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IZA DP No. 16801

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ABSTRACT

Estimating the Effects of Tobacco-21 on Youth Tobacco Use and Sales*

We examine the effect of raising the minimum legal sale age of tobacco to 21 (i.e., "T21"). We estimate difference-in-differences models using the Monitoring the Future (MTF) survey data and Nielsen Retail Scanner data from 2012 to 2019. Outcomes include cigarette and e-cigarette use and sales. We find sizable reductions in e-cigarette and cigarette use for 12th graders. T21 also reduced cigarette sales by 12.4% and e-cigarette sales by 69.3% in counties with the highest percent quartile of individuals under 21 years of age. In terms of mechanisms, we find that T21 increases ID checking and perceived risks of using both products.

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Keywords: Tobacco-21, cigarettes, e-cigarettes, smoking, vaping, youth

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1. Introduction

In the United States, tobacco use is estimated to cause approximately a half-million preventable deaths (Office of the Surgeon General, 2012) and $170 billion in tobacco-related healthcare expenditures (Xu et al., 2015) each year.[2] Various heart and respiratory diseases and several forms of cancer are among some of the well-known consequences of combustible tobacco use. According to the 2012 Surgeon General's Report, roughly 96 percent 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-2019 (the end of our study period), six states and 482 counties or cities had passed Tobacco 21 (T21) laws (American Lung Association, 2019). T21 was signed into law nationally at the end of 2019, though as of November 2022 the FDA has not yet promulgated final rules and so it is unclear the extent to which the law is being enforced.

Our paper contributes by expanding the literature on the effect of T21 in several key dimensions. First, we unpack mechanisms for how T21 laws operate. In particular, T21 laws should increase ID checking when purchasing tobacco for individuals newly covered by the ID

[2] We note that recent works suggest these estimates are upward biased (Darden et al., 2018).

requirement, which we will test directly. More speculatively, T21 laws could also raise perceptions of the dangers of tobacco product use, thus reducing use and sales. Additionally, T21 laws increase MLSAs for both cigarettes and e-cigarettes to 21 rather than a combustible-21 only strategy that allows e-cigarettes to continue to be sold at the previous MLSA. Therefore T21 could indirectly increase e-cigarette risk perceptions by more than cigarette risk perceptions if youth previously believed e-cigarettes to be safer products and are now more likely to believe them to be equally as harmful. Higher e-cigarette risk perceptions could offset public health gains that e-cigarettes could otherwise achieve (Viscusi, 2016; Viscusi, 2020).

A second major contribution of our paper is to use cigarette and e-cigarette sales data from the Nielsen Retail Scanner database, in addition to survey data on use. Self-reported tobacco product use information is vulnerable to systematic bias from T21 laws if newly covered individuals become less likely to admit to using a newly restricted product. Sales data thus provide an objective data source to explore key relationships observed from self-reported use information. In addition, we complement recent work on T21 by Hansen et al. (2023) by using a different survey data source – Monitoring the Future (MTF) -- to study the effects of T-21 laws on cigarette and e-cigarette use among those newly bound by T-21 laws (18-year-old 12th graders) as well as younger 12th graders, 8th graders, and 10th graders.

In sum, we make unique contributions in terms of studying how T21 laws work.

Our main finding is that T21 reduces cigarette use for all grades, with especially large effects for 12th graders. We also find causal evidence that T21 reduces e-cigarette use for 12th graders. T21 increases perceptions of the risk of both tobacco products, but more for e-cigarettes. We find complementary evidence using sales data that T21 reduces tobacco product sales.

The rest of the paper is organized as follows. In the next section, we provide a brief history of T21 legislation. We also critically review the current literature on T21 and tobacco MLSA laws in general. Section 3 describes the data and 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.

2. Background

2.1 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.

