	15,108	238
Mean Y	0.199	0.191	0.255	0.256	0.189	0.204
Dual	-0.003	-0.014	0.007	0.022	-0.008	0.022
SE	(0.016)	(0.029)	(0.027)	(0.062)	(0.029)	(0.040)
p-value	0.845	0.626	0.794	0.720	0.795	0.578
N	35,287	266	9,324	196	15,115	238
Mean Y	0.101	0.106	0.045	0.049	0.071	0.092

Panel C: Adults 25+

	BRFSS, White		**BRFSS, Black**		**BRFSS, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	-0.001	-0.001	-0.006	-0.005	-0.010	**-0.022***
SE	(0.004)	(0.004)	(0.013)	(0.015)	(0.008)	(0.012)
p-value	0.743	0.754	0.660	0.725	0.244	0.060
N	1,121,011	188	114,975	188	101,869	188
Mean Y	0.049	0.048	0.037	0.043	0.033	0.049
Cigarette	-0.005	-0.004	-0.002	-0.002	-0.007	0.011
SE	(0.005)	(0.005)	(0.011)	(0.018)	(0.010)	(0.015)
p-value	0.289	0.389	0.864	0.905	0.481	0.457
N	2,542,221	432	259,535	432	224,299	432
Mean Y	0.161	0.162	0.180	0.193	0.125	0.150
Other nicotine	-0.001	**-0.004****	0.002	0.000	-0.002	**-0.007****
SE	(0.001)	(0.002)	(0.004)	(0.010)	(0.005)	(0.003)
p-value	0.328	0.030	0.646	0.986	0.676	0.030
N	2,556,581	432	261,355	432	226,489	432
Mean Y	0.039	0.042	0.023	0.024	0.020	0.031
Dual	0.000	0.000	-0.001	-0.006	0.001	-0.003
SE	(0.002)	(0.003)	(0.009)	(0.014)	(0.007)	(0.007)
p-value	0.970	0.877	0.946	0.692	0.872	0.725
N	1,114,384	188	114,062	188	101,140	188
Mean Y	0.022	0.022	0.018	0.022	0.013	0.020
	PATH, White		**PATH, Black**		**PATH, Hispanic**	
	DID	SDID	DID	SDID	DID	SDID
E-cigarette	0.017	0.003	0.020	0.011	0.025	-0.017
SE	(0.010)	(0.011)	(0.022)	(0.029)	(0.022)	(0.042)
p-value	0.100	0.778	0.362	0.692	0.267	0.689
N	83,905	266	18,789	224	18,871	231
Mean Y	0.058	0.058	0.055	0.061	0.049	0.060
Cigarette	0.002	-0.009	-0.020	-0.016	0.040	**0.191***
SE	(0.009)	(0.012)	(0.028)	(0.087)	(0.046)	(0.101)
p-value	0.876	0.459	0.476	0.859	0.386	0.059
N	84,412	266	18,942	224	18,977	231
Mean Y	0.195	0.196	0.276	0.311	0.179	0.252
Other nicotine	-0.001	0.001	-0.019	-0.145	-0.008	-0.057
SE	(0.007)	(0.008)	(0.016)	(0.119)	(0.027)	(0.055)
p-value	0.873	0.859	0.221	0.221	0.766	0.300
N	83,553	266	18,730	224	18,770	231
Mean Y	0.083	0.083	0.147	0.165	0.072	0.093
Dual	0.005	-0.004	0.003	0.005	-0.003	-0.030
SE	(0.006)	(0.006)	(0.016)	(0.018)	(0.011)	(0.032)
p-value	0.454	0.524	0.844	0.800	0.779	0.337
N	83,885	266	18,780	224	18,859	231
Mean Y	0.038	0.039	0.038	0.043	0.030	0.041

Note: Authors' analyses of the YRBS, PATH, MTF, and BRFSS. All samples exclude Washington and Montana due to temporary flavor bans in these states. Youth sample is restricted to ages 14-17 for the PATH and ages 14+ for the MTF and YRBS. Young adult and adult samples are restricted to ages 18-24 and 25+ in all datasets. Table presents difference-in-differences (DID) and synthetic difference-in-differences (SDID) estimates of each outcome by race/ethnicity, bootstrapped standard errors that are clustered at the state level, p-values, sample sizes and weighted means of the dependent variables. Asian and other/multiracial categories are omitted due to insufficient sample size. Other nicotine use indicates cigar use, including cigarillos and little cigars, for MTF and YRBS; cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, hookah, and snus for PATH; and snus, snuff, and chewing tobacco for the BRFSS. Dual use indicates both e-cigarette and cigarette use. DID models use individual-level data. BRFSS and PATH DID models include all six treatment states. YRBS DID models exclude MA because that state is not in the YRBS in our sample period. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in DID MTF models. SDID models require balanced, aggregate state-level data. BRFSS SDID models include all six treatment states. PATH SDID models include all treatment states except RI. YRBS SDID models include MD, NY, and RI. The confidentiality agreement that we signed with the Inter-university Consortium for Political and Social Science Research (ICPSR) to access restricted MTF files with state identifiers prevent us from identifying the treatment states in SDID MTF models. All models control for age, sex (male/female), cigarette tax, e-cigarette tax (binary), internet sales ban (binary), and state-year COVID-19 death rates (per 100,000 population). Data were adjusted for sample weights.
***p < 0.01; **p < 0.05; *p < 0.1.

