Examining Early Effects of Tobacco 21 on Substance Use among Teenagers

Rahi Abouk[1]

William Paterson University

Prabal De

City University of New York

Michael F. Pesko

Georgia State University

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ABSTRACT

We examine the effect of Tobacco 21 laws, which raise the minimum legal sale age of tobacco to 21, on cigarette and e-cigarette use rates for middle school and high school students in the United States. We estimate difference-in-differences models using the Monitoring the Future (MTF) survey data from 2012 to 2018. Our results suggest that these laws reduce cigarette use among underage 12th graders by 28 percent. These effects were particularly pronounced for males and racial/ethnic minorities. We also find limited evidence of these laws affecting cigarette use for 8th and 10th graders. Finally, we find no evidence of these laws affecting e-cigarette use, alcohol use, or marijuana use.

[1] Corresponding author. William Paterson University, 300 Pompton Road, Wayne NJ 07470. Email: aboukr@wpunj.edu. We appreciate editorial assistance from Dr. Serena Phillips. Dr. Michael Pesko acknowledges funding from the National Institute on Drug Abuse of the National Institutes of Health under Award Number R01DA045016.

Introduction

The use of tobacco causes approximately a half-million preventable deaths in the United States each year (Office of the Surgeon General, 2012). Various heart and respiratory diseases and several forms of cancer are among some of the well-known health effects of tobacco use. The U.S. spends $170 billion in tobacco-related health care expenditures each year (Xu et al., 2015). Curbing tobacco consumption is a major focus of health policy in the United States. According to the 2012 Surgeon General's Report, roughly 96% of smokers began smoking before age 21 (U.S. Department of Health and Human Services, 2012). There is also evidence that the age of initiation has long-term effects on the intensity of addiction and capacity to quit, as many smokers that began smoking while young become addicted between the ages of 18 and 21 (Taioli and Wynder, 1991; Kwan et al., 2015).

Many public policies have been implemented to reduce smoking, such as imposing higher taxes, issuing statutory warnings on labels and packaging, and raising the minimum legal sales age (MLSA) for tobacco products. In 1992, the MLSA for tobacco products was set to 18 at the federal level. By 2005, only four states (Alabama, Alaska, New Jersey, and Utah) had raised their MLSA to 19. More recently, a significant push has been made to raise the MLSA to 21. As of mid-2018 (the end of our study period), four states and 281 areas had passed Tobacco 21 (T21) laws (American Lung Association, 2019). At the end of 2019, the federal government implemented a national T21 law.

We use annual Monitoring the Future (MTF) data from 2012 to 2018 to identify the effects of T21 adoption across three states and 15 areas contained in the data. Despite the law being in place nationally as of the end of 2019, there is relatively little research studying T21 laws. The work by Friedman and Wu (2020) is the closest to our current paper. Using Behavioral

Risk Factor Surveillance System SMART data from 2011 to 2016, they find that laws covering all parts of a large metropolitan area reduce smoking among 18-20-year-olds by 3.1 percentage points (pp). Our paper expands this work in several key dimensions. First, we extend our data through 2018 (compared to 2016), which was an active time for T21 law adoption, including laws adopted between January 2017 to June 2018 (the end of the MTF sample period) in New Jersey and Oregon as well as many municipalities. By our calculations, this increased T21 coverage from 18.7% of the population to 24.2% by the end of June 2018.

Second, we are the first study to examine the effect of T21 on e-cigarette use which is an important outcome to add to the T21 literature for various reasons. First, by the end of our study period in 2018, e-cigarettes were the most commonly used tobacco product among youth (1 in 5 high school students used e-cigarettes) (Wang et al., 2018), and such high use levels is described as an "epidemic" by the Surgeon General (Office of the Surgeon General, 2018). Second, this surge in the use of e-cigarettes was one of the factors behind the momentum to pass T21 at the federal level (Sindelar, 2020). Our study is therefore the first to shed light on how T21 laws affect "epidemic" levels of youth e-cigarette use.

Third, we are also the first study to examine the effect of T21 on other substances such as marijuana and alcohol use. The literature has previously studied the impact of financial changes in cigarettes on the use of these products, generally finding that marijuana is an economic substitute (Farrelly et al., 2001; Cameron and Williams 2001; Choi et al. 2019), but with unclear effects on alcohol consumption (Markowitz and Tauras 2009; Pacula, 1998; Shrestha, 2018; Yörük and Yörük 2013). We are unaware of any study previously using variation in tobacco age purchasing laws to study the substitute/complement relationship with alcohol and marijuana,

which provides a useful alternative source of variation than price variation to understand these relationships.

Finally, we expand the current literature by exploring potential effects on youth younger than 18. While these youth were not newly legally covered by T21, they may have still been impacted by T21 by reducing tobacco access through legal-of-age students. The average youth cigarette use rate during this period for 8th and 10th graders was 5.1%, thus providing an important population to continue targeting for reductions in cigarette use.

In sum, we are able to expand the scant literature in this space in multiple important directions. Our main finding suggests that raising the MLSA to 21 has been successful in reducing cigarette use, especially among underage 12th graders, who saw a decline in cigarette use of about 28%. We do not find evidence of T21 affecting e-cigarette use, alcohol use, or marijuana use.

The rest of the paper is organized as follows. In the next section, we start with a brief history of the T21 legislation and its gradual rollout culminating with the federal law at the end of 2019. We also critically review the current literature on T21 and MLSA laws in general. Section 3 describes the dataset used, choice of variables, and sample selection along with our empirical specifications. Section 4 reports the main results and those from sensitivity analyses. The last section concludes with a discussion of the policy implications of our findings.

1. Background

1.1 History and Current Status of T21

The campaign for T21 was launched in 1996 by a public health nonprofit organization *Preventing Tobacco Addiction Foundation*. The campaign currently covers all nicotine products,

including e-cigarettes, but excludes nicotine replacement therapy products (e.g., gum, patch, etc.). The campaign also advocates for strict enforcement provisions by encouraging policymakers to specify the dedicated funding source for such activities.

Until it became federal law, T21 was adopted in an uncoordinated manner using local and state laws over 15 years. The first municipality to implement T21 was Needham, MA in 2005. In the period following Needham's implementation, one survey found lower smoking rates in this municipality than in neighboring municipalities (Schneider et al., 2016). Hawaii became the first state to pass T21 statewide in January 2016, followed by California in June 2016. Two states passed T21 in 2017, four states in 2018, and ten states in 2019. Finally, T21 was implemented nationally on December 20, 2019, by amending the Federal Food, Drug, and Cosmetic Act (FDA, 2019a).

1.2. Current evidence on T21 and other MLSA changes on substance abuse

T21 laws may reduce tobacco use among adolescents by eliminating legal access to tobacco (Morain et al. 2016), thus raising the "hassle costs" of obtaining tobacco and reducing tobacco use as a result. It is well-documented that despite the minimum legal age of 18 years, many adolescents start (and sometimes get addicted to) tobacco before they turn 18 (Kessler et al. 1997). This might occur when teenagers obtain tobacco products from their friends who have legal access to them.

MLSA laws may also not be enforced enough to discourage youth use. The MLSA laws are often not obeyed by sellers, who have a conflict of interest between gaining revenue versus enforcing the law (Abouk and Adams 2017a; Silver et al. 2016). Anecdotal evidence suggests that the police department failed to enforce the new law in Cleveland.[2] On the other hand, there

[2] https://www.news5cleveland.com/news/e-team/obvious-oversights-and-lack-of-enforcement-discovered-with-clevelands-tobacco-21-law

has been successful enforcement of T21 laws in New York City (Moreland-Russell et al. 2016) under the Sensible Tobacco Enforcement (STE) law. Abouk and Adams (2017a) study the effect of tobacco retailer inspections to enforce the federal MLSA of 18 conducted as part of the 2009 Tobacco Control Act. They find that undercover buyer sting inspections are effective in reducing cigarette use among females, but not males. However, Feng and Pesko (2019) do not find a significant impact of the inspections when adding additional years of data.

Current empirical evidence provides evidence that MLSA laws reduce cigarette use. Friedman et al. (2019) find that T21 laws are associated with a lower incidence of smoking among 18- to 20-year-olds who already tried smoking. Friedman and Wu (2020) find that the laws reduce smoking among 18- to 20-year-olds in large metropolitan areas. Ali et al. (2020) find that California and Hawaii's T21 laws reduce tax-paid sales of cigarettes (overall, not specifically for young adults) by between 13.1%–18.2%.

Related research has explored the effect of cigarette MLSA laws in general. Yörük and Yörük (2016) find evidence using a regression discontinuity design that MLSA laws reduce smoking among youth in the United States, although a recent study in Switzerland finds little effect of MLSA laws (Meier et al. 2019). Three studies find evidence that e-cigarette MLSA laws reduce youth e-cigarette use (Nguyen, 2020; Dave et al., 2019; and Abouk and Adams, 2017b). E-cigarette MLSA laws may also raise cigarette use according to several studies (Friedman, 2015; Pesko et al., 2016; Dave et al., 2019; Pesko and Currie, 2019) or reduce it according to one study (Abouk and Adams, 2017b).

