NBER WORKING PAPER SERIES

DO STATE TOBACCO 21 LAWS WORK?

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Working Paper 28173
http://www.nber.org/papers/w28173

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 2020

Dr. Sabia acknowledges research support from the Center for Health Economics and Policy Studies (CHEPS) at San Diego State University, including grant funding received from the Troesh Family Foundation and the Charles Koch Foundation. We thank Rahi Abouk and session participants at the 2020 Southern Economic Association meetings for useful comments and suggestions on an earlier draft of this paper. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 28173
December 2020
JEL No. I12,I18,K42

ABSTRACT

Tobacco 21 (T-21) laws prohibit the sale of tobacco products to individuals under age 21. This study is the first to comprehensively examine the impacts of statewide T-21 laws on youth tobacco consumption, including spillovers to minor teens. Using data from the 2009-2019 Behavioral Risk Factor Surveillance Survey (BRFSS) and a difference-in-differences approach, we find that the enactment of a statewide T-21 law was associated with a 2.5 to 4.0 percentage-point decline in smoking participation among 18-to-20-year-olds. A causal interpretation of our estimates is supported by event-study analyses and falsification tests for young adults ages 21 and older. Next, using data from the 2009-2019 State Youth Risky Behavior Surveys (YRBS), we find that statewide T-21 laws reduced tobacco cigarette and electronic cigarette (e-cigarette) consumption among 18-year-old high school students. We also find that the public health benefits of T-21 laws extend to 16-to-17-year-olds, a group that relies heavily on the "social market" — including 18-year-old peers — to access tobacco. We conclude increasing the minimum legal purchasing age for tobacco to 21 appears to be a more effective current policy strategy to deter youth smoking than raising cigarette taxes.

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1. Introduction

> *"We should do everything we can to prevent young people from smoking and save lives. Increasing the tobacco age to 21 will help achieve these goals… Increasing the tobacco age to 21 [will also] reduce the likelihood that a high school student will be able to legally purchase tobacco products for other students and underage friends."*
>
> - Campaign for Tobacco-Free Kids (2020)

Tobacco use is the leading cause of preventable death in the United States, responsible for over 480,000 deaths each year (Centers for Disease Control and Prevention 2019). Its consumption has been linked to increased risk of heart disease, cancers of the lung, liver, head, and colon, diminished respiratory function, and stroke (U.S. Department of Health and Human Services 2014). The social costs of tobacco consumption are substantial, with estimates of the annual health care costs of treating tobacco-related illnesses totaling $199 billion (2019$) (Hall and Doran 2016), and estimates of the external costs of smoking — driven by exposure to secondhand, or even thirdhand, tobacco smoke — exceeding $7 billion (USDHHS 2014).[1]

The vast majority of adult smokers initiate tobacco use as minors (Everett 1999; Gilliland 2006), with the mean age of smoking initiation at 15.3 (CDC 2014). Given that youth smokers (i) may have time-inconsistent preferences that cause them to give insufficient weight to future costs of addiction (Crettez and Deloche 2020), (ii) often fail to account for the external costs of smoking when choosing current consumption (O'Donoghue and Rabin 2001), and (iii) typically obtain tobacco products via the informal social market (Hansen et al. 2013), policymakers have often targeted anti-smoking campaigns at youths (Lantz et al 2000).

[1] The Department of Health and Human Services (2014) reports an estimate of $5.6B in 2006$, which we adjust with the CPI to $7.1B in 2019$. The Hall and Doran (2016) report tobacco-related illness treatment costs of $170B in 2010$, which we adjust to $199B in 2019$.

Anti-smoking efforts of the 1990s and 2000s typically included increases in state cigarette excise taxes (Hansen et al. 2017, Carpenter and Cook 2008), enactment of clean indoor air laws (Chaloupka and Eriksen 2008), and restrictions or bans on tobacco advertising (Schroeder 2004). While these policies were largely successful in achieving their intended ends (CDC 2012), there is growing evidence that policy instruments may be less effective than they once were. For example, post-2007 increases in state excise taxes on cigarettes have had very little effect on adult and youth tobacco use (Anderson et al. 2020; Callison and Kaestner 2014; Carpenter and Simone 2020; Hansen et al. 2017).[2] This may be because today's marginal smoker is less price sensitive than the marginal smoker of prior decades, in part due to the success of prior tobacco control efforts (Hansen et al. 2017). Younger smokers may also be partially insulated from tobacco control policies because they rely on older peers for access to cigarettes via third-party purchases or bumming cigarettes (Hansen et al. 2013).

Finally, electronic cigarettes (e-cigarette) have rapidly emerged as an alternative nicotine source to traditional cigarettes for an increasing number of teenagers (Creamer et al. 2019; Cullen et al. 2019; Centers for Disease Control and Prevention; 2019). The wide availability of e-cigarettes has caused policymakers to play "catch-up" in regulating this fast-emerging market (Huang et al. 2019: Jankowski et al. 2017) through enactment of minimum legal purchasing ages for e-cigarettes (Friedman 2015; Abouk and Adams 2017), e-cigarette taxes (Cotti et al. 2020; Pesko et al. 2019), and bans on e-cigarette advertising (Dave et al. 2019). However, by changing relative prices of e-cigarettes and "traditional" tobacco cigarettes, such strategies may also have

[2] This is despite the increase variation in cigarette taxes in later years which should make identifying cigarette tax elasticities easier than before (Lillard et al. 2013). This may be because anti-smoking policies of prior decades were effective at removing those with relatively elastic cigarette demand for from the market, leaving only "hard core smokers" whose smoking behavior is far more difficult to change through tax increases (Courtemanche and Feng 2019; Hansen et al. 2017).

unintended consequences, including substitution toward cigarettes (Dave et al. 2019; Pesko et al. 2020; Friedman 2015), which may generate worse health outcomes (Viscusi 2016).

In an attempt to more comprehensively limit youth access to tobacco — which could generate large health benefits by preventing long-run nicotine addiction — tobacco control advocates prioritized advancing Tobacco 21 (T-21) laws. T-21 laws raise the minimum legal purchasing age (MLPA) for *all* tobacco products, including e-cigarettes, to 21.[3] These laws enjoy the support of the American Medical Association (Parks 2016), the American Academy of Pediatrics (AAP 2015), the American Public Health Association (Lowry 2019), the Institutes of Medicine (National Academy of Medicine 2015), the American Heart Association (AHA 2019), the American Cancer Society (ACS 2020), and the American Lung Association (ALA 2020). T-21 laws also enjoy support among the vast majority of the American public, including smokers. Seventy-four percent of U.S. adults, including 64 percent of current smokers and 74 percent of former smokers, support raising the MLPA for all tobacco products to 21 (Gallup 2019).

Most adult smokers began experimenting with cigarettes prior to age 14 (Centers for Disease Control and Prevention 2020). However, the period between age 18 and 20 appears to be a critical window on the path of addiction. While only 46 percent of adult smokers become everyday smokers prior to age 18, nearly 80 percent do so prior to age 21 (USDHHS 2014). Delaying the age at which a youth transitions from experimental or sporadic tobacco consumption to more frequent use may reduce the risk of everyday use and increase successful quitting attempts (Khudar et al. 1999). Thus, statewide T-21 laws may postpone tobacco

[3] The 1992 Synar Amendment set the Federal minimum legal age of access to 18 years. By 1993, all states had changed their minimum legal sales age to 18 or 19 years (Alabama, Alaska, and Utah; New Jersey raised their MLPA to 19 in 2005).

exposure to age groups that are particularly vulnerable to the addictive effects of nicotine (Bonnie 2015).

While a number of municipalities have experimented with minimum legal purchasing ages for tobacco of 19 and 21 (American Non-Smokers' Rights Foundation 2020), the localized nature of these mandates allows young adults a relatively low cost means of circumventing these laws by traveling to a nearby jurisdiction without such mandates (Friedman and Wu 2019). Statewide mandates were introduced, in part, to reduce such spillovers. Hawaii became the first state to implement a statewide T-21 law on January 1, 2016.[4] California soon followed on July 9, 2016, followed by 15 additional states by December 19, 2019.[5] On December 20, 2019, President Donald J. Trump signed the "Tobacco to 21 Act," which created an MLPA of 21 for all tobacco products sold nationwide. While the Federal T-21 law was largely a triumph for tobacco control policy, many public health experts remained alarmed that the legislation failed to regulate the sale of flavored vaping products (Howard 2019).

Proponents of T-21 laws have argued that these mandates will generate substantial public health benefits. The National Academy of Medicine (2015) forecast that a national T-21 law would result in "approximately 223,000 fewer premature deaths, 50,000 fewer deaths from lung cancer, and 4.2 million fewer years of life lost for those born between 2000 and 2019." These public health benefits may arise not only by reducing direct access to tobacco products among 18-20-year-olds, but also by drying up the informal "social market" on which minor teens heavily rely for access to tobacco products. For instance, Hansen et al. (2013) document that 77

[4] Needham, Massachusetts was the first town to enact a T-21 law (Reynolds 2019), followed by over 540 cities and counties (Preventing Teen Addiction 2020).

[5] New Jersey enacted a statewide Tobacco 21 law in 2017; Oregon, Maine, and Massachusetts enacted such laws in 2018, and Virginia, Illinois, Delaware, Arkansas, Washington, Maryland, Vermont, Texas, Connecticut, New York, and Ohio enacted in 2019. The Federal law raising the MLPA to 21 was signed into law on December 20, 2019.

percent of 16-to-17-year-old smokers obtain their cigarettes via the social market (i.e., third-party purchase, bumming or borrowing, stealing, or some other way).[6] Many third-party purchasers and tobacco lenders (i.e., those who allow minors to "bum" a cigarette or "borrow" a vaping pen) may be 18-year-old peers (Ahmad 2005; Chen 2014; Hansen et al. 2013).[7] Local, state, and federal policymakers have explicitly argued that T-21 policy is an important tool to reduce minor teenagers' access to tobacco, especially e-cigarettes. For instance, Senate Majority Leader Mitch McConnell (R-KY) stated:

> *"The most serious threat involves the use of vaping devices for teens under 18 years old. Far too often, 18-year-olds, who are still in high school and can legally buy vaping devices, are sharing them with their younger classmates and the problem isn't only high schoolers. In 2018, there was a nearly 50% increase of middle school students vaping throughout the country. Raising the age limit to 21 presents fewer opportunities for children to get their hands on vaping devices."*
>
> - Senator Mitch McConnell (2019)

In addition to reducing minors' access to the informal social market, T-21 laws are expected to reduce the likelihood that minor teens who initiate smoking will be able to falsely identify themselves as meeting the MLPA (Delnovo and Steinberg 2013). Finally, by requiring a common MLPA for all tobacco products, T-21 laws avoid the unintended consequence of inducing substitution between traditional cigarettes and e-cigarettes.

On the other hand, opponents of T-21 laws argue that such mandates will be ineffective in deterring youth tobacco use (Males 2016) and would impose limits on individuals'

[6] This number is reported from the 1995-2009 State Youth Risk Behavior Surveys (Hansen et al. 2013).
[7] Moreover, because many 18-year-olds attend high school with minors, reducing smoking among 18-year-olds could generate positive spillover effects to minors via behavioral role-modeling (Everett, 1999; Azagba et al., 2015).

consumption freedoms (Bergal 2017). They argue that at age 18 an American can vote, go to war, be responsible for contracts, and be tried as an adult in a court of law; thus, 18-to-20-year-olds should be trusted to make tobacco consumption decisions (Stroud 2016).[8] In addition, some opponents argue that T-21 laws would have adverse fiscal consequences by reducing state tobacco tax revenues (Bergal 2015) and have adverse distributional effects by causing disproportionate profit losses for locally owned small convenience stores (Mensik 2018).[9]

This study is the first to comprehensively examine the impact of statewide T-21 laws adopted nationwide on youth and young adult smoking. First, using data from the 2009-2019 Behavioral Risk Factor Surveillance Survey (BRFSS) and a difference-in-differences approach, we find that the enactment of a T-21 law led to a 4.0 percentage-point decline in prior 30-day smoking participation among 18-to-20-year-olds. A number of descriptive tests of the common trends assumption — including event-study analyses, falsification tests among young adults ages 21 and older, and difference-in-difference-and-differences models that control for full state-by-year interactions — provide support for a causal interpretation of these findings. Supplemental evidence also suggests that T-21 laws have reduced electronic cigarette use among 18-to-20-year-olds, suggesting that these laws reduce consumption of multiple types of tobacco products.

Our results uncover substantial heterogeneity in the effects of T-21 laws by respondent's demographic and socioeconomic characteristics. We find T-21 laws have a larger bite on smoking behavior for (i) 18-year-olds as compared to 19-to-20-year-olds, (ii) males as compared

[8] Moreover, some opponents argue that because tobacco use does not generate cross-state travel-related externalities of young adult alcohol use (i.e., drunk driving-related accidents), tobacco should be less regulated (Stroud 2016).
[9] In 1986, a Phillip Morris strategy brief stated "[R]aising the legal minimum age for cigarette purchaser to 21 could gut our key young adult market (17-20) where we sell about 25 billion cigarettes and enjoy a 70 percent market share" (Morris 1986). However, tobacco companies did support T-21 perhaps to avoid regulation of flavored tobacoo products (Myers 2019).

to females, (iii) African Americans as compared to whites, and (iv) high school dropouts as compared to with a high school degree or more (or who were still attending high school).

Next, turning to the 2009-2019 State Youth Risky Behavior Surveys (YRBS), we find that T-21 laws are associated with a 3.9 percentage-point reduction in tobacco cigarette use among 18-year-old high school students, and a 13.7 percentage-point decline in electronic cigarette use among 18-year-old high school students. Importantly, we find that T-21 laws appear to reduce tobacco cigarette use among 16-to-17-year-old high school students, an age group that often relies on 18-year-olds for "social sources" of tobacco (i.e. borrowing/bumming, third-party purchase). Moreover, we also present early descriptive evidence on how T-21 laws appear to disrupt the sources teens use for e-cigarettes, reducing access to social markets for 16-17-year-old males and decreasing direct purchase for 18 year-olds (these questions on social sources were only recently asked in 2017/2019). Finally, we find that 13-to-15-year-olds, who have fewer social ties to 18-year-olds, are largely unaffected by T-21 laws. Together, our findings suggest that statewide T-21 laws substantially reduce tobacco consumption among young adults and older minor teenagers. Given mounting evidence that modern cigarette tax increases have become less effective in curbing youth and young adult smoking (Hansen et al. 2017; Carpenter and Simone 2020), our findings point to a potentially more effective modern tobacco control policy.