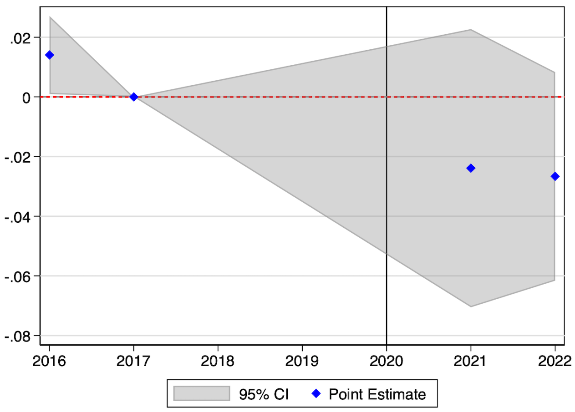
Figure A1.
Difference-in-differences event study plots for youth



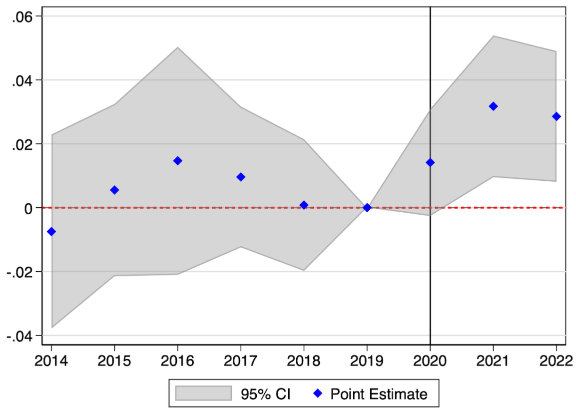
Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table 3. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A2.
Difference-in-differences event study plots for young adults 18-24