1.3. Hypotheses and Testable Predictions

Based on the available literature, we hypothesize that T21 laws will reduce the use of tobacco products, especially for 18-20-year-olds who can no longer purchase the product legally.

Therefore, the "hassle costs" of obtaining tobacco have increased for these young adults. Some will stop using tobacco altogether, while others will reduce their use. Therefore, we expect T21 laws to reduce 18-20-year-old tobacco product use on both margins. Individuals that were already aged 18-20 when the law came into effect may be able to evade the law in part by stockpiling prior to the law coming into place.

We also expect to observe decreases in tobacco product use for < 18-year-olds because high schools will no longer be co-populated by students above and below the MLSA of 18. The older students may have previously been the suppliers of tobacco.

T21 may have had a more significant impact on cigarette use than e-cigarette use because youth are more likely to get e-cigarettes from social sources than cigarettes (Bach 2020). Based on the 2018 MTF survey, 82% of respondents believed that it is 'fairly easy or very easy' to get e-cigarette devices while only 75% of them believed so for conventional cigarettes. According to YRBSS Online,[3] only 13.6% of youth e-cigarette users usually purchase e-cigarettes from stores in 2017. This, combined with e-cigarettes potentially requiring fewer purchases than cigarettes in general due to e-cigarettes providing higher nicotine volume, may cause T21 laws to have relatively less effect on e-cigarette use than cigarette use.

The effect of T21 on marijuana and alcohol use is less clear. Since T21 laws increase hassle costs, we can look to the literature that has studied how alcohol and marijuana have responded to changes aside from hassle costs (e.g., taxes). Cigarettes and marijuana have been found to be economic complements for youth and young adults in a number of studies (Farrelly et al. 2001; Cameron and Williams 2001; Choi et al. 2019). Two studies find that cigarette prices

[3] https://nccd.cdc.gov/youthonline/

(Markowitz and Tauras 2009) and taxes (Pacula 1998) increase alcohol use for youth and young adults on the extensive margin. One recent study finds that higher cigarette prices due to the Master Settlement Agreement reduced extensive margin alcohol use for young adults but increased the amount of drinking conditional on any drinking (Shrestha 2018). Another study used variation in minimum legal drinking age laws, finding little effect of this on cigarette use (Yörük and Yörük 2013). Therefore, the past literature suggests that T21 laws, if they operate similarly to other historical price changes, should reduce marijuana use, but the effect on alcohol use is not as clearly identified by the past literature.

2. Data and Empirical Strategy

2.1 Data

For this study, we use restricted MTF survey data between the years 2012 and 2018. The MTF is a nationally representative sample of students enrolled in public or private secondary schools and includes questions on their substance abuse behavior (Johnston et al., 2015). We use the period 2012 to 2018 to provide a sufficient length of time before significant policy changes started taking effect, such as the New York City law in 2014 and state laws in Hawaii and California in 2016. Data are collected in the MTF survey each spring (February to June) by interviewing around 50,000 students in 8^{th}, 10^{th}, and 12^{th} grades across the nation. For our study, we focus on students in the 8^{th}, 10^{th}, and 12^{th} grades who were below 18 years of age. One of the advantages of using the MTF survey is that it reports respondents' age in months, enabling us to identify those who were just below or above a certain age threshold. The restricted-use MTF also includes information about the city and county in which the school is located, providing the ability to estimate the effect of T21 laws enacted at both local and state levels.

The survey further asks respondents a variety of questions about their socioeconomic status. In the analysis, we control for students' gender, age indicators (in years), and race (white non-Hispanic [reference], black non-Hispanic, Hispanic, and other non-Hispanic). The survey asks two questions about weekly income: income from work and allowance from parents. We control for total income from these sources after converting them into 2018 dollars. Finally, five binary variables control for parental education categories: high school graduate, some college, college graduate, post-baccalaureate, and missing (separately for the mother and father, and using education less than high school as the reference group).

During the period of the study, several other concurrent policies were implemented or changed at the state or local level. To account for them, we control for cigarette taxes (at federal, state, and local levels);[4] the presence of an e-cigarette tax (at state-quarter level); marijuana decriminalization laws (at state-level); beer taxes (at state-level); smoke-free air laws (at county-level) that prohibited smoking and vaping (separate measures) fully in workplaces, restaurants, and bars (WRB).[5]

Data on cigarette taxes and beer taxes are from the *Tax Burden on Tobacco* and the *National Institute on Alcohol and Alcoholism* (NIAAA) and are adjusted for inflation using the Bureau of Labor Statistics' *Consumer Price Index*. Information on smoke-free air laws and vaping bans is from the *American Non-Smokers' Rights Foundation* (ANRF). Information on marijuana decriminalization laws is from the *Marijuana Policy Project*.

[4] Local cigarette taxes in the City of Chicago and Cook County changed during our study period.
[5] Some of these policies have been shown to affect smoking. For example, using data from the Youth Risk Behavior Surveillance System (YRBSS), Carpenter and Cook (2007) find that increases in state cigarette taxes are associated with significant reductions in smoking by youth on both extensive and intensive margins. Though evidence to the contrary also exists - using two waves of the National Longitudinal Survey, DeCicca et al. (2008) did not find evidence that taxes discourage smoking initiation. More recent studies also suggest that cigarette taxes are not as effective as they used to be in reducing smoking among youths (Hansen et al. 2017).

The primary policy variable is a binary variable equal to one if the state, county, or city has a T21 law and zero otherwise. The data on effective dates of the policy in each state, county, or city is from the *Preventing Tobacco Addiction Foundation*. By the end of June 2018, 262 cities, 19 counties (including the 5 counties in New York City), and four states increased the MLSA to 21. Table 1 lists cities, counties, and states represented in the MTF survey, which adopted the law along with the effective dates. Overall, T21 covered around 80 million Americans by mid-2018, out of whom 63.5 million were represented in the MTF survey.

2.2 Empirical strategy

We employ a difference-in-differences (DID) identification strategy to estimate the effect of raising the MLSA to 21 on substance use outcomes:

$$(1) \qquad Y_{icm} = \alpha + \gamma_c + \delta_m + \omega Tob21_{cm} + Z_{cm}\beta + X_{icm}\theta + \epsilon_{icm}$$

where *i* indexes individuals, *c* indexes county of residence, and *m* indexes year-by-month of the interview.

Variable Y is one of the following outcomes (all over the last 30 days): 1) any cigarette use, 2) average daily cigarettes smoked,[6] 3) any e-cigarette use,[7] 4) frequency of days using e-cigarettes, 5) any marijuana use, and 6) any alcohol use.

Variable *Tob21* is binary and equal to one if a state, county, or city had a T21 law at the time of the interview; and zero otherwise. Our coefficient of interest is ω, which measures the effect of raising the MLSA to 21 in a state, county, or city on the outcome variable.

[6] See Abouk and Adams (2017a) for explanations about the way the intensity measures are defined. Also, non-smokers are coded as zero.

[7] While we generally start the analysis in 2012, for e-cigarette variables we could only use data starting in 2014 since this was the first year that MTF added questions about e-cigarette use. Additionally, we only use data through 2017 for 8th/10th graders since we were unable to construct consistent measures for these grades in 2018.

Variable γ_c is a set of county dummies and δ_m represents year-month fixed effects, which controls for time-varying unobservable factors affecting the nation as a whole. Matrix Z contains a battery of policy variables at the state level (beer taxes, e-cigarette taxes, and marijuana decriminalization) and policy variables at both the state and local levels (cigarette taxes, smoke-free air laws, and vaping bans). The matrix X includes all the individual-level socioeconomic variables discussed in the previous section, including age dummies. Finally, ϵ is the error term clustered at the area level (s) to address the non-independence of observations from the same area over time (Bertrand et al., 2004).[8]

As in our main specification, we estimate the equation using a linear model. However, we report the results from a probit regression model as a robustness check.

The DID identification strategy relies on the assumption of parallel trends in the outcome variable in treated and control counties in the absence of a policy change. Table 1 shows that T21 has been sporadically adopted in the Eastern, Midwestern, and Western parts of the country without obvious clustering. We also empirically test this hypothesis by conducting an event study, where we replace the *Tob21* variable in equation (1) with six binary variables: the first four capturing the trend in the outcome variable up to the policy coming into effect and the last two capturing the policy after coming into effect. These policy lag and lead variables are set to zero for the areas with no T21 laws. We discuss the event study result in detail in section 4.3. However, the jointly insignificant and small estimated lead effects suggest that the trends in the outcome variable in treated versus control counties were parallel before the policy implementation. Therefore, the DID framework is internally valid.

[8] We also performed the analysis by clustering at other levels. Results are similar and not sensitive to clustering at the county or state level.