2. Background

Tobacco control legislation — including tobacco taxes and minimum legal purchasing ages — has long been a subject of debate amongst U.S. policymakers, dating back well before the Surgeon General's 1964 warning of the adverse health effects of tobacco consumption. The

first federal excise tax was proposed on "snuff" products in 1791 by Alexander Hamilton (Ali and Koplan 2010), cigarette taxes were first levied in 1864 (Smith 1914). By 1921, 5 states had completely banned the sale of cigarettes, beginning with South Dakota in 1895 (Alston et al. 2002).[10]

In 1883, New Jersey became the first state to enact a law that established a minimum legal purchasing age for tobacco (MLPA), setting it at sixteen (16) years old (Appolonio and Glants 2016). Three years later, New York followed suit and established an MLPA for tobacco purchasing and consumption of 16 (Appolonio and Glants 2016). As concerns over children smoking grew nationwide, 26 states established an MLPA for tobacco by 1890, with those restrictions ranging between 14 to 24 years old. By 1920, all but two states had passed a law enforcing a tobacco MLPA, with at least 14 states having set their age restriction at 21 years old or greater. [11]

From the 1950s to the late 1960s, many states lowered their tobacco MLPA as a result of lobbying efforts from the tobacco industry (Appolonio and Glants 2016). Massachusetts and Oregon unsuccessfully attempted to raise their MLPA to 21-years-old in 1963, a year in which five states had pending legislation to lower their MLPAs from 21- to 18-years-old.[12]. By 1971, only three states still had laws in place enforcing an MLPA of 21 years old (Tobacco Merchants Association 1971), and none by the 1980s.

In 1985, the U.S. Department of Health and Human Services considered a nationwide tobacco MLPA as a part of a broader tobacco control plan, with the American Medical Association recommending an MLPA of 21-years-old (Appolonio and Glants 2016). Eventually

[10] By 1927, all of these laws had been repealed.
[11] Ohio and Rhode Island were the last two states to enact an MLA, establishing them in 1939.
[12] Utah lowered their MLA to 19 years old.

this effort led to the Synar Amendment. Adopted in 1992, this law mandated states enforce a statewide MLPA of 18 years old in order to receive federal funding from the Substance Abuse and Mental Health Services Administration (DiFranza and Dussalt, 2005).[13] While the Synar Amendment has been credited with reductions in youth smoking nationwide (Ahmed et al. 2019), tobacco control advocates have suggested a further increase to age 21.

In April 2005, the town of Needham, Massachusetts became the first municipality to enact legislation raising the MLPA of tobacco to 21 years old, creating the first modern "Tobacco 21" law. Several other municipalities enacted similar laws leading up to New York City's adoption of a Tobacco 21 policy on May 18, 2014. The National Academy of Medicine released a report in 2015 that estimated raising the MLPA of tobacco to 21 years old would reduce adult smoking prevalence in the United States by 12 percent, a study cited by many state policymakers as evidence in support of adopting a T-21 policy (Bergal 2017; Aliferes 2016).

The motivation for T-21 mandates from the public health community stems from several arguments. First, tobacco is significantly less addictive when first initiated at later ages (Azagba et al. 2015; Laux 2000; Everett et al. 1999) and the 18-20 age window may be a particularly precarious time for addiction onset (Hegmann et al. 1993; Khuder et al. 1999).[14] Second, e-cigarette usage among teenagers has dramatically increased over the last decade (Centers for Disease Control and Prevention 2019). While a number of policies aimed at reducing e-cigarette consumption (i.e. minimum legal purchasing ages, e-cigarette taxes, and advertising bans) have

[13] Alabama and Utah kept their MLAs of 19, while Alaska chose to adopt an MLA of 19 following the passage of the Synar Amendment.

[14] There is an extensive literature documenting tobacco consumption's propensity for physical and mental addiction (Hatsukami et al. 2008; Jha et al. 2006; Addicott 2020), with a substantial number of studies finding that tobacco may be more addictive the earlier in life that it is initiated (Laux 2000). For instance, Everett (1999) found that among college students who reported daily smoking, 81 percent had first initiated smoking before they were 18 years old. In a study of high schoolers in Canada, Azagba et al. (2015) found that each year of delaying smoking initiation lowered thse likelihood of developing a daily smoking habit by 24 percent.

been effective at deterring e-cigarette use (Abouk and Adams 2017; Dave et al 2019, Durta et al 2018), they also may have the unintended consequence of inducing substitution toward "traditional cigarettes (Caponnetto et al. 2015; Friedman 2015; Pesko et al 2016; Dave et al. 2019; Pesko & Currie 2019). A comprehensive T-21 law might be expected to avoid this inter-tobacco product substitution. Third, public health advocates argue that increasing the MLPA for tobacco to 21 would dry up the social market through which many adolescent and teen smokers have obtained tobacco (Hansen et al. 2013).[15]

The nascent literature on the effectiveness of T-21 laws falls into two categories: (i) studies of local (i.e. municipal) T-21 laws (Schneider et al. 2016; Silver et al. 2016; Friedman et al. 2019; Friedman and Wu 2020), and (ii) case studies of a single state's T-21 law (Schiff et al. 2016; Boettiger and White 2020). Many are descriptive case studies with pre-post comparisons focused on particular cities (Schneider et al. 2016; Silver et al. 2016).[16]

A key insight from higher quality municipal-level studies of local T-21 policies (see, for example, Friedman et al. 2019 and Friedman and Wu 2020) is that local T-21 policies are accompanied with substantial "leakage" or spillovers. For instance, Friedman and Wu (2020) conclude if a T-21 policy only partially covered a metropolitan/micropolitan statistical areas (MMSs), the estimated decline in smoking attributed to local T-21 policies was approximately 60 percent smaller (in absolute magnitude) than that observed for a T-21 policy that covered the full MMSA. This finding suggests that many young adult smokers avoid local MLPAs by traveling

[15]Following the passage of a Tobacco 21 mandate in Texas in September 2019, Rep. John Zerwas stated, "it's a very powerful thing to move tobacco products and these e-cigarettes away from susceptible adolescents who can become very quickly addicted." (Price 2019).

[16] These studies generally do not conduct appropriate statistical inference with one treated unit, such as placebo-type tests (Buchmueller et al. 2011).

to neighboring jurisdictions without such laws, resulting in smaller city or county-level policy effects relative to those enacted at the state or national level.

A handful of other studies have focused on case studies of a particular state's T-21 policy.[17] Yan (2014) studies a T-21 policy adopted in Pennsylvania between June 1992 and July 2002 to explore the impact of this law on maternal smoking and infant health.[18] Using data from the restricted Natality Detailed File from 1992 to 2002 and a regression discontinuity design (RDD), he finds that Pennsylvania's Tobacco 21 law reduces smoking among pregnant mothers. Yan's results also reveal that Pennsylvania's increase of the tobacco purchasing age lead to a 1.5 percent decline in the incidence of low birth weight of all mothers, and a 2.7 percent decline among smoking mothers [19]

While suggestive that T-21 restrictions could be effective today, this study also has a number of limitations. First, the T-21 policy for Pennsylvania was enacted prior to growth in the market for e-cigarettes. Secondly, the external validity of their research is limited due to their sample consisting entirely of pregnant mothers in Pennsylvania. Moreover, the first stage effects identified might be biased based on incentives to report illegal maternal smoking. Lastly, the first stage effects might be compromised as the regression discontinuity approach is essentially asking whether pregnant mothers in the final days of their pregnancy disproportionately initiate smoking at age 21.

[17] Schiff et al. (2020) uses a before-after estimator to study California's statewide T-21 law in southern California. Boettiger and White (2020) use a synthetic control approach to study the joint effects of California's T-21 law and a subsequently enacted cigarette tax hike and find evidence that cigarette prices rose and sales fell after both policies were enacted.

[18] Pennsylvania's mandate stated it was illegal to sell or furnish a tobacco product to any minor below age 21, also making it illegal to place a tobacco vending machine anywhere accessible by someone under the age of 21.

[19] In order to avoid confounding the effects of granting legal access to drinking with smoking at the cutoff age of 21 years old, the author conducts the analysis both before and after the policy change in order to establish a baseline effect.

This study offers the first evidence of the impact of *statewide* T-21 laws adopted nationwide on young adult smoking.[20] Statewide T-21 laws are harder to avoid by cross-border shopping (requiring out of state travel instead of within-state travel) and cover much larger shares of the state population than municipal laws studied by prior authors. Second, this study is the first to explore the impact of T-21 laws on minors, who are explicitly targeted by T-21 policies because 18-year-olds are viewed as an important "social source" for cigarettes. Third, we are the first study to analyze how a statewide T-21 law affects electronic cigarette use, whose use has exploded with JuuL's entry into the (e-cigarette) tobacco market (FDA 2018). Fourth, this study is the first to study the impact of any T-21 law on frequent and everyday smoking, which capture more addictive tobacco use. Fifth, this study is the first to descriptively explore the mechanisms through which T-21 laws may operate, in particular through teens' use of the social market for tobacco (i.e., third party purchase and borrowing). Finally, given that our study considers a window close to the recent Federal "Tobacco to 21 Act" and considers statewide policies rather than local ordinances, our estimates likely represent local average treatment effects (LATEs) which are most relevant for considering the likely impact of the new Federal T-21 law.[21]

[20] While not specifically examining a T-21 policy, Yörük and Yörük (2016) use an RDD to study the effect of a minimum legal purchasing age for tobacco of 18 on tobacco consumption. Using nationally representative data from the 1998 to 2004 National Longitudinal Survey of Youth 1997, they find that granting legal access to tobacco at age 18 nationwide increases the probability of smoking participation by 1.9 to 2.9 percentage points and an increase on the number of cigarettes smoked per day of 3.7 to 6.5 percent. This study, while having important findings, does have limitations, the primary one being the difficulty of disentangling the effect on smoking behavior of granting legal tobacco access at 18 years old from the other significant "life changes" that occur at that age; including the rights to vote, apply for credit, or sign a legal contract. Another significant change likely to be happening in months leading up to or following an individual's 18th birthday is the completion of high school, which often means individuals will start working full time or begin college in the bandwidth around the cutoff of Yoruk & Yoruk's RDD.

[21] Moreover, evaluating the impact of the Federal T-21 law directly will be quite challenging given that its implementation was coincidental to the onset of the COVID-19 epidemic in the United States.

3. Data

3.1 Behavioral Risk Factor Surveillance System (BRFSS)

The first dataset we employ for our analysis is the Behavioral Risk Factor Surveillance System (BRFSS) survey. The BRFSS is a nationally representative telephone survey conducted annually by the Centers for Disease Control and Prevention (CDC) since 1984.[22] Respondents, aged 18 and older, are asked questions regarding their health and various health behaviors, including tobacco consumption. Our analysis sample uses approximately 700,000 individuals aged 18 to 28 years old from the repeated cross-sections of the BRFSS from 2009 to 2019.

We use responses from two smoking-related survey items in the BRFSS to create our three binary variables of interest (*Smoking Participation, Everyday Smoking,* and *Quit)*:

"Have you smoked at least 100 cigarettes in your entire life?"

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

Smoking Participation is set equal to 1 if the respondent reports having smoked at least 100 cigarettes in their lifetime and is currently either smoking "everyday" or "some days"; it is set equal to 0 otherwise.[23] In our sample 12.3 percent of 18-to-20-year-olds were current smokers (see Table 1A). Between 2009 and 2019, we observe smoking participation for this age group has declined by 54.2 percent (see Figure 2). For 21-to-23-year-olds, the average smoking participation rate was 19.3 percent, and for 24-to-28-year-olds, it is 22.7 percent.

[22] The BRFSS has been administered via both landline and cellular phones since 2011; the survey was conducted only over landline up to that point. When we restrict our analysis sample to the 2011-2019 period, our findings are quantitatively similar.

[23] One limitation is that we are unable to identify new current smokers who do not report having smoked at least 100 cigarettes in their lifetime, since they are not asked about their current smoking behavior.

Everyday Smoking is set equal to 1 if a survey respondent reports having smoked at least 100 cigarettes in his/her lifetime and is currently smoking "everyday," and 0 otherwise. For 18-to-20-year-olds, we find that 7.2 percent of individuals were everyday smokers as compared to 11.9 percent for 21-to-23-year-olds and 14.6 percent for 24-to-28-year-olds. The trends in everyday smoking depicted in Figure 2 suggest a decline of 66.3 percent among 18-to-20-year-olds.

Finally, *Quit* is set equal to 1 if the survey respondent reports having smoked at least 100 cigarettes in their lifetime currently does not smoke. *Quit* equals zero if the respondent is currently smoking either "everyday" or "some days." Thus, the sample for our Quit measure is the sample of current and former smokers. We find that 24.9 percent of 18-to-20-year-olds had quit smoking during the sample period. Between 2009 and 2019 (see Figure 2), we find that quits among 18-to-20-year-olds increased 81.7 percent. Quit rates among 21-to-23-year-olds and 24-to-28-year-olds were higher at 30.3 and 36.9 percent, respectively.

3.2 State Youth Risky Behavior Survey (YRBS)

The second source of data used for our analysis is the state-level YRBS, a biennial survey coordinated by the CDC and administered by state education and health agencies, designed to be representative of all students in grades 9 through 12 in each state. These data are used by government agencies to follow trends in the behaviors of high school students including physical activity, mental health, unhealthy eating, sexual activity, and the use of tobacco, alcohol, and other illicit substances. Our analysis sample covers state YRBS survey waves from 2009 to 2019, including high school students from 43 states.

For a majority of the state YRBS surveys, trained data collectors travel to each participating school to administer the questionnaires.[24] The data collection process is designed keeping survey respondent privacy in mind by maintaining anonymity and allowing voluntary participation. Students complete the questionnaire during one class period, recording their answers in a computer-scannable booklet, while spread out throughout the classroom as much as possible in order to keep students from seeing each other's answers. When finished with the survey, student answers are sealed in an envelope and placed in a box.

We use responses to one question in the YRBS to create three binary variables (*Smoking Participation, Frequent Smoking,* and *Everyday Smoking)* pertaining to smoking status:

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

Smoking Participation is set equal to 1 if the respondent reports having smoked a cigarette in the last 30 days, and 0 otherwise; *Frequent Smoking* is set equal to 1 if the respondent reports having smoked a cigarette in 20 or more of the last 30 days and 0 otherwise; and *Everyday Smoking* is set equal to1 if the respondent has smoked a cigarette every day in the last 30 days and 0 otherwise.

We find that 18.3 percent of 18-year-olds smoked cigarettes in the last 30 days (see Table 1B). This rate declined during the 2009 through 2019 period from 24.5 to 9.9 percent. For minor teens ages 16-to-17, we estimate a mean smoking rate of 12.5 and 7.3 percent for 13-to-15-year-olds.

[24] In some states, the questionnaires are sent directly to schools, and teachers administer the survey following a standardized script (CDC 2013)

One advantage of using the State YRBS survey, is that in 2015 they began asking survey respondents about e-cigarette use. We use responses to one question in the YRBS to create three binary variables (*E-Cigarette Participation, Frequent E-Cigarette Use,* and *Everyday E-Cigarette Use)* pertaining to e-cigarette usage.

"During the past 30 days, on how many days did you use an electronic vapor product?"

E-Cigarette Participation is set equal to 1 if the respondent reports having used an electronic cigarette in the last 30 days, and 0 otherwise; *Frequent E-Cigarette Use* is set equal to 1 if the respondent reports having used an electronic cigarette in 20 or more of the last 30 days, and 0 otherwise; *Everyday E-Cigarette Use* is set equal to 1 if the respondent has used an electronic cigarette every day in the last 30 days, 0 otherwise.