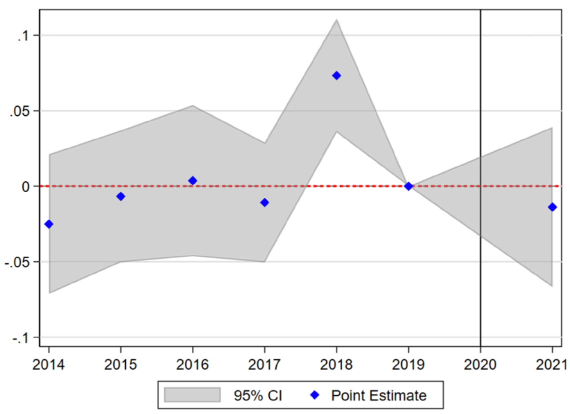
(A2.a) BRFSS, e-cigarette use



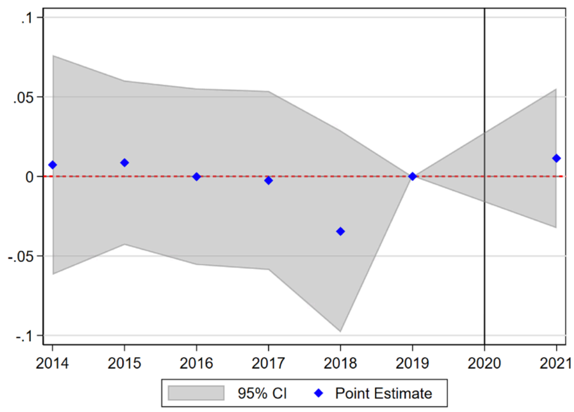
(A2.b) BRFSS, cigarette use



(A2.c) PATH, e-cigarette use

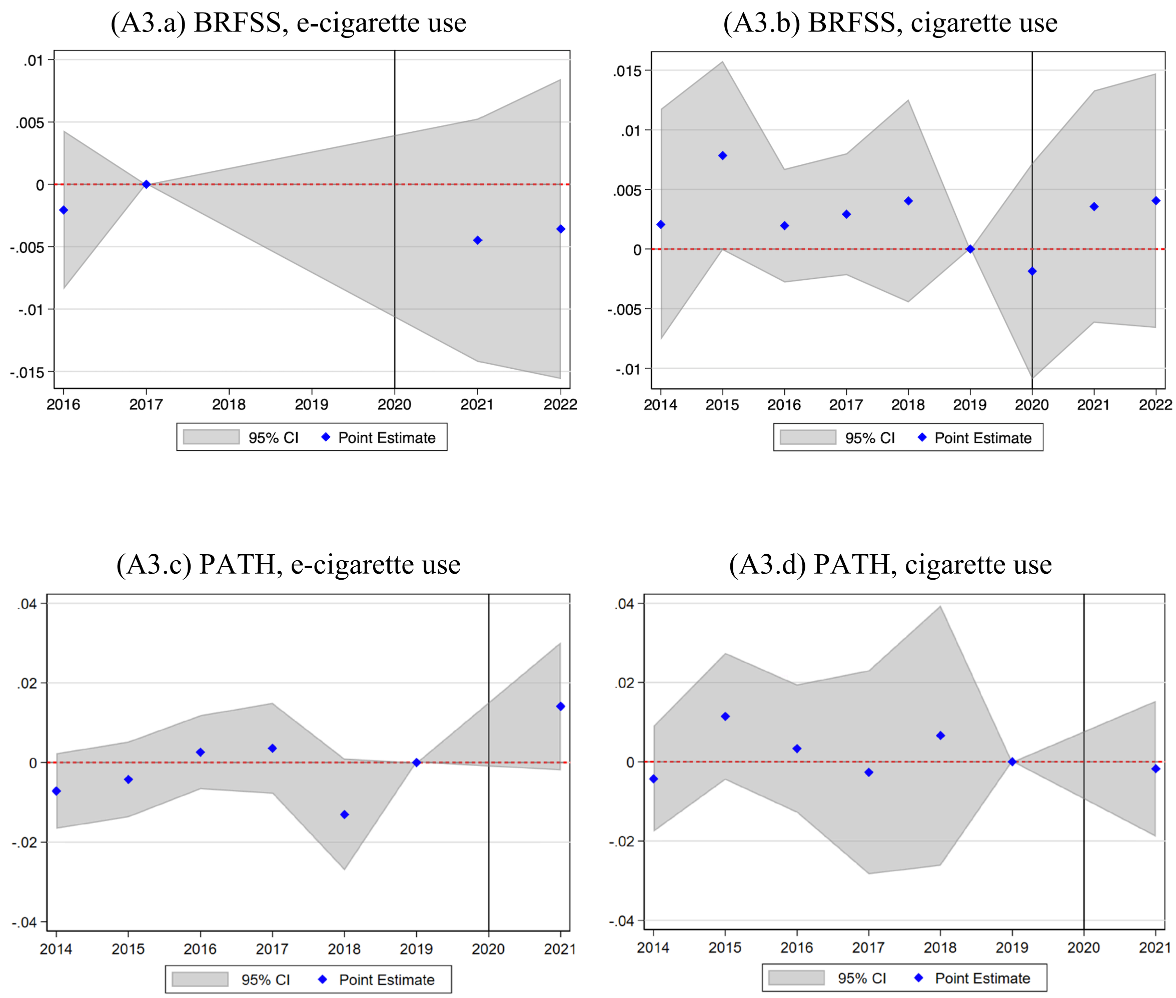


(A2.d) PATH, cigarette use