4. Results

4.1. Descriptive statistics

Columns 1-2 of Table 2 show the descriptive statistics for the key variables and their means for 8^{th}/10^{th} graders for the 2012-2013 period. Columns 3-4 of the same table report those statistics for underage 12^{th} graders. Descriptive statistics are also provided for areas that did not implement T21 (Columns 1 and 3) and those that did (Columns 2 and 4). The first row contains the relevant statistics for our primary outcome variable: 30-day cigarette use participation. Results suggest that T21 areas had a lower rate of cigarette use prior to the implementation of T21 compared to non-adopters. In addition, T21 areas are more likely to implement other tobacco policies such as smoke- and vape-free air laws and e-cigarette sales bans. Cigarette taxes were also higher in T21 areas. These differences are not surprising given the differences in tobacco and e-cigarette regulations across these areas. For example, areas that passed T21 also had a much higher incidence of other strict anti-tobacco laws. Seventy percent of the 'treated' areas had a 100% smoking ban in workplaces, restaurants, and bars compared to around 30% of the areas with no T21 laws. A similar pattern is present for vaping bans as well. Individual-level characteristics such as the respondent's age, gender, income, and parental education were similar for both groups. However, T21 areas had a higher Hispanic population compared to non-adopters. We control for all of these differences in our regression models.

4.2. Difference-in-differences estimates

Table 3 presents our main results — the adjusted difference-in-differences estimates of the implementation of T21 law on the incidence and intensity of cigarette use for both the 8^{th} and 10^{th} graders (Panel A) and underage 12^{th} graders (Panel B). Columns 1-2 present the results for

the current cigarette use measure, and columns 3-4 present results for the average daily cigarettes smoked in the past 30 days (setting this equal to 0 for non-smokers). We control for county fixed effects, year-month fixed effects, individual-level demographics, and policy variables in all regression models. In Columns 2 and 4, we present the results using the approach proposed in Goodman-Bacon (2018). Specifically, we partial out pre-treatment trends from the outcome variable and regress the adjusted outcome on the right-hand-side variables.

For 8th and 10th graders, T21 does not significantly lower current cigarette use (Panel A, Columns 1) or average daily cigarettes (Panel A, Column 3).[9] However, the estimated coefficient at the extensive margin becomes larger and statistically significant after using the Goodman-Bacon approach (0.7 pp, 16.2%). For underage 12th graders, T21 significantly reduces cigarette use by 2.46 pp (28%).[10] We do not find any significant changes in cigarette use intensity for either group (Column 3).

Full results to accompany Table 3 are reported in Tables A1-A2. Being male and higher income increases the likelihood of cigarette use. Being black or Hispanic reduces it, as well as having a higher level of parental education.

Following Pei et al. (2018), we conduct a series of balancing tests to investigate the possibility of correlation of T21 laws with other regressors used in the analysis. For this test, we aggregate the regressors at the year-county level. We then regress the T21 policy variable on the remaining explanatory variables and control for year and county dummies. Results for underage 12th graders are reported in Table A3. The p-value from the F-test of joint significance for the individual-level variables is 0.413, suggesting that T21 is likely independent of demographic

[9] Results are robust if we study adolescents in the 8th and 10th grades, separately. Among 8th (10th) graders, the estimated effect on the incidence of smoking in the past 30 days ranges from -0.008 to -0.002 (-0.007 to 0.003).
[10] Percentage change in smoking conventional cigarettes$= \frac{-0.0246}{0.088} \times 100 = 28.0\%$.

variables. However, the p-value from the F-test of joint significance for other policy variables is 0.002, suggesting that policymakers pass T21 and other tobacco control policies simultaneously. This motivates controlling for these other tobacco control policies in our regression models.

In Table 4, we report the effect of T21 laws on e-cigarette use during the past 30 days for both participation and intensity measures. E-cigarette use data became available in the MTF in 2014. Therefore, we have a shorter period to study the effect of T21 laws on this outcome. The estimated coefficient of T21 on e-cigarette use is small and statistically insignificant for $8^{th}/10^{th}$ graders, although, after the inclusion of state-specific trends, it becomes relatively large but still statistically insignificant. We investigate this issue later using an event study analysis. Among underage 12^{th} graders, e-cigarette use increases by about 0.69 pp (5%) after the implementation of T21. However, the effect is not precisely estimated. Note that the estimated coefficient for e-cigarette use at the extensive margin using the Goodman-Bacon approach (Panel B, Column 2) is much smaller and close to zero.

So far, we have investigated the overall effect of T21 laws. In the next section, we conduct a series of event study analyses to study pre-trends and explore the dynamics of changes in cigarette and e-cigarette use before and after the implementation of the laws.

4.3. Event study estimates

Throughout the paper, we assume that individuals receive the 'treatment' in a randomized way, implying that their locations passed T21 laws exogenously. The event study analysis provides supporting evidence for the parallel pre-treatment assumption. Overall, we find no evidence suggesting differences in trends in cigarette use and e-cigarette use in areas with and without T21 among both studied samples ($8^{th}/10^{th}$ graders and underage 12^{th} graders) before the

implementation of the policy. In other words, we do not detect evidence that the policy was adopted endogenously to changing tobacco use rates in the pre-period.

Event study results are reported in Figures 1-2 for cigarette and e-cigarette use. We estimate the effect of T21 four to one years before the law takes effect, during the first year of the implementation, and then two or more years after the law is in effect. For implementation, we replace the *Tob21* variable in the model (1) with six binary variables corresponding to the aforementioned timing. The estimated coefficient for the year before the implementation of T21 is normalized to zero. For the e-cigarette use event study, the pre-period was shorter due to the unavailability of e-cigarette data in the MTF until 2014.

Please insert Figures 1-2 here

In these figures, the estimated changes are presented on the vertical axis, and years relative to the implementation date of the T21 policy are presented on the horizontal axis.

For cigarette use (Figure 1), we do not see any evidence of non-parallel trends in the pre-period for either sample, with some evidence of reductions in cigarette use in the post-period for the underage 12^{th}-grade sample. This pattern broadly matches DID results shown in Table 3. For e-cigarette use (Figure 2), we do not see evidence of T21 changing in the post-period, though there is some evidence of non-parallel trends for the $8^{th}/10^{th}$-grade sample.

4.4. Subgroup analysis

Several studies have found significant differences in adolescents' smoking rates by gender (Nonnemaker and Farrelly, 2011; Mermelstein, 1999; Chaloupka et al., 1999). Therefore, we examine if cigarette use and e-cigarette use are different between sociodemographic categories. Table 5 reports the effect of T21 on cigarette and e-cigarette use among underage 12^{th} graders by gender, race, and ethnicity. The effect of T21 is more pronounced for males compared

to females. After the adoption of T21, cigarette use declines nearly 43% among males while it declines by 21% among females. We do not find any statistically significant evidence of changes in e-cigarette use for either males or females. Investigating the effect by race and ethnicity, we find no statistically significant changes in cigarette use among non-Hispanic whites, but we do find large reductions for non-Hispanic blacks and Hispanics. Surprisingly, our results also suggest that T21 increases e-cigarette use among non-Hispanic whites at $p<0.10$, although since we present 12 estimates in Table 5 one is bound to be statistically significant at this level by random chance.

4.4. Sensitivity Analysis

In this section, we report results from several sensitivity analyses using alternative samples, specifications, and outcome variables.

We first explore whether any specific locality is driving the effects we observe by re-estimating our model leaving out each T21 locality one at a time. Results reported in Table 6 provide evidence suggesting that the estimated effect is consistent and is not driven by a particular locality. Dropping the largest state of California does result in a loss of precision due to an increase in the standard error, though the estimated effect remains similar to the baseline estimate. A similar analysis for the $8^{th}/10^{th}$ graders is reported in Table A4.

In Table 7, row 1, we report the main results for cigarette use from Table 3 to make it easier to compare estimates. Row 2 reports the effect of T21 on 12^{th} graders aged 18 to 20. These respondents are still in high school in the MTF instead of in college or have graduated, and so may not be generalizable for 18-20-year-olds in general; however, we are interested in examining what impact the MLSAs have on these older students since the MLSA is newly covering them (though could be avoided in part by stockpiling prior to the law coming into

effect). The estimated effect for these older students is smaller compared to the estimate for underage 12th graders (0.89 pp decrease compared to 2.46 pp decrease in row 1). These results along with other findings on the limited effects of T21 on 8th/10th-grade smoking, suggest that the benefit of T21 in reducing youth smoking is primarily experienced by young high school seniors.

The next robustness check reported in row 3 addresses a limitation in using the MTF in that participating schools might change each year. It is possible that no school from a given state, particularly from less populated ones, gets selected in a given year. To address this issue, we re-estimate the model using a sample of states that participated in all the years between 2012 and 2018.[11] Except for Oregon, we did not lose any areas adopting T21 policies during the sample period when using this restriction (see Table 1). Again, the results are similar to our original estimates.

