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The Effect of E-Cigarette Flavor Bans on Tobacco Use*

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Abstract

Advocates for sales restrictions on flavored e-cigarettes argue that flavors appeal to young people and lead them down a path to nicotine addiction. This study is among the first to examine the effect of state and local restrictions on the sale of flavored electronic nicotine delivery system (ENDS) products on youth and young adult tobacco use. Using data from the State and National Youth Risk Behavior Surveys, we find that the adoption of an ENDS flavor restriction reduces frequent and everyday youth ENDS use by 1.2 to 2.5 percentage points. Auxiliary analyses of the Behavioral Risk Factor Surveillance System show similar effects on ENDS use for young adults ages 18-20. However, we also detect evidence of an unintended effect of ENDS flavor restrictions that is especially clear among 18-20-year-olds: inducing substitution to combustible cigarette smoking. Finally, there is no evidence that ENDS flavor restrictions affect ENDS use among adults aged 21 and older or non-tobacco-related health behaviors such as binge drinking and illicit drug use.

Keywords: ENDS flavor restrictions; flavored e-cigarettes; youth tobacco use
JEL codes: I12; I18

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> "The tobacco industry is well aware that flavors appeal to and attract kids, and that young people are uniquely vulnerable to nicotine addiction… [W]e all must work with even greater urgency to protect our nation's youth from all flavored e-cigarettes, including disposables."
>
> -Truth Initiative (2023)

1. Introduction

Electronic nicotine delivery systems (ENDS) are devices in which nicotine and other ingredients such as flavors are heated into a vapor and inhaled. Since 2014, electronic cigarettes (e-cigarettes) have surpassed combustible tobacco products (e.g., cigarettes, cigars, cigarillos) as the most commonly used tobacco products among youths in the United States (Wang, 2020). In 2011, just 1.5 percent of U.S. high school students reported prior month ENDS use. This figure surged to 20.8 percent in 2020 before declining to 14.1 percent in 2022 and 10.0 percent in 2023 (Centers for Disease Control and Prevention, 2024). In recent years, the U.S. Surgeon General has deemed high rates of teen ENDS use an "epidemic" (U.S. Surgeon General, 2018).

Tobacco control advocates and public health agencies consistently point to the availability of flavored e-cigarettes as attracting youths to nicotine vaping (Helgertz & Kingsbury, 2023; Marynak, 2018; Tsai, 2018; U.S. Department of Health and Human Services, 2016). While the Family Smoking Prevention and Tobacco Control Act (TCA) of 2009 banned the sale of flavored combustible cigarettes (with the exception of menthol flavoring), this legislation did not restrict the sale of other flavored tobacco products such as e-cigarettes.[1]

E-cigarettes are available in various flavors, including fruit, candy, mint, and menthol (Birdsey et al., 2023), many of which are popular among teenagers. According to the 2023 National Youth Tobacco Survey, 89 percent of youths who state that they currently vape nicotine report using flavored varieties (Birdsey et al., 2023). Among the most common flavors vaped are fruit (63 percent); candy, desserts, or other sweets (35 percent); mint (28 percent); and menthol (20 percent) (Birdsey et al., 2023). At the time of writing, sales of disposable e-cigarettes in so-called "youth-appealing flavors" are higher than pre-filled units (Ali, 2023), owing in part to JuuL's decision to voluntarily remove mango, creme, fruit, mint, and cucumber flavored cartridges from retail stores in November 2018 and online in October 2019 (Ali, 2020).[2]

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[1] Family Smoking Prevention and Tobacco Control Act, HR 1256, 111th Cong (2009-2010). Accessed March 2, 2020. https://www.congress.gov/bill/111th-congress/house-bill/1256.

[2] JuuL produces pre-filled e-cigarette cartridges, and it is among the five top-selling e-cigarette brands in the U.S. In December 2022, the top-selling ENDS brand was Vuse, followed by JuuL, Elf Bar, NJOY, and Breeze Smoke, with Elf Bar emerging as the top-selling disposable brand in the United States (Birdsey et al., 2023).

While many of the chemicals present in e-liquid flavors are generally considered safe for ingestion, there nonetheless remains a lack of scientific consensus regarding the safety of e-cigarette flavors (U.S. Department of Health and Human Services, 2016). This lack of evidence is, in part, because the safety of flavors heated at varying temperatures and inhaled in aerosolized form has only relatively recently been extensively evaluated (Barrington-Trimis et al., 2014).

The impact of restricting access to flavored ENDS on youth and young adult nicotine vaping is still a matter of conjecture. More than three-quarters of youths and young adults who vape nicotine state they would cease using these products if they were not flavored (Harrell et al., 2017). However, the revealed behavior of these vapers is, as yet, untested. While there is descriptive evidence from surveys on tobacco use that teen and young adult initiation into e-cigarette use is linked to ENDS flavor availability (Landry et al., 2019; Schneller et al., 2019; Soneji et al., 2019; Zare et al., 2018), there is little causal evidence on this question, despite the relevance for regulation and public health.

With the goal of curbing ENDS use among young people, by 2023 nine states,[3] the District of Columbia, and over 370 sub-state localities had adopted policies restricting the sale of flavored e-cigarettes (Campaign for Tobacco-Free Kids, 2023). Minneapolis was the first large city in the U.S. to adopt an ENDS flavor restriction on January 1, 2016, while Massachusetts was the first state to adopt a statewide ENDS flavor restriction on September 24, 2019.

The effect of ENDS flavor restrictions on youth tobacco use is, a priori, ambiguous. On the one hand, if flavors generate added utility from vaping for youths, then ENDS flavor bans may be effective in reducing youth ENDS use as tobacco control officials anticipate (Helgertz & Kingsbury, 2023). However, if flavored ENDS and unflavored ENDS are substitutes, e-cigarette flavor restrictions might have little to no effect on *net* e-cigarette use among teenagers. Moreover, if flavored ENDS and combustible tobacco products are substitutes — or if unflavored ENDS and combustible tobacco products are complements — e-cigarette flavor restrictions could have the

[3] These states include seven states — California (2023), Maryland (2020), Massachusetts (2019), New Jersey (2020), New York (2020), Rhode Island (2019), and Utah (2020) — that adopted that adopted ENDS flavor restrictions that remain in effect as of May 15, 2024 and two states that adopted such laws that were in effect for at least three months (one quarter) before being lifted (Montana in December 2019 and Washington in October 2019) in response to the e-cigarette, or vaping, product use associated lung injury (EVALI) outbreak that was responsible for 68 deaths and nearly 3,000 hospitalizations for severe respiratory problems (Centers for Disease Control and Prevention, 2021). There were four other occasions where a state enacted a statewide ENDS restriction (Michigan in October 2019; New York in September 2019; Oregon in October 2019; and Utah in October 2019) via emergency decree, but these laws were in effect for less than one month. These four state events are not counted as meaningful ENDS flavor restriction in the context of our analysis given the lack of consistent high frequency tobacco use data.

unintended consequence of inducing youths to substitute toward combustible cigarettes and cigars (see, for example, evidence on overall e-cigarette sales Friedman et al. (2023)). Moreover, emerging evidence suggests that policies designed to curb youth and young adult access to ENDS may have important spillover effects on alcohol and marijuana, particularly among the targeted youths and young adults (Dave, Liang, Maclean, Muratori, & Sabia, 2024; Dave, Liang, Maclean, Sabia, & Braaksma, 2024).

This study is among the first to explore the impact of ENDS flavor restrictions on youth and young adult ENDS use. Using data from the 2015-2021 State and National Youth Risk Behavior Survey and a "difference-in-differences" regression approach, we find that adoption of ENDS flavor restrictions is associated with a relatively small and statistically insignificant decline in any prior-month ENDS use. However, the connection is more pronounced when we turn to the outcomes that represent more intensive use. Specifically, the implementation of an ENDS flavor restriction is associated with a 1.2 to 2.5 percentage-point reduction in frequent and everyday ENDS use. These are sizeable magnitudes, as they represent at least 30 percent of the pre-treatment rates for those outcomes. Event-study analyses are consistent with parallel pre-treatment trends between adopting and non-adopting localities, and therefore a causal interpretation of our findings. We further find that estimated youth ENDS use reductions in response to flavor restrictions are largest among Hispanic and Black youth. Moreover, in an auxiliary analysis of the Behavioral Risk Factor Surveillance Survey (BRFSS), we find evidence that ENDS flavor restrictions reduce current ENDS use, particularly among young adults ages 18-20, with estimated treatment effects of approximately three to five percentage points. These findings are consistent with the intended effect of the policy. On the other hand, we find no evidence that flavor restrictions affect ENDS use among adults aged 21 and older, consistent evidence that adults of legal tobacco consuming age are less likely to consume flavored ENDS products than their younger counterparts.

Despite providing evidence that these policies are effective in reducing vaping, we also find that ENDS flavor restrictions may generate an important and unintended consequence: inducing youths and young adults to substitute toward combustible cigarettes. This finding is especially clear for 18–20-year-olds, among whom adoption of an ENDS flavor restriction is associated with a statistically significant 2.4 to 2.6 percentage-point *increase* in the likelihood of smoking any cigarettes. This finding is consistent with the hypothesis that ENDS and combustible cigarettes are substitutes among young people. Given the plausibly higher health risks of combustible cigarettes relative to e-

cigarettes, such substitution implies that the net effect of ENDS flavor restrictions on public health may be limited or potentially even negative.

Finally, given recent evidence that policies that restrict access to ENDS products may cause spillovers to alcohol consumption, marijuana use, or harder drug use among youths (Dave, Liang, Maclean, Muratori, & Sabia, 2024; Dave, Liang, Maclean, Sabia, & Braaksma, 2024), we also explore whether ENDS flavor restrictions affect these outcomes. We find little evidence of such spillovers to non-tobacco health behaviors.

Overall, our findings provide reasons for both enthusiasm and caution among policymakers and tobacco control advocates on the effectiveness of e-cigarette flavor restrictions. On one hand, these restrictions appear to achieve the intended objective of reducing youth and young adult vaping by a substantial amount. On the other hand, at least some of the reduction in vaping appears to occur via substitution towards combustible cigarette smoking. Such substitution is arguably more surprising and noteworthy in the context of flavor bans than other policies such as e-cigarette taxes. This finding is noteworthy because flavored cigarettes (aside from menthol) have been banned since 2009, so consumers cannot simply obtain their preferred flavors by switching to cigarettes. Therefore, young consumers appear, at least in part, to be switching from flavored ENDS products to unflavored (or menthol flavored) cigarettes rather than unflavored (or menthol flavored) e-cigarettes. In turn, such switching implies that, holding flavor constant, some young people prefer cigarettes to e-cigarettes in spite of the greater relative health harms of cigarettes.

2. Background

2.1 Rise of ENDS Policy Strategies to Curb Use, and Unintended Consequences

Combustible tobacco product (e.g., cigarette and cigar) use is the leading cause of preventable deaths in the U.S., resulting in 480,000 deaths annually (U.S. Department of Health and Human Services, 2014), and contributing to 40 percent of all cancer diagnoses (Centers for Disease Control and Prevention, 2019). In addition, combustible tobacco product smoking leads to increased risks for (1) emphysema; (2) cancers of the colon, liver, head, and lung; and (3) stroke (U.S. Department of Health and Human Services, 2020).

Tobacco product use among young people is a particular concern. Descriptive data from the National Longitudinal Survey of Children and Young Adults (NLSCYA) show that 61 percent of all cigarette smoking initiation begins before the age of 18, with children the age of eight having the same smoking initiation hazard rate as an average 23-year-old young adult (Miller & Miller, 2023).

Concerns arise with respect to tobacco product use among youths and young adults as risk-taking is developmentally normal during this stage of the life course (Romer, 2010), and youth and young adults may be vulnerable to hyperbolic discounting of the future costs of addiction (Gruber & Köszegi, 2001), leading to a failure to fully incorporate future costs into decision-making and over-consumption of tobacco products. Because tobacco products generally contain nicotine, which is addictive, such decisions can have long-term implications for health and other related outcomes. Nicotine may have important effects on brain development, as the pre-frontal cortex of the brain (important for decision making and impulse control) continues to develop well into one's 20s (Romer, 2010). Youth nicotine use may therefore affect cognition, attention, mood, and psychosocial health (U.S. Department of Health and Human Services, 2016).

E-cigarettes have rapidly emerged as an alternative nicotine source to combustible cigarettes for an increasing number of teenagers (Abouk, Courtemanche, et al., 2023; Centers for Disease Control and Prevention, 2019; Cullen et al., 2019). ENDS products are not without health risks, including respiratory disease, heart disease (National Academies of Sciences, 2018), and cancer from carcinogens (U.S. Department of Health and Human Services, 2016). Nonetheless, ENDS products are largely considered to be less harmful than combustible tobacco products (National Academies of Sciences, 2018). A 2020 survey of 137 tobacco scholars reveals that the median tobacco expert believes that the effect of vaping ENDS on quality-adjusted life expectancy is 25 percent as large as the effect of smoking (Allcott & Rafkin, 2022). Along the same lines, a 2013 expert panel concludes that the health harms caused by ENDS use are unlikely to exceed five percent of the risk of cigarettes when accounting for harm to others as well as the consumer (Nutt et al., 2014). The above-referenced National Academies of Sciences (2018) report concludes that:

> "…e-cigarettes appear to pose less risk to an individual than combustible tobacco cigarettes …[E]-cigarette aerosol contains fewer numbers and lower levels of toxicants than smoke from combustible tobacco cigarettes."

Between 2011 and 2019, youth combustible cigarette smoking and ENDS use were on opposite trajectories. As prior-month teen ENDS use rose from 1.5 to 27.5 percent between 2011 and 2019, combustible cigarette use fell from 16 percent to less than six percent (Birdsey et al., 2023). Beginning in 2020 (following the adoption of the federal tobacco-21 law, which raised the minimum legal purchasing age for all tobacco products to 21 nationally), both e-cigarette and combustible cigarette use have fallen.

Some tobacco control experts suggest that ENDS use among youths and young adults could serve as a "gateway" to more harmful health behaviors (Gorman, 2016; U.S. Department of Health and Human Services, 2016). However, there is also growing evidence that reducing youth access to ENDS — for instance through higher prices via ENDS taxes (Abouk, Courtemanche, et al., 2023; Pesko & Warman, 2022) — could increase youth combustible cigarette smoking as the two products may be economic substitutes among youths and young adults. Thus, an important policy question arises when one observes a youth or young adult using ENDS products: if access to that ENDS product were restricted, would that individual abstain from all tobacco products (i.e., abstinence) or substitute toward combustible tobacco products?

Policymakers have undertaken several policy strategies to reduce ENDS use, with particular attention to youths. Among the most high-profile policy strategies to curb ENDS use include raising the minimum legal purchasing ages for e-cigarettes (Abouk & Adams, 2017; DeSimone et al., 2023; Friedman, 2015; Pesko, 2023), establishing and increasing taxes on ENDS (Abouk, Adams, et al., 2023; Abouk, Courtemanche, et al., 2023; Cotti et al., 2022; Pesko et al., 2020), and requiring retailers to obtain state licenses to sell ENDS products (Courtemanche et al., 2024). In the main, the findings from studies to date suggest that most policies intended to curb ENDS use can reduce vaping among youths and young adults (Abouk & Adams, 2017; Abouk, Courtemanche, et al., 2023; Azagba et al., 2020; DeSimone et al., 2023; Friedman et al., 2021; Pesko, 2023; Pesko et al., 2020).[4] However, these policies also often have the unintended consequence of inducing substitution toward combustible tobacco products (Abouk, Adams, et al., 2023; Abouk, Courtemanche, et al., 2023; Dave et al., 2019; Friedman, 2015; Pesko, 2023). Given the relatively higher health risks of combustible tobacco use, these findings suggest that policy strategies designed to curb ENDS use may have the inadvertent consequence of harming overall tobacco-related public health.

On the other hand, emerging evidence suggests that policies that affect access to ENDS may have important *beneficial* spillovers to non-tobacco-related behavioral health. These general equilibrium effects may also be important in assessing such policies' welfare effects. For instance, using increased ENDS taxes as a policy shock, Dave and co-authors find evidence consistent with the hypothesis that e-cigarettes are an economic complement to (1) binge drinking among youths and young adults (Dave, Liang, Maclean, Sabia, & Braaksma, 2024), and (2) youth and adult

[4] Courtemanche et al. (2024) provide limited evidence that state ENDS licensure laws reduce vaping among youths. One exception to this pattern of (null) findings is that Black youth reduce vaping following the passage of such a law.

experimental marijuana use (Dave, Liang, Maclean, Muratori, & Sabia, 2024), suggesting that broader social welfare implications of policies that affect ENDS access are still being explored.

2.2 Trends in ENDS Flavor Sales

To assess trends in sales of e-cigarettes in the United States, by product and flavor, the Truth Initiative and Centers for Disease Control and Prevention (CDC) periodically analyze retail scanner data from Information Resources, Inc. (IRI), a U.S. data analytics and market research company. Between 2014 and 2020, e-cigarette sales rose by 122 percent, from 7.7 million to 17.1 million units per four-week interval. Among pre-filled cartridge sales, sales of mint, one of the most popular flavors, increased from less than 0.1 percent in September 2014 to 47.6 percent in August 2019, followed by a decrease in the subsequent period (August 2019 to May 2020) from 47.6 percent to 0.3 percent as JuuL voluntarily removed many flavored ENDS products from the market. Over this same period, there was a substantial rise in menthol sales (from 10.7 percent to 61.8 percent), consistent with the hypothesis that menthol and other flavored pre-filled cartridges are substitutes. Among disposable e-cigarettes, during the period September 2014–May 2020 the proportion of mint sales increased (<0.1 percent to 10.5 percent), although tobacco-flavored (from 52.2 percent to 17.2 percent) and menthol-flavored (from 30.3 percent to 10.2 percent) sales decreased; during the same period, sales of all other flavors combined increased (from 17.2 percent to 62.1 percent) (Ali, 2020).