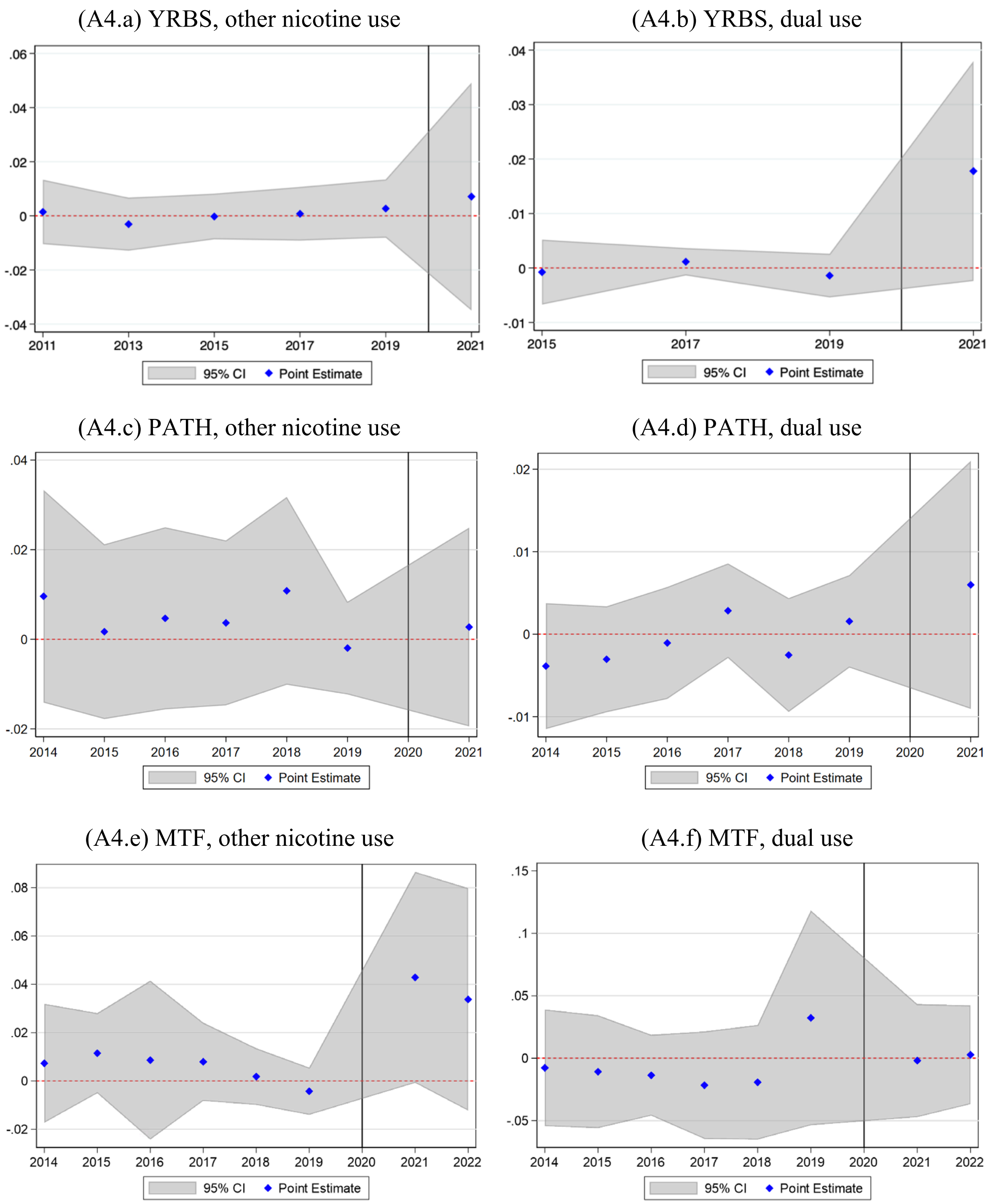
Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table 3. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A3.
Difference-in-differences event study plots for adults 25+