In row 4, we present the results for early (before 2017) vs. late (2017 and later) adopters using an interaction term. The estimated coefficients of T21 laws for early and late adopters are comparable, although the former is more precisely estimated than the latter. The 95% confidence intervals overlap, suggesting the coefficients are not statistically different from each other.

In rows 5-6, we drop areas with either local- (city or county) level or state-level T21 policies. The coefficient is larger in absolute magnitude when dropping areas adopting local laws than areas adopting state laws. The percentage decline in cigarette use due to the state-level T21 policies (-37%) is larger compared to that of the local policies (-13%). These results suggest that state-level T21 is more effective in reducing cigarette use compared to local-level T21 laws, potentially because the local laws are easier to evade.

[11] These states are: CA, FL, GA, IL, IA, KS, LA, MD, MA, MI, MS, MO, NJ, NY, NC, OH, OK, PA, TN, TX, VA, and WA.

In rows 7-8, we study the effect of state-level T21 in inner counties, with less travel-related T21 evasion opportunities, compared to border counties. We include counties with local laws as "border counties" since these laws can also be more easily evaded by traveling. While the coefficient for border counties is larger in magnitude, as a percent of the mean, these results are very similar,[12] suggesting that these high school students were unlikely to cross state borders to evade T21 laws.

In row 9, we estimate the effect of T21 using a probit regression model rather than a linear model (which we have used for indicator outcome variables up to this point). The estimated marginal effect is similar and statistically significant.

Finally, in row 10, we report results using an unweighted linear regression model. The estimated effect is smaller compared to the baseline model. This deviation from the main result reported in row 1 highlights the importance of sampling weights in our analysis.[13]

Finally, we also test if the self-reported use of marijuana or alcohol changes significantly following the passage of T21. As mentioned in the introduction, estimating the effects of tobacco regulations on alcohol and marijuana use is a viable approach to identify whether these substances are substitutes or complements. These results are reported in Table 8. Our estimates find that T21 does not have a significant effect on cannabis and alcohol use. The coefficient estimates are positive and negative for marijuana and alcohol use, respectively, though both of them are statistically insignificant. These results suggest that the products are neither economic substitutes nor complements. This conclusion was also supported by the event study analysis in Appendix Figure A1.

[12] The mean smoking rate in inner counties was 7.7% and in border counties was 12.0%.
[13] As mentioned earlier in Section 4.1, areas with higher Hispanic population are more likely to adopt T21. Our analysis suggests that the T21 estimated coefficient for Hispanics using an unweighted regression model is comparable to that from a weighted regression model.

5. Conclusion

Overall, we find that T21 laws reduce cigarette use among underage 12thgraders. We find limited evidence of beneficial spillovers for younger grades. The magnitude of the effect is consistent with those in Friedman et al. (2019) and Friedman and Wu (2020). Friedman et al. (2019) estimated a 39% decline in smoking participation for 18-20-year-olds compared to 21-22-year-olds, which is close to the estimated effect found by this research of a 28% reduction for underage 12th graders. Friedman and Wu (2019) estimate a 3.1 pp reduction in smoking among 18-20-year-olds from local T21 policies, which is much larger than our estimate of 0.89 pp (Table 7, row 2). Our estimate may be smaller because our 18-20-year-olds are high school students versus 18-20-year-olds in general used in Friedman and Wu (2019). Another difference could be that we use two extra years of data in our analysis compared to Friedman and Wu (2019).

T21 has a much larger effect on reducing cigarette use than enacting cigarette taxes in recent years (Hansen et al. 2017, Callison and Kaestner 2014). Early evidence suggests that e-cigarette taxes are effective in reducing e-cigarette use, but this comes at the expense of higher cigarette use (Pesko et al. 2020; Cotti et al. 2020; Pesko and Warman 2017). E-cigarette taxes are therefore estimated to be more effective in reducing youth e-cigarette use than T21 laws, but with unintended negative consequences.

Our study has several limitations. First, MTF does not survey adolescents from some locations adopting T21, although it covers nearly 80% of the population under T21 through 2018. Second, MTF does not include respondents from all U.S. states each year, nor is the data state-representative. Also, the survey does not include respondents who dropped out of high school. Third, the e-cigarette results should be interpreted with caution due to data unavailability

until the year 2014. Finally, the self-reporting of tobacco, alcohol, and other substance consumption is susceptible to misrepresentation and measurement errors.

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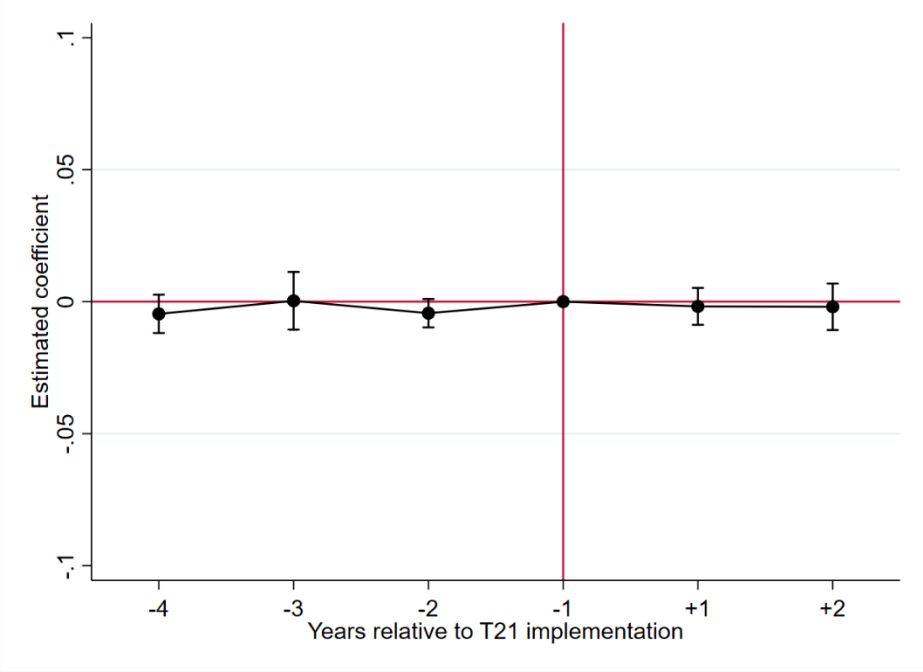
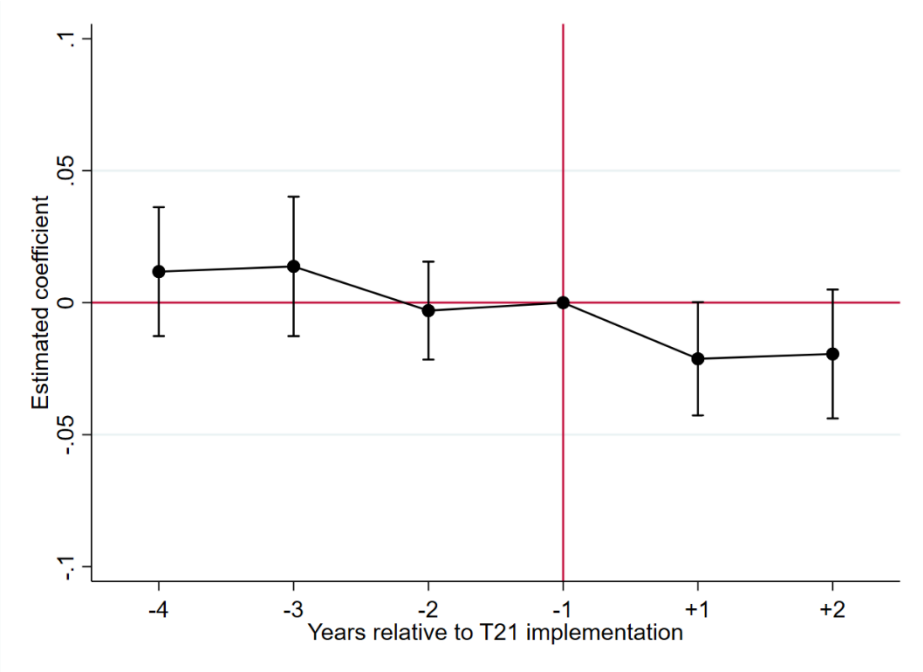
Figure 1. Event study of the effect of Tobacco 21 on current cigarette use