We find that 25.8 percent of 18-year-olds used e-cigarettes in the last 30 days (Table 1B), compared to 21 percent of 16-to-17-year-olds and 20.8 percent of 13-to-15-year-olds. Similarly, we find that 5 percent of 18-year-olds use e-cigarettes frequently, and 6.2 use them on a daily. For 16-to-17-year-olds, we find a frequent e-cigarette use rate of 8.0 percent, and a daily use rate of 3.5 percent.

4. Empirical Methods

4.1 Difference-in-Differences Estimates

We begin using data from the 2009-2019 BRFSS to estimate the impact of T-21 laws on tobacco cigarette consumption among 18-to-20-year-olds. We estimate a standard binary logit model in which an indicator of prior 30-day smoking participation, daily smoking or quit

behavior (among prior smokers), Y, is equal to 1 if an unobserved variable, Y^*, is positive. Y^* is related to a set of observable variables and fixed effects by the following equation:

$$Y^*_{ist} = \beta_0 + \beta_1 T\text{-}21\ Law_{st} + \boldsymbol{X}_{ist}\boldsymbol{\gamma} + \mu_s + \tau_t + \varepsilon_{ist} \quad (1)$$

where $\underline{i}$ indexes survey respondents, s indexes states, t indexes month-by-years, and the distribution of ε_{ist} is logistic.[25] Our key right-hand side variable, *T-21 Law*$_{st}$ is an indicator set equal to 1 if a state has a statewide minimum legal purchasing age for tobacco of 21 years and 0 otherwise. In the estimates presented below, local T-21 laws are unaccounted, which is expected to attenuate our estimate of β_1. Our estimates should, therefore, be interpreted as the impact of a statewide T-21 law over and above existing average state conditions, which could include a share of local jurisdictions having a T-21 law. In alternate specifications discussed below, we (i) code *T-21 Law*$_{st}$ as the share of the population of state *s* covered by any T-21 law — state or municipal policy for municipalities with population size of at least 10,000 persons) — in month-by-year *t*, and (ii) generate a separate policy variable *Local T-21 Law*$_{st}$, defined as the share of the population of state *s* covered by a local T-21 law in month-by-year *t*, and add this measure as an additional covariate along with the original statewide-only *T-21 Law*$_{st}$ variable.

In all models, align policy effective dates with the relevant month of the interview (i.e. tobacco cigarette use measured during the month prior to the interview date). Appendix Table 1 shows effective dates for state T-21 laws and Figure 1 shows the geographic and temporal variation using a U.S. map.

[25] We explore the robustness of estimated policy impacts obtained from equation (1) to the use of a linear probability model (LPM). The estimated marginal effects from an LPM are qualitatively similar to those produced with logistic regression.

The vector $\boldsymbol{X}$ includes a set of observable individual-level and state-level characteristics. Among the individual controls are race/ethnicity, gender, age, and age-specific linear time trends (to allow each aged individual to be on its own smoking trend). In addition, we control for macroeconomic conditions via state per capita income and the state unemployment rate. To disentangle the effects of Tobacco-21 laws from other tobacco-related policies, we control for the state excise tax on cigarettes, clean indoor air laws, whether a state has implemented an electronic cigarette tax (ad valorem or excise), and whether the state enacted a minimum legal purchasing age for electronic cigarettes of 18. Finally, we control for policies related to alcohol and marijuana, which may be substitutes or complements for tobacco: state beer taxes and indicators for whether the state has implemented a medical marijuana law and a recreational marijuana law.[26] Means of these descriptive statistics are shown in Table 1. In addition, μ_s is a time-invariant state effect, and τ_t is a month-by-year effect. All regressions are weighted by survey weights and standard errors are clustered at the state-level.

The estimate of our key parameter of interest, β_1, is identified from 17 states that enacted T-21 laws over the sample period. Obtaining an unbiased estimate of β_1 will require the common trends assumption to be satisfied. This assumption will be violated in the presence of time-varying unobservables correlated with the enactment of Tobacco-21 laws and smoking behavior among young adults, or reverse causality. We take several tacks to address these concerns and reduce the likelihood that our estimated policy effects are biased. First, we conduct event-study analyses to ensure that pre-treatment trends in smoking participation are similar in

[26]Sources for control variables are as follows: state-level unemployment rates (Bureau of Labor Statistics) and income per capita (Bureau of Economic Analysis), state-level cigarette taxes, e-cigarette MLSA laws and clean indoor air laws (Centers for Disease Control), state-level e-cigarette taxes and beer taxes (Tax Foundation), state-level recreational marijuana laws (Marijuana Policy Project), and state-level medical marijuana laws (National Conference of State Legislatures).

treatment states as compared to control states in the period leading up to the enactment of T-21 laws:

$$Y^{*}_{ist} = \beta_0 + \sum_{j\neq -1} \beta^{j}_{1}\, 1\{T-21\ Law\}_{st} * 1\{Event\ Year\}_{j(s,t)} + \boldsymbol{X}_{ist}\boldsymbol{\gamma} + \mu_s + \tau_t + \varepsilon_{ist} \qquad (2)$$

where the subscript *j* denotes the number of years before and after a state enacts a Tobacco-21 law ("event time"). Each β^{j}_{1} describes the change in smoking participation among 18-to-20-year-olds in states that enacted T-21 laws compared to those that did not. Specifically, it involves a differential change from year *j* relative to the event period j(s,t) = -1, one year prior to enactment. If pre-treatment trends (up to 4 or more years prior to the enactment of T-21) are common among "treatment" and "control" states, this would tend to lend support to the claim that post-treatment breaks in smoking trends were caused by the policy. Out main post-treatment period examines up to one or more years following adoption of a T-21 law to permit a more balanced event study, but we also experiment with a less balanced event study that explores up to two or more years following adoption.[27]

As a second approach to ensure that our estimate of β_1 is unbiased, we explore the sensitivity of our estimates to additional controls for spatial heterogeneity. These include region-by-year fixed effects to control for common time shocks to states within census regions, thereby restricting counterfactuals for T-21 states to be geographically proximate states. In addition, we control for state-specific time trends (of second-order polynomial) to control for within-state unobservables trends such as anti-smoking sentiment.

[27] A total of 17 states enacted T-21 laws between 2009 and 2019. Of the 17 states that have post-treatment smoking participation data in the BRFSS, 6 have one or more years of post-treatment data and 3 have two or more years of post-treatment data.

Our third approach is to conduct placebo-type tests by estimating "difference-in-differences" (DD) models identical to equation (1) for older young adults, who should be less likely to be affected by T-21 laws. Specifically, we examine the impact of T-21 laws on smoking behavior among 21-to-23-year-olds and 24-to-28-year-olds, each of whom should be less directly affected by the statutes. We expect that the estimate of β_1 for 21-through-28-year-olds to be much smaller than for our "treatment age" of 18-to-20. However, we do note that some 21-to-23-year-olds smoking behavior could be affected by T-21 laws with a lag, as "current" 21-year-old's smoking behavior one year after the implementation of T-21 could have been affected by T-21 laws when they were 20 years-old. If, for example, a 21-year old whose state's T-21 law was enacted last year was induced to quit smoking a year ago, then his current smoking behavior at age 21 may have been affected. Given that no treatment state in our sample has more than 3 years of post-treatment data, no 24-to-28-year-old should have been impacted at any point (except through indirect effects via younger peers).[28]

We also estimate a formal "difference-in-difference-in-differences" (DDD) logit model by pooling a sample of 18-to-20-year-olds and 21-to-23-year-olds (or 24-to-28-year-olds) and estimating:

$$Y^*_{ist} = \alpha_0 + \alpha_1 \textit{T-21 Law}_{st} + \alpha_2 \textit{Age1820}_{ist} + \alpha_3 \textit{T-21 Law}_{st}*\textit{Age1820}_{ist} + \boldsymbol{X_{ist}\alpha_4} + \boldsymbol{X_{ist}}*\textit{Age1820}_{ist}\boldsymbol{\alpha_5} + \nu_s + \nu_s*\textit{Age1820}_{ist} + \omega_t + \omega_t*\textit{Age1820}_{ist} + \varepsilon_{ist}. \quad (2)$$

where our DDD estimate α_3 is the differential effect of a T-21 laws for 18-to-20-year-olds as compared to older young adults. Moreover, we also estimate a specification similar to equation

[28] As discussed below, we also attempt an alternate approach where we use state-specific birth cohort to identify treated individuals and differentiate individuals by length of exposure to the T-21 policy at any point in their lives.

(2) where we include a full set of state-by-year fixed effect interactions, which will control for any unmeasured common shocks that affected 18-to-20-year-olds and older young adults. Together, we expect the above descriptive tests to lend support to the common trends assumption.

Next, we turn to the State YRBS survey data, where we estimate a model very similar to equation (1) for 18-year-old U.S. high school students. The State YRBS sample from 2009 through 2019 is comprised of biennial waves (in odd numbered years). Thus, the time fixed effect is a wave fixed effect for the survey years 2009, 2011, 2013, 2015, 2017, and 2019. In addition, the State YRBS allows us to measure electronic cigarette consumption as well as traditional cigarette consumption. As noted in Appendix Table 1 and Appendix Figure 1, 12 states identify our T-21 law effects in our YRBS-based analysis.[29]

Finally, while our YRBS-based difference-in-differences analysis does not permit an examination of older young adults as a counterfactual (the data are comprised of U.S. high school students), we are able to explore spillover effects to minor teens under the age of 18. Thus, we also estimate equation (1) for 16-to-17-year-olds, who may rely on some 18-year-old classmates for access to tobacco. We also examine effects of T-21 laws on 13-to-15-year-olds, who are less likely to be able to access peers around age 18, and thus may be a more appropriate "placebo" age group.

5. Results

[29] In the YRBS, our T-21 variable is coded as the share of the year the T-21 law is in effect. Some YRBS-based studies assume that the school-based surveys are only distributed between January and June of the survey year, though the Centers for Disease Control and Prevention (CDC) has offered mixed guidance on this point. If we recode our T-21 variable based on only policies in effect during the first two quarters of the survey year, our findings are qualitatively similar.

5.1 BRFSS Findings

Our main BRFSS findings are shown in Tables 2 through 5. The tables report marginal effects generated from logit models, with standard errors clustered at the state level. All regressions are weighted using the sampling weight provided by the BRFSS survey.

We begin in Table 2 by showing logit estimates of the relationship between Tobacco 21 (T-21) laws and tobacco cigarette use among young adults. The first three columns show "difference-in-differences" estimates for adults ages 18-to-20. These are the individuals who are directly bound by state T-21 law changes, which raise the minimum legal purchasing age (MLPA) for tobacco from 18-to-20. Our baseline specification in column (1) includes individual demographic characteristics (gender, race/ethnicity, age, age-specific time trends), state macroeconomic conditions (unemployment rate, per capita income), and tobacco policy controls (per pack excise tax on cigarettes, clean indoor air laws). In this model, we find that T-21 laws are associated with a 2.5 percentage-point decline in prior 30-day tobacco cigarette use (Panel I). Relative to the mean smoking participation rate in state-months without T-21 laws, this represents a 19.7 percent decline in smoking participation among 18-to-20-year-olds.[30] The addition of controls for electronic cigarette policies (the minimum legal purchasing age for e-cigarettes and the presence of an e-cigarette tax) in column (2) has little effect on the estimated effect of T-21 laws on smoking participation. In our fully specified model (column 3, Panel I), which also includes controls for alcohol and marijuana policies (beer taxes, medical marijuana laws, and recreational marijuana laws), we find that T-21 laws lead to a 4 percentage-point (31.5 percent relative to the mean) reduction in smoking participation among 18-to-20-year-olds.

[30] The pre-treatment mean is calculated as the weighted mean in treatment states prior to T-21 adoption.

Information on electronic cigarette use is only available in the 2016-2019 BRFSS surveys. Nonetheless, in Appendix Table 5 we examine the effect of T-21 laws e-cigarette use reported in the BRFSS. While imprecisely estimated, we find that T-21 laws reduce e-cigarette use among 18-to-20-year-olds by 1 to 2 percentage points. This finding is consistent with the hypothesis that T-21 laws reduce consumption of multiple types of tobacco produces.[31]

What margins of smoking behavior are affected by T-21 laws? It appears that the reduction in smoking participation likely comes from an increase in quitting behaviors (Panel III), which is what we might expect given that the vast majority of 18-to-20-year-olds initiate smoking between ages 13 and 14. While imprecisely estimated because the sample is conditioned on "ever smokers," we find that T-21 laws are associated with a statistically insignificant 4.3 to 5.5 percentage-point increase in the probability of quitting smoking (17.5 to 22.4 percent) for 18-to-20-year-olds. Finally, we find that the enactment of a T-21 law reduces the (unconditional) probability of everyday smoking by 1.6 to 2.4 percentage-points (Panel II), which could suggest some effect of T-21 laws in the intensive margin (days) of smoking. We also find evidence T-21 laws reduce everyday smoking, the type of smoking behavior mostly likely to develop addiction.

To explore the credibility of the common trends assumption in columns (1) through (3), we show the results of several diagnostic tests. First, panel (a) of Figure 4 shows results from our event-study analysis for smoking participation. We find that in the five years prior to the enactment of T-21 laws, trends in smoking participation in "treatment" and "control" states appeared to be common, diverging only following with the enactment of T-21 laws.

[31] The BRFSS survey question on electronic cigarettes asks respondents: "Do you now use ecigarettes or other electronic vaping products every day, some days, or not at all?" We set *E-Cigarette Participation* equal to 1 if respondents report every day or some days and 0 otherwise.

Because state T-21 laws are relatively new, we are limited in examining their long-run impacts.[32] Moreover, the onset of COVID-19 in 2020 will make it very difficult to disentangle the effect of the Federal T-21 law from the smoking impacts of COVID-19. With these limitations in mind, difference-in-differences results suggest that T-21 laws had an immediate negative effect on smoking participation. When we extend the event study to include two or more years following enactment (4 states), the results are qualitatively similar (see Appendix Figure 2).

Our second test of the credibility of the common trends assumption is to explore the robustness of our estimated policy impacts to additional controls for state-specific linear time trends, and region-specific year effects. These controls capture geographic-specific time shocks that may be related to T-21 enactment and adult smoking (i.e. anti-smoking sentiment), which may ameliorate bias in our prior estimates. On the other hand, it is not obvious that states within the same census region comprise better counterfactuals for states that enact T21 laws than non-geographically proximate states. Moreover, controlling for state linear time trends may (i) reduce precision in the estimated T-21 effect, and (ii) generate bias in the estimated policy impact if there are heterogeneous treatment effects among early and later adopters. Reassuringly, our findings in Appendix Table 6 show that the estimated impact of T-21 laws on smoking participation is robust to controls for spatial heterogeneity.