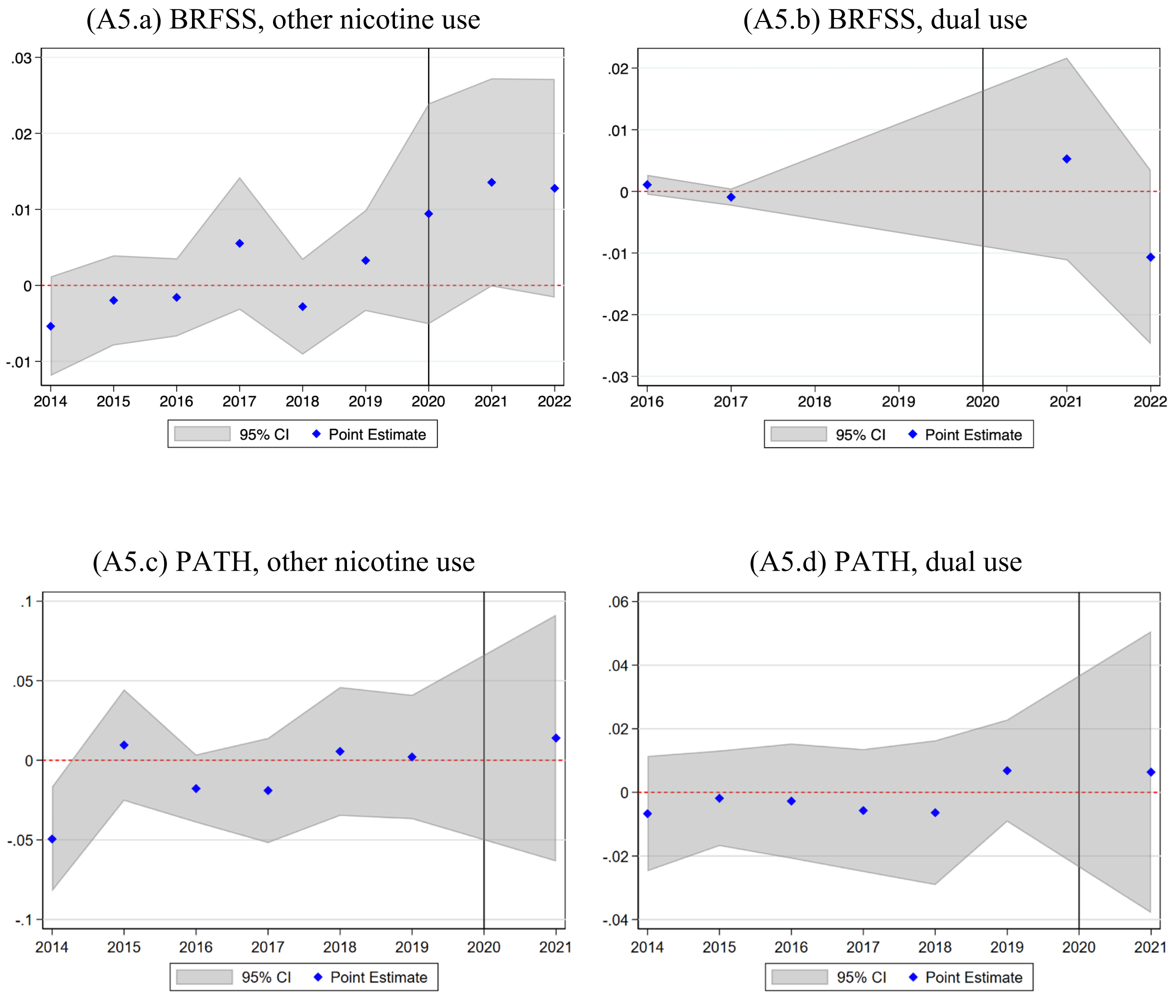
Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table 3. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A4.
Synthetic difference-in-differences event study plots for dichotomous tobacco use for youth



Note: Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table A1. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

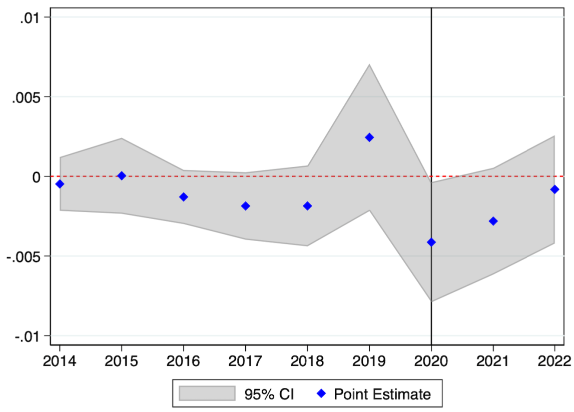
Figure A5.
Synthetic difference-in-differences event study plots for dichotomous tobacco use for young adults 18-24



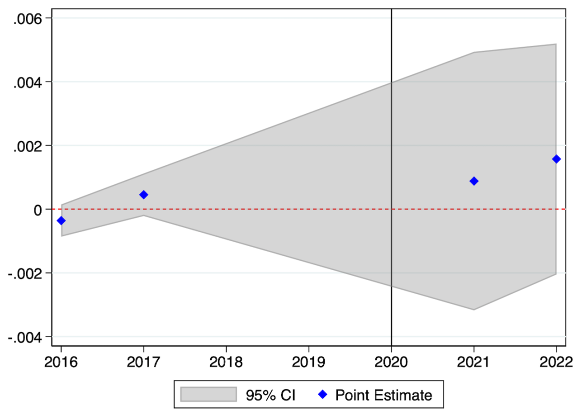
Note: Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table A5. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A6.
Synthetic difference-in-differences event study plots for dichotomous tobacco use for adults 25+