1.A 8th/10th graders



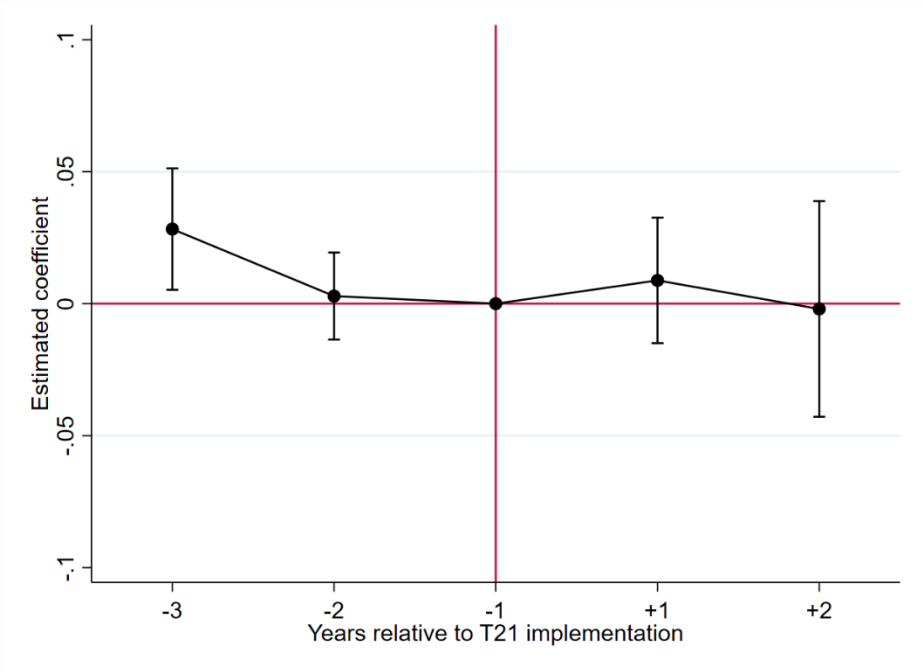
1.B Underage 12th graders



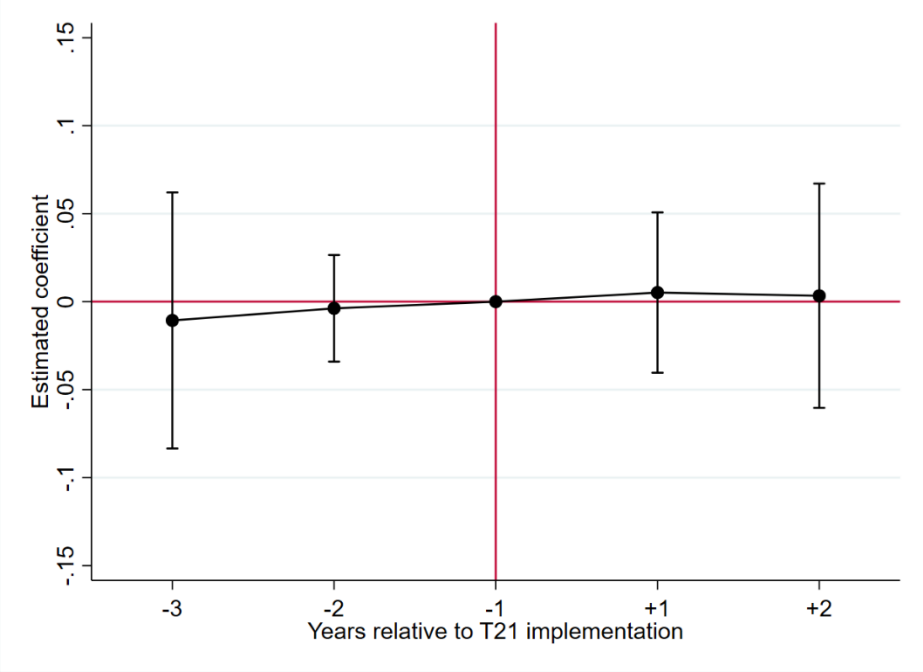
Notes: Each estimated coefficient reports the effect from a linear regression model along the 95% confidence intervals.

Figure 2. Event study of the effect of Tobacco 21 on current e-cigarette use

2.A 8th/10th graders



2.B Underage 12th graders



Notes: Each estimated coefficient reports the effect from a linear regression model along the 95% confidence intervals.

Table 1. States and areas adopting Tobacco 21 laws in the MTF data

Locality	Effective Date
City of Andover, MA	02/01/2015
City of Beverly, MA	11/01/2017
City of Greenfield, MA	07/01/2015
City of North Andover, MA	09/01/2015
City of Gloucester, MA	06/01/2016
City of Chicago, IL	07/01/2016
City of Cleveland, OH	04/14/2016
City of Columbus, OH	10/01/2017
Bronx County, NY	04/18/2014
Kings County, NY	04/18/2014
New York County, NY	04/18/2014
Queens County, NY	04/18/2014
Richmond County, NY	04/18/2014
Suffolk County, NY	01/01/2015
Genesee County, MI	05/17/2017
California	06/09/2016
New Jersey	11/01/2017
Oregon	01/01/2018

Source: Tobacco21.org

Table 2. Summary statistics, 2012-2013 Monitoring the Future Survey

	(1)	(2)	(3)	(4)
	8th/10th graders		Underage 12th graders	
Variables	Non-adopters	T21 areas	Non-adopters	T21 areas
Cigarette use past 30 days	0.0760	0.0505*	0.1526	0.1023*
	(0.2650)	(0.2190)	(0.3596)	(0.3031)
Average daily cigarettes past 30 days	0.3529	0.2109*	0.7089	0.3506*
	(2.9464)	(2.4095)	(3.4692)	(2.5884)
Cigarette tax in 2018 $ city-county-state-federal	1.5797	2.0588	1.7243	2.1989
	(0.9754)	(1.8911)	(0.9867)	(2.0935)
Beer tax in 2018 $	0.3126	0.1950	0.2766	0.1986
	(0.2805)	(0.0378)	(0.2385)	(0.0304)
E-cigarette Sales Ban	0.1192	0.8494*	0.1460	0.8145*
	(0.3240)	(0.3576)	(0.3531)	(0.3888)
100% smoking ban in WRB (county-level)	0.3049	0.7018*	0.2820	0.6821*
	(0.4604)	(0.4575)	(0.4500)	(0.4657)
100% vaping ban in WRB (county-level)	0.0167	0.1808*	0.0243	0.1088
	(0.1203)	(0.3792)	(0.1257)	(0.3114)
Any e-cigarette tax (state/quarter)	0.0247	0.0000*	0.0000	0.0000
	(0.1553)	(0.0000)	(0.0000)	(0.0000)
MJ decriminalization	0.2365	0.8327*	0.2446	0.9573*
	(0.4249)	(0.3733)	(0.4299)	(0.2023)
Male	0.4947	0.4843*	0.4484	0.4600
	(0.5000)	(0.4998)	(0.4974)	(0.4985)
Age in years	14.6095	14.6599*	16.9889	16.9916
	(1.1501)	(1.1224)	(0.1141)	(0.0948)
Black non-Hispanic	0.1489	0.0732*	0.1323	0.0851*
	(0.3559)	(0.2604)	(0.3389)	(0.2791)
Hispanic	0.1278	0.3146*	0.1150	0.2625*
	(0.3339)	(0.4644)	(0.3190)	(0.4401)
Others non-Hispanic	0.0896	0.1559*	0.0720	0.1557*
	(0.2856)	(0.3628)	(0.2586)	(0.3626)
Missing race	0.0081	0.0190*	0.0048	0.0097*
	(0.0896)	(0.1365)	(0.0694)	(0.0981)
Log weekly income in 2018 $	2.2789	2.1471*	3.2330	2.7876*
	(1.8360)	(1.7380)	(2.0002)	(1.9801)
Income missing	0.0775	0.0874*	0.0688	0.1052*
	(0.2674)	(0.2824)	(0.2532)	(0.3069)
Mother below high school	0.0971	0.1333*	0.0878	0.1214*
	(0.2961)	(0.3399)	(0.2831)	(0.3266)
Mother high school	0.1871	0.1772*	0.2191	0.2036
	(0.3900)	(0.3818)	(0.4137)	(0.4028)
Mother some college	0.1513	0.1439*	0.2100	0.2004
	(0.3583)	(0.3510)	(0.4073)	(0.4004)
Mother college graduate	0.2975	0.2592*	0.3049	0.2684*
	(0.4571)	(0.4382)	(0.4604)	(0.4432)
Mother graduate degree	0.1677	0.1602*	0.1409	0.1496
	(0.3736)	(0.3668)	(0.3479)	(0.3567)
Mother educ. Missing	0.0995	0.1263*	0.0372	0.0567*
	(0.2993)	(0.3321)	(0.1893)	(0.2312)
Father below high school	0.1158	0.1444*	0.1201	0.1622*
	(0.3200)	(0.3515)	(0.3251)	(0.3687)
Father high school	0.2265	0.1939*	0.2673	0.2114*
	(0.4186)	(0.3953)	(0.4426)	(0.4084)
Father some college	0.1191	0.1217	0.1698	0.1690
	(0.3239)	(0.3270)	(0.3755)	(0.3748)
Father college graduate	0.2362	0.2158*	0.2393	0.2133*
	(0.4247)	(0.4114)	(0.4267)	(0.4097)
Father graduate degree	0.1469	0.1464	0.1335	0.1541*
	(0.3540)	(0.3535)	(0.3401)	(0.3611)
Father educ. Missing	0.1555	0.1779*	0.0700	0.0900*
	(0.3624)	(0.3824)	(0.2551)	(0.2862)
Observations	43,197	12,586	7,844	3,089
Marijuana use past 30 days	0.1169	0.1333*	0.2120	0.2599*
	(0.3213)	(0.3399)	(0.4087)	(0.4386)
Observations	42,445	12,371	7,732	3,040
Alcohol use past 30 days	0.1815	0.2003*	0.3787	0.4579*

	(0.3854)	(0.4003)	(0.4851)	(0.4983)
Observations	41,382	12,051	7,620	3,016

Note: Each row reports the mean of the listed variable for different samples weighted by MTF sampling weights (standard deviations in parentheses). The asterisks indicate that the differences in each variable among non-adopters vs. T21 areas are statistically significant at the 0.05 level. E-cigarette use descriptive statistics are not available before 2014.