Our final approach to address the common trends assumption is to estimate the impact of T-21 laws on individuals ages 21 and older who are less likely to be directly affected by these statutes. In columns (4) through (6) of Table 2, we present logit estimates of the effect of T-21 laws on smoking behavior of 21-to-23-year-olds. While this is a credible placebo group, we note

[32] Of the 17 states enacting T-21 laws over our sample period, only 7 states have post-treatment data a year or more following enactment. Ten (10) states have post-treatment data only for the year of enactment.

that some 21-to-23-year-olds in Tobacco-21 states were "bound" by the law when they were younger. And current smoking behavior among 21-to-23-year-olds could have been affected by prior exposure to a T-21 law.[33]

With these caveats in mind, our results in Panel I show no evidence that T-21 laws affect smoking participation among 21-to-23-year-olds. The estimated policy impact for 21-to-23-year-olds is 20 percent smaller than for 18-to-20-year-olds (0.1 to 0.8 percentage-points) and is nowhere near statistically different from zero. An event-study analysis in panel (b) of Figure 4 also suggests a null result. This result suggests that our smoking participation findings for 18-to-20-year-olds are not contaminated by unmeasured shocks that commonly affect 18-to-20 and 21-to-23-year-olds. We also find no evidence that T-21 laws impact everyday smoking or quit behavior for 21-to-23-year-olds.

In columns (7) through (9) of Table 2, we examine smoking behavior of 24-to-28-year-olds. This age group has the advantage that none were bound by any state's T-21 law when they were younger (i.e., the first state T-21 law was adopted by Hawaii in 2016; thus, the oldest individual in our sample who was bound by a T-21 law in 2019 was age 23). The main disadvantage is that this age group is quite a bit older than "treated" individuals and hence may be a poorer control group.

Our results show no evidence that T-21 laws affect smoking participation, daily smoking, or quit behavior among 24-to-28-year-olds.[34] The estimated policy impacts for this age group are uniformly smaller (in absolute magnitude) as compared to 18-to-20-year-olds.

[33] For example, New Jersey enacted a T-21 law in 2017. Thus, 21-year-olds living in New Jersey in 2018 and 21- and 22-year-olds living there in 2019 would have been bound by the T-21 law when they were younger.
[34] The event-study analysis in panel (c) of Figure 4 shows no evidence that T-21 laws affect smoking participation among 24-to-28-year-olds.

In Table 3, we show results from a "difference-in-difference-in-differences" specification. This is a test of whether the estimated T-21 law impacts in columns (1)-(3) of Table 2 are statistically different from the estimates in columns (4)-(6), and then (7)-(9). Our results in Panel I of Table 3 show that T-21 laws are associated with a statistically significant 3.1 to 4.0 percentage-point (24.4 to 31.4 percent) reduction smoking participation of 18-to-20-year-olds relative to 21-to-23-year-olds, and a statistically significant 3.4 to 5.0 percentage-point (27.5 to 39.4 percent) reduction smoking participation of 18-to-20-year-olds relative to 24-to-28-year-olds.

These logit estimates are comparable to those from linear probability models (Appendix Table 7) and, importantly, when we augment our "triple-differences" specification with a full set of state-by-year dummy interactions (to capture any common shocks that may have impacted smoking behavior of 18-to-20 and 21-to-23-year-olds (Appendix Table 7), we continue to find that T-21 laws reduce smoking among 18-to-20-year-olds.

One concern with the above estimates is that some individuals ages 21-to-23-years-old may be impacted by T-21 laws with a lag. Thus, we attempt an alternate identification strategy where we pool individuals ages 18-to-28 from 2009 through 2019 (representing birth years 1981 through 2001). Our key "treatment variable" is the interaction of *T-21 Law* and an indicator for whether an individual was born in a year such that he/she was aged 18-to-20 (at any time) when their state had a T-21 law.[35] The results from this exercise, shown in Appendix Table 8 reflect that smoking participation decreased among 18-to-20-year-olds and individuals who were ages 18-20 when a T-21 law was implemented.

[35] This specification includes both birth cohort and age fixed effects as well as time trends for each, along with each of our controls. Because the BRFSS do not include mobility data, we are forced to assume that state of residence at the time of the survey was the same state of residence when they were of age to be affected by a T-21 law (and similarly for "control" individuals).

Taken together, the above results provide strong evidence that T-21 laws were effective at reducing smoking participation among 18-to-20-year-olds. We next turn to an exploration of heterogeneity in the impacts of T-21 laws by demographic and socioeconomic characteristics of individuals ages 18-to-20.

Table 4 explores whether the effects of T-21 laws differ for 18 as compared to 19-to-20-year-olds. 19-to-20-year-olds are more likely to have 21-year-old peers from whom to access cigarettes via the social market (i.e. bumming or borrowing, third-party purchase) than are 18-year-olds, many of whom are still in high school. Our results in Table 4 provide strong evidence that 18-year-olds see a much larger decline in smoking participation in response to T-21 laws than 19-to-20-year-olds. We find that T-21 laws are associated with a 7.3 to 12.2 percentage-point decline in smoking participation among 18-year-olds, and a 2.8 to 3.3 percentage-point decline in smoking participation among 19-to-20-year-olds. This highlights the potential differences in the social markets. 19-20 years old are likely either in college or the labor force, providing them with social networks not subject to the T-21 law. This suggests it's possible that much of the effective bite of a T-21 law, could potentially be achieved with a T-19 law.

Together, the estimated effects of statewide T-21 laws presented above are somewhat larger than have been detected in studies of local T-21 policies. Indeed, for 18-year-olds, we find T-21 may reduce smoking by as much as 70 percent. This is consistent with higher travel costs of avoidance associated with a statewide mandate. [36] Moreover, we find little evidence that

[36] In Appendix Tables 2 and 3 we report estimates where we control for local T-21 policies, either through incorporating local policies (via the share of the state population covered by local policies) into the coding of our main T-21 policy variable (columns 1-3) or via a separate control alongside our statewide T-21 policy. Our results show that statewide policies have larger smoking reducing effects than local policies, consistent with more cross-jurisdiction shopping for local laws.

border state T-21 laws significantly affect the marginal impact of own state T-21 laws on young adult smoking (see Appendix Table 4).[37]

In Table 5, we explore heterogeneity across an additional set of individual and household characteristics. The first five columns explore heterogeneity in the impacts of T-21 laws by gender (columns 1-2) and race/ethnicity (columns 3-5). We find larger (in absolute magnitude) T-21-induced decreases in smoking participation for males relative to females; moreover, there is a much larger T-21-induced increase in successful quits for males as compared to females. Turning to race, we find some evidence that African Americans may be more affected by T-21 laws, especially in percentage-point terms relative to mean smoking rates (which are much lower for blacks than whites). This larger impact on African Americans could reflect that black Americans are more likely to face differential race-based enforcement of these laws (i.e., ID checks) than are others.

Next in columns (6) and (7), we explore whether the effects of T-21 laws differ by whether the 18-to-20-year-old has (i) dropped out of high school, or (ii) is currently attending high school or has received a high school diploma. We find T-21 laws reduce smoking participation for high school dropouts by 9.8 percentage points and by 3.2 percentage points for individuals with a high school degree or currently in high school. This result is consistent with the hypothesis that less-educated individuals are more affected by the policy.

Finally, in columns (8) and (9), we explore whether T-21 laws differently affect 18-to-20-year-olds from poor versus non-poor households. The results suggest that T-21 laws decrease

[37] In Appendix Table 4, we explore whether the effect of a statewide T-21 law depends on whether a border state also has a T-21 law. While the coefficient on the interaction between own state and border state T-21 law is negative for smoking participation and everyday smoking, it is economically small and never statistically distinguishable from zero at conventional levels.

smoking participation relatively more poor households than non-poor households; however, for everyday smoking, the pattern is reversed.

5.2 State YRBS Results

Tables 6 through 8 show our main findings using the State YRBS data. As above, standard errors are clustered at the state level, and regressions are weighted to be nationally representative of 18-year-old high school students.[38]

In Table 6, we explore the effect of T-21 laws on tobacco use of 18-year-old high school students using State YRBS data from 2009-2019. The first three panels show estimates of the effect of T-21 laws on smoking participation, frequent smoking (20 or more days in the prior month), and daily smoking, respectively. Consistent with the results from the BRFSS, we find that T-21 laws are associated with a statistically significant 3.8 to 4.9 percentage-point (19.6 to 25.4 percent) reduction in smoking participation among 18-year-old high school students. [39] We find little evidence that frequent or everyday smoking is affected, which again suggests that the intensive margin of smoking behavior appears to be less affected by T-21 laws.

In Panels IV through VI, we explore the effect of T-21 laws on electronic cigarette use among 18-year-olds. As noted above, these data were collected over the 2015-2019 period, covering the window over which T-21 laws were enacted. While imprecisely estimated, we find consistent evidence that T-21 reduced e-cigarette use among 18-year-old high school students. In our most saturated specification we find that T-21 laws are associated with a 13.7 percentage-

[38] We note that the age category available in the State YRBS survey is actually 18+, which does include a very small share of 19-year-old high school students. Our weight variable is calculated as the product of (i) each state's YRBS-provided weight (designed to make the state sample representative of the state population of 9th through 12th graders), rescaled to sum to 1, and (ii) the state-by-year intercensal population estimate of 18-year-olds from the Surveillance, Epidemiology, and End Results (SEER) program.

[39] In Appendix Table 9 we explore the evolution of our smoking participation results in event time. We find decreases in smoking participation are largest 3 years or more after a state T-21 law.

point decline in prior 30-day e-cigarette consumption, a 6.7 percentage-point decline in frequent (> 19 days) prior month consumption of e-cigarettes, and 6.8 percentage-point decline in daily e-cigarette use. While estimated with a very limited panel (the 2015, 2017, and 2019 waves of the YRBS), the findings in Appendix Figure 3 suggest little evidence that the decline in e-cigarette use was driven by a differential pre-treatment trend.[40]

Are these results concentrated in particular demographic groups, as we say in the BRFSS? In Table 7, we show results by gender (columns 1-2) and race/ethnicity (columns 3-5).[41] In fact, our findings are generally consistent with our BRFSS-based results. The effect of T-21 laws on smoking behavior is larger for males relative to females and to blacks relative to whites (though this latter estimate is very imprecisely estimated).

As discussed above, an important policy rationale for T-21 laws is to reduce *minors*' (< 18 years-old) tobacco use. Minor teenagers who wish to access cigarettes often rely on 18-year-old peers to bum or borrow cigarettes or for third-party purchase (Hansen et al. 2013). By making it more difficult for 18-year-olds to access tobacco, proponents of T-21 laws aim to reduce minors' tobacco consumption.

In Table 8, we explore the impact of T-21 laws on tobacco consumption among 16-to-17-year-olds, an age group that is likely to have access to 18-year-old peers who may attend the same grade. The first three panels show results for tobacco cigarette consumption and the final three panels for e-cigarette use. We find evidence of decreased smoking behavior among 16-to-17-year-olds across all 3 columns, though only column (3) is statistically distinguishable from

[40] In unreported results, we also explore the impact of T-21 laws on cigar use and any tobacco product use (traditional cigarettes, e-cigarettes, or cigars). For 18-year-olds, we find that T-21 laws are associated with a (statistically insignificant 7.3 percentage-point (standard error = 0.046) decline in cigar use (sample period = 2009-2019), and a statistically significant 8.7 percentage-point decline (standard error = 0.036) in any tobacco product use (sample period 2015-2019).

[41] The YRBS does not include information on household income or poverty.

zero. For e-cigarette behavior, we find evidence that T-21 laws decreased 16-to-17-year-old participation however these results are not statistically distinguishable from zero by conventional standards. Importantly, when we examine the effects of T-21 laws on 13-to-15-year-olds, who have relatively less access to 18-year-old peers, we find little evidence that T-21 laws affect their smoking behavior (Appendix Table 10).

Taken together, our YRBS findings (i) are consistent with smoking participation effects for 18-year-olds in the BRFSS, (ii) suggest that electronic cigarette consumption also declines following the passage of T-21, and (iii) show that the benefits of T-21 laws extend to 16-to-17-year-olds, who often rely on 18-year-old classmates for access to the "social market" for e-cigarettes.

5.3 Descriptive Exploration of Mechanisms

In our final descriptive analysis, we explore the mechanisms through which state T-21 laws reduce tobacco use among youths. Beginning in the 2017 State YRBS, states began asking high school students about usual sources of e-cigarette use, the most common type of tobacco cigarette use at this time. Respondents were asked:

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

Among possible responses to this question were:

> *"I did not use any electronic vapor products during the past 30 days*
> *I bought them in a store such as a convenience store, supermarket, discount store, gas station, or vape store.*
> *I got them on the Internet.*
> *I gave someone else money to buy them for me.*
> *I borrowed them from someone else.*
> *A person 18 years old or older gave them to me.*
> *I took them from a store or another person.*
> *I got them some other way."*

Using responses to this question, we descriptively explore how state T-21 laws affected how 18-year-old youths obtained e-cigarettes. In panel (a) of Figure 6, we document that between 2017 and 2019, e-cigarette use rose both in states that implemented T-21 laws during this period (from 17.6 to 23.6 percent) and among those states where T-21 laws were not in effect (from 20.6 to 30.8 percent). However, rates rose 4.2 percentage-points more slowly in states that enacted T-21 laws, a difference statistically significantly different from zero at the 1 percent level. When we decompose e-cigarette users by where they obtained their cigarettes, we find that the biggest relative decline occurred via direct purchase of e-cigarettes, consistent with state bans on sales (6.3 percentage point relative decline in treatment versus control states).[42] We find modest evidence of substitution toward the social market, with T-21 laws associated with a 2.5 percentage-point higher probability of borrowing e-cigarettes. This suggests that some of the T-21 law effect is offset by 18+ year-olds perhaps accessing older peers for e-cigarette use.

When we examine males (panel b), who saw the largest e-cigarette declines in response to T-21 laws (see Table 6), the results are even more stark. We find a larger decline in direct purchase of e-cigarettes (7.7 percentage-points) for males in T-21 states as compared to control states, as well as larger increases in borrowing 1.7 percentage-points) and third-party purchase (1.0 percentage-points). Again, this suggests evidence that some 18-year-olds may turn to informal social sources for e-cigarettes.

In panel (c) of Figure 6, we condition the sample on e-cigarette users and examine usual source of e-cigarettes among vapers. We find strong evidence that direct purchase of e-cigarettes

[T]We group those categories into 5 groups. Participation is defined by the first response. Direct own purchase from a store is the second possible response. "Third party purchase" corresponds to "I gave someone else money to buy them for me." "Bumming or borrowing" corresponds to "I borrowed them from some else" or "A person 18 years old or older gave them to me." We combine internet, stealing, and other into the final category due to their overall rarity.

fell more in T-21 states after enactment, but also that borrowing e-cigarettes and use of other sources to obtain cigarettes (i.e., the internet) rose after T-21 laws were adopted. These findings suggest that peers in the social market may mute the full impact of T-21 laws.

In columns (1) and (3) of Appendix Table 11, we estimate a multinomial logit model of the effect of statewide T-21 laws on the usual source by which 18-year-olds typically obtain e-cigarettes (the omitted outcome category is "non-use"). Consistent with Figure 6, we find consistent evidence that T-21 laws reduce direct purchase of e-cigarettes among 18-year-olds, but do lead to some substitution toward borrowing e-cigarettes. For 16-to-17-year-olds (columns 2 and 4), we find that e-cigarette use declines occur for those who typically obtain their cigarettes via third party purchase or borrowing, consistent with their losing access to 18-year-old peers as a "social source" for tobacco, though these effects are not statistically distinguishable from zero.