Beginning in 2020, sales of e-cigarette products changed in response to multiple factors, including, potentially, local and state regulations targeting flavored e-cigarette sales (Friedman et al., 2023), regulations from the Food and Drug Administration (FDA),[5] and COVID-19 disruptions in global supply chains. While overall e-cigarette monthly unit sales increased by about 47 percent (15.5 million units at the start of 2020 to 22.7 million units by the end 2022), the distribution of ENDS sales also changed. In the post-COVID-19 period (2021-2022), sales of tobacco-flavored and mint-flavored products decreased from 28.4 percent to 20.1 percent and from 10.1 percent to 5.9 percent,

[5] The FDA began regulating ENDS in August 2016 with the "Deeming Rule." This rule gives the FDA regulatory authority over all ENDS and other tobacco products in ways the agency already was regulating cigarettes, smokeless tobacco, and roll-your-own tobacco. As part of these new federal regulations on ENDS, ENDS manufacturers have been obligated to submit product applications to the FDA for agency review by September 9, 2020. So far, the agency has denied the marketing of more than one million flavored ENDS products. This authority, if utilized, offers the FDA substantial ability to shape the size and composition of the ENDS market in the U.S. Part of this regulatory action is also a federal rule in effect since December 20, 2019 that imposes the minimum age to purchase tobacco products as 21.

respectively. However, the sales of other flavors (such as fruit, clove/spice, candy/sweets, and chocolate) increased from 29.2 percent to 41.3 percent (Ali, 2023).

2.3 Health Risks of Flavors

While many public health experts regard the most substantial danger of youth-attractive ENDS flavors lying in their potential to "lure" youths and young adults on a path of early nicotine addiction, there remains some concern that the safety of flavors themselves — particularly when heated and inhaled in aerosolized form — has not been sufficiently evaluated in terms of their long-run health dangers (Barrington-Trimis et al., 2014). For instance, Bahl et al. (2012) demonstrate cytotoxic effects of e-cigarette solutions, attributed not to nicotine but to the concentration of chemicals used as flavors. These effects are notably pronounced in mouse neural stem cells and human embryonic stem cells compared to human pulmonary fibroblast cells.

Dacetyl (DA) and acetyl propionyl (AP) chemicals are most commonly used for the flavoring of e-cigarette products. DA belongs to a broader category of organic compounds that provides a buttery flavor. While generally recognized as safe when ingested, exposure through inhalation has been linked to respiratory function decline (Clark & Winter, 2015; Egilman et al., 2011). Inhalation of DA is associated with (1) fixed obstructive lung disease in affected individuals (Chaisson et al., 2010), and (2) the onset of bronchiolitis obliterans, an irreversible respiratory ailment commonly referred to as "popcorn lung disease" (Harber et al., 2006). AP shares chemical and structural similarities with DA and despite the rise of AP as a popular substitute for DA, AP causes airway epithelial damage upon acute inhalation exposure (Hubbs et al., 2012).

While common, the presence of these chemicals in e-cigarettes appears to be substantially lower than in combustible cigarettes. For instance, Farsalinos et al. (2015) examine 159 e-liquids sourced from various European and American manufacturers and retailers to explore the presence of DA and AP in these products. The authors show that 74.2 percent of the samples contained either of these chemicals, with DA present in 69.2 percent of samples. Both DA and AP were found in 28.3 percent of the e-liquids analyzed.[6] However, exposure to DA and AP was 100 and ten times lower, respectively, compared to exposure from smoking cigarettes.

2.4 Restrictions on Flavored Combustible Tobacco Products

[6] Notably, these chemicals were identified even in samples from manufacturers who claimed their products did not contain these flavorings.

Flavored combustible cigarettes (other than menthol) were prohibited in the U.S. on September 22, 2009, as part of the Family Smoking Prevention and Tobacco Control Act (TCA). The TCA gave the FDA substantial regulatory authority over tobacco products. While menthol was notably excepted by TCA regulations, as of March 2023, over 190 localities in the U.S. have implemented laws prohibiting the sale of menthol-flavored combustible tobacco products (Campaign for Tobacco-Free Kids, 2023). In November 2019, Massachusetts became the first state to pass a law (implemented in 2020) restricting the sale of all flavored tobacco products, including menthol cigarettes, followed by California in 2022 (Campaign for Tobacco-Free Kids, 2023).

Courtemanche et al. (2017) explore the impact of the 2009 FDA ban on flavored cigarettes (aside from menthol) on youth tobacco product use. Using data from the 1999–2013 National Youth Tobacco Surveys on middle and high school students, they find that the federal ban on flavored combustible tobacco products is associated with a 17 percent reduction in the probability that a youth is a current cigarette smoker and a 58 percent reduction in the number cigarettes smoked by smokers. However, the authors also demonstrate an unintended consequence of the ban: a 34 percent to 55 percent increase in the probability that a youth smoked menthol cigarettes, cigars, or pipes. This result demonstrates substitutability of menthol with other flavors, and also of cigarettes with other tobacco products (which did not face flavor restrictions at the time).

Carpenter and Nguyen (2021) evaluate the effects of menthol cigarette bans in Canada on smoking outcomes among youths and adults. They exploit variation across Canadian provinces that adopt menthol cigarette bans (including the more populous provinces of Alberta, Ontario, and Quebec[7]) between 2015 and 2017 and use a difference-in-differences approach to show that the bans are associated with a 2.4 percentage-point reduction in the probability of smoking menthol cigarette among youths and a 3.1 percentage-point reduction among adults. The effect size among youths is nearly 100 percent of the pre-reform mean, while that among adults is more than 100 percent of the mean, implying strong compliance. Similarly to the results of Courtemanche et al. (2017), Carpenter and Nguyen (2021) also find evidence of substitution: the ban increases non-menthol cigarette smoking among youths by 1.7 percentage-points and shifts cigarette purchases among adults to unregulated Native Peoples reservations ("First Nations People").

2.5 E-Cigarette Flavor Restrictions in the U.S.

[7] For their analysis, British Columbia, Saskatchewan, and Manitoba serve as "never adopters."

As noted in the Introduction, as of December 2023, nine states, D.C., and over 370 localities have restricted access to flavored ENDS products (Campaign for Tobacco-Free Kids, 2023). Statewide restrictions were adopted in Massachusetts, Rhode Island, New Jersey, New York, Maryland and Utah in 2020 and California in 2022 (Campaign for Tobacco-Free Kids, 2023).

There is some heterogeneity across states and jurisdictions that adopted ENDS flavor restrictions in terms of the exemptions that are allowed. For instance, Massachusetts exempts certain types of retailers, including tobacco/smoking bars, tobacco retailers that receive a high proportion of their total revenues from tobacco products, e-cigarette establishments, adult-only retailers, and liquor stores. New York exempts ENDS products that have received a marketing order from the FDA, though at present, no flavored e-cigarettes have received such an order. Maryland's statute prohibits the sale of all flavored cartridge-based and disposable e-cigarettes except for menthol-flavored products while Utah prohibits the sale of flavored e-cigarettes in non-retail tobacco specialty businesses, except mint- and menthol-flavored products (Campaign for Tobacco-Free Kids, 2023).[8] In our main analyses, we do not differentiate between bans that are more and less restrictive, but we explore this heterogeneity in sensitivity analyses.

Four recent studies of which we are aware have examined the effects of restricting flavored ENDS on tobacco sales. Asare et al. (2022) investigate the effect of the comprehensive flavor ban implemented in Massachusetts in June 2020 – which applies to all tobacco products, including menthol cigarettes – on cigarettes sales. The authors use Nielsen Retail Scanner Data and a difference-in-differences design comparing Massachusetts to 27 states not adopting a flavor ban, finding that the comprehensive flavor ban is associated with a statistically significant decrease in state-level menthol and all cigarette sales (Asare et al., 2022).

Gammon et al. (2022) use Nielsen weekly retail sales data (July 2015 – December 2019) and an interrupted time series approach to assess the effects of a comprehensive 2018 flavor ban (including menthol cigarettes) in San Francisco, California on flavored tobacco sales. The authors find a 96 percent decrease in sales of flavored tobacco products in San Francisco, relative to the

[8] At the same time that some jurisdictions have adopted restrictions on e-cigarettes, some have also tightened restrictions on flavored combustible tobacco products. For instance, 250 localities, five states, and D.C. also restrict sales of menthol flavored ENDS, including Massachusetts, California, and D.C. that implemented comprehensive bans that apply to both flavored e-cigarette and menthol cigarettes (Campaign for Tobacco-Free Kids, 2023). In addition, Maine prohibits the sale of flavored non-premium cigars (Campaign for Tobacco-Free Kids, 2023) and New Jersey restricts the sale of flavored cigarettes, excluding menthol and clove flavors.

comparison cities San Jose and San Diego, from the period before to the period after implementation of the flavored tobacco product policy.

Two studies move beyond examining effects of flavor bans in a single state or locality. Using retail data from 2014 to 2020 and a difference-in-differences approach, Ali et al. (2022) compare e-cigarette unit sales in four states that adopted ENDS flavor restrictions (Massachusetts, New York, Rhode Island, and Washington) to those in 35 comparison states. Their findings show that statewide restrictions on flavored e-cigarettes are associated with a 25 to 31 percent decline in total e-cigarette sales. The reductions are attributable mostly to decreases in non–tobacco-flavored e-cigarette sales.

Finally, Friedman et al. (2023) use data from IRI retail sales data from January 2018 through March 2023 to study the effects of state and local ENDS flavor restrictions on e-cigarette and combustible cigarette sales. The restrictions are associated with a decline in flavored ENDS sales, but also an increase in cigarette sales. Specifically, ENDS flavor restrictions lead to 15 additional cigarettes for every one fewer 0.7 mL ENDS pod sold. The authors further find evidence of increases in cigarette sales for brands disproportionately used by youths, though using sales data they are not directly able to test whether youth consumption is affected by the bans.

Only one study of which we are aware explores the effect of an ENDS flavor restriction on youth ENDS use. Using data from the 2011-2019 local school district Youth Risk Behavior Survey and a difference-in-differences approach, Friedman (2021) tests the impact of San Francisco's prohibition on all flavored tobacco product sales (applying to both ENDS and combustible tobacco products) on cigarette smoking among San Francisco high school students. The author finds that San Francisco's flavor ban is associated with higher odds of recent smoking among underage high school students relative to concurrent changes in other districts, consistent with the hypothesis that flavored e-cigarettes and combustible cigarette smoking are substitutes.

2.6 Contributions of the Current Study

This study makes five important contributions to the small literature evaluating the impacts of e-cigarette flavor bans. First, we comprehensively examine the effects of ENDS flavor restrictions adopted nationwide — including statewide and by large cities and counties — as opposed to just one or a few states or localities. Second, we use survey data as opposed to sales data, which enables the comparison of the effects of flavor restrictions across youths, young adults, and other adults. Aggregate sales data do not permit the researcher to study how impacts vary across groups of consumers, potentially masking important heterogeneity since young people are the most likely to

consume flavored ENDS, while adults are the most likely to consume unflavored e-cigarettes and as a harm reduction strategy (i.e., among those who formally smoked and cannot quit their nicotine addiction). Further, estimation of treatment effects using sales data is vulnerable to bias from "stockpiling," or buying large quantities of a durable good knowing that a policy change limiting access is approaching. Third, again taking advantage of the individual-level nature of our survey data, we explore heterogeneity in the effects of ENDS flavor restrictions along other demographic dimensions besides age. We pay particular attention to vulnerable, historically marginalized populations, including Hispanic and Black youth. Fourth, we study heterogeneity in the bans themselves by separately estimating effects for state and local bans, and for bans that vary in their stringency. Fifth, this study explores spillover effects of ENDS flavor restrictions on combustible tobacco and non-tobacco-related health behaviors. Such general equilibrium effects are essential to assessing overall public health effects and social welfare implications.

3. Data

3.1 YRBS Data

We measure our key tobacco outcomes, youth ENDS use and combustible tobacco smoking, using data drawn from the 2015-2021 State and National Youth Risk Behavior Surveys (YRBS). Coordinated by the Centers for Disease Control and Prevention, the YRBS is a school-based biennial survey administered in odd-numbered years that, when weighted, is designed to be representative of high school-aged students (aged 14-18) at both the state and national levels.[9] These data are well-suited to carrying out this study because they include information on youth ENDS use during a period over which ENDS flavor restrictions were adopted.

While our primary analysis uses data from the combined State and National YRBS to maximize identifying variation in ENDS flavor restrictions (e.g., including large jurisdiction and statewide policies, 11 states identify the treatment effect in the YRBS over our analysis period), we also estimate regressions separately for the State and National YRBS surveys. The National YRBS is,

[9] Adjusted population weights are generated from the Surveillance Epidemiology and End Results Program (http://seer.cancer.gov/popdata/). We calculate the state-by-year share of the youth population that falls in each age-by-gender-by-race/ethnicity bin *i*, s_{ist} (age 12-14, age 15, age 16, age 17, age 18, male, female, non-Hispanic White, non-Hispanic Black, Hispanic, and other race/ethnicity). We then calculate each respondent's sample weight as $[s_{ist}/n_{ist}]$*StatePop14_18$_{st}$, where n_{ist} is the number of YRBS sampled individuals in age-by-gender-by-race-ethnicity bin *i* in state *s* at year *t* and StatePop14_18$_{st}$ is the SEER estimated population of 14-to-18-year-olds in state *s* at year *t*. In this construction, we are following the recent literature that applies similar SEER-constructed weights in analyses of the combined YRBS data (Hansen et al., 2023; Rees et al., 2021; Sabia & Anderson, 2016).

when weighted, designed to be representative of all U.S. high school students. However, the data are not designed to be representative at the state level. In contrast, the State YRBS are designed, when weighted, to be representative of youth health behaviors at the state level. Moreover, using data from the Surveillance of Epidemiology and Ends Research (SEER) on state-by-year population, these data can also be made nationally representative of those aged 14-18.

Our main outcome captures youth ENDS use during the prior 30 days using responses to the following YRBS questionnaire item:

> "During the past 30 days, on how many days did you use an electronic vapor product?" [Examples: electronic vapor product includes e-cigarettes, vapes, vape pens, e-cigars, e-hookahs, hookah pens, and mods (such as JuuL, SMOK, Suorin, Vuse, and blu)]

The variable *Current ENDS Use* is set equal to one for respondents who reported use of an electronic vapor product on a positive number of days in the prior 30 days; it is set equal to zero otherwise. As shown in Appendix Table 1A, in the combined YRBS sample, we find that 20.5 percent of youths reported prior-month ENDS consumption. A similar prevalence rate is observed in the separate State and National YRBS samples.

In addition, we examine measures of ENDS use that capture more habitual vaping. The variable *Everyday ENDS Use* is set equal to one if the respondent reports using e-cigarettes on all 30 of the last 30 days and is set to zero otherwise. We find that 4.0 percent of youths in the combined YRBS sample report daily ENDS use. *Frequent ENDS Use* is set equal to one if the respondent reports using e-cigarettes on at least 20 of the last 30 days and zero otherwise. We find that 5.7 percent of the combined analysis sample report frequent ENDS use.

In 2017, the YRBS survey began collecting data on youths' usual sources of ENDS products. Specifically, respondents to the YRBS are asked:

> "During the past 30 days, how did you usually get your electronic vapor products?"

We build a categorical variable, grouping the question's choices into five categories. The first category measures whether the respondent "did not use any electronic vapor products during the past 30 days" (*Non-User*); the second category measures whether the respondent typically bought e-cigarettes "in a vape shop or tobacco shop," "in a convenience store, supermarket, discount store, or gas station," or "at a mall or shopping center kiosk or stand" (*Retail*); the third category measures

whether the respondent bought them "on the Internet, such as from a product website, vape store website, or other website like eBay, Amazon, Facebook Marketplace, or Craigslist" (*Internet);* the fourth category measures whether the respondent "got or bought them from a friend, family member, or someone else" or if the respondent "took them from a store or another person" (*Social Source*); and the fifth category measures whether respondent "got them in some other way" (*Other*). We find that 4.4 percent of teens purchase e-cigarettes from a retailer, 0.5 percent from the Internet, 11.1 percent from social sources, and 2.8 percent from some other way.

In addition to nicotine vaping, we also measure combustible tobacco product use. Respondents to the YRBS are asked:

> "During the past 30 days, on how many days did you smoke cigarettes?"

For teenagers who report combustible cigarette use on a positive number of days in the prior month, *Current Cigarette Use* is set equal to one; it is set equal to zero otherwise. We find that 7.1 percent of teenagers report prior-month cigarette smoking. Additionally, 9.8 percent report prior-month cigarette or cigar consumption.[10] 1.4 percent report daily cigarette use and 1.7 percent report daily cigarette or cigar use.

Finally, we measure a set of spillover outcomes that could be affected by ENDS access policies – youth alcohol consumption, marijuana use, and harder illicit drug use – following the recent literature on general equilibrium effects of ENDS policies on non-tobacco-related health outcomes (Dave, Liang, Maclean, Muratori, & Sabia, 2024; Dave, Liang, Maclean, Sabia, & Braaksma, 2024). First, we measure youth binge drinking using responses to the following survey item:

> "During the past 30 days, on how many days did you have 4 or more drinks of alcohol in a row, that is, within a couple of hours (if you are female) or 5 or more drinks of alcohol in a row, that is, within a couple of hours (if you are male)?"

The variable *Binge Drinking* is set equal to one if the respondent reported drinking four or more drinks of alcohol within a couple of hours (if female) or five or more drinks of alcohol within a

[10] For this measure, if either cigarette or cigar consumption is missing, current cigarette or cigar use is set equal to missing.

couple of hours (if male) for at least one day in the previous month; it is set equal to zero otherwise. We find that 13.6 percent of YRBS respondents reported binge drinking in the last month.