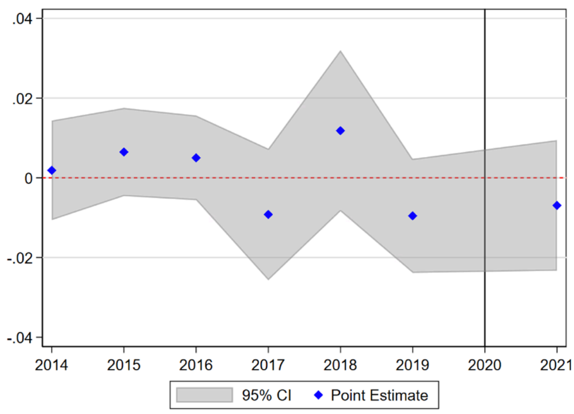
(A6.a) BRFSS, other nicotine use



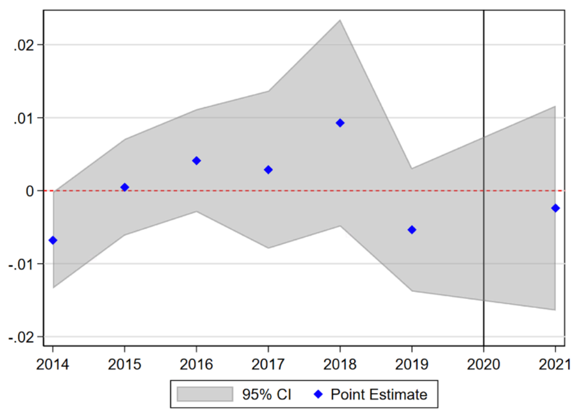
(A6.b) BRFSS, dual use



(A6.c) PATH, other nicotine use



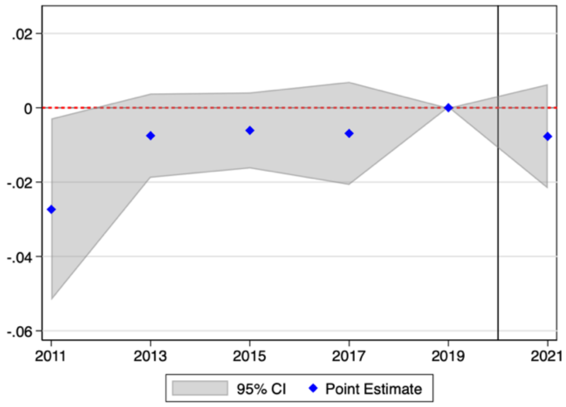
(A6.d) PATH, dual use



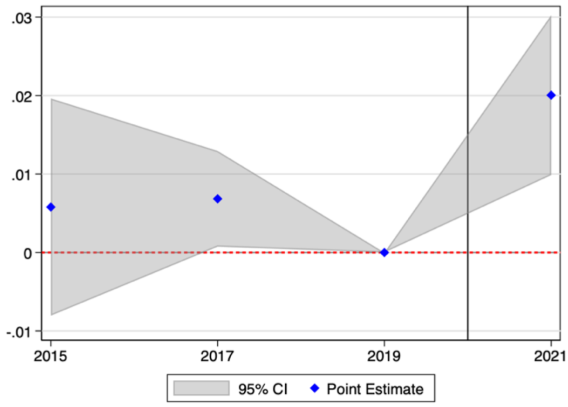
Note: Figure presents the event study analysis of the synthetic difference-in-differences (SDID) estimates from Table A5. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A7.
Difference-in-differences event study plots for dichotomous tobacco use for youth