The patterns described above is even stronger when we restrict the sample to males, the demographic group whose e-cigarette was most affected by T-21 laws. In particular, T-21 laws appear to have had stronger spillover effects on males ages 16-to-17. We find that T-21 laws were associated with a statistically significant decline in e-cigarette consumption among males who typically obtain their cigarettes via third-party purchase. This is consistent with T-21 laws partially "drying up" the social market for tobacco among older minor teens.

6. Conclusion

This study provides the first national estimates of the effects of statewide T-21 laws on young adult and minor smoking behavior. First, using data drawn from the 2019-2019 BRFSS and 2009-2019 State YRBS, we find strong evidence that T-21 laws reduce tobacco use among

young adults. Difference-in-differences estimates from the BRFSS suggest that T-21 laws are associated with an approximately 4 percentage-point reduction in smoking participation among 18-to-20-year-olds. Event study analyses and falsification tests among older individuals ages 21-to-28 generate findings consistent with a causal interpretation of our results. Turning to the YRBS, we find that T-21 laws are associated with reductions in smoking participation and an even larger reduction in e-cigarette use. Importantly, some of the benefits of T-21 laws appear to extend to minors ages 16-to-17, suggesting that T-21 laws may help to "dry up" the social market for tobacco or may create better "role modeling" of healthy behaviors by 18-year-olds.

Our results suggest that statewide T-21 laws have had important beneficial public health effects, which could suggest that the Federal T-21 law, signed into law by President Trump in late December 2019, will have important impacts in non-adopting states. Moreover, to the extent young smokers are more likely to have time-inconsistent preferences (Gruber and Koszegi 2001) or are more impacted by exogenous peer effects (Robalino and Macy 2018), T-21 restrictions may enhance social welfare. However, providing direct evidence on the effects of the Federal T-21 policy will be extremely challenging for future scholars given the coincident timing of the Federal change with the onset of the COVID-19 pandemic, which may have substantial effects on tobacco use given the link between respiratory illness and COVID-19-related mortality (Nowakowski 2020). Thus, the evidence provided in this study is likely to be far less contaminated than studies trying to disentangle policy from the 2020 pandemic.

At present, only a handful of other countries currently have T-21 laws: Ethiopia, Honduras, Philippines, Sri Lanka, and Uganda (Tobacco Control Laws 2020). In considering the external validity of our estimates, the United States has far lower smoking rates than other

OECD countries (Greenhalg et al 2015). Thus, the comparative health benefits of effective T-21 laws in countries with higher rates of youth smoking may be larger.

More generally, the effects of T-21 laws may also depend upon other policies which interact with T-21 laws, including local tobacco prices. Moreover, most states and cities routinely use auditing programs to verify compliance with age restrictions. The level of compliance might vary depending on the size of local markets, the risk of audits, and the ensuing fines. Avoidance may take other forms as well. Prior research has demonstrated cross-state border shopping or using the internet to avoid local sales taxes (Merriman 2010; Goolsbee et al. 2010). With regard to T-21, we might expect youth to use technology and false IDs to avoid laws that restrict access to tobacco. Indeed, while the "terms and conditions" of many tobacco-selling websites state they expect people purchasing products to be over 21, most do not ask for proof of age. This may reduce the effective shadow price of these laws in the United States, and in other countries where T-21 laws may be implemented in the future.

Finally, while T-21 laws may be perceived as a public health success, it appears to have come at a cost. Many have argued that U.S.-based tobacco companies endorsed T-21 legislation to avoid regulation of flavored tobacco products (Myers 2019). Revealed preference by such firms would suggest the benefits of the high MLPA likely came at the expense of continued unregulated flavored e-cigarettes. This even more apparent with the explosion of e-cigarette use rates among youth, which some have attributed to JuuL products containing high nicotine content, appealing flavors, and the ability to easily be concealed (FDA 2018).

Tobacco companies may have been willing to lose sales from 18-to-20-year-old smokers in the hope of retaining additional current and future smokers through flavored e-cigarettes. The Tobacco Master Settlement Agreement (MSA) is over two decades old. Just as a dramatic shift

from traditional cigarette sales to e-cigarette sales has occurred, advertising and targeting to youth has evolved to incorporate social media and distribution has shifted to online markets. With this in mind, for T-21 laws to have maximum benefits in the long run, public health experts and policymakers will need to be better understand the types of new tobacco regulations or restrictions that might complement these laws intended to limit access at the lowest social cost.

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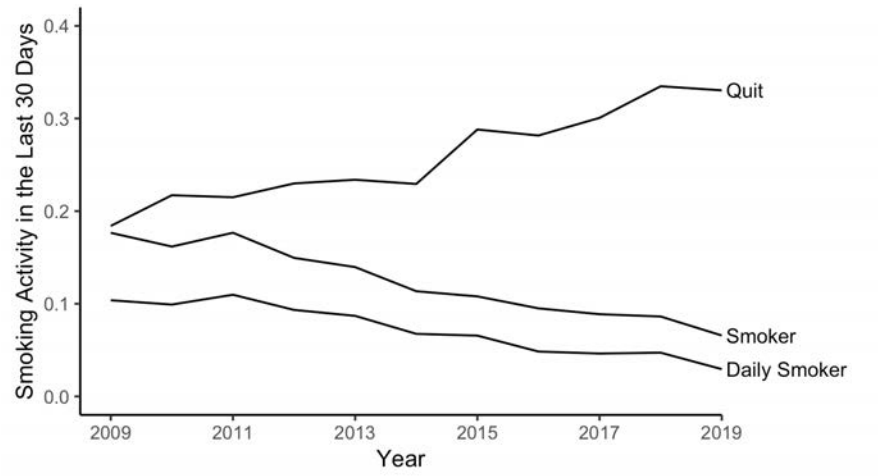
Tables and Figures

Figure 1. Enactment of State Tobacco 21 (T-21) Laws Prior to Federal T-21 Mandate

Source: Preventing Tobacco Addiction Foundation, available at: https://tobacco21.org/

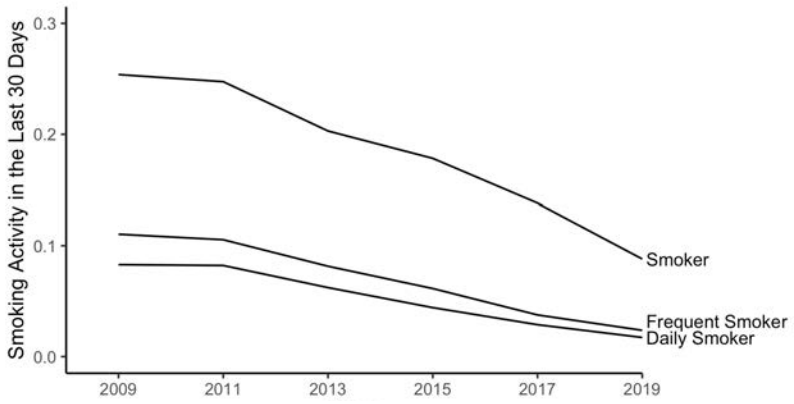
Figure 2. Prior 30-Day Tobacco Cigarette Smoking Behavior Among 18-to-20-Year-Olds, 2009-2019 BRFSS



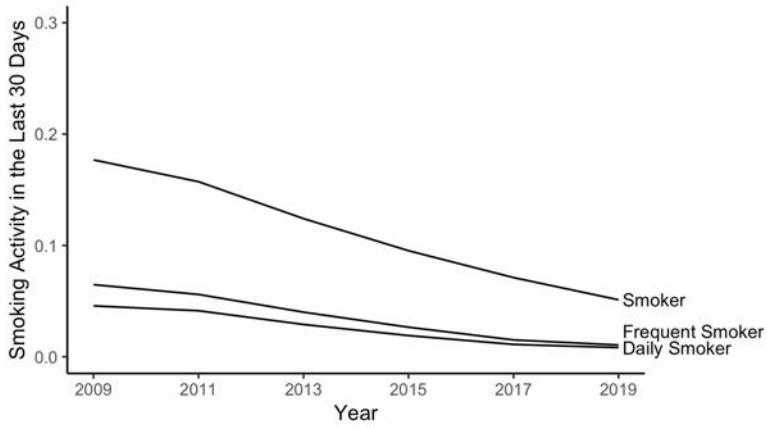
Data Source: 2009-2019 BRFSS

Figure 3. Prior 30-Day Tobacco Cigarette Smoking Behavior Among 18-Year-Olds and Minor Teens, 2009-2019 YRBS

Panel (a): 18-Year-Olds



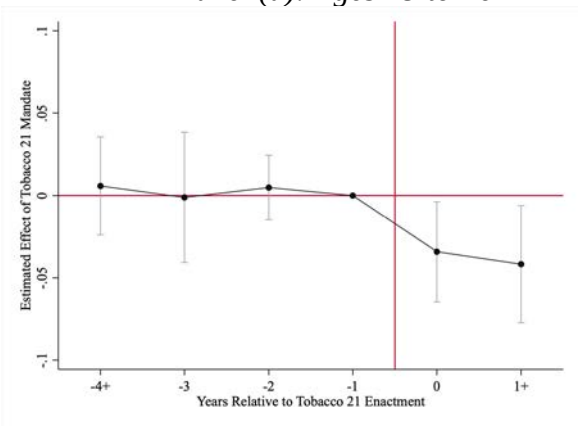
Panel (b): 16-to-17-Year-Olds



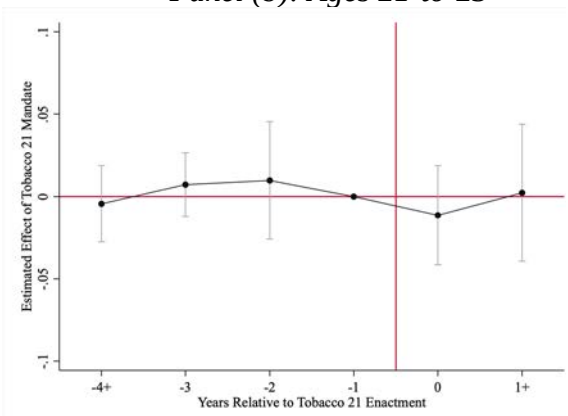
Notes: Data Source 2009-2019 State YRBS

Figure 4. Event-Study Analysis (DD Logit Models), Smoking Participation, 18-to-20-Year-Olds, BRFSS

Panel (a): Ages 18-to-20



Panel (b): Ages 21-to-23



Panel (c): 24-to-28

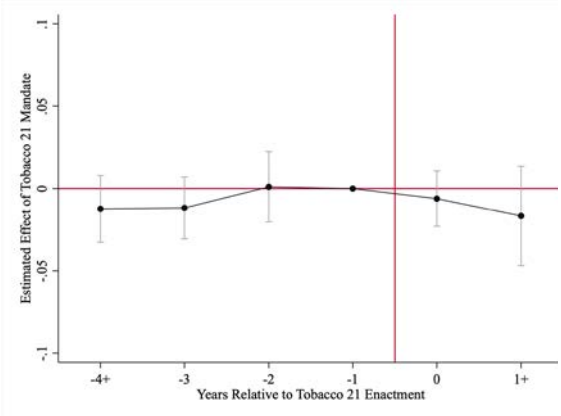


Figure 5. Event-Study Analysis (DDD Logit Models), Smoking Participation, 18-to-20-Year-Olds vs Older Young Adults, BRFSS

Ages 18-to-20 vs Ages 21-to-23

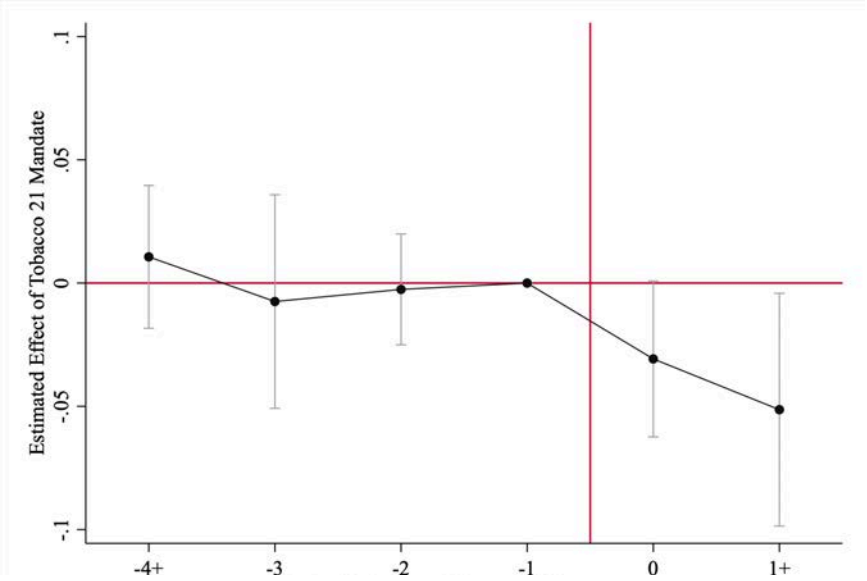
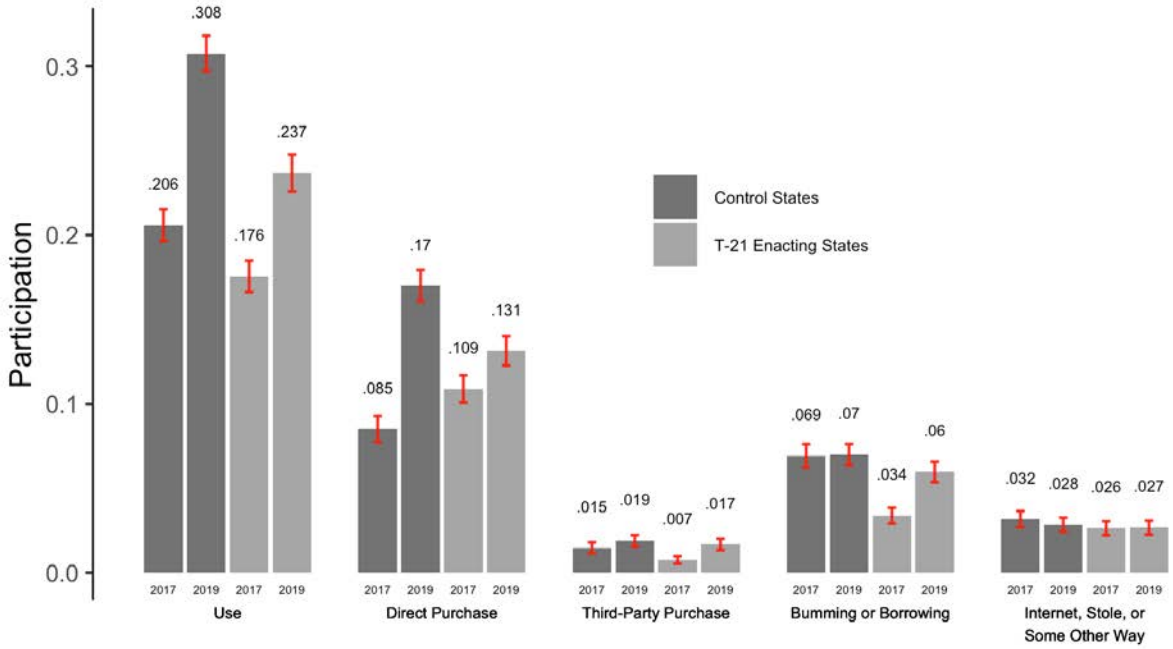