Next, we measure *Current Marijuana Use* using responses to the following survey item:

> "During the past 30 days, how many times did you use marijuana?"

We find that 18.8 percent of respondents reported marijuana use in the prior 30 days.

Finally, we measure *Cocaine Use* using the following questionnaire items:

> "During your life, how many times have you used any form of cocaine, including powder, crack, or freebase?"

Because this measure captures "ever use" (to avoid very small recent use means), estimated treatment effects in a difference-in-differences framework will largely capture the initiation margin (Dave, Liang, Maclean, Sabia, & Braaksma, 2024). We find that 4.2 percent of youths report having ever used cocaine.

3.2 Auxiliary Analysis from BRFSS

In addition to exploring youth risky behaviors, we also measure adult tobacco use using data from the Behavioral Risk Factor Surveillance Survey (BRFSS). First, we generate measures of adult ENDS use — available during the 2016-2021 period — using responses to the following survey item:

> "Do you now use e-cigarettes or other electronic vaping products every day, some days, or not at all?"

Current ENDS Use is set equal to one if respondents report using ENDS products either every day or some days; it is set equal to zero otherwise. *Everyday ENDS Use* is set equal to one if respondents report using e-cigarettes each day; it is set equal to zero otherwise. As shown in Appendix Table 1B, we find that 17.0 percent of young adults aged 18-20 (under the minimum legal purchasing age for tobacco products following the federal tobacco-21 law) are current users of ENDS and 6.3 percent were everyday users. Among those aged 21-and older, these numbers are 3.9 percent and 1.6 percent, respectively. Importantly for our study, the BRFSS do not include any questions on ENDS use in the 2019 survey and beginning in 2020 ENDS questions are not collected in the core survey

and instead are included in modules in which only a sub-set of states elect to participate. ENDS use questions are available in the main BRFSS survey in all years 2016 to 2018.

In addition, we measure *Current Cigarette Smoking* and *Everyday Cigarette Smoking* using responses to the following survey item, which is available in the main BRFSS survey for every year between 2015 and 2021 (to match our main YRBS analysis sample):

"Do you now smoke cigarettes every day, some days, or not at all?"

We find that 10.8 percent of respondents aged 18-20 and 14.7 percent of those aged 21-and-older are current smokers. Smoking questions are included in the main BRFSS survey in all years of our study period.

3.3 ENDS Flavor Restrictions

We measure ENDS flavor restrictions using policy data from a variety of sources, including the Public Health Law Center (2023), the Campaign for Tobacco-Free Kids (2023), and our own review of state and local statutes. We define an ENDS flavor restriction as a statewide law or a law adopted by a large jurisdiction (defined for the purposes of our study as city or county with population of at least 200,000 persons using U.S. Census data) that limits the sale of any e-cigarette flavor. Focusing our attention to 2015-2021, eight states, D.C., and 23 large substate jurisdictions adopted ENDS flavor restrictions. The staggered rollout of these policies is reported in Figure 1. Many of the flavor restrictions were adopted during the COVID-19 pandemic, which creates empirical challenges that we attempt to address by controlling for heterogeneous impacts of the pandemic across jurisdictions.

Appendix Table 2 shows the effective dates for all ENDS flavor restrictions considered in this study. Since our data do not contain geographic identifiers narrower than state, we incorporate city and county regulations by coding *ENDS Flavor Restriction (ENDSFR)* as the share of the population in each state-by-time cell that is covered by a large jurisdiction or statewide e-cigarette flavor restriction. A total of 11 states (including both statewide and large jurisdiction laws) contribute to identification of treatment effects in the combined State and National YRBS and 13 states including D.C. contribute to identification in the BRFSS.

4. Empirical Approach

Using repeated cross-sectional data from the combined State and National YRBS (and later the BRFSS), we begin with a two-way fixed effects (TWFE) difference-in-differences strategy, estimated via ordinary least squares (OLS):

$$Y_{isptd} = \beta_0 + \beta_1 ENDSFR_{spt} + \mathbf{X}_{isptd}\boldsymbol{\beta}_2 + \gamma_s + \eta_p + \tau_t + \alpha_d + \varepsilon_{ispdt} \quad (1a)$$

where Y_{isptd} measures use of tobacco (ENDS use, combustible cigarette smoking) and other substances (binge drinking, marijuana use, cocaine use) for person *i* residing in state *s* in semester *p* (fall or spring) in the YRBS (or quarter *p* in the BRFSS) at year *t* in data source *d* (State YRBS vs. National YRBS in Combined YRBS analysis; in BRFSS we do not have a dataset fixed effect as there is just one survey). As discussed above, $ENDSFR_{spt}$ is the state-by-semester-year (or state-by-quarter-year) measure of the share of the population covered by an ENDS flavor restriction. $\mathbf{X}_{isptd}$ is a vector of observable controls for: individual demographic characteristics (sex, grade, age, and race/ethnicity), state macroeconomic conditions (natural log of the unemployment rate and the natural log of the poverty rate), COVID-19 (cumulative COVID-19 case and death rate), e-cigarette policies (ENDS taxes, ENDS licensure requirements for retailers, clean indoor air law for vaping, online purchase shipment bans, minimum legal age sale), combustible tobacco policies (tobacco-21 laws, combustible cigarette taxes, cigarette licensure requirements for retailers, clean indoor air laws for smoking, online purchase shipment bans, menthol-flavored cigarette restrictions), and alcohol and marijuana policies (beer tax, recreational marijuana law and medical marijuana law).[11] In addition, γ_s is a time-invariant state effect, η_p is a fixed effect for semester in the YRBS[12] (quarter in the BFRSS), τ_t is a state-invariant year effect in the YRBS and year effect in the BRFSS, α_d is a fixed effect for survey (State or National) in the YRBS analysis (there is no dataset fixed effect in BRFSS analysis), and ε_{ist} is the error term. Regressions are weighted and standard errors are clustered at the

[11] Descriptive statistics may be found in Appendix Table 1A and 1B. State tobacco-21 laws come from the Preventing Tobacco Addiction Foundation and are available at https://tobacco21.org. Cigarette taxes and ENDS minimum legal sales age, clean indoor air, and combustible tobacco licensure laws come from the Centers for Disease Control and Prevention STATE system. E-cigarette licensure laws come from data collected by Courtemanche et al. (2024). E-cigarette taxes come from Cotti et al. (2023) and were used in Abouk, Courtemanche, et al. (2023). Menthol cigarette restrictions were collected from the same sources as the e-cigarette flavor restrictions discussed above. Beer taxes come from the Alcohol Policy Information System and are available at https://alcoholpolicy.niaaa.nih.gov/apis-policy-topics/beer/30. Data on marijuana laws were collected by Anderson and Rees (2023). Per capita income and unemployment rate come from the Bureau of Labor Statistics. The COVID-19 variables are cumulative counts divided by population from the New York Times digital COVID-19 data repository.

[12] The CDC provides information on the seasonality of the State YRBS (by state and year) between 2011 and 2021. This information is available via the CDC by emailing: yrbsdatareq@cdc.gov.

state level. For the YRBS-based analysis, we merge in state policy data at the state-by-year-semester (fall vs spring) level and for the BRFSS-based analysis at the state-by-year-quarter level. All monetary variables are inflated to 2021 dollars using the Consumer Price Index – Urban Consumers.

While our goal in including a wide set of state-specific tobacco- and non-tobacco-related health policy controls is to reduce bias in the estimated effect of ENDS flavor restrictions on teen tobacco use, one concern might be a reduction in efficiency of our estimator. Thus, we also (1) present results using a more parsimonious specification, and (2) use a Least Absolute Shrinkage and Selection Operator (LASSO) estimator to select an optimal set of observable state-level policy controls. Specifically, we use the LASSO double-selection method as described by Belloni et al. (2014), and further outlined by Urminsky et al. (2016). This method selects state-level policy controls that predict either the dependent variable or the treatment variable, ensuring a robust and efficient estimation procedure. The set of potential controls includes the wide set of tobacco control and other substance use policies listed above. We always include demographic, macroeconomic, and COVID-19 controls in the selection process.

To supplement the OLS regression outlined in equation (1), we also estimate logistic regressions of the form:

$$Pr(Y_{isptd} = 1) = \frac{\exp(g(i,s,p,t,d))}{1+\exp(g(i,s,p,t,d))}, \quad (1b)$$

where $g(i,s,p,t,d)$ is simply $\beta_0 + \beta_1 ENDSFR_{spt} + \mathbf{X}_{isptd}\boldsymbol{\beta}_2 + \gamma_s + \eta_p + \tau_t + \alpha_d$. We report average marginal effects rather than logistic regression coefficient estimates for ease of interpretation. While logit marginal effects are generally similar to those obtained using OLS, functional form might be important in this case because the sample means of some of our outcome variables (particularly everyday ENDS and combustible cigarette use) are small in magnitude (less than five percent). Moreover, logistic regression can be more efficient than OLS in some cases.

We use changes in state and local ENDS flavor restriction policies adopted between 2015 and 2021 to identify our key parameters of interest β_1 and γ_1 in equations (1a) and (1b). These policy changes are described in Appendix Table 2. In order for our regressions to provide unbiased estimates of β_1, (1) there must be no jurisdiction-specific, time-varying unobservables associated with the adoption of ENDS flavor restrictions and youth tobacco (or other substance use) use; (2) reverse causality, in which youth tobacco use affects the adoption of ENDS flavor restrictions, must

not be present; and (3) heterogeneous and dynamic effects of ENDS flavor restrictions must not lead to biased estimates when using the TWFE estimator

We undertake several strategies to descriptively test the identifying assumptions underlying equations (1a) and (1b). First, we explore the sensitivity of our estimate of β_1 to the inclusion of a wide set of controls for background characteristics and potentially confounding policies. A relatively stable coefficient estimate would be consistent with the hypothesis that ENDS flavor restrictions are adopted exogenously to youth tobacco product use. Second, and relatedly, to ensure that β_1 does not simply capture the effects of a bundle of policies correlated with e-cigarette flavor restrictions, we are careful to control for other tobacco control policies that may be adopted contemporaneously, including menthol cigarette flavor restrictions, minimum legal purchasing ages for tobacco products, ENDS licensure laws, ENDS taxes, restrictions on internet sales of tobacco products, and cigarette taxes (while also experimenting with the LASSO approach described above).[13]

Third, to descriptively test the common trends assumption as well as explore the possibility of reverse causality (whereby youth tobacco use influences ENDS flavor restriction adoption), we estimate an event-study model where we replace the treatment variable with a mutually exclusive set of leads (1-2, 3-4, and 5 or more years prior to the adoption of an ENDS flavor restriction) and lags (0-1 and 2 or more years after adoption).[14] Recall that our treatment variable is proportional rather than binary because local laws lead to part of the state population being covered. Therefore, we adopt the approach of Schmidheiny and Siegloch (2023) and interact the continuous variables with the time-to-treatment indicators as opposed to dichotomizing the treatment. The reference event time, 1-2 years prior to the e-cigarette flavor ban adoption, is omitted to normalize the estimated treatment effects to zero in those years (and, in the case of the YRBS, account for the biennial nature of the survey). If the coefficient estimates on the policy lead variables are small and statistically indistinguishable from zero, this pattern of (null) results would tend to support the common trends assumption.

We also explore the sensitivity of our estimated treatment effect to controls for spatial heterogeneity, including the addition of variables to the right-hand side of our estimating equations

[13] We have explored correlations between policies and state-level demographics. The mean variance inflation factor across our policy and state-level controls is just 5.0, well below the benchmark of ten at which multicollinearity is generally considered problematic (Kennedy, 2008).

[14] We follow earlier work using the YRBS (State or combined State and National) to study ENDS-related regulation effects and use two-year event-time leads and lags due to (1) the newness of ENDS policies and (2) the bi-annual nature of the YRBS data (Dave, Liang, Maclean, Muratori, & Sabia, 2024; Dave, Liang, Maclean, Sabia, & Braaksma, 2024). We use the same structure in the BRFSS (which is annual) to maintain a consistent event-study specification across datasets.

(1a) and (1b) for (1) census region-specific year fixed effects (i.e., a separate fixed effect for each region-by-year pair in YRBS and region-by-year fixed effects in BRFSS), (2) census division-by-year fixed effects (comparable to [1] but using the nine Census divisions vs. the four Census regions), and (3) treatment state-specific linear time trends.[15] These approaches will control for some potentially important forms of unmeasured heterogeneity, including unmeasured region-specific shocks and state-specific unobservables unfolding linearly that could be correlated with the adoption of ENDS flavor restrictions and youth tobacco product use. On the other hand, it is not always true that geographically proximate controls are preferable to non-geographically proximate controls (Burkhauser et al., 2023; Neumark et al., 2014). Moreover, the inclusion of state-specific time trends may leave variation in the treatment variable that is less likely to be exogenous to the outcome under study (Neumark et al., 2014). Thus, we will treat results stemming from these sensitivity tests as descriptive rather than dispositive.

Finally, in the presence of heterogeneous and dynamic treatment effects and a staggered policy rollout, TWFE regression estimates may be biased, and the direction of the bias is *ex ante* ambiguous (Goodman-Bacon, 2021). Thus, we also re-estimate our treatment effects using two approaches: (1) the two-step approach developed by Gardner (2022) and the stacked difference-in-differences estimator (Cengiz et al., 2019). In each case, we restrict the set of counterfactuals to include never-adopters of ENDS flavor restrictions.

5. Results

Our main findings appear in Tables 1 through 9 and Figures 2 through 6. Supplemental analyses appear in the appendix. All regressions are weighted, and standard errors are corrected for clustering at the state level as described in Section 4.[16]

5.1 ENDS Flavor Restrictions and Youth ENDS Use

[15] These trends are coded in the following manner: each treatment state dummy is interacted with a linear time trend beginning in the first year that the state is observed in the survey. This time trend is set equal to zero for states that did not adopt an ENDS flavor restriction over the sample period.

[16] In the presence of few treated clusters (as is potentially the case in our setting, see Appendix Table 2), conventional inference methods (e.g., clustering at the level of treatment) may be unreliable because large-sample assumptions do not hold. For this reason, as a robustness check, we estimate the *t*-statistic generated by testing the null of no treatment effect using a score bootstrap approach (Brewer et al., 2018; Kline & Santos, 2012; Roodman et al., 2019). Inferential findings are similar when using this approach and results are reported later in the manuscript.

Panel I of Table 1 presents estimates of β_1 from a series of linear probability (OLS) models. We begin by present findings from five specifications: one with parsimonious controls, including state, semester, dataset, and year fixed effects, as well as demographic controls (column 1); another that adds controls for state-level macroeconomic conditions and COVID-19 variables (column 2); a third specification that adds controls for the wide set of ENDS and combustible tobacco product policies (column 3); a "fully saturated" specification that add controls for beer taxes, medical marijuana laws, and recreational marijuana laws (column 4); and finally a regression that uses LASSO to select which policy controls to include (column 5).

The results in panel I-a suggest that ENDS flavor restrictions have little effect on the extensive margin of youth ENDS use. Controlling for only state effects, semester effects, year effects, dataset effects, and demographic characteristics (column 1), we find that the adoption of an ENDS flavor restriction is associated with a statistically insignificant 0.95 percentage-point (4.5 percent) decline in prior-month youth ENDS use (panel I-a, column 1). The results are qualitatively similar across the other specifications, with the estimated effect remaining negative but statistically insignificant and relatively small. This null finding may be explained by youths being able to obtain flavored ENDS from other non-retail sources (i.e., online sales, social sources, black market), because experimental ENDS users substitute unflavored for flavored ENDS in response to new legal restrictions, or, less likely given higher transportation costs for teens, cross-border shopping (which we explore below).

On the other hand, when we turn to measures of more intensive youth ENDS use — frequent ENDS use (panel I-b) and everyday ENDS use (panel I-c) — we find that ENDS flavor restrictions have more bite. For instance, for everyday ENDS use (panel I-c), we find that adoption of an ENDS flavor restriction is associated with a 1.7 percentage-point reduction in the probability of everyday ENDS use. While less precisely estimated, the pattern of results on frequent use (panel I-b) is similar, with estimated marginal effects around two percentage-points. The magnitudes of these effects are large relative to the pre-treatment mean of habitual use (at least 30 percent of the pre-treatment mean), which is not surprising given the substantial share of teen ENDS users who report consuming flavored ENDS (Birdsey et al., 2023).

In panel II of Table 1, we use logistic regression instead of OLS. The average marginal effects reported from logistic regression are very similar to those obtained when using OLS and are more precisely estimated. That is, across specifications (as well as use of a LASSO), we find that ENDS flavor restriction adoption is associated with a 1.3 to 1.9 percentage-point reduction in

frequent and everyday ENDS use.[17] Due to the improved precision, all ten estimates for frequent and everyday ENDS use are statistically significant at the ten percent level or better, and five are significant at the five percent level. Together with our findings in panel I of Table 1, these results suggest that ENDS flavor restrictions appear to be most effective at reducing youth ENDS use on the intensive rather than the extensive margin. The findings in Appendix Table 3 — which condition the sample on ENDS users — are consistent with an intensive margin effect.[18] One interpretation of these findings is that ENDS flavor restrictions are not inducing youths to quit, but rather to notably reduce the number of days of consumption.