Table 3. Effects of adopting Tobacco 21 on current cigarette use, 2012-2018 Monitoring the Future Survey

	(1)	(2)	(3)	(4)
	Cigarette use past 30 days		Average daily cigs.	
Panel A: 8th/10th graders	[0.042]		[0.173]	
Tobacco 21	-0.0006	-0.0068**	0.0181	-0.0380
	(0.0030)	(0.0030)	(0.0451)	(0.0286)
Area and year-month dummies	✓	✓	✓	✓
Individual-level & policy variables	✓	✓	✓	✓
Area-specific trends, Goodman-Bacon approach	×	✓	×	✓
Observations	194,844	194,844	194,844	194,844
R-squared	0.053	0.048	0.020	0.019
Panel B: Underage 12th graders	[0.088]		[0.330]	
Tobacco 21	-0.0246***	-0.0229**	-0.0494	-0.0641
	(0.0089)	(0.0089)	(0.1303)	(0.1344)
Area and year-month dummies	✓	✓	✓	✓
Individual-level & policy variables	✓	✓	✓	✓
Area-specific trends, Goodman-Bacon approach	×	✓	×	✓
Observations	36,484	36,484	36,484	36,484
R-squared	0.068	0.058	0.037	0.034

Notes: each column in each panel reports the results from a single regression using MTF weights and the 2012-2018 data. Results report the estimated effects using a linear regression model. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Effects of adopting Tobacco 21 on current e-cigarette use, 2014-2018 Monitoring the Future Survey

	(1)	(2)	(3)	(4)
	E-cigarette use past 30 days		E-cigarette use frequency	
Panel A: 8th/10t graders	[0.096]		[1.215]	
Tobacco 21	0.0024	-0.0143	0.0178	-0.0422
	(0.0121)	(0.0120)	(0.0377)	(0.0387)
Area and year-month dummies	✓	✓	✓	✓
Individual-level & policy variables	✓	✓	✓	✓
Area-specific trends, Goodman-Bacon approach	×	✓	×	✓
Observations	51,377	51,377	51,377	51,377
R-squared	0.067	0.066	0.071	0.072
Panel B: Underage 12th graders	[0.128]		[1.279]	
Tobacco 21	0.0069	0.0010	0.0085	0.0111
	(0.0208)	(0.0273)	(0.0717)	(0.0968)
Area and year-month dummies	✓	✓	✓	✓
Individual-level & policy variables	✓	✓	✓	✓
Area-specific trends, Goodman-Bacon approach	×	✓	×	✓
Observations	15,330	15,330	15,330	15,330
R-squared	0.095	0.095	0.112	0.107

Notes: each column in each panel reports the results from a single regression using MTF weights and the 2014-2018 data. Results report the estimated effects using a linear regression model. Note that 2014 was the first year that questions about e-cigarette use were asked in the survey. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

Table 5. Effect by gender, race and ethnicity, underage 12th graders, Monitoring the Future Survey

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Cigarette use past 30 days	Males [0.102]	Females [0.077]	White Non-Hispanic [0.118]	Black Non-Hispanic [0.052]	Hispanic [0.076]	Other Non-Hispanic [0.055]
Tobacco 21	-0.0427***	-0.0143	-0.0039	-0.0484**	-0.0685***	-0.0411
	(0.0122)	(0.0128)	(0.0177)	(0.0190)	(0.0209)	(0.0361)
Observations	16,254	20,230	21,072	4,891	6,662	3,537
R-squared	0.084	0.079	0.081	0.121	0.114	0.184
Panel B: E-cigarette use past 30 days	[0.155]	[0.108]	[0.154]	[0.149]	[0.117]	[0.105]
Tobacco 21	-0.0130	0.0261	0.0565*	0.0383	-0.0293	0.0128
	(0.0379)	(0.0199)	(0.0307)	(0.0544)	(0.0342)	(0.0380)
Observations	6,709	8,621	8,689	2,115	2,872	1,519
R-squared	0.121	0.101	0.117	0.186	0.185	0.238

Notes: each column in each panel reports the estimated effects from a single linear regression model using MTF weights and the 2012-2018 data in Panel A and 2014-2018 data in Panel B. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

Table 6. Sensitivity analysis, drop each T21 area one at a time, underage 12th graders, Monitoring the Future Survey, 2012-2018

Outcome: Cigarette use past 30 days	(1) CA [0.126]	(2) NJ [0.086]	(3) OR [0.087]	(4) MA [0.088]	(5) Chicago [0.088]	(6) New York City [0.088]	(7) Suffolk County, NY [0.087]	(8) Genesee County, MI [0.088]	(9) Cleveland [0.085]	(10) Columbus [0.088]
Tobacco 21	-0.0211	-0.0233**	-0.0242***	-0.0312***	-0.0252***	-0.0246***	-0.0276***	-0.0246***	-0.0187**	-0.0250***
	(0.0143)	(0.0095)	(0.0089)	(0.0087)	(0.0089)	(0.0101)	(0.0102)	(0.0089)	(0.0074)	(0.0090)
Observations	29,614	35,991	36,412	35,294	36,008	36,484	35,777	36,484	36,179	36,444
R-squared	0.071	0.068	0.068	0.069	0.068	0.068	0.069	0.068	0.068	0.068

Notes: each column reports the estimated effects from a single linear regression model using MTF weights and the 2012-2018 data. The area listed in the column title is dropped from the analysis. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Additional estimations, 12th graders, Monitoring the Future Survey, 2012-2018

Outcome: Cigarette use past 30 days	Estimated effect of Tobacco 21 policy	N
(1) Main result from Table 3, Panel B, Column 1	-0.0246*** (0.0089)	36,484
(2) 12th graders, over 18	-0.0089 (0.0111)	47,587
(3) States surveyed all years	-0.0238** (0.0093)	30,321
(4) Early vs. late T21		
T21 adopted 2014 to 2016	-0.0251** (0.0093)	36,484
T21 adopted 2017 to 2018	-0.0214 (0.0235)	
(5) Drop areas with local-level T21	-0.0302*** (0.0111)	33,508
(6) Drop areas with state-level T21	-0.01675 (0.0159)	29,049
(7) Drop border counties or cities with T21	-0.0190* (0.0101)	32,944
(8) Drop inner counties with T21	-0.0248 (0.0155)	29,729
(9) Probit regression model	-0.0290** (0.0112)	36,484
(10) Unweighted	-0.0074 (0.0088)	36,484

Note: Results report the estimated effect of raising MLSA to 21 using a linear regression model (except row 9). Row 4 reports two estimated coefficients from the same regression model. Numbers in parentheses are standard errors clustered at the area-level. All regressions are weighted by the MTF sampling weights except row 10. In each regression, all individual-level and policy covariates along with county and year-month dummies are included. *** p<0.01, ** p<0.05, * p<0.1

Table 8. Effect of T21 on other substances, underage 12th graders, Monitoring the Future Survey, 2012-2018