Figure 6. Descriptive Analysis, E-Cigarette Participation and Source, 18-Year-Olds, State YRBS, 2017-2019

Panel (a): E-Cigarette Use & Source



Panel (b): E-Cigarette Use & Source Among Males

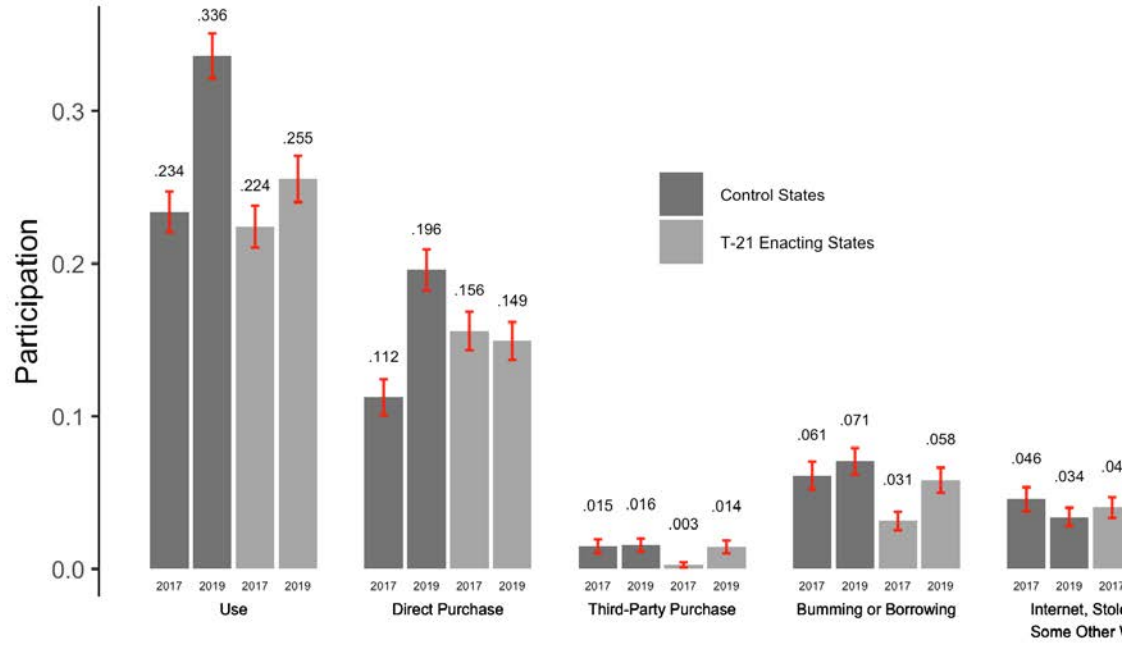


Figure 6 Continued. Descriptive Analysis, E-Cigarette Participation and Source, 18-Year-Olds, State YRBS, 2017-2019

Panel (c): E-Cigarette Use & Source Among E-Cigarette Users

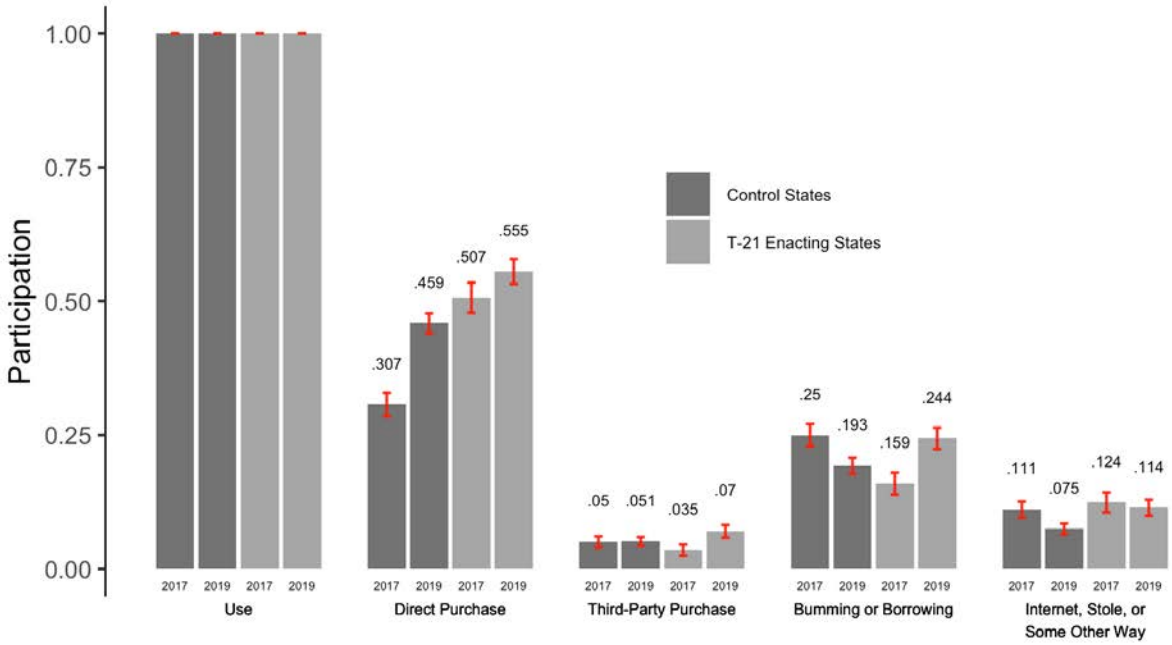


Table 1A. Descriptive Statistics, BRFSS, 2009-2019

	Means of Variables, by Age		
	Ages 18-to-20	*Ages 21-to-23*	*Ages 24-to-28*
Dependent Variables			
Smoking Participation (Any Smoking in Last 30d)	.123	.193	.227
Everyday Smoking (Daily Smoking in Last 30d)	.072	.119	.146
Quit (Former Smoker)	.249	.303	.369
Key Policy Variable			
Tobacco 21 Law	.057	.056	.06
Controls			
Female	.463	.491	.485
High School Degree Only	.466	.305	.268
Some College	.355	.427	.319
College Degree	.009	.174	.298
Black	.13	.128	.13
Hispanic	.213	.212	.22
Other Race	.115	.11	.103
State Unemployment Rate	6.457	6.359	6.396
(Standard Deviation)	(2.43)	(2.39)	(2.39)
State Per Capita Income	47628.4	47706.41	47872.05
(Standard Deviation)	(8841.80)	(8798.78)	(8955.72)
Excise Per Pack Tax on Cigarettes (Nominal)	2.647	2.644	2.653
Clean Air Law — Bars	.481	.478	.473
Clean Air Law — Government Multi-Unit Housing	.666	.664	.661
Clean Air Law — Private Multi-Unit Housing	.614	.606	.609
Clean Air Law — Restaurant	.583	.58	.579
Any E-Cigarette Tax	.089	.091	.09
E-Cigarette Minimum Legal Purchase Age Law	.587	.599	.601
Beer Taxes (Nominal)	.276	.283	.282
Medical Marijuana Law	.438	.419	.433
Recreational Marijuana Law	.082	.08	.086
Observations	99,141	145,516	171,121

Notes: All means are weighted. Data on smoking outcomes and individual demographic controls obtained from the 2009-2019 BRFSS. State unemployment rate data obtained from BEA. Data on state per capita income obtained from FRED. Data on state excise taxes on cigarettes obtained from the CDC's Tax Burden on Tobacco. Data on clean indoor air laws are obtained from the CDC. Beer tax and E-Cig tax data are obtained from the Tax Foundation. Data on medical and recreational marijuana laws, as well as e-cigarette minimum legal purchasing age laws, were obtained from our own investigation of each state's policies.

Table 1B. Descriptive Statistics, YRBS, 2009-2019

	Means of Variables, by Age	
	Age 18	*Ages 16-to-17*
Dependent Variables		
Smoking Participation (Any Smoking in Last 30d)	.183	.125
Frequent Smoking (20 + Day Smoking in Last 30d)	.070	.042
Everyday Smoking (Daily Smoking in Last 30d)	.053	.030
E-Cigarette Use (E-Cigarette Use in Last 30d)	.258	.210
Frequent E-Cigarette Use (Use in 20+d in Last 30d)	.080	.050
Everyday E-Cigarette Use (Daily E-Cigarette Use in last 30d)	.062	.035
Independent Variable		
Tobacco 21 Law	.045	.062
Controls		
Female	.461	.495
Black	.191	.174
Hispanic	.209	.212
Other Race	.072	.081
State Unemployment Rate	6.369	6.257
(Standard Deviation)	(2.39)	(2.37)
State Per Capita Income	46476.95	47357.69
(Standard Deviation)	(9100.53)	(9524.06)
Excise Per Pack Tax on Cigarettes (Nominal)	2.559	2.626
Clean Air Law — Bars	.386	.425
Clean Air Law — Government Multi-Unit Housing	.628	.655
Clean Air Law — Private Multi-Unit Housing	.547	.578
Clean Air Law — Restaurant	.518	.548
Any E-Cigarette Tax	.13	.145
E-Cigarette Minimum Legal Purchase Age Law	.562	.581
Beer Taxes (Nominal)	.319	.306
Medical Marijuana Law	.337	.364
Recreational Marijuana Law	.054	.077
Observations	91,254	454,577

Notes: All means are weighted. Data on smoking outcomes and individual demographic controls obtained from the 2009-2019 YRBS. State unemployment rate data obtained from BLS. Data on state per capita income obtained from BEA. Data on state excise taxes on cigarettes obtained from the CDC's Tax Burden on Tobacco. Data on clean indoor air laws are obtained from the CDC. Beer tax and E-Cig tax data are obtained from the Tax Foundation. Data on medical and recreational marijuana laws, as well as e-cigarette minimum legal purchasing age laws, were obtained from our own investigation of each state's policies.

Table 2. "Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Cigarette Use, BRFSS, 2009-2019

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ages 18-to-20			*Ages 21-to-23*			*Ages 24-to-28*		
					Panel I: Smoking Participation				
Tobacco 21 Law	-0.025**	-0.029***	-0.040***	0.001	-0.001	-0.008	0.001	0.000	-0.003
	(0.012)	(0.011)	(0.011)	(0.014)	(0.014)	(0.014)	(0.007)	(0.007)	(0.009)
Pre-Treat DV Mean	0.127	0.127	0.127	0.198	0.198	0.198	0.232	0.232	0.232
Observations	95,557	95,557	95,557	103,701	103,701	103,701	201,827	201,827	201,827
					Panel II: Everyday Smoking				
Tobacco 21 Law	-0.016*	-0.019**	-0.024***	0.007	0.006	0.003	-0.008	-0.010	-0.010
	(0.008)	(0.008)	(0.009)	(0.011)	(0.011)	(0.012)	(0.007)	(0.007)	(0.008)
Pre-Treat DV Mean	0.075	0.075	0.075	0.123	0.123	0.123	0.150	0.150	0.150
Observations	95,557	95,557	95,557	103,701	103,701	103,701	201,827	201,827	201,827
					Panel III: Quit				
Tobacco 21 Law	0.040	0.045	0.052	0.022	0.022	0.031	0.011	0.010	0.018
	(0.054)	(0.053)	(0.058)	(0.027)	(0.027)	(0.027)	(0.021)	(0.021)	(0.024)
Pre-Treat DV Mean	0.246	0.246	0.246	0.299	0.299	0.299	0.364	0.364	0.364
Observations	16,726	16,726	16,726	28,570	28,570	28,570	71,756	71,756	71,756
Demographic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
E-cigarette Polices?		Y	Y		Y	Y		Y	Y
Alcohol and Marijuana Policies?			Y			Y			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 3. "Difference-in-Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Cigarette Use, BRFSS, 2009-2019

	(1)	(2)	(3)	(4)	(5)	(6)
	Ages 18-to-20 vs Ages 21-to-23			*Ages 18-to-20 vs Ages 24-to-28*		
	Panel I: Smoking Participation					
Tobacco 21 Law	0.002	-0.000	-0.007	-0.000	-0.001	-0.004
	(0.011)	(0.011)	(0.011)	(0.006)	(0.006)	(0.007)
Tobacco 21 Law *18-to- 20	-0.031***	-0.034***	-0.040***	-0.033*	-0.038**	-0.049***
	(0.011)	(0.011)	(0.012)	(0.017)	(0.016)	(0.016)
Pre-Treat DV Mean	0.127	0.127	0.127	0.127	0.127	0.127
Observations	199,258	199,258	199,258	297,384	297,384	297,384
	Panel II: Everyday Smoking					
Tobacco 21 Law	0.005	0.004	0.002	-0.007	-0.009	-0.009
	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)
Tobacco 21 Law *18-to- 20	-0.025**	-0.029***	-0.032**	-0.016	-0.020	-0.026*
	(0.011)	(0.011)	(0.012)	(0.013)	(0.013)	(0.014)
Pre-Treat DV Mean	0.075	0.075	0.075	0.075	0.075	0.075
Observations	199,258	199,258	199,258	297,384	297,384	297,384
	Panel III: Quit					
Tobacco 21 Law	0.021	0.021	0.029	0.011	0.009	0.018
	(0.026)	(0.026)	(0.026)	(0.020)	(0.020)	(0.023)
Tobacco 21 Law *18-to- 20	0.022	0.026	0.027	0.035	0.043	0.043
	(0.043)	(0.042)	(0.048)	(0.056)	(0.055)	(0.064)
Pre-Treat DV Mean	0.246	0.246	0.246	0.246	0.246	0.246
Observations	45,296	45,296	45,296	88,482	88,482	88,482
Demographic Controls?	Y	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y	Y
E-cigarette Polices?		Y	Y		Y	Y
Alcohol and Marijuana Policies?			Y			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 4. Heterogeneity in the Effects of Tobacco 21 Laws, by Age