The estimated treatment effects for the more intensive ENDS use measures all represent at least 32 percent of the pre-treatment mean, with the average being 52 percent. While quite large, we consider these magnitudes plausible. As of 2023, 89 percent of youth vapers used flavored products (Birdsey et al., 2023). Our estimates are therefore consistent with roughly half of flavored e-cigarette users reducing their amount of vaping to levels below frequent or everyday use (but not zero, given the null result for any vaping). Moreover, the Courtemanche et al. (2017) study discussed earlier found that the 2009 FDA ban on flavored cigarettes led to a 58 percent reduction in the number of cigarettes smoked by youth smokers, but a smaller 17 percent reduction in the prevalence of youth who smoke at all. Comparably to our results, the Courtemanche et al paper finds clearer effects along the intensive margin than the extensive margin and estimates the size of the reduction along the intensive margin to be in the vicinity of 50 percent. Moreover, researchers have frequently made the point that, when base rates are very low, expressing estimates percentage terms can make effect sizes seem misleadingly large (see for example, Cotti et al. (2022)). In our context, the more intensive ENDS use outcomes have pre-treatment means below 5.0 percent, and our confidence intervals are at least 1.3 percentage points wide. Therefore, any statistically discernable effect necessarily represents a sizeable percentage of the mean.

Event-study analyses of ENDS flavor restrictions and more habitual ENDS use are shown in Figure 2.[19] Our findings are, in the main, consistent with parallel pre-treatment trends between

[17] Appendix Figure 2 shows event-study analyses of ENDS flavor restrictions and everyday ENDS use using logistic regression. The marginal effects generated are quite similar to those generated via OLS.

[18] While we find no effect of ENDS flavor restrictions on youth ENDS use, this regression may still be contaminated by sample selection if there are changes in the composition of ENDS users in response to the policy change (i.e., a greater share of ENDS users who consume unflavored as compared to flavored e-cigarettes).

[19] Results using linear regression are discussed here. Appendix Figure 2 shows event-study analyses of ENDS flavor restrictions and everyday ENDS use using logistic regression. The marginal effects generated are quite similar to those generated via OLS.

flavor ban adopting and non-adopting states. Coefficient estimates show that in the pre-treatment period, frequent and everyday ENDS use trending similarly in treatment and control states. In the post-treatment period, we find evidence that the probabilities of frequent and everyday ENDS use decline. This finding is true in specifications that include parsimonious controls (those described in column 1 of Table 1) and macroeconomic and COVID-19 controls (those described in column 2 of Table 1), as well as a wide set of tobacco and non-tobacco policies chosen by the LASSO specification (those described in column 5 of Table 1).[20]

5.2 Sensitivity Checks

In the next set of tables and figures, we explore a set of sensitivity checks to test the robustness of our findings. First, in Table 2 we explore the sensitivity of our coefficient estimates in column (4) of panel II of Table 1 (shown in panel I of Table 2) to controls for spatial heterogeneity, as measured by census region-specific year fixed effects (panel I), census division-specific year fixed effects (panel III), and treatment state-specific linear time trends (panel IV).[21,22] For frequent and everyday ENDS use, in each case, the absolute magnitude of the estimated treatment effect is larger relative to specifications that exclude these additional controls; for instance, these added controls produce coefficient estimates that suggest ENDS flavor restrictions reduce frequent and everyday ENDS use by two to three percentage-points. While the treatment effect is least precisely estimated with the inclusion of treatment state-specific time trends (panel IV), the magnitudes of the estimated treatment effects are similar; moreover, the effect of ENDS flavor restrictions on any prior-month ENDS use (panel IV, column 1) becomes much larger in absolute magnitude at -0.040.

In Table 3, we explore the sensitivity of our baseline logistic estimates (column 1) to the use of alternative difference-in-differences estimators that expunge bias in TWFE estimators from potentially heterogeneous and dynamic treatment effects with a staggered policy rollout. In our setting, which features little staggering in the years in which flavor bans took effect as well as the availability of states that never adopted a ban as "clean controls," it is not obvious that this bias

[20] These include t obacco-21 laws, cigarette taxes, ENDS taxes, minimum legal sales age for ENDS, bans on online sales of ENDS and tobacco, ENDS and tobacco licensure laws, menthol cigarette restrictions, indoor smoking bans, beer taxes, and medical and recreational marijuana laws. In Appendix Figure 1, we show an event-study analysis of ENDS flavor restrictions and current use with no evidence of a causal impact.

[21] As described in Section 4, the treatment state-specific linear time trends are coded as the interaction between individual treatment state dummies and a linear time trend (measured at their first appearance in the state-year panel) for treated states and zero otherwise.

[22] Analogous robustness checks using the other specifications in Table 1 lead to similar results; they are not shown to save space but are available upon request.

would be empirically important. Nonetheless, we implement two robustness checks to explore the possibility. Column (2) uses a two-step Gardner (2022) difference-in-differences estimator, and column (3) uses a stacked difference-in-differences estimator. Using these alternative difference-in-differences estimators, we continue to find that ENDS flavor restrictions are associated with a 1-2 percentage-point decline in frequent and everyday ENDS use among youths.

Our main regression estimates rely on the combined State and National YRBS in to allow us to maximize identifying variation in ENDS flavor restrictions. In Table 4, we examine the robustness of our estimated treatment effects to separately estimating regressions for the State YRBS (panel I) and National YRBS (panel II). The results show negative effects of ENDS flavor restrictions on frequent and everyday youth ENDS use across each dataset, with the estimated effects on ENDS use are generally larger (in absolute magnitude) in the national YRBS.

In Table 5, we explore whether ENDS flavor restrictions have different effects on youths depending on their usual source of e-cigarettes. The vast majority of teens who use ENDS (76.6 percent) obtain their e-cigarette products through sources other than direct purchase from retailers (authors' analysis of the Combined YRBS). We estimate the effects of ENDS flavor restrictions on the probability that youths vape ENDS obtained from various sources. As noted above, this analysis uses all available data from the 2017-2021 YRBS. The results show that the adoption of ENDS flavor restrictions principally reduce the probability that youths obtain ENDS products online or from sources other than retailers and friends.

In Appendix Table 4, we examine statewide versus sub-state (i.e., large jurisdiction local) ENDS flavor restrictions. In the main, the findings point to the most robust effects of statewide ENDS flavor restrictions, consistent with the hypothesis that local laws may be more easily circumvented via traveling to nearby jurisdictions.[23]

Recall that we incorporate local flavor bans into our coding if they are from a "large" jurisdiction, which we define as 200,000 or more people. In Appendix Table 5, we show that our results are robust to using a population of 500,000 as the cutoff for including local bans.

[23] Additionally, we aimed to test the hypothesis that youths evade flavor bans by cross-border shopping at the state level by exploring whether youths living in a state with a ban are more likely to vape if border states do not have a ban. However, given the geographic clustering of flavor bans (shown in Figure 1), we found that there was insufficient identifying variation to disentangle own-state and border-state effects with meaningful precision. Regardless, we consider it unlikely that cross-state-border smuggling occurs on a large enough scale to meaningfully influence our main econometric estimates. This is because of both the large geographic size of states relative to localities and the fact that our main sample focuses on teens, who are more geographically constrained than adults.

Together, the above findings suggest that while ENDS flavor restrictions have relatively little effect on the extensive margin of youth ENDS use, these regulations generate a 1.3 to 2.5 percentage-point reduction in the probability of frequent and everyday ENDS use. This intended policy impact is consistent with the hypothesis that flavors play an important role in attracting teens to more habitual ENDS use. Moreover, from a public health perspective, more habitual use of ENDS is likely more harmful to health than light use of or experimentation with these products. While this finding could suggest a tobacco-related public health benefit of ENDS flavor restrictions, assessing spillovers to combustibles (and other substances) is necessary to more fully assess flavor restrictions overall health effects.

5.3 ENDS Flavor Restrictions and Combustible Tobacco Products

In Table 6, we explore the spillover effects of ENDS flavor restrictions on youth combustible tobacco use, including cigarette smoking (columns 1-5) and cigarette or cigar smoking (columns 6-10). Our findings in panel I provide only weak evidence of substitution effects from ENDS flavor restrictions with respect to cigarettes. Here, we find that the adoption of an ENDS flavor restriction is associated with a statistically insignificant (in the case of columns 1-4) or marginally significant (in the case of column 5) 0.7 to 1.9 percentage-point increase in the probability of prior-month cigarette use. Corresponding event-study estimates in Figure 3 are somewhat inconclusive but provide some support for increases in cigarette smoking that may occur with a lag. This result could suggest that some more frequent ENDS users who reduce ENDS use following flavor bans may substitute toward cigarettes, which have larger adverse respiratory, heart, and caner-related health effects relative to e-cigarettes (McNeill et al., 2018; National Academies of Sciences, 2017; Viscusi, 2016). Our findings provide little support for the hypothesis that ENDS flavor restrictions increase more habitual cigarette use (panels II and III, columns 1-5). When cigars are included (columns 6-10), there are some negative coefficient estimates on habitual use (panels II-III), but the pattern is not consistent and highly depends on specification choice, thus we interpret findings for cigar use with caution.

In Table 7, we explore whether ENDS flavor restrictions impact the probability of any ENDS or combustible cigarette use (column 1) or dual use of ENDS and cigarettes (columns 2-4). The pattern of findings suggests that ENDS flavor restrictions do not affect the probability of net current use of any tobacco product (column 1). Moreover, there is little evidence that flavor restrictions impact dual use of ENDS and combustible tobacco product use, even on the intensive

margin of use (columns 3-4). Only in the specification that includes region-by-year fixed effects is there some evidence that ENDS flavor restrictions are associated with a (marginally significant) 0.9 percentage-point reduction in the probability that a youth uses ENDS every day and is a current cigarette smoker (panel II, column 3). The pattern of findings is generally consistent with the hypothesis that ENDS flavor restrictions redistribute the type of tobacco product consumed (i.e., from ENDS to cigarettes) rather than generate large net reductions in youth tobacco product use.

Recall that the sample period for our main analyses is 2015-2021 to match the availability of survey questions on ENDS use. However, information on combustible tobacco use is available for a longer time period. In Appendix Table 7, we show that the estimated effects on use of combustibles remain similar if we use 2011-2021 as the sample period.

5.4 Disparities in Estimated Treatment Effects by Gender, Race/Ethnicity, Age, and Sexual Identity

In Figure 4, we explore heterogeneity in treatment effects across groups of youths, focusing on the margins of ENDS use (everyday use, panel I) and combustible cigarette use (current use, panel II) where we found the strongest evidence for first-stage effects for the average teenager. With respect to sex, we find that ENDS flavor restrictions significantly reduce everyday ENDS use among both male and female students, with little difference in estimated marginal effects. However, we find some evidence that ENDS flavor restrictions reduce everyday ENDS use more among Black and Hispanic (non-White) teenagers than Whites. This finding suggests that marginalized groups who have been historically targeted for addictive tobacco consumption by tobacco-producing firms appear to most affected (and protected) by ENDS flavor restrictions. Finally, the effect is somewhat larger among youths who identify as lesbian, gay, bisexual, or questioning (LGBQ) as compared to heterosexuals, but the large confidence interval surrounding the LGBQ estimate prevents a definitive conclusion.[24]

In panel (II), we explore whether ENDS flavor restrictions have heterogeneous effects on cigarette smoking. An important result is that we find little evidence that Black and Hispanic youth view combustible cigarettes as a substitute for ENDS products. This finding suggests that ENDS flavor restrictions likely generate little tobacco-related public health harm for these youths. For

[24] LGBQ youths are coded as those who identify as "gay or lesbian," "bisexual," "not sure," (after 2019) "I describe my sexual identity some other way," or "I do not know what this question is asking." Over this period, the YRBS data do not allow us to meaningfully explore heterogeneous impacts for others who identify as part of the larger LGBTQ+ community, including but not limited to transgender- or asexual-identifying persons).

others, however, particularly females and non-Hispanic White youths, we do find evidence that reductions in everyday ENDS use may lead to substitution toward combustible cigarettes.

Additionally, in Appendix Figure 3, we examine heterogeneity in estimated treatment effects for *Current ENDS Use*. Recall that we observed no evidence of an effect of flavor bans on the probability of any prior-month ENDS use. While this null result holds for most of the subgroups, there is one notable exception: a large reduction in the probability of any use among Black youths.

5.5 Spillovers to Non-Tobacco Related Health Behaviors: Use of Alcohol, Marijuana, and Cocaine

Recent evidence suggests that policies that restrict access to e-cigarettes may have important spillover effects on non-tobacco-related health outcomes (Dave, Liang, Maclean, Muratori, & Sabia, 2024; Dave, Liang, Maclean, Sabia, & Braaksma, 2024; Hansen et al., 2023). Thus, in Table 8, we examine the impact of ENDS flavor restrictions on non-tobacco-related health behaviors. Our results in columns 1-2 provide no evidence that the adoption of ENDS flavor restrictions affects the probability that a teenager binge drinks in the last month (columns 1 and 2). Using our estimate in column (1), we can rule out, with 95 percent confidence, reductions in prior-month binge drinking of less than 2.6 percentage-points (18.6 percent) and increases in prior-month binge drinking of greater than 1.4 percentage-points (9.9 percent).

Turning to marijuana (columns 3-4) and cocaine use (column 5-6), we also find no evidence that ENDS flavor restrictions generate important spillovers to substance use. Together, these results suggest that the general equilibrium effects of ENDS flavor restrictions are, at least in the shorter run, confined to the tobacco market.

5.6 Young Adults and Older Adults

The findings thus far have documented that ENDS flavor restrictions have both intended and, for some demographic groups, unintended effects on youth tobacco use. In Table 9, we draw data from the BRFSS to explore the effect of ENDS flavor restrictions on adult ENDS use (panels I-II) and combustible cigarette smoking (panels III-IV). Our results focus on young adults under age 21 (18-20) and ages 21 and older, reflecting the minimum legal purchasing age for tobacco products in the period following December 2019. A limitation of the BRFSS, for our study, is that relying on small sub-samples (such as young adults 18-20 years) rather than the full sample may not produce state-representative estimates, so we interpret the BRFSS results with some caution. Our findings suggest that ENDS flavor restrictions are negatively related to ENDS use for young adults aged 18-

20. Specifically, we find that adoption of an ENDS flavor restriction is associated with a three to five percentage-point (28 percent to 41 percent) reduction in prior-month ENDS use among 18-20-year-olds (columns 1-3). Event-study estimates of ENDS flavor restrictions and ENDS use among 18-20 -year-olds in panel (a) of Figure 5 are consistent with common pre-treatment trends and a post-policy decline in young adult current ENDS use. While the effect on everyday ENDS use (panel b) is negative and economically large, the estimated treatment effects are not statistically distinguishable from zero at conventional levels.

In contrast, we find little evidence that ENDS flavor restrictions affect ENDS use among adults aged 21 and older (columns 4-6). These null findings are consistent with evidence that flavored ENDS are more commonly consumed among youth and younger adults rather than older adults (Helgertz & Kingsbury, 2023; Marynak, 2018; Tsai, 2018; U.S. Department of Health and Human Services, 2016).

Turning to combustible cigarettes, we find that ENDS flavor restrictions may induce substitution to smoking among those aged 18-20. Specifically, we find that ENDS flavor restrictions are associated with a 2.4 to 2.6 percentage-point increase in prior-month cigarette smoking (all estimates statistically significant at the 1 percent level) and a 0.8 to 1.3 percentage-point increase in everyday smoking (two of the three estimates significant at the 10 percent level or better). This set of results points to important substitution effects of ENDS flavor restrictions to combustible cigarettes among those most likely to consume flavored ENDS (young adults). Event-study estimates in panels (c) and (d) are consistent with a causal interpretation of this substitution effect. Together with scientific evidence on the relative health-related harms of nicotine vaping and combustible cigarette smoking, this could suggest that ENDS flavor restrictions could generate net tobacco-related health harm for young adults. Finally, for adults aged 21 and older, there is little support for the hypothesis that ENDS flavor restrictions increases cigarette smoking, which is what we might expect without a first-stage ENDS use effect.

6. Conclusions

High rates of ENDS use among teenagers have prompted tobacco control advocates to identify potential causes of youth and young adult ENDS use and to explore policy strategies to curb consumption. One explanation for the popularity of e-cigarettes among teenagers is the wide availability of flavored e-cigarettes such as fruit, candy, mint, and menthol, which have particular appeal to youths. As of December 2023, nine states, D.C., and over 370 sub-state jurisdictions have

adopted restrictions on the sales of flavored ENDS. This study comprehensively explores (1) the effects of ENDS flavor restrictions on youth and young adult ENDS use, (2) the spillover effects of ENDS flavor restrictions on combustible tobacco use, and (3) the effects of ENDS flavor restrictions on non-tobacco related substance use such as alcohol, marijuana, and harder illicit drugs, which may be economic complements or substitutes for ENDS.

First, using data from the State and National Youth Risk Behavior Surveys, we find little evidence that ENDS flavor restrictions affect youth ENDS use on the extensive margin. However, we find stronger evidence that ENDS flavor restrictions reduce frequent or everyday youth ENDS use, suggesting an effect on the intensive margin. We find that adoption of an ENDS flavor restriction is associated with a 1.2 to 2.5 percentage-point decline in the probability of frequent and everyday ENDS use among teenagers, respectively. The effects on more habitual use are larger in absolute magnitude than on more experimental use, which could suggest experimental users may substitute to non-flavored e-cigarettes. Moreover, for adults under age 21 (aged 18-20), we also find that ENDS flavor restrictions reduce ENDS use propensities, on the order of three to as much as five percentage-points. For adults who have attained the minimum legal purchasing age for tobacco products (those aged 21 and older), we find little evidence that ENDS flavor restrictions reduce ENDS use, consistent with flavored ENDS being a less popular tobacco product for older adults, who are more likely to use ENDS as a smoking cessation tool.

Despite the above intended effect of the laws, we also find that ENDS flavor restrictions may also have an unintended tobacco-related public health cost. We demonstrate that adoption of a restriction is associated with a one to three percentage-point increase in the probability of combustible cigarette smoking. The magnitude of these spillover effects for youths and young adults, coupled with the large tobacco-related adverse health consequences of combustible tobacco use (Centers for Disease Control and Prevention, 2019, 2020), suggests that the tobacco-related health effects of ENDS flavor restrictions may be negative.