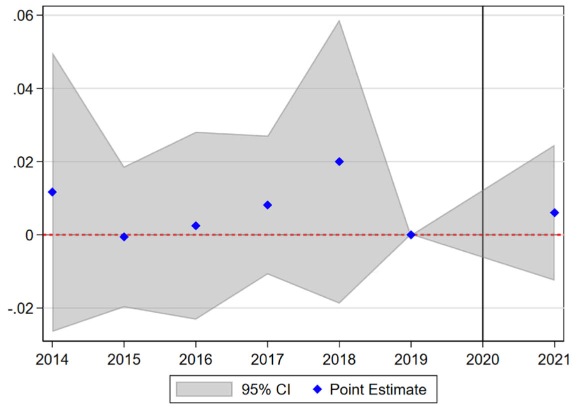
(A7.a) YRBS, other nicotine use



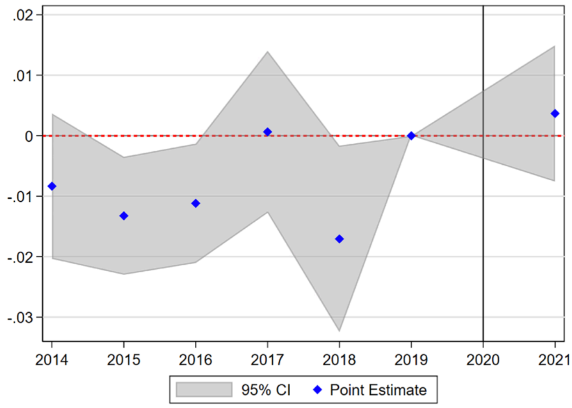
(A7.b) YRBS, dual use



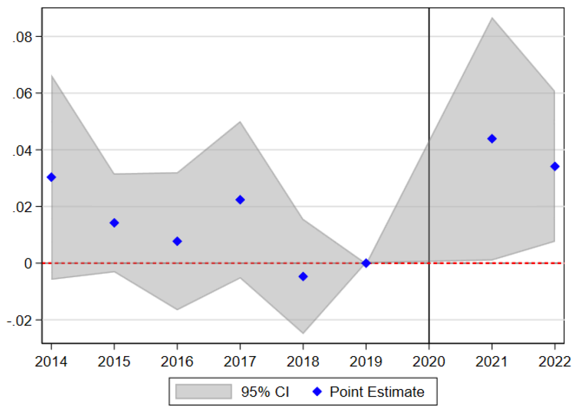
(A7.c) PATH, other nicotine use



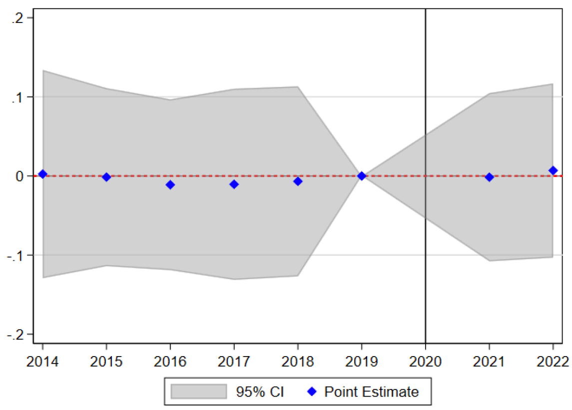
(A7.d) PATH, dual use



(A7.e) MTF, other nicotine use

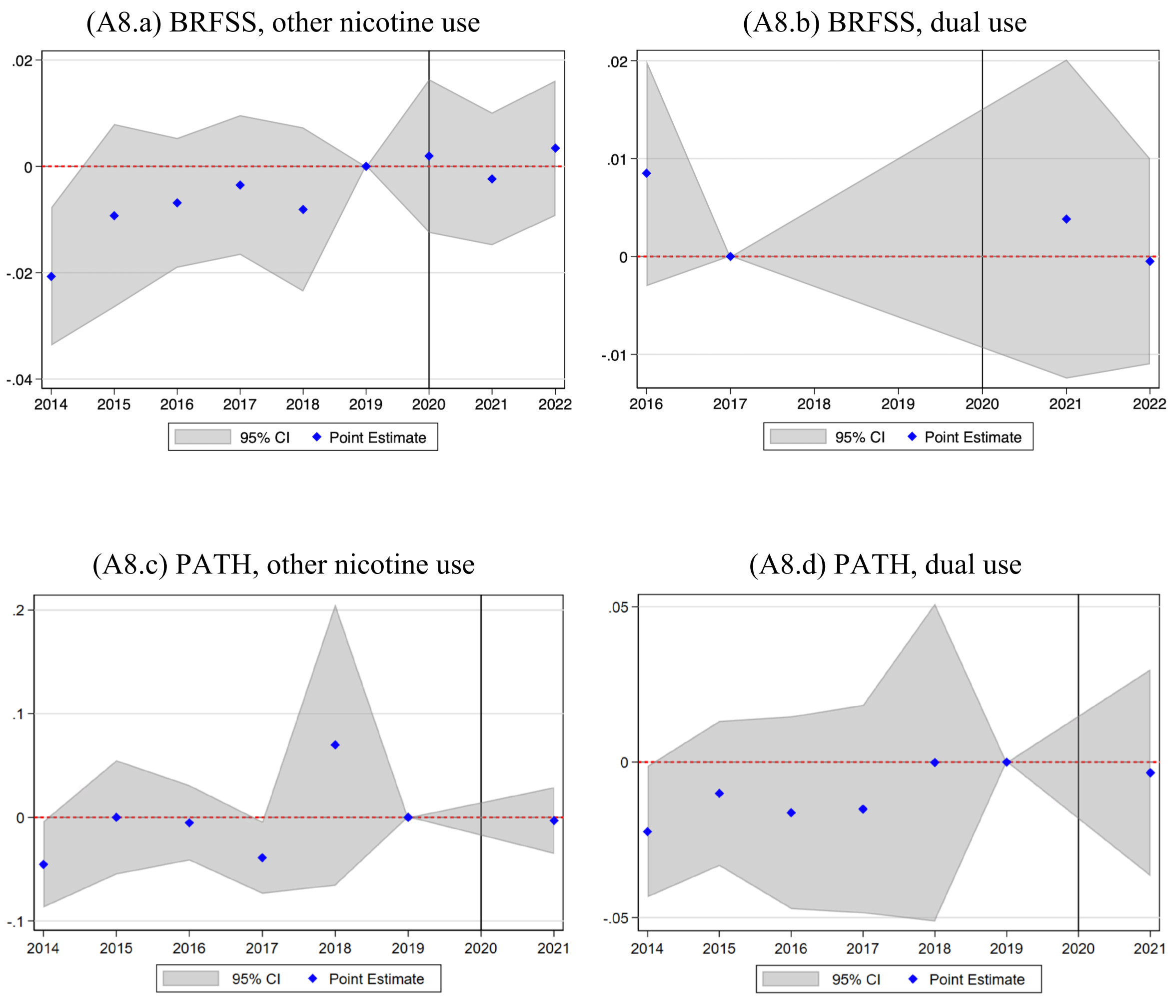


(A7.f) MTF, dual use



Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table A5. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

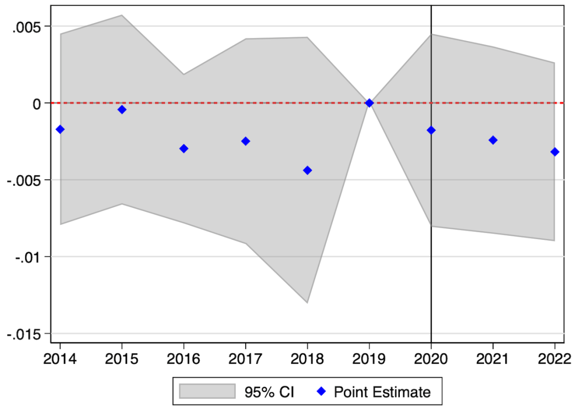
Figure A8.
Difference-in-differences event study plots for dichotomous tobacco use for young adults 18-24



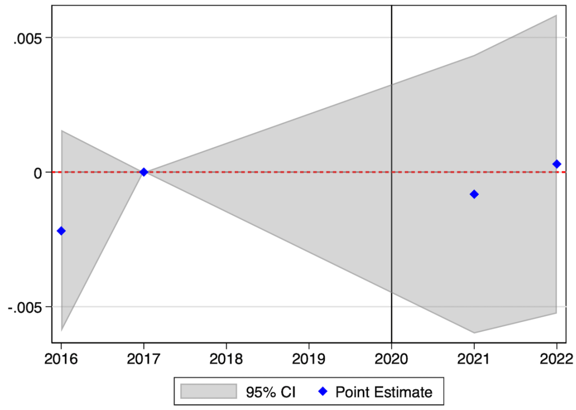
Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table A5. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.