	(1)	(2)	(3)	(4)	(5)	(6)
	DD	*DDD*	*DDD*	*DD*	*DDD*	*DDD*
	Age 18	*Age 18 vs. Age 21-to-23*	*Age 18 vs. Age 24-to-28*	*Ages 19-to-20*	*Age 19-to-20 vs. Age 21-to-23*	*Age 19-to-20 vs. Age 24-to-28*
			Panel I: Smoking Participation			
Tobacco 21 Law	-0.074***	-0.059***	-0.076***	-0.027**	-0.015**	-0.017
	(0.017)	(0.014)	(0.016)	(0.013)	(0.007)	(0.011)
Pre-Treat DV Mean	0.100	0.167	0.202	0.144	0.173	0.202
Observations	33,399	137,100	235,226	62,158	165,859	263,985
			Panel II: Everyday Smoking			
Tobacco 21 Law	-0.044***	-0.080***	-0.101***	-0.020**	-0.015**	-0.018**
	(0.013)	(0.014)	(0.018)	(0.010)	(0.007)	(0.008)
Pre-Treat DV Mean	0.061	0.103	0.130	0.084	0.105	0.128
Observations	33,399	137,100	235,226	62,158	165,859	263,985
			Panel III: Quit			
Tobacco 21 Law	0.018	-0.040	-0.048	0.064	-0.006	0.002
	(0.118)	(0.091)	(0.098)	(0.072)	(0.027)	(0.037)
Pre-Treat DV Mean	0.206	0.284	0.350	0.261	0.287	0.344
Observations	4,292	32,862	76,048	12,434	41,004	84,190
Demographic Controls?	Y	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y	Y
E-cigarette Polices?	Y	Y	Y	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 5. Heterogeneity in the Effects of Tobacco 21 Laws, by Demographic Group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Male	*Female*	*White*	*Black*	*Other*	*HSD*	*No HSD*	*Below Poverty Line*	*Above Poverty Line*
					Panel I: Smoking Participation				
Tobacco 21 Law	-0.048**	-0.026	-0.056**	-0.064**	-0.015	-0.033***	-0.086**	-0.054**	-0.034***
	(0.023)	(0.019)	(0.024)	(0.032)	(0.019)	(0.010)	(0.036)	(0.024)	(0.010)
Pre-Treat DV Mean	0.152	0.107	0.152	0.086	0.102	0.109	0.216	0.169	0.113
Observations	46,032	40,789	59,180	9,434	26,904	83,536	12,021	25,362	70,195
					Panel II: Everyday Smoking				
Tobacco 21 Law	-0.019*	-0.026	-0.044**	-0.089*	0.005	-0.017*	-0.066*	0.002	-0.031***
	(0.011)	(0.020)	(0.019)	(0.050)	(0.011)	(0.009)	(0.040)	(0.023)	(0.010)
Pre-Treat DV Mean	0.086	0.069	0.098	0.049	0.047	0.061	0.145	0.103	0.066
Observations	46,032	40,789	59,180	9,208	26,904	83,536	12,021	25,362	70,195
					Panel III: Quit				
Tobacco 21 Law	0.118	0.031	0.092	0.036	0.029	0.049	0.097	0.015	0.058
	(0.075)	(0.087)	(0.088)	(0.190)	(0.056)	(0.064)	(0.076)	(0.074)	(0.060)
Pre-Treat DV Mean	0.239	0.248	0.240	0.201	0.274	0.276	0.160	0.231	0.253
Observations	9,306	6,360	11,478	883	4,315	13,395	3,331	5,739	10,976
Demographic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
E-cigarette Polices?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Alcohol/Marijuana Policies?	Y	Y	Y	Y	Y	Y	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 6. "Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Use Among 18-Year-Olds, YRBS, 2009-2019

	(1)	(2)	(3)
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.038**	-0.049***	-0.039**
	(0.019)	(0.017)	(0.016)
Pre-Treat DV Mean	0.193	0.193	0.193
Observations	85,780	85,780	85,780
	Panel II: Frequent Smoking		
Tobacco 21 Law	-0.069**	-0.067***	-0.065***
	(0.027)	(0.026)	(0.025)
Pre-Treat DV Mean	0.076	0.076	0.076
Observations	85,780	85,780	85,780
	Panel III: Everyday Smoking		
Tobacco 21 Law	-0.050*	-0.050*	-0.049*
	(0.028)	(0.028)	(0.028)
Pre-Treat DV Mean	0.058	0.058	0.058
Observations	85,780	85,780	85,780
	Panel IV: E-Cigarette Use		
Tobacco 21 Law	-0.134***	-0.146***	-0.137***
	(0.043)	(0.037)	(0.040)
Pre-Treat DV Mean	0.262	0.262	0.262
Observations	41,638	41,638	41,638
	Panel V: Frequent E-Cigarette Use		
Tobacco 21 Law	-0.077***	-0.065**	-0.067**
	(0.026)	(0.027)	(0.027)
Pre-Treat DV Mean	0.076	0.076	0.076
Observations	41,638	41,638	41,638
	Panel VI: Everyday E-Cigarette Use		
Tobacco 21 Law	-0.076***	-0.067***	-0.068***
	(0.021)	(0.021)	(0.021)
Pre-Treat DV Mean	0.060	0.060	0.060
Observations	41,638	41,638	41,638
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?		Y	Y
Alcohol and Marijuana Policies?			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 7. "Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Use Among 18-Year-Olds, YRBS, 2009-2019, by Gender and Race

	(1)	(2)	(3)	(4)	(5)
	Male	*Female*	*White*	*Black*	*Other*
			Panel I: Smoking Participation		
Tobacco 21 Law	-0.024*	0.001	-0.0001	-0.026	0.009
	(0.014)	(0.017)	(0.021)	(0.027)	(0.013)
Pre-Treat DV Mean	0.223	0.159	0.227	0.108	0.184
Observations	46,168	39,612	48,970	11,877	24,915
			Panel II: Frequent Smoking		
Tobacco 21 Law	-0.032*	-0.039	-0.057**	-0.006	0.002
	(0.019)	(0.024)	(0.023)	(0.024)	(0.009)
Pre-Treat DV Mean	0.091	0.060	0.100	0.037	0.053
Observations	46,168	39,415	48,902	11,788	24,915
			Panel III: Everyday Smoking		
Tobacco 21 Law	-0.018	-0.043*	-0.034*	-0.007	0.001
	(0.017)	(0.023)	(0.020)	(0.022)	(0.008)
Pre-Treat DV Mean	0.069	0.045	0.076	0.029	0.039
Observations	46,168	39,415	48,902	11,788	24,915
			Panel IV: E-Cigarette Participation		
Tobacco 21 Law	-0.063***	-0.004	-0.059*	-0.042	0.032
	(0.019)	(0.030)	(0.031)	(0.074)	(0.031)
Pre-Treat DV Mean	0.303	0.215	0.312	0.148	0.227
Observations	22,716	18,922	24,019	5,062	12,538
			Panel V: Frequent E-Cigarette Use		
Tobacco 21 Law	-0.037*	-0.021*	-0.038	0.023	-0.006
	(0.019)	(0.011)	(0.024)	(0.016)	(0.011)
Pre-Treat DV Mean	0.102	0.046	0.105	0.017	0.052
Observations	22,716	18,922	24,019	4,758	12,404
			Panel VI: Everyday E-Cigarette Use		
Tobacco 21 Law	-0.027*	-0.026**	-0.035	0.025	-0.004
	(0.016)	(0.013)	(0.023)	(0.020)	(0.011)
Pre-Treat DV Mean	0.081	0.035	0.082	0.013	0.042
Observations	22,716	18,922	24,019	4,319	12,404
Demographic Controls?	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y
E-cigarette Polices?	Y	Y	Y	Y	Y
Alcohol & Marijuana Policies?	Y	Y	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Table 8. "Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Use Among 16-to-17-Year-Olds, YRBS, 2009-2019

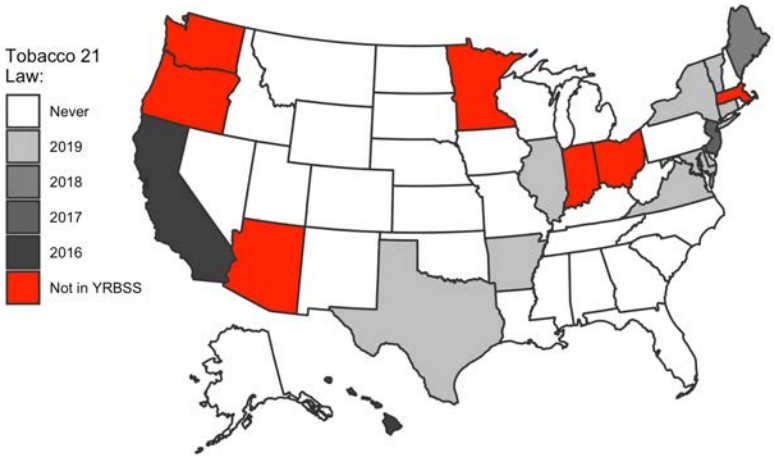
	(1)	(2)	(3)
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.021	-0.028	-0.031*
	(0.015)	(0.018)	(0.017)
Pre-Treat DV Mean	0.134	0.134	0.134
Observations	433,827	433,827	433,827
	Panel II: Frequent Smoking		
Tobacco 21 Law	-0.013	-0.015	-0.016
	(0.011)	(0.011)	(0.010)
Pre-Treat DV Mean	0.045	0.045	0.045
Observations	433,827	433,827	433,827
	Panel III: Everyday Smoking		
Tobacco 21 Law	-0.005	-0.006	-0.008
	(0.006)	(0.006)	(0.006)
Pre-Treat DV Mean	0.033	0.033	0.033
Observations	433,827	433,827	433,827
	Panel IV: E-Cigarette Participation		
Tobacco 21 Law	-0.015	-0.018	-0.017
	(0.057)	(0.057)	(0.058)
Pre-Treat DV Mean	0.207	0.207	0.207
Observations	234,125	234,125	234,125
	Panel V: Frequent E-Cigarette Use		
Tobacco 21 Law	-0.011	-0.009	-0.007
	(0.019)	(0.020)	(0.021)
Pre-Treat DV Mean	0.047	0.047	0.047
Observations	234,125	234,125	234,125
	Panel VI: Everyday E-Cigarette Use		
Tobacco 21 Law	-0.009	-0.005	-0.005
	(0.017)	(0.018)	(0.018)
Pre-Treat DV Mean	0.033	0.033	0.033
Observations	234,125	234,125	234,125
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?		Y	Y
Alcohol and Marijuana Policies?			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

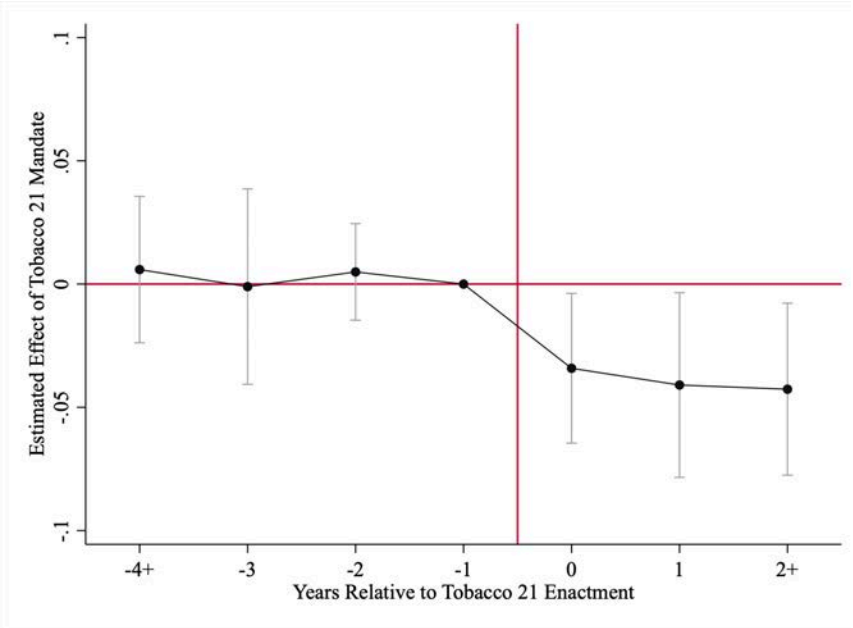
Appendix Tables and Figures

Appendix Figure 1. States Identifying Tobacco-21 Effects in State YRBS

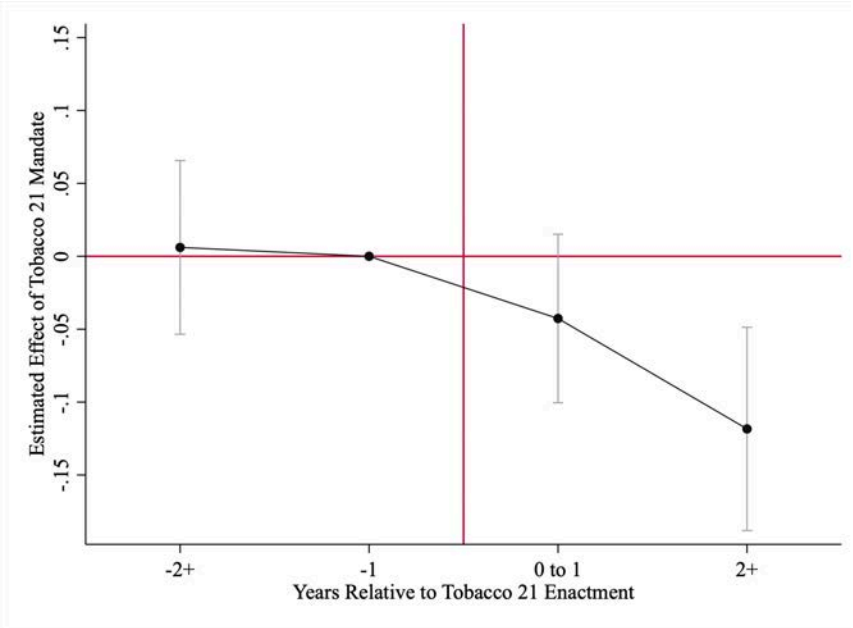


Notes: Grey and black states represent T-21 states where the state YRBS included both before and after data on smoking participation.

Appendix Figure 2. Event-Study Analysis Extended to Two or More Years Post-Treatment, "Difference-in-Differences" Logit Estimates for Smoking Participation for 18-to-20-Year-Olds, BRFSS



Appendix Figure 3. Event-Study Analysis, "Difference-in-Differences" Logit Estimates for E-E-Cigarette Participation for 18-Year-Olds, BRFSS



Appendix Table 1. Effective Dates of State Tobacco-21 Laws and Identifying Variation Across Two National Datasets

State	*Effective Date*	*Contributes to Identification in BRFSS*	*Contributes to Identification in State YRBS*
Hawaii	1-01-2016	Y	Y
California	6-09-2016	Y	Y
District of Columbia	2-18-2017	Y	N
New Jersey	11-01-2017	Y	Y
Oregon	1-01-2018	Y	N
Maine	7-01-2018	Y	Y
Massachusetts	12-31-2018	Y	N
Illinois	7-01-2019	Y	Y
Virginia	7-01-2019	Y	Y
Delaware	7-16-2019	Y	N
Arkansas	9-01-2019	Y	Y
Texas	9-01-2019	Y	Y
Vermont	9-01-2019	Y	Y
Connecticut	10-01-2019	Y	Y
Maryland	10-01-2019	Y	Y
Ohio	10-16-2019	Y	N
New York	11-13-2019	Y	Y

Sources: Preventing Tobacco Addiction Foundation, available at: https://tobacco21.org/

Appendix Table 2. Sensitivity of Estimates to Share of State Population Currently Bound By T-21 Policies BRFSS, 2009-2019 Ages.

	18-to-20	21-to-23	24-to-28
	(1)	(2)	(3)
	Panel I: Smoking Participation		
Any Tobacco 21 Law	-0.033***	-0.010	0.001
	(0.012)	(0.015)	(0.007)
Pre-Treat DV Mean	0.127	0.198	0.232
Observations	95,557	103,701	201,827
	Panel II: Everyday Smoking		
Any Tobacco 21 Law	-0.006	-0.009	0.000
	(0.010)	(0.009)	(0.008)
Pre-Treat DV Mean	0.075	0.123	0.150
Observations	95,557	103,701	201,827
	Panel III: Quit		
Any Tobacco 21 Law	0.036	0.026	-0.004
	(0.045)	(0.031)	(0.018)
Pre-Treat DV Mean	0.246	0.299	0.364
Observations	16,726	28,570	71,756
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 3. Sensitivity of Estimates to Share of State Population Currently Bound By T-21 Policies BRFSS, 2009-2019 Ages.