Our study has a number of limitations worthy of note. First, neither the YRBS nor the BRFSS data include information on flavored versus unflavored ENDS products, menthol cigarettes, or flavored cigars. We are only able to detect net effects on ENDS, cigarette, and cigar use. While flavors do not have independent effects on health (and affect health only through their ultimate effect on tobacco use), having data on flavored and unflavored tobacco products would offer us more ability to study the degree to which youth substitution to unflavored ENDS may result in a smaller net effect of ENDS flavor restrictions on youth ENDS use. Moreover, data on these

outcomes would allow one to compare estimated effects to those obtained in the flavored combustibles literature. Second, most of the statewide ENDS flavor restrictions (and many of the larger jurisdiction restrictions) were adopted during the period following the onset of the COVID-19 pandemic in the U.S. While we attempt to control for the heterogeneous impact of the pandemic across states to disentangle the effects of these policies from other health and economic shocks—including to changes in beliefs about the COVID-19-related risks associated with tobacco use, especially during the pre-vaccination period—we note that our estimated treatment effects could, in part, capture some residual unmeasured effects of the pandemic.

Third, the YRBS does not have sub-state local identifiers that would allow us to merge information on more localized (and smaller) jurisdiction policies. Research using more localized geocode data would have important value in this literature. Finally, ENDS flavor restrictions are relatively new, with the first state (Massachusetts) adopting this policy in just 2019. Thus, our estimated treatment effects should be interpreted as short-run effects on youth tobacco use among early adopting states over the period during which the COVID-19 pandemic began. Future research will be important in examining medium- and longer-run tobacco use effects in the post-COVID era, which could be especially important in exploring spillover effects to combustibles, alcohol, and marijuana, as addictive behaviors may take time to unfold.

Finally, the market has changed since our sample period due to the recent FDA marketing denial orders (MDOs) of tens of thousands of types of flavored e-cigarettes (Food and Drug Administration, 2023). Such orders are intended to remove these products from the market, but compliance and enforcement has been inconsistent, and flavored e-cigarettes are still widely available in states that do not have their own policies banning them (Noguchi, 2023). To the extent that these MDOs have reduced availability of flavored ENDS products, the effects of future state flavor bans may be somewhat smaller than those presented here. At the same time, though, our results provide useful information for ongoing questions about enforcement, as they shed light on the possible impacts of continuing to issue MDOs for all flavored products while also strengthening enforcement so that compliance improves. Moreover, our finding that bans on flavored ENDS products induce substitution toward combustible tobacco products for at least some groups, which could be seen as surprising since flavored cigarettes have been banned nationally since 2009, provides new information that may be relevant to future regulatory decisions.

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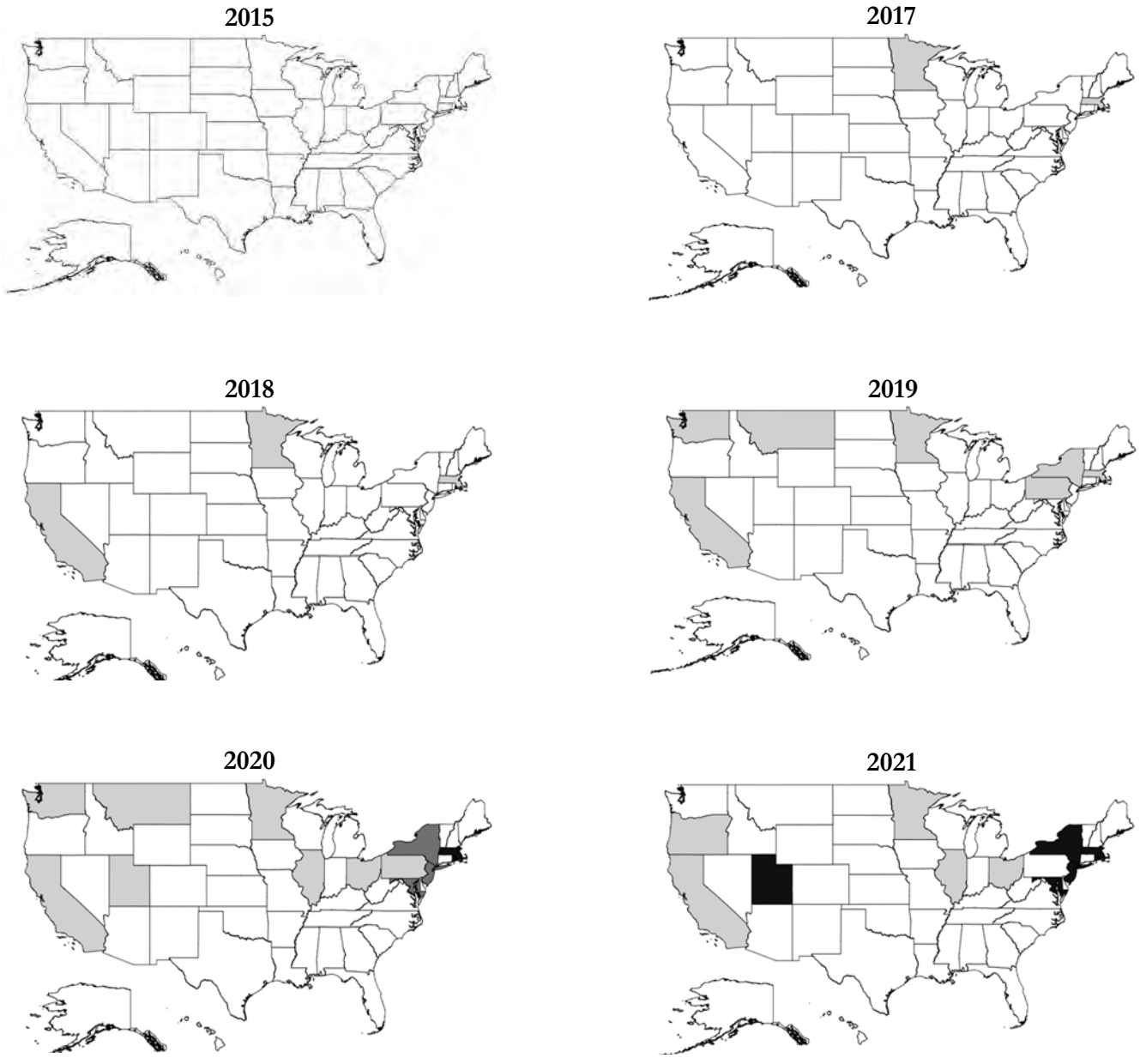
Figure 1. Geographic and Temporal Variation in Statewide and Large Jurisdiction (> 200,000 Population) ENDS Flavor Restrictions, 2015-2021

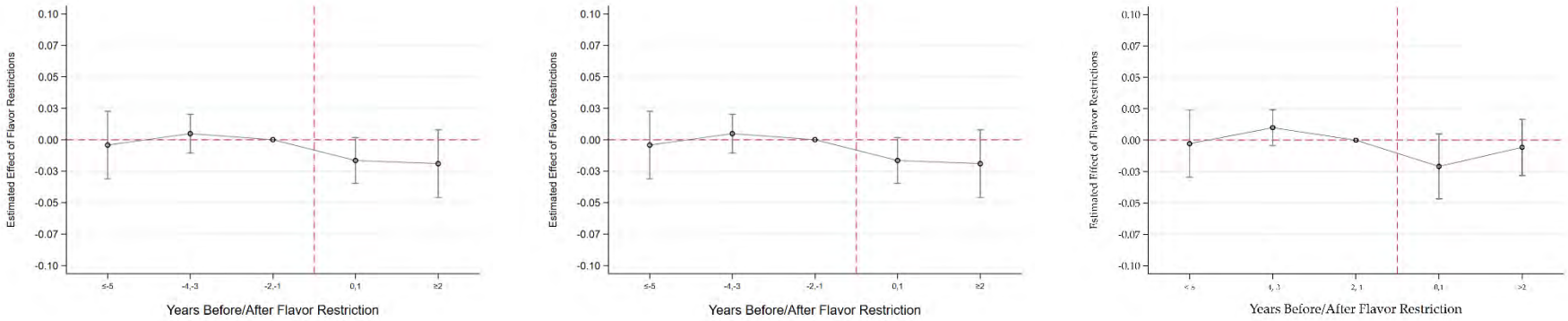


Notes: See Appendix Table 2 for details on the sources used to collect information on statewide and large jurisdiction (> 200,000 population) laws on ENDS flavor restrictions. Statewide bans exclude states with temporary emergency restrictions in place for less than one month.

Figure 2. Event-study Analysis of ENDS Flavor Restrictions and Habitual ENDS Use, Combined YRBS

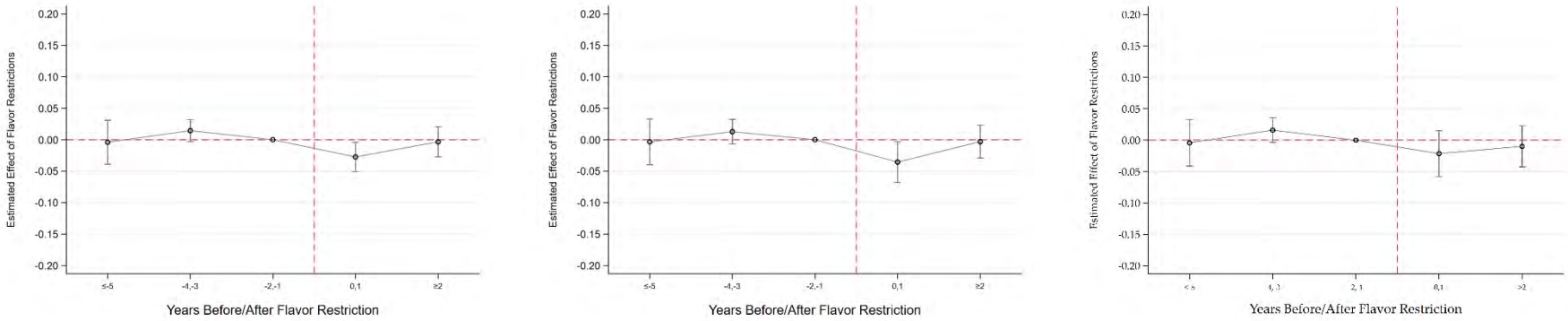
Panel I: Everyday ENDS Use

(a): Demographic Controls *(b): Demographic, Macro, and COVID Controls* *(c): LASSO Controls*



Panel II: Frequent ENDS Use

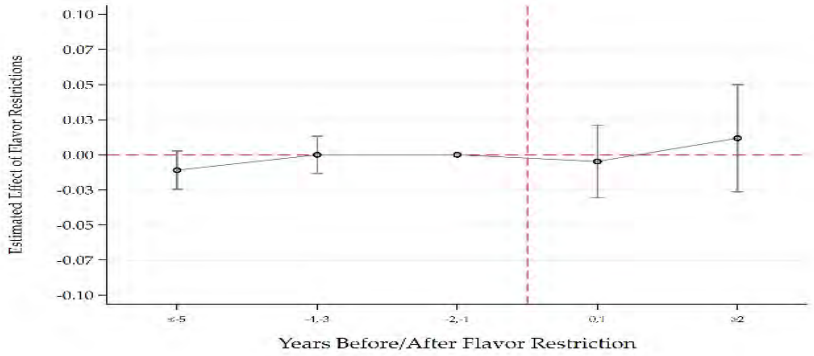
(a): Demographc Controls *(b): Demographic, Macro, and COVID Controls* *(c): LASSO Controls*



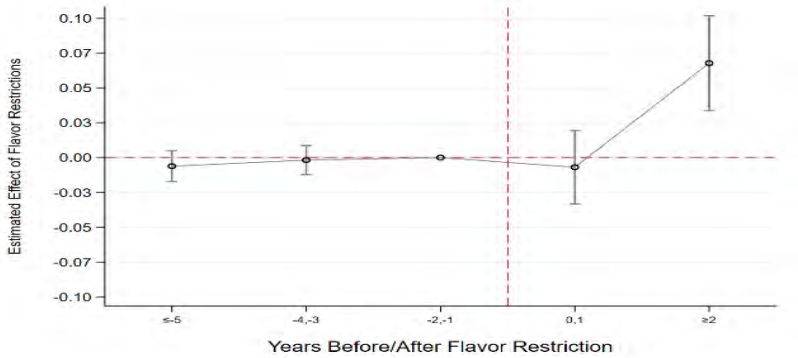
Notes: Estimates are obtained from weighted OLS regressions based on data from the 2015-2021 State and National Youth Risk Behavior Surveys. All regressions include fixed effects for state, semester, year, and dataset. In addition, event-study regression (a) includes demographic controls (age, race/ethnicity, grade, and gender). Column (b) includes demographic controls, the log of the unemployment rate, log of poverty rate, and cumulative state COVID-19 cases and death rates. The LASSO model adds controls for tobacco-21 laws, cigarette taxes, ENDS taxes, minimum legal sales age for ENDS, bans on online sales of ENDS and tobacco, ENDS and tobacco licensure laws, menthol cigarette restrictions, indoor smoking bans, beer taxes, and medical and recreational marijuana laws. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Figure 3. Event-study Analysis of END Flavor Restrictions and Current Cigarette Use, Combined YRBS

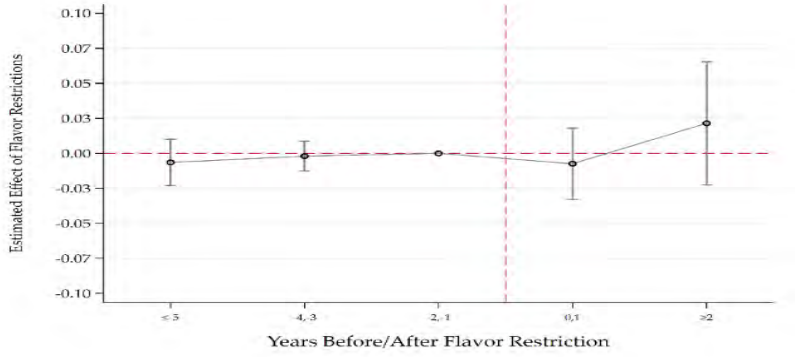
Panel I: OLS, LASSO Controls



Panel II: Demographics, Macroeconomic, and COVID Controls, Logistic Regression



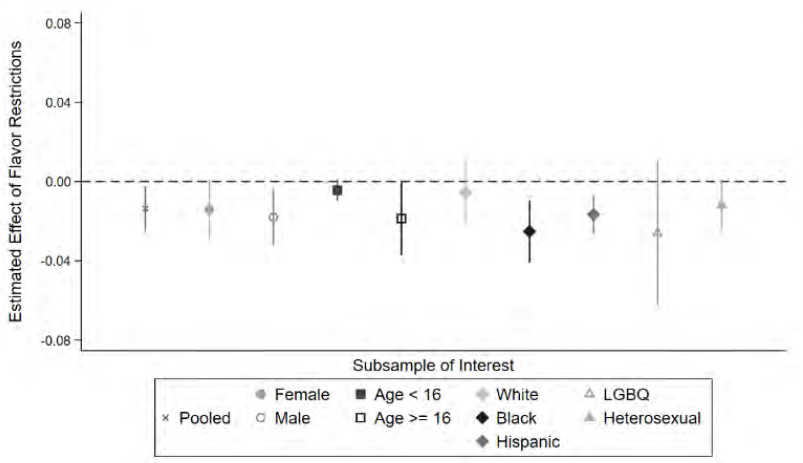
Panel III: LASSO Controls, Logistic Regression



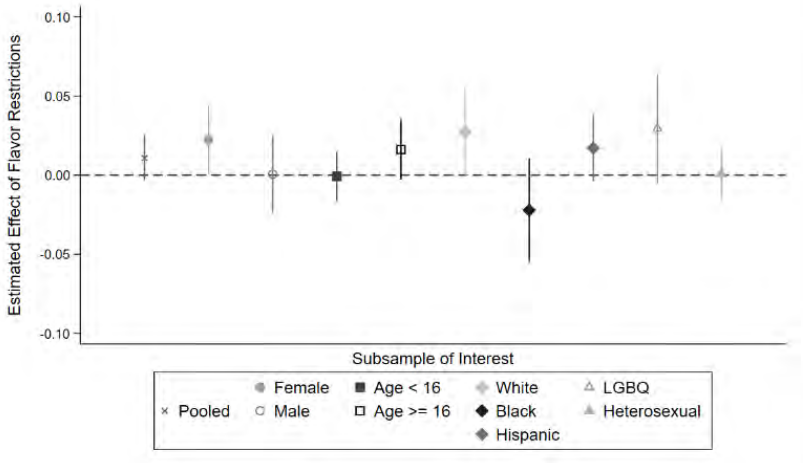
Notes: Estimated are obtained using weighted OLS and logit regressions with data from the 2015 to 2021 State and National Youth Risk Behavior Surveys. All regressions include fixed effects for state, semester, year, and dataset, as well as demographic, macroeconomic and COVID-19 controls; the LASSO selected variables include tobacco-21 laws, cigarette taxes, ENDS taxes, minimum legal sale age for ENDS, bans on online sales of ENDS and tobacco, ENDS and tobacco licensure laws, menthol cigarette restrictions, indoor smoking bans, beer taxes, and medical and recreational marijuana laws. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Figure 4. Heterogeneity in Effects of ENDS Flavor Restrictions on Everyday ENDS Use and Current Cigarette Use, Combined YRBS