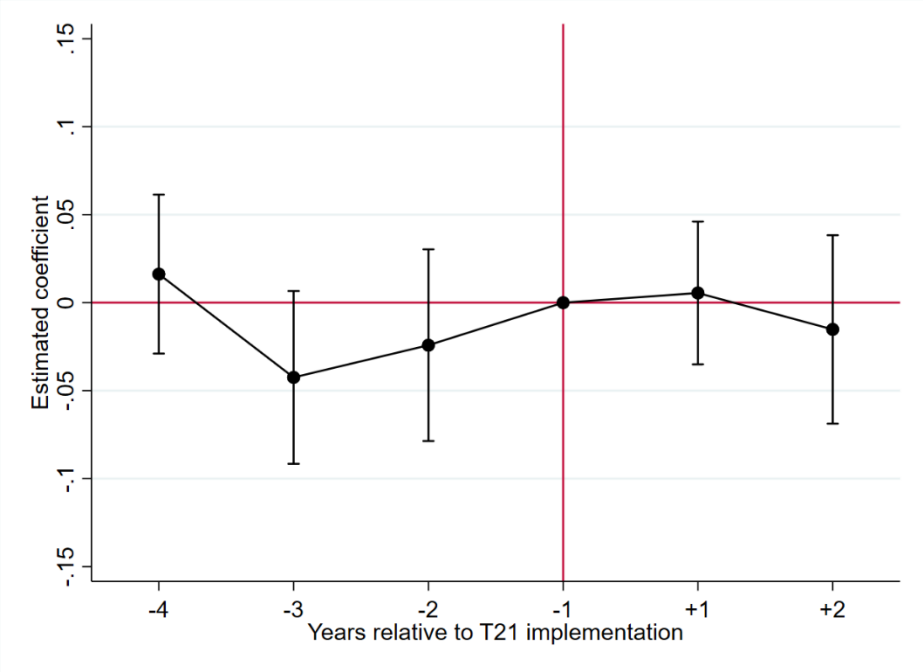
	Marijuana use past 30 days	Alcohol use past 30 days
	[0.238]	[0.397]
Tobacco 21	0.0147	-0.0128
	(0.0167)	(0.0266)
Observations	35,798	35,296
Pseudo R-squared	0.059	0.087

Notes: each column reports the estimated effects using a linear regression model, the MTF weights, and the 2012-2018 data. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

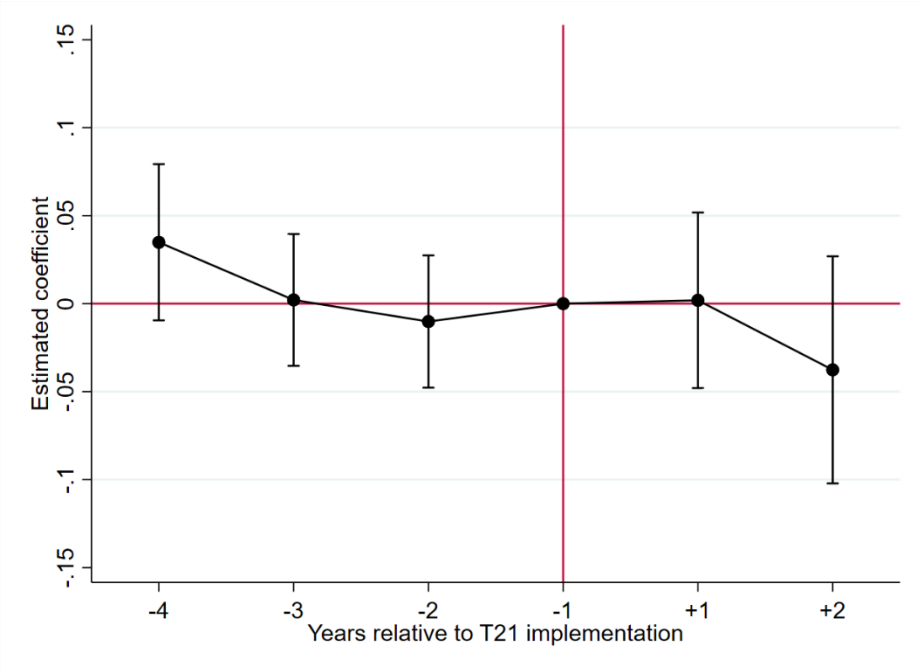
Appendix

Figure A1. Event study graphs for other substance, 2012-2018 Monitoring the Future Survey, underage 12th graders

A1.1 Marijuana use in past 30 days



A1.2 Alcohol use in past 30 days



Notes: each estimated coefficient reports the effect from a linear regression model along the 95% confidence intervals.

Table A1. Effects of Tobacco 21 on current cigarette use, 2012-2018 Monitoring the Future Survey, 8th/10th graders (full)

	(1)	(2)	(3)	(4)
VARIABLES	Smoked past 30 days		Average daily cigs. past 30 days	
Tobacco 21	-0.0006	-0.0068**	0.0181	-0.0380
	(0.0030)	(0.0030)	(0.0451)	(0.0286)
Cigarette tax in 2018 $ city-county-state-federal	0.0036	0.0038	0.0188	0.0250
	(0.0025)	(0.0025)	(0.0245)	(0.0235)
Beer tax in 2018 $	-0.0018	-0.0024	0.1679	0.1427
	(0.0117)	(0.0118)	(0.1712)	(0.1738)
E-cigarette Sales Ban	-0.0030	-0.0031	0.0034	-0.0099
	(0.0036)	(0.0036)	(0.0337)	(0.0323)
100% smoking ban in WRB (county-level)	0.0188**	0.0188**	-0.0203	-0.0237
	(0.0075)	(0.0075)	(0.0564)	(0.0563)
100% vaping ban in WRB (county-level)	0.0039	0.0037	-0.1030	-0.0988
	(0.0146)	(0.0149)	(0.0832)	(0.0820)
Any e-cigarette tax (state/quarter)	0.0001	0.0003	0.0177	0.0172
	(0.0045)	(0.0046)	(0.0584)	(0.0569)
MJ decriminalization	0.0071*	0.0069*	0.0095	0.0047
	(0.0037)	(0.0037)	(0.0223)	(0.0234)
Male	0.0008	0.0009	0.0833***	0.0829***
	(0.0016)	(0.0016)	(0.0135)	(0.0135)
Age in years = 11	-0.2254**	-0.2250**	2.4870	2.4924
	(0.1095)	(0.1096)	(3.3625)	(3.3632)
Age in years = 12	-0.3002***	-0.2998***	-2.4524	-2.4458
	(0.0917)	(0.0917)	(1.9093)	(1.9096)
Age in years = 13	-0.3188***	-0.3184***	-3.0286	-3.0227
	(0.0928)	(0.0928)	(1.8685)	(1.8685)
Age in years = 14	-0.3127***	-0.3123***	-2.9762	-2.9718
	(0.0925)	(0.0925)	(1.8641)	(1.8641)
Age in years = 15	-0.2751***	-0.2747***	-2.6497	-2.6470
	(0.0921)	(0.0921)	(1.8691)	(1.8691)
Age in years = 16	-0.2667***	-0.2663***	-2.5641	-2.5624
	(0.0921)	(0.0921)	(1.8675)	(1.8675)
Age in years = 17	-0.2245**	-0.2241**	-2.1377	-2.1353
	(0.0916)	(0.0917)	(1.8797)	(1.8797)
Age in years = 18	-0.0222***	-0.0227***	-0.3383***	-0.3242***
	(0.0075)	(0.0074)	(0.0825)	(0.0821)
Grade 10	-0.0319***	-0.0319***	-0.0868**	-0.0857**
	(0.0036)	(0.0036)	(0.0380)	(0.0379)
Black non-Hispanic	-0.0246***	-0.0246***	-0.1020***	-0.1066***
	(0.0029)	(0.0029)	(0.0284)	(0.0282)
Hispanic	-0.0030	-0.0030	-0.0050	-0.0047
	(0.0026)	(0.0026)	(0.0245)	(0.0246)
Others non-Hispanic	-0.0133**	-0.0133**	-0.0769	-0.0754
	(0.0054)	(0.0054)	(0.0504)	(0.0504)
Missing race	0.0096***	0.0096***	0.0619***	0.0617***
	(0.0006)	(0.0006)	(0.0055)	(0.0055)
Log weekly income in 2018 $	0.0301***	0.0301***	0.2351***	0.2343***
	(0.0023)	(0.0023)	(0.0284)	(0.0285)
Income missing	-0.0103***	-0.0103***	-0.0793**	-0.0810**
	(0.0039)	(0.0039)	(0.0313)	(0.0313)
Mother high school	-0.0114***	-0.0114***	-0.0920***	-0.0939***
	(0.0037)	(0.0037)	(0.0266)	(0.0266)
Mother some college	-0.0214***	-0.0214***	-0.1326***	-0.1345***
	(0.0044)	(0.0044)	(0.0346)	(0.0344)
Mother college graduate	-0.0168***	-0.0168***	-0.0789**	-0.0803**
	(0.0044)	(0.0044)	(0.0361)	(0.0361)
Mother graduate degree	-0.0164***	-0.0164***	-0.0203	-0.0209
	(0.0043)	(0.0043)	(0.0342)	(0.0344)
Mother educ. Missing	-0.0169***	-0.0169***	-0.1253***	-0.1252***
	(0.0034)	(0.0034)	(0.0316)	(0.0316)
Father high school	-0.0264***	-0.0264***	-0.1619***	-0.1614***
	(0.0041)	(0.0041)	(0.0364)	(0.0364)
Father some college	-0.0353***	-0.0353***	-0.2012***	-0.2006***
	(0.0040)	(0.0041)	(0.0373)	(0.0372)
Father college graduate	-0.0364***	-0.0364***	-0.2055***	-0.2054***
	(0.0043)	(0.0043)	(0.0390)	(0.0389)