	18-to-20	21-to-23	24-to-28
	(1)	(2)	(3)
	Panel I: Smoking Participation		
State Only Tobacco 21 Law	-0.041***	-0.009	-0.003
	(0.012)	(0.014)	(0.008)
Local Only Tobacco 21 Law	-0.011	-0.013	0.014
	(0.023)	(0.030)	(0.015)
Pre-Treat DV Mean	0.127	0.198	0.232
Observations	95,557	103,701	201,827
	Panel II: Everyday Smoking		
State Only Tobacco 21 Law	-0.021**	-0.001	-0.008
	(0.009)	(0.010)	(0.008)
Local Only Tobacco 21 Law	0.029	-0.029	0.026*
	(0.019)	(0.023)	(0.014)
Pre-Treat DV Mean	0.075	0.123	0.150
Observations	95,557	103,701	201,827
	Panel III: Quit		
State Only Tobacco 21 Law	0.051	0.031	0.012
	(0.058)	(0.028)	(0.022)
Local Only Tobacco 21 Law	-0.008	0.007	-0.061*
	(0.056)	(0.071)	(0.037)
Pre-Treat DV Mean	0.246	0.299	0.364
Observations	16,726	28,570	71,756
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 4. Exploration of Whether Tobacco-21 Law is More Effective if Border State has a Tobacco-21 Law, BRFSS, 2009-2019

	(1)	(2)	(3)
	Ages 18-to-20		
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.024**	-0.028**	-0.038***
	(0.012)	(0.011)	(0.011)
Tobacco 21 Law *Border state Tobacco 21 Law	-0.003	-0.003	-0.004
	(0.017)	(0.017)	(0.016)
Pre-Treat DV Mean	0.127	0.127	0.127
Observations	95,557	95,557	95,557
	Panel II: Everyday Smoking		
Tobacco 21 Law	-0.011	-0.015*	-0.019**
	(0.008)	(0.008)	(0.009)
Tobacco 21 Law * Border state Tobacco 21 Law	-0.021	-0.021	-0.022
	(0.016)	(0.016)	(0.016)
Pre-Treat DV Mean	0.075	0.075	0.075
Observations	95,557	95,557	95,557
	Panel III: Quit		
Tobacco 21 Law	0.054	0.058	0.065
	(0.053)	(0.052)	(0.056)
Tobacco 21 Law * Border state Tobacco 21 Law	-0.055	-0.055	-0.055
	(0.042)	(0.042)	(0.041)
Pre-Treat DV Mean	0.246	0.246	0.246
Observations	16,726	16,726	16,726
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?		Y	Y
Alcohol and Marijuana Policies?			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 5. The Effects of Tobacco 21 Laws on E-Cigarette Participation, BRFSS 2016-2018

	(1)	(2)	(3)	(1)	(2)	(3)	(4)	(5)	(6)
	DD	*DDD*	*DDD*	*DD*	*DDD*	*DDD*	*DD*	*DDD*	*DDD*
	Age 18-to 20	*Age 18-to-20 vs. Age 21-to-23*	*Age 18-to-20 vs. Age 24-to-28*	*Age 18*	*Age 18 vs. Age 21-to-23*	*Age 18 vs. Age 24-to-28*	*Ages 19-to-20*	*Age 19-to-20 vs. Age 21-to-23*	*Age 19-to-20 vs. Age 24-to-28*
Tobacco 21 Law	-0.015	-0.014	-0.018**	-0.076	-0.024*	-0.030***	0.012	-0.009	-0.012
	(0.038)	(0.010)	(0.009)	(0.055)	(0.013)	(0.012)	(0.033)	(0.009)	(0.008)
Pre-Treat DV Mean	0.112	0.112	0.112	0.114	0.114	0.114	0.111	0.111	0.111
Observations	19,698	41,475	61,214	6,682	28,465	48,204	13,010	34,787	54,526
Demographic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Economic Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y	Y	Y	Y	Y	Y	Y
E-cigarette Polices?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y	Y	Y	Y	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 6. Sensitivity of Estimated Tobacco-21 Effects to Controls for Spatial Heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
	Ages 18-to-20		Ages 21-to-23		Ages 24-to-28	
	Panel I: Smoking Participation					
Tobacco 21 Law	-0.037***	-0.034***	-0.006	-0.031	-0.008	-0.005
	(0.010)	(0.010)	(0.012)	(0.020)	(0.009)	(0.010)
Pre-Treat DV Mean	0.127	0.127	0.198	0.198	0.232	0.232
Observations	95,557	95,557	103,701	103,701	201,827	201,827
	Panel II: Everyday Smoking					
Tobacco 21 Law	-0.019**	-0.014*	0.002	-0.004	-0.013	-0.015*
	(0.008)	(0.008)	(0.011)	(0.016)	(0.008)	(0.008)
Pre-Treat DV Mean	0.075	0.075	0.123	0.123	0.150	0.150
Observations	95,557	95,557	103,701	103,701	201,827	201,827
	Panel III: Quits					
Tobacco 21 Law	0.053	0.033	0.040	0.061	0.024	0.018
	(0.056)	(0.050)	(0.027)	(0.042)	(0.028)	(0.032)
Pre-Treat DV Mean	0.246	0.246	0.299	0.299	0.364	0.364
Observations	16,726	16,726	28,570	28,570	71,756	71,756
Region-by-Year FE	Y	Y	Y	Y	Y	Y
State Specific Time Trend		Y		Y		Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 7. Ordinary Least Squares (LPM) Estimates of the Effect of Tobacco 21 Laws on Tobacco Cigarette Use, BRFSS, 2009-2019

	(1)	(2)	(3)
	DD Age 18-to-20	*DDD Age 18-to-20 vs. Age 21-to-23*	*DDD Age 18-to-20 vs. Age 21-to-23*
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.025***	-0.003	-0.001
	(0.007)	(0.010)	(0.014)
Tobacco 21 Law *18-to-20		-0.021**	-0.024**
		(0.010)	(0.010)
Pre-Treat DV Mean	0.127	0.127	0.127
Observations	95,557	199,258	199,258
	Panel II: Everyday Smoking		
Tobacco 21 Law	-0.011**	0.005	0.011
	(0.005)	(0.009)	(0.010)
Tobacco 21 Law *18-to-20		-0.016*	-0.016*
		(0.009)	(0.009)
Pre-Treat DV Mean	0.075	0.075	0.075
Observations	95,557	199,258	199,258
	Panel III: Quit		
Tobacco 21 Law	0.060	0.036	-0.056
	(0.071)	(0.031)	(0.039)
Tobacco 21 Law *18-to-20		0.023	0.043
		(0.052)	(0.059)
Pre-Treat DV Mean	0.246	0.246	0.246
Observations	16,726	45,296	45,296
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y
State-by-Year Fully Interacted FE			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted OLS estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 8. Sensitivity of Estimates to Use of Birth Cohort Instead of Age Group to Define Affected Individuals, BRFSS, 2009-2019

	(1)	(2)	(3)
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.011	-0.012	-0.014
	(0.008)	(0.008)	(0.010)
Tobacco 21 Law * Affected Birth Cohort	-0.040*	-0.040*	-0.042*
	(0.023)	(0.023)	(0.023)
Pre-Treat DV Mean	0.127	0.127	0.127
Observations	401,085	401,085	401,085
	Panel II: Everyday Smoking		
Tobacco 21 Law	-0.010	-0.011*	-0.008
	(0.006)	(0.007)	(0.008)
Tobacco 21 Law * Affected Birth Cohort	-0.027	-0.028	-0.028*
	(0.017)	(0.017)	(0.017)
Pre-Treat DV Mean	0.075	0.075	0.075
Observations	401,085	401,085	401,085
	Panel III: Quit		
Tobacco 21 Law	0.017	0.017	0.029
	(0.023)	(0.024)	(0.028)
Tobacco 21 Law * Affected Birth Cohort	-0.026	-0.026	-0.025
	(0.019)	(0.019)	(0.021)
Pre-Treat DV Mean	0.246	0.246	0.246
Observations	117,052	117,052	117,052
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?		Y	Y
E-cigarette Polices?		Y	Y
Alcohol and Marijuana Policies?			Y
State Specific Time Trend?			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 9. YRBS Leads and Lags
2009-2019, *Smoking Participation*

	(1)	(2)	(3)
	Age 18	*Age 16-to-17*	*Age 18-to-16*
2+ waves prior to T21	0.007	0.005	0.005
	(0.017)	(0.005)	(0.006)
1 wave prior to T21	-	-	-
	-	-	-
First wave with T21	-0.006	-0.010	-0.009
	(0.015)	(0.009)	(0.010)
Second wave with T21	-0.048**	-0.046***	-0.045***
	(0.019)	(0.015)	(0.011)
Observations	85,780	433,827	519,607
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?	Y	Y	Y
Alcohol and Marijuana Policies?	Y	Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 10. "Difference-in-Differences" Logit Estimates of the Effect of Tobacco 21 Laws on Tobacco Use Among 13-to-15-Year-Olds, YRBS, 2009-2019

	(1)	(2)	(3)
	Panel I: Smoking Participation		
Tobacco 21 Law	-0.010	-0.014	-0.013
	(0.011)	(0.011)	(0.011)
Pre-Treat DV Mean	0.084	0.084	0.084
Observations	369,547	369,547	369,547
	Panel II: Frequent Smoking		
Tobacco 21 Law	-0.003	-0.005	-0.004
	(0.009)	(0.010)	(0.008)
Pre-Treat DV Mean	0.021	0.021	0.021
Observations	369,547	369,547	369,547
	Panel III: Everyday Smoking		
Tobacco 21 Law	0.001	0.001	0.001
	(0.007)	(0.008)	(0.006)
Pre-Treat DV Mean	0.015	0.015	0.015
Observations	369,547	369,547	369,547
	Panel IV: E-Cigarette Participation		
Tobacco 21 Law	-0.031	-0.030	-0.029
	(0.042)	(0.039)	(0.039)
Pre-Treat DV Mean	0.155	0.155	0.155
Observations	208,153	208,153	208,153
	Panel V: Frequent E-Cigarette Use		
Tobacco 21 Law	-0.012	-0.011	-0.011
	(0.009)	(0.009)	(0.009)
Pre-Treat DV Mean	0.025	0.025	0.025
Observations	208,153	208,153	208,153
	Panel VI: Everyday E-Cigarette Use		
Tobacco 21 Law	-0.012	-0.012	-0.012
	(0.008)	(0.008)	(0.008)
Pre-Treat DV Mean	0.016	0.016	0.016
Observations	208,153	208,153	208,153
Demographic Controls?	Y	Y	Y
Economic Controls?	Y	Y	Y
Cigarette Policy Controls?	Y	Y	Y
E-cigarette Polices?		Y	Y
Alcohol and Marijuana Policies?			Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted logit estimates are generated using data from the 2009-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 11. Multinomial Logit Estimates of the Effect of Tobacco 21 Laws on Source of E-Cigarette, YRBS, 2017-2019

	(1)	(2)	(3)	(4)
	18-Year-Olds	16-to-17-Year-Olds	18-Year-Olds	16-to-17-Year-Olds
Panel I: E-Cigarette Participation				
Tobacco 21 Law	-0.195***	-0.060	-0.123**	0.002
	(0.037)	(0.083)	(0.053)	(0.059)
Mean	0.177	0.126	0.177	0.126
Observations	26,859	147,634	26,859	147,634
Panel II: Usual Source of E-Cigarettes				
	Direct Purchase			
Tobacco 21 Law	-0.211***	-0.001	-0.237***	0.022
	(0.037)	(0.013)	(0.062)	(0.030)
Mean	0.109	0.018	0.109	0.018
	Third-Party Purchase			
Tobacco 21 Law	0.011	-0.025	0.000	-0.025
	(0.013)	(0.016)	(0.014)	(0.019)
Mean	0.007	0.014	0.007	0.014
	Bumming or Borrowing			
Tobacco 21 Law	0.002	-0.058	0.122*	-0.019
	(0.033)	(0.046)	(0.064)	(0.036)
Mean	0.034	0.059	0.034	0.059
	Internet, Stole, or Some Other Way			
Tobacco 21 Law	0.035	-0.002	0.036	-0.016
	(0.023)	(0.011)	(0.048)	(0.016)
Mean	0.026	0.025	0.026	0.025
Observations	22,921	124,988	22,921	124,988
Demographic Controls?	Y	Y	Y	Y
Economic Controls?			Y	Y
Cigarette Policy Controls?			Y	Y
E-cigarette Polices?			Y	Y
Alcohol and MJ Policies?			Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted multinomial logit estimates are generated using data from the 2017-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.

Appendix Table 12. Multinomial Logit Estimates of the Effect of Tobacco 21 Laws on Source of E-Cigarette Among Males, YRBS, 2017-2019

	(1)	(2)	(3)	(4)
	18-Year-Olds	16-to-17-Year-Olds	18-Year-Olds	16-to-17-Year-Olds
Panel I: E-Cigarette Participation				
Tobacco 21 Law	-0.164***	-0.089	-0.079	-0.022
	(0.063)	(0.106)	(0.063)	(0.065)
Mean	0.226	0.143	0.143	0.143
Observations	14,605	72,787	14,605	72,787
Panel II: Usual Source of E-Cigarettes				
	Direct Purchase			
Tobacco 21 Law	-0.249***	-0.024	-0.245***	-0.034*
	(0.045)	(0.017)	(0.064)	(0.019)
Mean	0.156	0.035	0.156	0.035
	Third-Party Purchase			
Tobacco 21 Law	0.047***	-0.031**	0.005	-0.056***
	(0.017)	(0.016)	(0.018)	(0.015)
Mean	0.013	0.032	0.013	0.032
	Bumming or Borrowing			
Tobacco 21 Law	0.051	-0.028	0.053	-0.052
	(0.042)	(0.056)	(0.051)	(0.036)
Mean	0.059	0.084	0.059	0.084
	Internet, Stole, or Some Other Way			
Tobacco 21 Law	0.026	-0.026	0.055	-0.033
	(0.033)	(0.022)	(0.038)	(0.027)
Mean	0.038	0.045	0.038	0.045
Observations	12,461	61,754	12,461	61,754
Demographic Controls?	Y	Y	Y	Y
Economic Controls?			Y	Y
Cigarette Policy Controls?			Y	Y
E-cigarette Polices?			Y	Y
Alcohol and MJ Policies?			Y	Y

***Significant at 1% level **Significant at 5% level *Significant at 10% level

Notes: Weighted multinomial logit estimates are generated using data from the 2017-2019 BRFSS. Demographic controls include indicators for sex, race, educational attainment, and household income; economic controls include state unemployment rate and state per capita income, cigarette policy controls include state cigarette tax; e-cigarette policy controls include state e-cigarette tax and an indicator for the sale of e-cigarettes being over 18; and alcohol and marijuana policies include state beer tax, indicators for legalized medical marijuana, and legalized recreational marijuana.