Figure A9.
Difference-in-differences event study plots for dichotomous tobacco use for adults 25+

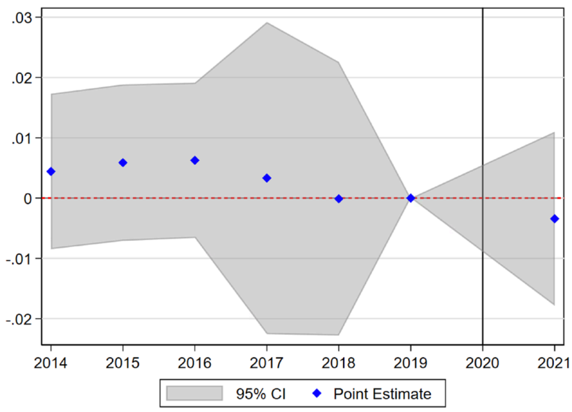
(A9.a) BRFSS, other nicotine use



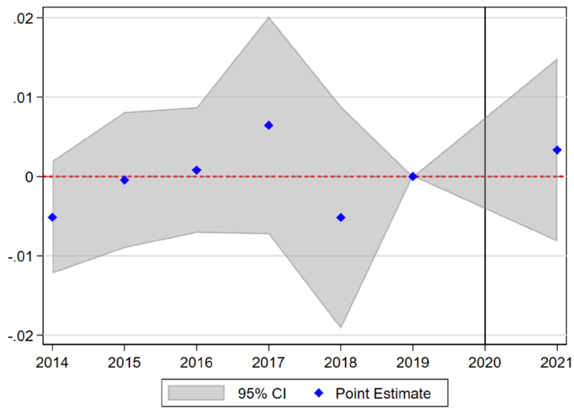
(A9.b) BRFSS, dual use



(A9.c) PATH, other nicotine use



(A9.d) PATH, dual use



Note: Figure presents the event study analysis of the difference-in-differences (DID) estimates from Table A5. Points represent time-specific treatment effect coefficients from leads and lags of the treatment indicator variable. The time period before the treatment is the omitted term. Shaded areas represent 95% confidence interval around the point estimates based on the bootstrapping method.