Panel I: Everyday ENDS Use

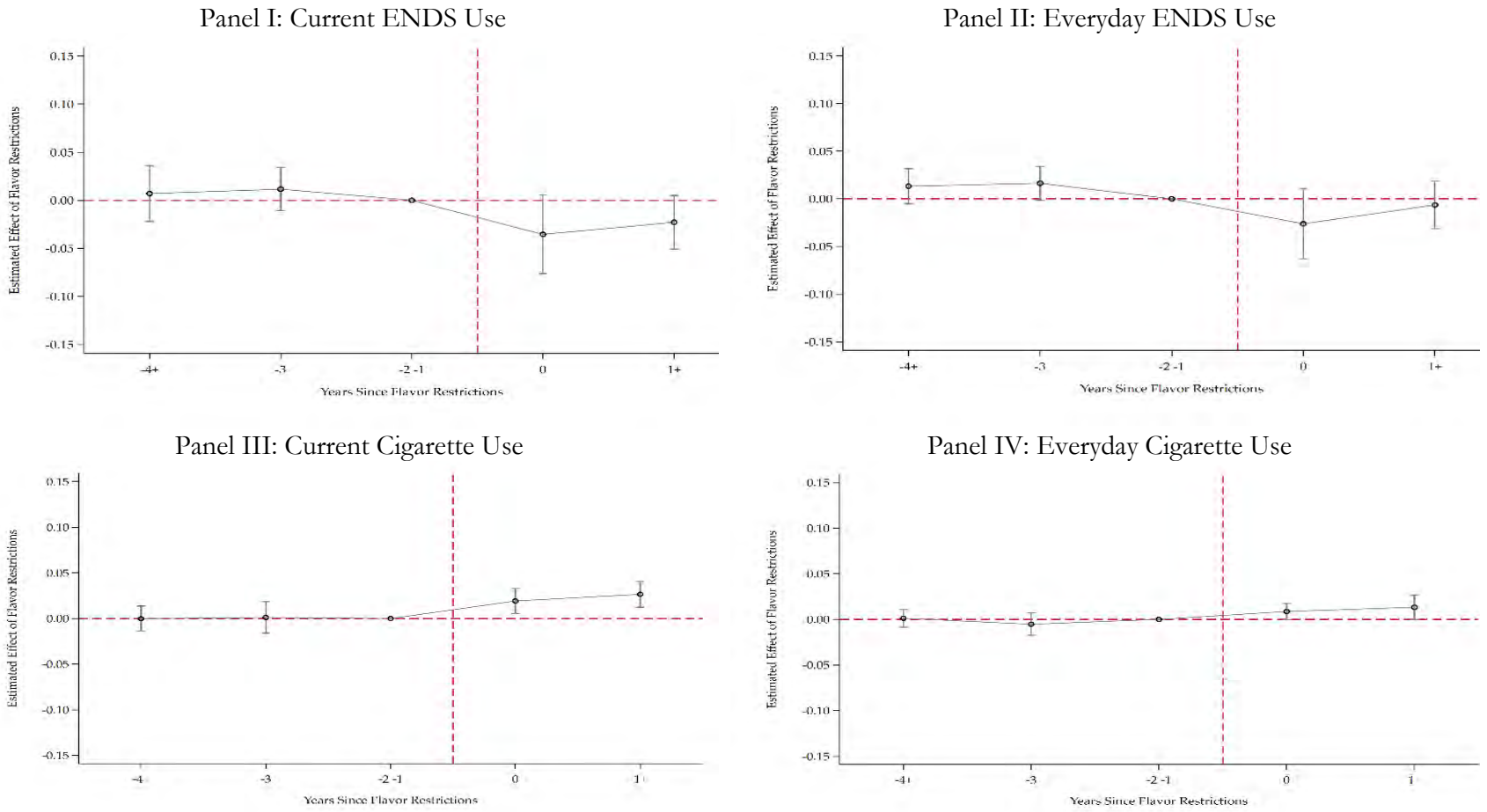


Panel II: Current Cigarette Use



Notes: Estimated average marginal effects are obtained using weighted logistic regression with data from the 2015 to 2021 State and National Youth Risk Behavior Surveys. All regressions include controls for state, semester, year and dataset fixed effects, individual demographic controls, economic controls, tobacco policy controls, and substance policy controls. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Figure 5. Event-study Estimates of ENDS Flavor Restrictions and Tobacco Use Among Those Aged 18-20, BRFSS



Notes: Estimates are generated using weighted least squares estimates using data from the Behavioral Risk Factor Surveillance Survey. ENDS outcomes rely on data from years 2016 to 2021 (though there are no data in 2019 and from 2020-2021 ENDS questions are queried in an optional module for states), and combustible cigarette outcomes are based on years 2015 to 2021. All models include state, year, and quarter fixed effects. The LASSO selected variables include demographic controls, log of unemployment rate, log of poverty rate, cumulative state COVID-19 case and death rate, cigarette taxes, ENDS taxes, minimum legal sale age for ENDS, ENDS and tobacco licensure laws, online sale bans for ENDS, menthol cigarette restrictions, indoor vaping restrictions, and medical marijuana laws.
Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Table 1. Estimates of the Effect of ENDS Flavor Restrictions on ENDS Use, Combined YRBS

	(1)	(2)	(3)	(4)	(5)
			Panel I: OLS Regression		
			(a) Current ENDS Use		
ENDS Flavor Restriction	-0.0095	-0.0100	-0.0042	-0.0006	-0.0113
	(0.0102)	(0.0189)	(0.0187)	(0.0198)	(0.0214)
Pre-Treatment Mean DV	*0.2128*	*0.2128*	*0.2128*	*0.2128*	*0.2128*
N	676563	676563	676563	676563	676563
			(b) Frequent ENDS Use		
ENDS Flavor Restriction	-0.0191*	-0.0245**	-0.0219*	-0.0186	-0.0200*
	(0.0095)	(0.0111)	(0.0122)	(0.0111)	(0.0101)
Pre-Treatment Mean DV	*0.0407*	*0.0407*	*0.0407*	*0.0407*	*0.0407*
N	676563	676563	676563	676563	676563
			(c) Everyday ENDS Use		
ENDS Flavor Restriction	-0.0167**	-0.0173**	-0.0172*	-0.0171*	-0.0165**
	(0.0065)	(0.0067)	(0.0100)	(0.0090)	(0.0072)
Pre-Treatment Mean DV	*0.0267*	*0.0267*	*0.0267*	*0.0267*	*0.0267*
N	676563	676563	676563	676563	676563
			Panel II: Logistic Regression		
			(a) Current ENDS Use		
ENDS Flavor Restriction	-0.0091	-0.0159	-0.0107	-0.0065	-0.0160
	(0.0100)	(0.0201)	(0.0196)	(0.0216)	(0.0228)
Pre-Treatment Mean DV	*0.2128*	*0.2128*	*0.2128*	*0.2128*	*0.2128*
N	676563	676563	676563	676563	676563
			(b) Frequent ENDS Use		
ENDS Flavor Restriction	-0.0130*	-0.0204**	-0.0205**	-0.0180*	-0.0186*
	(0.0075)	(0.0087)	(0.0096)	(0.0094)	(0.0095)
Pre-Treatment Mean DV	*0.0407*	*0.0407*	*0.0407*	*0.0407*	*0.0407*
N	676563	676563	676563	676563	676563
			(c) Everyday ENDS Use		
ENDS Flavor Restriction	-0.0120**	-0.0139**	-0.0131*	-0.0136**	-0.0129*
	(0.0054)	(0.0058)	(0.0072)	(0.0069)	(0.0068)
Pre-Treatment Mean DV	*0.0267*	*0.0267*	*0.0267*	*0.0267*	*0.0267*
N	676563	676563	676563	676563	676563
Control Variables:					
Demographic Controls?	Yes	Yes	Yes	Yes	Yes
Macroeconomic Controls?	No	Yes	Yes	Yes	Yes
COVID-19 Controls?	No	Yes	Yes	Yes	Yes
Tobacco Policy Controls?	No	No	Yes	Yes	Yes
Substance Policy Controls?	No	No	No	Yes	Yes
Double-selection LASSO	No	No	No	No	Yes

** p<.1, ** p<.05, *** p<.01*

Notes: Weighted estimates are generated using data from the 2015-2021 State and National Youth Risk Behavior Surveys. Panel I uses weighted OLS regression and panel II uses weighted logistic regression (reporting average marginal effects). All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 2. Sensitivity of Estimated Treatment Effects to Controls for Spatial Heterogeneity, Combined YRBS

	(1)	(2)	(3)
	Current ENDS Use	**Frequent ENDS Use**	**Everyday ENDS Use**
	Panel I: Baseline Estimates (Comparable to Column 4, Panel II, Table 1)		
ENDS Flavor Restriction	-0.0065	-0.0180*	-0.0136**
	(0.0216)	(0.0094)	(0.0069)
Pre-Treatment Mean DV	*0.2128*	*0.0407*	*0.0267*
N	676563	676563	676563
	Panel II: Census Region-by-Year (Year) Fixed Effects		
ENDS Flavor Restriction	0.0072	-0.0201	-0.0213**
	(0.0313)	(0.0129)	(0.0098)
Pre-Treatment Mean DV	*0.2128*	*0.0407*	*0.0267*
N	676563	676563	676563
	Panel III: Census Division-by-Year (Year) Fixed Effects		
ENDS Flavor Restriction	-0.0003	-0.0220*	-0.0228**
	(0.0272)	(0.0131)	(0.0111)
Pre-Treatment Mean DV	*0.2128*	*0.0407*	*0.0267*
N	676563	676563	676563
	Panel IV: Treatment State-Specific Linear Time Trends		
ENDS Flavor Restriction	-0.0402	-0.0209	-0.0162
	(0.0315)	(0.0151)	(0.0121)
Pre-Treatment Mean DV	*0.2128*	*0.0407*	*0.0267*
N	676563	676563	676563

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted logistic regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 3. Sensitivity of Estimated Treatment Effects to Use of Gardner Two-Step and Stacked DD Estimators, Combined YRBS

	(1)	(2)	(3)
	Baseline Logistic Estimate (Comparable to Column 4, Panel II, Table 1)	**Gardner Two-Step**	**Stacked DD**
	Panel I: Current ENDS Use		
ENDS Flavor Res.	-0.0069	-0.0079	-0.0287
	(0.0216)	(0.0294)	(0.0231)
Pre-Treatment Mean	*0.2128*	*0.2128*	*0.2117*
N	676563	676563	1527991
	Panel II: Frequent ENDS Use		
ENDS Flavor Res.	-0.0181*	-0.0145	-0.0224**
	(0.0094)	(0.0175)	(0.0097)
Pre-Treatment Mean	*0.0407*	*0.0407*	*0.0434*
N	676563	676563	1527991
	Panel III: Everyday ENDS Use		
ENDS Flavor Res.	-0.0136**	-0.0188*	-0.0181**
	(0.0069)	(0.0111)	(0.0079)
Pre-Treatment Mean DV	*0.0267*	*0.0267*	*0.0282*
N	676563	676563	1527991

** p<.1, ** p<.05, *** p<.01*

Notes: The estimates presented are marginal effects derived from weighted logistic regressions (column 1), two-step Gardner (column 2), stacked DD (column 3, employing never-adopters as counterfactuals) using data from the State and National Youth Risk Behavior Surveys spanning 2015 to 2021. All models include state, semester, year, and dataset fixed effects, as well as a set of full observable controls. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 4. Sensitivity of Estimated Treatment Effects to Separate Estimates in State and National YRBS

	(1)	(2)	(3)
	Current ENDS Use	**Frequent ENDS Use**	**Everyday ENDS Use**
		Panel I: Combined State and National YRBS	
ENDS Flavor Restriction	-0.0065	-0.0180*	-0.0136**
	(0.0216)	(0.0094)	(0.0069)
Pre-Treatment Mean DV	*0.2128*	*0.0407*	*0.0267*
N	676563	676563	676563
		Panel II: State YRBS	
ENDS Flavor Restriction	-0.0150	-0.0141**	-0.0136***
	(0.0197)	(0.0063)	(0.0047)
Pre-Treatment Mean DV	*0.1953*	*0.0376*	*0.0265*
N	622122	622122	622122
		Panel III: National YRBS	
ENDS Flavor Restriction	-0.0508	-0.0425**	-0.0344**
	(0.0451)	(0.0209)	(0.0149)
Pre-Treatment Mean DV	*0.2157*	*0.0449*	*0.0295*
N	54441	54441	54441

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted logistic regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, and year fixed effects; Panel I also includes a fixed effect for the dataset. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 5. Multinomial Logistic Regression Estimates of the Effects of ENDS Flavor Restrictions on Usual Sources of E-Cigarettes

	(1)	(2)	(3)	(4)
	Retail	**Internet**	**Social Sources**	**Other**
ENDS Flavor Restrictions	0.0001	-0.0050	-0.0187	-0.0056
	(0.0066)	(0.0033)	(0.0130)	(0.0045)
Pre-Treatment Mean DV	*0.0380*	*0.0074*	*0.1217*	*0.0228*
N	412007	412007	412007	412007

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from a weighted multinomial logit using data from the 2017-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 6. The Effect of ENDS Flavor Restriction on Combustible Tobacco Use, Combined YRBS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Cigarette Use					**Cigarette or Cigar Use**				
						Panel I: Current Use				
ENDS Flavor Restriction	0.0090	0.0055	0.0110	0.0074	0.0191*	0.0146	0.0110	0.0127	0.0214**	0.0181
	(0.0080)	(0.0085)	(0.0087)	(0.0079)	(0.0105)	(0.0096)	(0.0107)	(0.0107)	(0.0103)	(0.0128)
Pre-Treatment Mean DV	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.0758*	*0.1059*	*0.1059*	*0.1059*	*0.1059*	*0.1059*
N	716481	716481	716481	716481	716481	622014	622014	622014	622014	622014
						Panel II: Frequent Use				
ENDS Flavor Restriction	-0.0041	-0.0054	-0.0108	-0.0104	0.0002	-0.0062	-0.0069	-0.0175**	-0.0131	-0.0004
	(0.0061)	(0.0060)	(0.0066)	(0.0068)	(0.0069)	(0.0079)	(0.0123)	(0.0078)	(0.0087)	(0.0092)
Pre-Treatment Mean DV	*0.0214*	*0.0214*	*0.0214*	*0.0214*	*0.0214*	*0.0270*	*0.0270*	*0.0270*	*0.0270*	*0.0270*
N	716481	716481	716481	716481	716481	622014	622014	622014	622014	622014
						Panel III: Everyday Use				
ENDS Flavor Restriction	-0.0023	-0.0031	-0.0073	-0.0092*	0.0020	-0.0054	-0.0061	-0.0136**	-0.0123*	0.0022
	(0.0057)	(0.0056)	(0.0058)	(0.0052)	(0.0058)	(0.0072)	(0.0074)	(0.0068)	(0.0066)	(0.0081)
Pre-Treatment Mean DV	*0.0158*	*0.0158*	*0.0158*	*0.0158*	*0.0158*	*0.0195*	*0.0195*	*0.0195*	*0.0195*	*0.0195*
N	716481	716481	716481	716481	716481	622014	622014	622014	622014	622014
Control Variables:										
Observable Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Double-Selection LASSO	No	Yes	No	Yes	No	No	No	No	Yes	No
Census Region-by-Year FE?	No	No	No	No	Yes	No	Yes	No	No	Yes
Specification	OLS	OLS	Logit	Logit	Logit	OLS	OLS	Logit	Logit	Logit

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted OLS (columns 1,2,6,7) or logistic (columns 3,4,5,7,8,9) regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Observable controls include demographic, macroeconomic, COVID-19, tobacco policy, and alcohol and marijuana policy controls. The LASSO selected variables include demographic controls, log of unemployment rate, log of poverty rate, cumulative state COVID-19 case and death rate, tobacco-21 laws, cigarette taxes, ENDS taxes, minimum legal sale age for ENDS, ENDS and tobacco licensure laws, online sale bans for ENDS and tobacco, menthol cigarette restrictions, indoor smoking restrictions, beer taxes, medical and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 7. Exploration of Effects of Flavor Restriction on Any and Dual Use of Tobacco Products, Combined YRBS

	(1)	(2)	(3)	(4)
	Any ENDS or Cigarette Use	**Dual ENDS and Cigarette Use**	**Everyday ENDS Use and Any Cigarette Use**	**Everyday ENDS Use and Everyday Cigarette Use**
		Panel I: Baseline Specification		
ENDS Flavor Restriction	-0.0005	0.0004	-0.0023	-0.0009
	(0.0215)	(0.0053)	(0.0033)	(0.0020)
Pre-Treat. Mean of DV	*0.2255*	*0.0572*	*0.0114*	*0.0037*
N	648458	648458	648458	648458
	Panel II: Panel I + Census Region-by-Year (Year) FE			
ENDS Flavor Restriction	0.0253	-0.0008	-0.0091**	-0.0009
	(0.0321)	(0.0079)	(0.0044)	(0.0028)
Pre-Treat. Mean of DV	*0.2255*	*0.0572*	*0.0114*	*0.0037*
N	648458	648458	648458	648458

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted logistic regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Table 8. The Effect of ENDS Flavor Restriction on Alcohol and Substance Use, Using OLS and Logit Estimates, 2015-2021, Combined YRBS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Binge Drinking			**Marijuana Use**			**Cocaine Use**		
ENDS Flavor Restriction	0.0075	0.0059	0.0111	-0.0039	-0.0088	0.0059	0.0020	-0.0061	-0.0060
	(0.0078)	(0.0096)	(0.0148)	(0.0135)	(0.0142)	(0.0204)	(0.0070)	(0.0059)	(0.0076)
Pre-Treatment Mean DV	*0.1470*	*0.1470*	*0.1470*	*0.2007*	*0.2007*	*0.2007*	*0.0431*	*0.0431*	*0.0431*
N	662385	662385	662385	724916	724916	724916	622347	622347	622347
Control Variables:									
Observable Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Region-by-Year FE?	No	No	Yes	No	No	Yes	No	No	Yes
Specification	OLS	Logit	Logit	OLS	Logit	Logit	OLS	Logit	Logit

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted OLS (columns 1, 4, and 7) or logistic (columns 2,3,5,6,8,9) regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, and any ENDS licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