Father graduate degree	-0.0136***	-0.0136***	-0.0570	-0.0578
	(0.0036)	(0.0036)	(0.0426)	(0.0424)
Father educ. Missing	-0.0006	-0.0068**	0.0181	-0.0380
	(0.0030)	(0.0030)	(0.0451)	(0.0286)
Year-month and county dummies	Yes	Yes	Yes	Yes
Area-specific trends, Goodman-Bacon approach	No	Yes	No	Yes
Observations	194,844	194,844	194,844	194,844
R-squared	0.0528	0.0479	0.0198	0.0189

Notes: each column reports the estimated effects from a single linear regression model using MTF weights and the 2012-2018 data. County and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1

Table A2. Effects of Tobacco 21 on current cigarette use, 2012-2018 Monitoring the Future Survey, underage 12th graders (full)

VARIABLES	(1) Smoked past 30 days	(2) Smoked past 30 days	(3) Average daily cigs.	(4) Paste 30 days
Tobacco 21	-0.0246***	-0.0229**	-0.0494	-0.0641
	(0.0089)	(0.0089)	(0.1303)	(0.1344)
Cigarette tax in 2018 $ city-county-state-federal	-0.0036	-0.0040	-0.1744**	-0.1732*
	(0.0057)	(0.0057)	(0.0865)	(0.0872)
Beer tax in 2018 $	-0.1429***	-0.1429***	-1.2451***	-1.2422***
	(0.0262)	(0.0263)	(0.4201)	(0.4200)
E-cigarette Sales Ban	-0.0241***	-0.0243***	-0.0265	-0.0216
	(0.0072)	(0.0073)	(0.0690)	(0.0696)
100% smoking ban in WRB (county-level)	0.1417***	0.1421***	0.6531***	0.6507***
	(0.0117)	(0.0117)	(0.1359)	(0.1364)
100% vaping ban in WRB (county-level)	-0.0451*	-0.0443*	0.1343	0.1280
	(0.0242)	(0.0242)	(0.3054)	(0.3063)
Any e-cigarette tax (state/quarter)	0.0070	0.0068	0.2864**	0.2874**
	(0.0087)	(0.0088)	(0.1122)	(0.1145)
MJ decriminalization	0.0262*	0.0256*	0.2161	0.2235
	(0.0147)	(0.0147)	(0.1458)	(0.1443)
Male	0.0261***	0.0261***	0.1716***	0.1715***
	(0.0051)	(0.0051)	(0.0334)	(0.0334)
Age in years = 15	0.1088	0.1095	5.3998	5.3921
	(0.1136)	(0.1135)	(3.2477)	(3.2481)
Age in years = 16	-0.0325	-0.0324	-1.1511	-1.1501
	(0.1108)	(0.1108)	(2.0032)	(2.0028)
Age in years = 17	-0.0530	-0.0529	-1.7287	-1.7271
	(0.1123)	(0.1122)	(1.9257)	(1.9253)
Age in years = 18	-0.0800***	-0.0800***	-0.3236***	-0.3244***
	(0.0092)	(0.0092)	(0.0755)	(0.0757)
Black non-Hispanic	-0.0567***	-0.0567***	-0.2503***	-0.2498***
	(0.0074)	(0.0074)	(0.0687)	(0.0688)
Hispanic	-0.0090	-0.0089	-0.0130	-0.0143
	(0.0057)	(0.0057)	(0.0860)	(0.0861)
Others non-Hispanic	-0.0323	-0.0324	-0.1562	-0.1535
	(0.0219)	(0.0219)	(0.3021)	(0.3021)
Missing race	0.0145***	0.0145***	0.0691***	0.0691***
	(0.0011)	(0.0011)	(0.0119)	(0.0119)
Log weekly income in 2018 $	0.0614***	0.0614***	0.3168***	0.3159***
	(0.0088)	(0.0088)	(0.0708)	(0.0709)
Income missing	-0.0176**	-0.0176**	-0.1908**	-0.1906**
	(0.0068)	(0.0068)	(0.0887)	(0.0888)
Mother high school	-0.0184**	-0.0184**	-0.1864*	-0.1856*
	(0.0071)	(0.0071)	(0.1007)	(0.1008)
Mother some college	-0.0313***	-0.0313***	-0.2878***	-0.2872***
	(0.0091)	(0.0091)	(0.1034)	(0.1034)
Mother college graduate	-0.0361***	-0.0361***	-0.1716	-0.1707
	(0.0088)	(0.0088)	(0.1199)	(0.1200)
Mother graduate degree	-0.0158*	-0.0157*	-0.0737	-0.0749
	(0.0091)	(0.0091)	(0.1168)	(0.1169)
Mother educ. Missing	-0.0188*	-0.0188*	-0.1678**	-0.1675**
	(0.0100)	(0.0100)	(0.0671)	(0.0671)
Father high school	-0.0381***	-0.0381***	-0.2971***	-0.2969***
	(0.0112)	(0.0112)	(0.1050)	(0.1050)
Father some college	-0.0460***	-0.0460***	-0.3550***	-0.3550***
	(0.0116)	(0.0116)	(0.0944)	(0.0945)
Father college graduate	-0.0477***	-0.0477***	-0.3747***	-0.3748***
	(0.0130)	(0.0130)	(0.1057)	(0.1057)
Father graduate degree	-0.0061	-0.0061	-0.0110	-0.0108
	(0.0088)	(0.0088)	(0.0659)	(0.0659)
Father educ. Missing	0.3520***	0.2113*	3.8837*	2.8328
	(0.1196)	(0.1108)	(1.9703)	(1.9044)
Year-month and area dummies	Yes	Yes	Yes	Yes
Area-specific trends, Goodman-Bacon approach	No	Yes	No	Yes
Observations	36,484	36,484	36,484	36,484
R-squared	0.0681	0.0581	0.0369	0.0340

Notes: see Table A1.

Table A3. Balancing test, underage 12th graders, Monitoring the Future Survey, 2012-2018

Variables	Tobacco 21
Cigarette tax in 2018 $ city-county-state-federal	0.2119***
	(0.0722)
Beer tax in 2018 $	-0.0553
	(0.0382)
E-cigarette Sales Ban	-0.0984***
	(0.0340)
100% smoking ban in WRB (county-level)	-0.2354***
	(0.0887)
100% vaping ban in WRB (county-level)	-0.3908***
	(0.1450)
Any e-cigarette tax (state/quarter)	-0.0594
	(0.0901)
Marijuana decriminalization	-0.0108
	(0.0828)
Male	0.0702
	(0.0617)
Age in years	-0.7064
	(0.4302)
White non-Hispanic	-0.3491*
	(0.1798)
Black non-Hispanic	-0.1587
	(0.1334)
Hispanic	-0.1722
	(0.1754)
Others non-Hispanic	-0.1292
	(0.1731)
Log weekly income in 2018 $	0.0171
	(0.0265)
Mother high school	-0.1519
	(0.1410)
Mother some college	-0.0712
	(0.1361)
Mother college graduate	-0.1127
	(0.1315)
Mother graduate degree	-0.1204
	(0.1868)
Father high school	0.0205
	(0.1196)
Father some college	0.1471
	(0.1683)
Father college graduate	0.1413
	(0.1353)
Father graduate degree	0.0561
	(0.1618)
Observations	580
R-square	0.687
Test of joint significance of policy variables (p-value)	0.002
Test of joint significance of individual-level variables (p-value)	0.413

Notes: results are based on a linear regression model. In addition to the listed variables, we control for county and year dummies. Unit of observation is each county in each year. Numbers in parentheses report cluster-robust standard errors at county level. *** p<0.01, ** p<0.05, * p<0.1

Table A4. Sensitivity analysis, drop each Tobacco 21 area one at a time, 8th/10th graders, Monitoring the Future Survey, 2012-2018

Outcome: Cigarette use past 30 days	(1) CA	(2) NJ	(3) OR	(4) MA	(5) Chicago	(6) New York City	(7) Suffolk County, NY	(8) Genesee County, MI	(9) Cleveland	(10) Columbus
Tobacco 21	-0.0016	0.0005	-0.0003	-0.0005	-0.0009	-0.0006	-0.0001	-0.0001	-0.0009	-0.0008
	(0.0031)	(0.0032)	(0.0031)	(0.0031)	(0.0030)	(0.0030)	(0.0031)	(0.0030)	(0.0030)	(0.0030)
Observations	169,638	188,798	191,063	191,066	193,160	194,844	194,279	194,018	194,227	193,894
R-squared	0.055	0.052	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053

Notes: each column reports the estimated marginal effects from a single linear regression model using MTF weights and the 2012-2018 data. The area listed in the column title is dropped from the analysis. All individual-level and policy variables in addition to county and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at area-level. *** p<0.01, ** p<0.05, * p<0.1