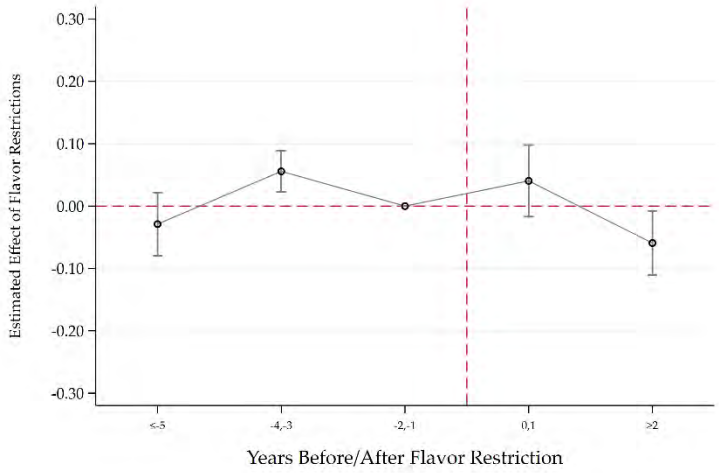
Table 9. Exploring Effects of ENDS Flavor Restrictions on Adult Tobacco Use, BRFSS

	(1)	(2)	(3)	(4)	(5)	(6)
	Aged 18-20			**Aged 21+**		
	Panel I: Current ENDS Use					
ENDS Flavor Restriction	-0.033**	-0.036*	-0.048**	-0.006	-0.002	-0.0002
	(0.014)	(0.019)	(0.019)	(0.004)	(0.003)	(0.003)
Pre-Treatment Mean DV	*0.116*	*0.116*	*0.116*	*0.041*	*0.041*	*0.041*
N	38086	38086	38086	1548893	1548893	1548893
	Panel II: Everyday ENDS Use					
ENDS Flavor Restriction	-0.021	-0.025	-0.034	-0.004	-0.001	0.001
	(0.013)	(0.020)	(0.021)	(0.002)	(0.002)	(0.001)
Pre-Treatment Mean DV	*0.037*	*0.037*	*0.037*	*0.015*	*0.015*	*0.015*
N	38086	38086	38086	1548891	1548891	1548891
	Panel III: Current Cigarette Use					
ENDS Flavor Restriction	0.024***	0.026***	0.024***	-.0006*	-0.005	-0.009**
	(0.007)	(0.010)	(0.005)	(0.003)	(0.004)	(0.004)
Pre-Treatment Mean DV	*0.069*	*0.069*	*0.069*	*0.141*	*0.141*	*0.141*
N	68902	68902	68902	2875370	2875370	2875370
	Panel IV: Everyday Cigarette Use					
ENDS Flavor Restriction	0.012*	0.008	0.013**	-0.004	-0.003	-0.006
	(0.007)	(0.007)	(0.005)	(0.003)	(0.003)	(0.004)
Pre-Treatment Mean DV	*0.036*	*0.036*	*0.036*	*0.096*	*0.096*	*0.096*
N	68902	68902	68902	2875370	2875370	2875370
Specification	OLS	OLS	Logit	OLS	OLS	Logit
Control Variables:						
Observable Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Region-by-Year Fixed Effects?	No	Yes	Yes	No	Yes	Yes

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are generated using weighted OLS regression (columns 1,2,4,5) and weighted logistic regression (columns 3 and 6) using data from the Behavioral Risk Factor Surveillance Survey. ENDS outcomes rely on data from years 2016 to 2021 (there is no data in 2019 and from 2020-2021 ENDS questions are included in an optional module that states must select), and combustible cigarette outcomes are based on years 2015 to 2021. All models include state, year, and quarter fixed effects. Demographic controls include gender, age, education, and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, and any ENDS licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

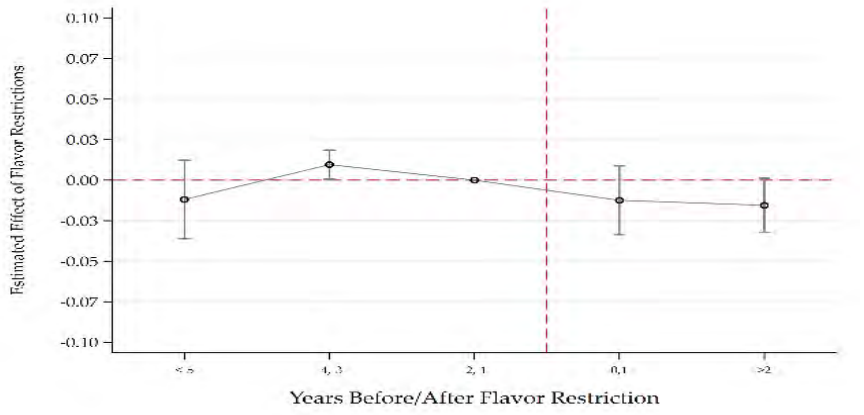
Appendix Figure 1. Logit Event-study Analysis of ENDS Flavor Restrictions and Current ENDS Use, Combined YRBS



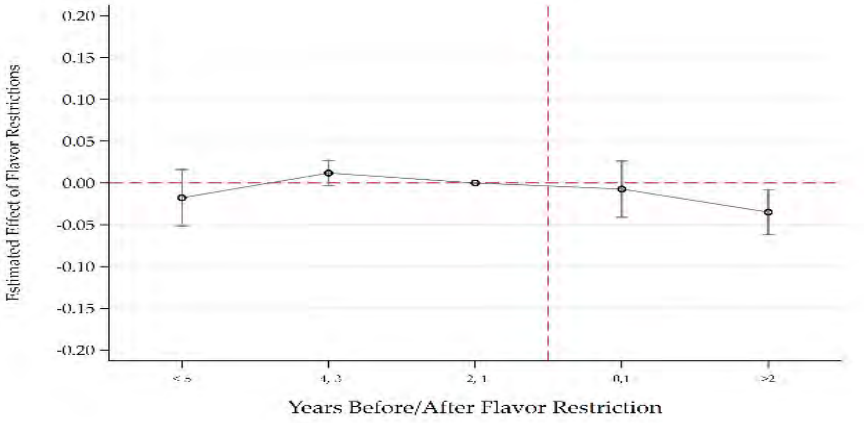
Notes: Estimates are obtained from double-selection LASSO regressions based on data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include fixed effects for state, semester, year, and dataset. In addition, event-study regression includes demographic controls, the log of the unemployment rate, log of poverty rate, and cumulative state COVID-19 cases and death rates and the LASSO selected controls for tobacco-21 laws, cigarette taxes, ENDS taxes, minimum legal sale age for ENDS, bans on online sales of ENDS and tobacco, ENDS and tobacco licensure laws, menthol cigarette restrictions, indoor smoking bans, beer taxes, and medical and recreational marijuana laws. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Appendix Figure 2. Logit Event-study Analysis of ENDS Flavor Restrictions and Habitual ENDS Use

Panel I: Everyday ENDS Use

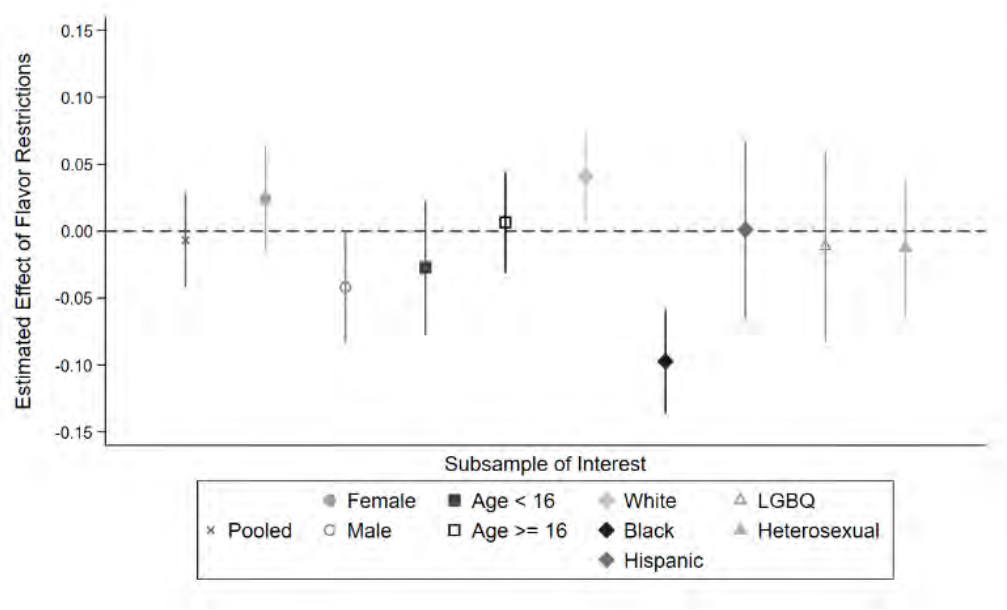


Panel II: Frequent ENDS Use



Notes: Estimates are obtained from weighted logistic regressions based on data from the 2015-2021 State and National Youth Risk Behavior Surveys. Event-study analyses are based on parsimonious specifications, including state, semester, year, and dataset fixed effects, and demographic controls. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Appendix Figure 3. Heterogeneity in Effects of ENDS Flavor Restrictions on Current ENDS Use, Combined YRBS



Notes: Estimated average marginal effects are obtained using weighted logistic regression with data from the 2015 to 2021 State and National Youth Risk Behavior Surveys. All regressions include controls for state, semester, year, and dataset fixed effects; individual demographic controls; economic controls; tobacco policy controls; and substance policy controls. Coefficient estimates reported with circles. Vertical lines show the 90 percent confidence intervals that account for within-state clustering.

Appendix Table 1A. Summary Statistics, YRBS, 2015-2021

	Combined YRBS	State YRBS	National YRBS
Outcome Variables			
*ENDS Use**			
Current	0.205	0.192	0.220
	[N=676563]	[N=622122]	[N=54441]
Frequent	0.057	0.051	0.060
	[N=676563]	[N=622122]	[N=54441]
Everyday	0.040	0.036	0.041
	[N=676563]	[N=622122]	[N=54441]
Cigarette Use			
Current	0.071	0.066	0.072
	[N=716481]	[N=660524]	[N=55957]
Frequent	0.018	0.016	0.019
	[N=716481]	[N=660524]	[N=55957]
Everyday	0.014	0.012	0.014
	[N=716481]	[N=660524]	[N=55957]
Cigarette or Cigar Use			
Current	0.098	0.092	0.099
	[N=622014]	[N=568422]	[N=53592]
Frequent	0.023	0.021	0.024
	[N=622014]	[N=568422]	[N=53592]
Everyday	0.017	0.015	0.017
	[N=622014]	[N=568422]	[N=53592]
ENDS Sources (2017-2021)			
Retail	0.044	0.035	0.040
	[N=412007]	[N=376520]	[N=35487]
Internet	0.005	0.006	0.007
	[N=412007]	[N=376520]	[N=35487]
Social	0.111	0.107	0.133
	[N=412007]	[N=376520]	[N=35487]
Other	0.028	0.028	0.030
	[N=412007]	[N=376520]	[N=35487]
Other Substances			
Current Binge Drinking	0.136	0.124	0.139
	[N=662385]	[N=611540]	[N=50845]
Current Marijuana Use	0.188	0.181	0.196
	[N=724916]	[N=667793]	[N=57123]
Ever Use Cocaine	0.042	0.043	0.038
	[N=622347]	[N=569717]	[N=52630]
Individual Characteristics			
Female	0.489	0.494	0.494
Grade			
9th	0.297	0.267	0.268

	Combined YRBS	State YRBS	National YRBS
10th	0.207	0.256	0.255
11th	0.207	0.242	0.242
Age			
≤12	0.002	0.002	0.002
13	0.003	0.002	0.001
14	0.192	0.136	0.134
15	0.201	0.252	0.252
16	0.201	0.254	0.252
17	0.201	0.235	0.240
≥18	0.200	0.118	0.118
Race			
White, non-Hispanic	0.540	0.494	0.525
Black, non-Hispanic	0.148	0.154	0.129
Hispanic	0.245	0.253	0.202
Independent Variables			
ENDS Policies			
Flavored ENDS Restriction	0.045	0.041	0.041
	(0.188)	(0.189)	(0.173)
ENDS Tax (2021 $)	0.314	0.232	0.461
	(0.665)	(0.515)	(0.839)
ENDS MLSA Law	0.907	0.925	0.899
	(0.290)	(0.263)	(0.301)
ENDS Licensure Law	0.329	0.307	0.369
	(0.469)	(0.460)	(0.481)
Clear Indoor Vaping Law	0.253	0.220	0.246
	(0.434)	(0.413)	(0.430)
Online ENDS Sales Ban	0.022	0.020	0.019
	(0.145)	(0.139)	(0.135)
Tobacco Policies			
Cigarette Tax (2021 $)	1.905	1.836	2.015
	(1.172)	(1.177)	(1.109)
Tobacco-21 Law	0.358	0.350	0.356
	(0.479)	(0.477)	(0.479)
Tobacco Licensure Law	0.771	0.734	0.814
	(0.420)	(0.442)	(0.389)
Clear Indoor Smoking Law	0.687	0.683	0.770
	(0.463)	(0.464)	(0.421)
Online Tobacco Sales Ban	0.219	0.187	0.223
	(0.414)	(0.390)	(0.417)
Menthol Cigarette Restriction	0.011	0.001	0.013
	(0.075)	(0.006)	(0.077)
Other Substance Policies			
Beer Tax (2021 $)	0.335	0.328	0.306
	(0.306)	(0.294)	(0.285)

	Combined YRBS	State YRBS	National YRBS
Recreational Marijuana Law	0.230	0.193	0.227
	(0.420)	(0.394)	(0.419)
Medical Marijuana Law	0.613	0.603	0.687
	(0.487)	(0.489)	(0.462)
Covid Controls			
Cumulative COVID-19 Case Rate	0.038	0.036	0.039
	(0.064)	(0.063)	(0.065)
Cumulative COVID-19 Death Rate	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
Economic Controls			
Log Unemployment Rate	1.512	1.495	1.523
	(0.230)	(0.233)	(0.233)
Log Poverty Rate	2.467	2.470	2.415
	(0.227)	(0.223)	(0.246)
N	752635	694230	58405

Notes: Data are weighted by the combined weights in the Combined YRBS and by CDC-provided weights in the State and National YRBS. ENDS Sources related outcomes available in the 2017 YRBS onwards

Appendix Table 1B. Summary Statistics, BRFSS

	Mean	Std. Dev.	N
ENDS and Cigarette Use			
Current ENDS Use, Aged 18-20	.17	.376	38108
Everyday ENDS Use, Aged 18-20	.063	.242	38108
Current Cigarette Use, Aged 18-20	.108	.31	107034
Everyday Cigarette Use, Aged 18-20	.064	.245	107034
Current ENDS Use, Aged 21+	.039	.193	1549832
Everyday ENDS Use, Aged 21+	.016	.124	1549830
Current Cigarette Use, Aged 21+	.147	.354	4730115
Everyday Cigarette Use, Aged 21+	.106	.307	4730115
Demographic Characteristics			
Female	.569	.495	4892389
Age	55.101	17.407	4890266
Black	.08	.271	4893850
White	.767	.423	4893850
Hispanic	.07	.256	4893850
No High School	.076	.265	4893851
Some College	.274	.446	4893851
College Grad or More	.367	.482	4893851

Notes: ENDS variables are from the 2016-2021 (ENDS data are not available in 2019, and are only available in an optional module in 2020-2021) years of the Behavioral Risk Factor Surveillance System (BRFSS). Data are weighted by BRFSS-provided weights. Combustible cigarette and demographic characteristics use data from 2015 to 2021 waves of the BRFSS.

Appendix Table 2. Flavored ENDS and Menthol Cigarette Restrictions Effective Dates and Sources, 2015-2021

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
District/State			
District of Columbia	9/22/2021	9/22/2021	https://code.dccouncil.gov/us/dc/council/laws/24-25#percentC2percentA72(h)
[1]Maryland	2/6/2020		https://marylandtaxes.gov/forms/Tax_Publications/Tax_Bulletins/Tobacco_Tax_Bulletins/bl_tt77.pdf
[3]Massachusetts	9/24/2019	6/1/2020	https://malegislature.gov/Laws/SessionLaws/Acts/2019/Chapter133 https://www.mass.gov/doc/english-ban-on-e-cigarettes-and-vaping-products/download https://www.publichealthlawcenter.org/resources/states-and-tribes-stepping-protect-communities-dangers-e-cigarettes-actions-and-options
Montana	12/18/2019-4/16/2020		https://www.publichealthlawcenter.org/resources/states-and-tribes-stepping-protect-communities-dangers-e-cigarettes-actions-and-options https://rules.mt.gov/gateway/ShowNoticeFile.asp?TID=9416 https://pub-missoula.escribemeetings.com/filestream.ashx?DocumentId=15318 https://web.archive.org/web/20200101195931/https://dphhs.mt.gov/Portals/85/publichealth/documents/Tobacco/ECigarettes/OpinionOrderTemporaryRestrainingOrder101819DISSOLVED.pdf
[3]New Jersey	4/20/2020		2019 NJ Sess. Law Serv. Ch. 425 (SENATE 3265) (WEST)
[2]New York	5/18/2020		https://www.nysenate.gov/legislation/laws/PBH/1399-MM-1
[2]Rhode Island	10/4/2019		https://rules.sos.ri.gov/Regulations/part/216-50-15-6?reg_id=10881
[2]Utah	7/1/2020		https://le.utah.gov/xcode/Title76/Chapter10/76-10-S113.html?v=C76-10-S113_2020051220200701 https://le.utah.gov/xcode/Title76/Chapter10/76-10-S101.html?v=C76-10-S101_2020051220200701 https://le.utah.gov/~2020/bills/static/HB0023.html
Washington	10/10/2019-2/8/2020		http://opb-imgserve-production.s3-website-us-west-2.amazonaws.com/original/2019-10-21_petition_for_declaratory_and_injunctive_relief_1571695786362.pdf https://sboh.wa.gov/sites/default/files/2022-01/Tab08h-Emergencyrulevaporflavors-FINAL.pdf

Appendix Table 2, Continued

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
County/City			
[3]Fremont, CA	11/8/2019	11/8/2019	https://www.codepublishing.com/CA/Fremont/#!/Fremont08/Fremont0875.html https://web.archive.org/web/20191217182615/https://www.fremont.gov/DocumentCenter/View/42782/FAQs-for-Tobacco-Retail-License-Program
[3]Glendale, CA	5/27/2021	5/27/2021	https://www.glendaleca.gov/government/departments/tobacco-and-vaping-products https://www.glendaleca.gov/home/showpublisheddocument/63120/637604925749570000
[3]Long Beach, CA	1/4/2020-1/4/2021, 5/15/2021-4/27/2023	1/4/2020-1/4/2021, 5/15/2021-4/27/2023	https://library.municode.com/ca/long_beach/codes/municipal_code?nodeId=TIT5REBUTRPR_CH5.81TOREPE_5.81.010DE https://library.municode.com/ca/long_beach/ordinances/municipal_code?nodeId=992864 https://library.municode.com/ca/long_beach/ordinances/municipal_code?nodeId=1080961 https://library.municode.com/ca/long_beach/ordinances/municipal_code?nodeId=1208298
[1]Oakland, CA	7/1/2018	7/1/2018	https://library.municode.com/ca/oakland/ordinances/code_of_ordinances?nodeId=854090
[3]Oxnard, CA	1/17/2020	1/17/2020	https://www.oxnard.org/wp-content/uploads/2020/02/Tobacco-Ordinance-2973.pdf#page=4
[3]Sacramento, CA	10/1/2019	10/1/2019	https://www.cityofsacramento.org/-/media/Corporate/Files/CDD/Code-Compliance/Business/Tobacco-FAQ-Final.pdf https://sacramento.granicus.com/MetaViewer.php?view_id=22&clip_id=4379&meta_id=551581
[1]San Francisco, CA	7/21/2018	7/21/2018	https://www.sfdph.org/dph/EH/Tobacco/flavoredtobacco.asp https://tobacco.ucsf.edu/how-san-francisco-successfully-implemented-its-comprehensive-flavor-ban-tobacco-products

Appendix Table 2, Continued

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
[3]San Jose, CA	11/5/2021	11/5/2021	https://www.sanjoseca.gov/Home/Components/News/News/4244/4699#:~:text=(Junepercent2023percent2Cpercent202022)percent20percentE2percent80percent93,inpercent20thepercent20Tobaccopercent20Retailpercent20Ordinance. https://vaping360.com/vape-news/111355/san-jose-prohibits-flavored-vape-and-tobacco-products/ https://sanjose.legistar.com/MeetingDetail.aspx?ID=890210&GUID=55D3BDC5-ECBE-4962-8CCD-6C84992CB15D&Options=&Search= https://records.sanjoseca.gov/Ordinances/ORD30675.pdf
[3]Los Angeles County, CA	10/31/2019	10/31/2019	http://publichealth.lacounty.gov/tob/tobaccoretail.htm https://file.lacounty.gov/SDSInter/bos/supdocs/140919.pdf https://library.municode.com/ca/los_angeles_county/codes/code_of_ordinances?nodeId=TIT11HESA_DIV1HECO_CH11.35TORE
[3]San Diego County, CA	2/27/2020	2/27/2020	https://www.publichealthlawcenter.org/sites/default/files/case/RJR-v-San-Diego-County-Complaint.pdf https://codelibrary.amlegal.com/codes/san_diego/latest/sandiego_regs/0-0-0-100330 https://www.sandiegocounty.gov/content/dam/sdc/hhsa/programs/phs/MCFHS/TCRP/TRLpercent204percent20Informationalpercent20PowerPoint.pdf https://www.publichealthlawcenter.org/litigation-tracker/rj-reynolds-v-county-san-diego-2020#:~:text=Thispercent20casepercent20ispercent20yetpercent20another,thepercent20restrictionpercent20exemptedpercent20hookahpercent20tobacco.
[1]Chicago, IL	9/9/2020		https://www.chicago.gov/city/en/depts/cdph/provdrs/healthy_living/news/2020/september/city-council-passes-ordinance-banning-the-sale-of-flavored-vapin.html https://occprodstoragev1.blob.core.usgovcloudapi.net/lsmatterattachmentspublic/c00d0158-d2d1-4571-85e9-e5e32e2c24cb.pdf https://chicityclerkelms.chicago.gov/Matter/?matterId=86959BEC-E10D-ED11-82E3-001DD80693B4#

Appendix Table 2, Continued

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
Montgomery County, MD	7/3/2020		https://codelibrary.amlegal.com/codes/montgomerycounty/latest/montgomeryco_md/0-0-0-132738#JD_24-16 https://apps.montgomerycountymd.gov/ccllims/DownloadFilePage?FileName=2630_1_10595_Bill_32-19_Signed_20200403.pdf
[3]Boston, MA	2/15/2016		https://www.boston.gov/sites/default/files/file/2021/05/Tobaccopercent20Controlpercent20Youthpercent20Accesspercent20Regulationpercent20Aspercent20Amendedpercent2011percent2025percent202019.pdf https://www.boston.gov/sites/default/files/file/2021/05/Youthpercent20Accesspercent20Regulationpercent20Guidelinespercent20-percent20Revisedpercent207percent2010percent2020.pdf#page=8 https://www.bigcitieshealth.org/front-lines-blog-innovative-policies-to-reduce-tobacco-use-in-big-cities-boston/ https://www.boston.gov/sites/default/files/file/2021/03/2019percent20Tobaccopercent20Controlpercent20Youthpercent20Accesspercent20Regulationpercent20Proposedpercent20Amendments.pdf
[3]Worcester, MA	1/1/2019		https://www.worcesterma.gov/uploads/67/3d/673dd6983143254b543f6bdfca714ca6/cigar-flavored-tobacco-regulations.pdf#page=3
[3]Minneapolis, MN	1/1/2016	8/1/2018	https://library.municode.com/mn/minneapolis/codes/code_of_ordinances?nodeId=COOR_TIT13LIBURE_CH281TODE_281.45RESATOPR https://library.municode.com/mn/minneapolis/ordinances/code_of_ordinances?nodeId=725808 https://library.municode.com/mn/minneapolis/ordinances/code_of_ordinances?nodeId=844233
[3]St. Paul, MN	4/5/2016	11/1/2018	https://library.municode.com/mn/st._paul/codes/code_of_ordinances?nodeId=PTIILECO_TITXXIXLI_CH324TO_S324.03DE https://www.ansrmn.org/issues-resources/flavored-tobacco/ https://stpaul.legistar.com/LegislationDetail.aspx?ID=2505190&GUID=B46BFAE3-7386-42CE-A440-96CB41EA804B&Options=&Search=&FullText=1 https://www.centerforpreventionmn.com/wp-

content/uploads/2020/02/Implementing-Menthol-Tob-Restrictions.pdf

Appendix Table 2, Continued

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
Jersey City, NJ	3/3/2020		https://cityofjerseycity.civicweb.net/document/15292/Ordinancepercent20banningpercent20thepercent20salepercent20and_orpercent20distributionpercent20.pdf?handle=EB5A6EFCC87F41228FDD6FF8FBB4773F#page=2
Hempstead, NY	4/12/2021		https://ecode360.com/32323351 https://hempsteadny.gov/AgendaCenter/Search/?term=&CIDs=7,2,&startDate=&endDate=01/01/2022&dateRange=&dateSelector= https://publications.aap.org/view-large/figure/8758592/PEDS_2021051223_f1.tif https://ecode360.com/15522915#15522915
Nassau County, NY	1/1/2020		https://www.nassaucountyny.gov/DocumentCenter/View/17813/Administrative-Code-as-of-January-15-2021?bidId=#page=293 https://www.nassaucountyny.gov/DocumentCenter/View/27806/Local-Law-29-2019?bidId=
New York, NY	7/1/2020		https://codelibrary.amlegal.com/codes/newyorkcity/latest/NYCadmin/0-0-0-128646
Yonkers, NY	10/1/2019		https://ecode360.com/YO0144/laws/LF1134624.pdf#page=2
[3]Toledo, OH	1/10/2020		https://codelibrary.amlegal.com/codes/toledo/latest/toledo_oh/0-0-0-159628 https://nbc24.com/news/local/toledo-city-council-approves-ban-on-pre-filled-flavored-vaping-cartridges
[3]Washington County, OR	12/2/2021-9/19/2022	12/2/2021-9/19/2022	https://www.opb.org/article/2021/11/02/washington-county-first-in-oregon-to-ban-sale-of-flavored-tobacco-products/ https://www.washingtoncountyor.gov/public-health/flavor-ban-ordinance-878 https://library.municode.com/or/washington_county/ordinances/code_of_ordinances?nodeId=1116493 https://assets.tobaccofreekids.org/content/what_we_do/federal_issues/federal-court-cases/Schwartz-v-Washington-County-Washington-

County-Circuit-Court/2022.09.19-Order-in-Schwartz-et-al-v-Washington-County.pdf

Appendix Table 2, Continued

Locality	Flavored E-Cigarette Restrictions	Menthol Cigarette Restrictions	Source
Philadelphia, PA	12/18/2019-11/13/2020		https://codelibrary.amlegal.com/codes/philadelphia/latest/philadelphia_pa/0-0-0-277740#JD_9-638 https://www.govinfo.gov/content/pkg/USCOURTS-paed-2_20-cv-03220/pdf/USCOURTS-paed-2_20-cv-03220-1.pdf

Notes: There were four (4) other occasions where a state enacted a statewide ENDS restriction (Michigan in October 2019; New York in September 2019; Oregon in October 2019; and Utah in October 2019) via emergency decree, but these laws were in effect for less than one month. These four state events are not counted as meaningful ENDS flavor restriction in the context of our analysis given the lack of consistent high frequency tobacco use data.

[+] CA SB 793 was originally intended to go into effect on January 1, 2021. However, following the passage of a petition, the legislation was subjected to a referendum, appearing as Proposition 31 in the 2022 ballot. SB 793 finally passed again and went into effect December 21, 2022. In addition, on October 8, 2019, the City of Santa Clarita, CA adopted a 45-day moratorium on the sale of e-cigarette products that only applied to new tobacco retailers; it was extended by 10 months on November 12, 2019, and further extended on September 22, 2020, to be in effect for an additional year or until California Senate Bill 793 went into effect, whichever came first.

[1]States that contribute to identification in the combined YRBS.
[2]States that contribute to identification in the state YRBS.
[3]States that contribute to identification in the national YRBS.

[*]Additional sources for all jurisdictions:
https://www.publichealthlawcenter.org/sites/default/files/resources/US-sales-restrictions-flavored-tobacco-products.pdf
https://assets.tobaccofreekids.org/factsheets/0398.pdf

Appendix Table 3. Effect of ENDS Flavor Restrictions on Conditional ENDS Use, Combined YRBS

	(1)	(2)	(3)	(4)
	Panel II: Frequent ENDS Use | Current ENDS Use			
ENDS Flavor Restriction	-0.0574	-0.0812**	-0.1028***	-0.0983***
	(0.0418)	(0.0389)	(0.0299)	(0.0330)
Pre-Treatment Mean DV	*0.1913*	*0.1913*	*0.1913*	*0.1913*
N	138305	138305	138305	138305
	Panel III: Everyday ENDS Use | Current ENDS Use			
ENDS Flavor Restriction	-0.0488**	-0.0505***	-0.0616**	-0.0682***
	(0.0221)	(0.0180)	(0.0256)	(0.0264)
Pre-Treatment Mean DV	*0.1253*	*0.1253*	*0.1253*	*0.1253*
N	138305	138305	138305	138305
Control Variables:				
Demographic Controls?	Yes	Yes	Yes	Yes
Macroeconomic Controls?	No	Yes	Yes	Yes
COVID-19 Controls?	No	Yes	Yes	Yes
Tobacco Policy Controls?	No	No	Yes	Yes
Substance Policy Controls?	No	No	No	Yes

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted logistic regressions using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, and any ENDS licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Appendix Table 4. Sensitivity of YRBS Estimates to Heterogeneous Treatment Effects by State vs. Large Jurisdiction of ENDS Flavor Restriction

	Panel I: Current ENDS Use				
Sub-State (Local) ENDS	-0.1428	-0.0410	0.0248	0.0795	-0.1428
Flavor Restriction	(0.1849)	(0.1635)	(0.0817)	(0.0782)	(0.1849)
Statewide ENDS Flavor Restriction	-0.0104	-0.0159	-0.0088	-0.0024	-0.0104
	(0.0101)	(0.0198)	(0.0190)	(0.0208)	(0.0101)
Pre-Treatment Mean DV	*0.2128*	*0.2128*	*0.2128*	*0.2128*	*0.2128*
N	676563	676563	676563	676563	676563
	Panel II: Frequent ENDS Use				
Sub-State (Local) ENDS	0.0046	0.0374	0.0310	0.0770	0.0046
Flavor Restriction	(0.0727)	(0.0901)	(0.0866)	(0.0912)	(0.0727)
Statewide ENDS Flavor Restriction	-0.0127	-0.0200**	-0.0210**	-0.0158	-0.0127
	(0.0081)	(0.0093)	(0.0107)	(0.0103)	(0.0081)
Pre-Treatment Mean DV	*0.0407*	*0.0407*	*0.0407*	*0.0407*	*0.0407*
N	676563	676563	676563	676563	676563
	Panel III: Everyday ENDS Use				
Sub-State (Local) ENDS	-0.0172	0.0237	0.0543	0.0776	-0.0172
Flavor Restriction	(0.0593)	(0.0658)	(0.0595)	(0.0660)	(0.0593)
Statewide ENDS Flavor Restriction	-0.0121**	-0.0136**	-0.0145*	-0.0124*	-0.0121**
	(0.0055)	(0.0059)	(0.0079)	(0.0074)	(0.0055)
Pre-Treatment Mean DV	*0.0267*	*0.0267*	*0.0267*	*0.0267*	*0.0267*
N	676563	676563	676563	676563	676563
Control Variables:					
Demographic Controls?	Yes	Yes	Yes	Yes	Yes
Macroeconomic Controls?	No	Yes	Yes	Yes	Yes
COVID-19 Controls?	No	Yes	Yes	Yes	Yes
Tobacco Policy Controls?	No	No	Yes	Yes	Yes
Substance Policy Controls?	No	No	No	Yes	Yes
Double-selection LASSO	No	No	No	No	Yes

** p<.1, ** p<.05, *** p<.01*

Notes: Weighted logistic regression estimates (reporting average marginal effects) are generated using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Appendix Table 5. Sensitivity Analysis of Estimates of the Effect of ENDS Flavor Restrictions on ENDS Use, Utilizing 500,000 Population Cutoff to Define Flavor Restrictions for Large Jurisdictions

	(1)	(2)	(3)	(4)
		(a) Current ENDS Use		
ENDS Flavor Restriction	-0.0090	-0.0175	-0.0141	-0.0104
	(0.0097)	(0.0197)	(0.0194)	(0.0217)
Pre-Treatment Mean DV	0.2039	0.2039	0.2039	0.2039
N	676563	676563	676563	676563
		(b) Frequent ENDS Use		
ENDS Flavor Restriction	-0.0142*	-0.0228***	-0.0237**	-0.0217**
	(0.0074)	(0.0087)	(0.0097)	(0.0097)
Pre-Treatment Mean DV	0.0397	0.0397	0.0397	0.0397
N	676563	676563	676563	676563
		(c) Everyday ENDS Use		
ENDS Flavor Restriction	-0.0128**	-0.0156**	-0.0152**	-0.0161**
	(0.0057)	(0.0061)	(0.0073)	(0.0071)
Pre-Treatment Mean DV	0.0271	0.0271	0.0271	0.0271
N	676563	676563	676563	676563

** p<.1, ** p<.05, *** p<.01*

Notes: Weighted logit estimates (reporting average marginal effects) are generated using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, online sale bans for ENDS and tobacco, and ENDS and tobacco licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.

Appendix Table 6. Sensitivity of Logit Estimates of the Effect of ENDS Flavor Restriction on Combustible Tobacco Use (Marginal Effects) to Use of 2011-2021 Sample Period, YRBS

	(1)	(2)	(3)	(4)
	Cigarette Use		**Cigarette or Cigar Use**	
ENDS Flavor Restriction	0.0334***	0.0289***	0.0348***	0.0309***
	(0.0087)	(0.0084)	(0.0098)	(0.0098)
Pre-Treatment Mean DV	*0.1061*	*0.1061*	*0.1397*	*0.1397*
N	1009906	1009906	868590	868590
Control Variables:				
Observable Controls?	Yes	Yes	Yes	Yes
Census Region-by-Year FE?	No	Yes	No	Yes

** p<.1, ** p<.05, *** p<.01*

Notes: Estimates are marginal effects generated from weighted logits using data from the 2015-2021 State and National Youth Risk Behavior Surveys. All models include state, semester, year, and dataset fixed effects. Demographic controls include gender, age, grade and race dummies. Macroeconomic and COVID-19 controls include the log of unemployment rate, log of poverty rate, cumulative state COVID-19 death and case rate. Tobacco policy controls include tobacco-21 laws, cigarette taxes, any tobacco licensure laws, indoor smoking restrictions, menthol cigarette restrictions, ENDS taxes, minimum legal sale age laws for ENDS, indoor vaping restrictions, and any ENDS licensure laws. Alcohol and marijuana policy controls include the state beer taxes, medical marijuana laws, and recreational marijuana laws. Standard errors adjusted to account for clustering at the state level are reported in parentheses.