T21 was adopted in a staggered manner through both local and state laws. 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 and California were the first states to pass T21 in 2016, followed by New Jersey and Washington DC in 2017, four states in 2018, and ten states in 2019. Some laws have a grandfather provision that allows youth that were already between the ages of 18 to 20 when T21 came into place to continue to purchase tobacco.[3] Other laws allow tobacco sales to individuals performing active military service.[4]

[3] For example, https://capitol.texas.gov/tlodocs/86R/billtext/html/SB00021I.htm and https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter157.
[4] For example, https://health.maryland.gov/notobaccosalestominors/Documents/T21 Retailer FAQ 8.15.22.pdf

The Federal Food, Drug, and Cosmetic Act (FDA, 2019a) was amended on December 20, 2019 to include T21. However, while federal T-21 is "effective," it cannot be fully enforced by the FDA until 90 days after publishing a Final Rule,[5] which has not yet been published as of Nov. 2022. Because of unclear enforcement of the federal law, localities and states continue to pass T21 in the aftermath of the implementation of the federal law. For example, since the federal law took effect, 16 states and 42 localities have implemented T21 in 2020. As of Nov. 2022, 41 states have adopted T21.[6] Therefore, our research continues to provide ongoing evidence for the possible effects of T21 in states that do not yet have it.

2.2. Hypotheses and Testable Predictions

We hypothesize that T21 will reduce the use of tobacco products by increasing the "hassle costs" of obtaining tobacco (Leicester, 2016; Maclean et al., 2018). Sellers may now not sell to individuals previously of legal age (e.g., 20 year olds) because of legal repercussions. Spillovers to younger teens could occur as well by drying up social sources of tobacco and by making it harder for young people to fake being of legal age.

T21 could have different effects on cigarette and e-cigarette use for at least two reasons. First, T21 could communicate new information about the risks of both products, especially for e-cigarettes, as these are newer products on which individuals may have less information. If T21 increases e-cigarette risk perceptions by more for e-cigarettes than cigarettes, this could cause larger reductions in e-cigarette use. In contrast, a competing mechanism is that youth may be less likely to get e-cigarettes from retail sources in general, and hence their e-cigarette use could be

[5] https://tobacco21.org/federal-tobacco-21-faq/
[6] https://tobacco21.org/

less affected by T21 laws. According to YRBSS Online,[7] only 13.6 percent of youth e-cigarette users usually purchased e-cigarettes from stores in 2017. Whether T21 has differential effects across e-cigarettes and cigarettes is, therefore, a-priori ambiguous.

2.3. Current evidence on T21 and other MLSA changes

T21 may reduce tobacco use among youth 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 youth start (and sometimes get addicted to) tobacco before they turn 18 (Kessler et al., 1997). MLSA laws may also not be enforced enough to discourage youth use, or youth may use individuals that are legally of age to buy tobacco to purchase tobacco for them. Sellers often do not comply with MLSA laws because enforcement of these laws is generally weak (Abouk and Adams 2017a; Silver et al. 2016). The evidence is mixed on whether federal compliance inspection checks change youth tobacco purchasing patterns and use (Abouk and Adams 2017a; Feng and Pesko 2019).

Several studies find that MLSA laws reduce cigarette use. Friedman et al. (2019) find that T21 is associated with a lower incidence of smoking among 18- to 20-year-olds who already tried smoking or vaping. Friedman and Wu (2020) find that T21 reduces smoking among 18- to 20-year-olds in large metropolitan areas. Ali et al. (2020) find that California and Hawaii's T21 law reduces tax-paid sales of cigarettes (overall, not specifically for young adults) by between 13.1 and 18.2 percent. Liber et al. (2021) uses a trend-break analysis to find that T21 is associated with a larger reduction in disproportionate young brand cigarette sales. Dai et al.

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

(2021) find that areas of Kansas with local T21 laws experienced slower growth in youth e-cigarette use than places without local T21 laws.

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 by approximately 1.9 to 2.9 percentage point (ppt), although a recent study finds little effect of MLSA laws in Europe (Meier et al. 2019). Five studies find evidence that e-cigarette MLSA laws reduce youth e-cigarette use (Nguyen, 2020; Dave et al., 2019; and Abouk and Adams, 2017b; Pesko,3; DeSimone et al. 2022). E-cigarette MLSA laws may also raise cigarette use according to five studies (Friedman, 2015; Pesko et al., 2016; Dave et al., 2019; Pesko and Currie, 2019; Pesko et al., 2023) or reduce it according to one study (Abouk and Adams, 2017b).

Finally, a recent study by Hansen et al. (2023), also looks at the effects of statewide T-21 laws. Using data from the Behavioral Risk Factor Surveillance Survey (BRFSS) and the Youth Risk Behavior Surveillance Survey (YRBSS), the authors find that T-21 laws are associated with a reduction in tobacco use among 18-to-20-year-olds. They also detect some evidence of spillovers to those under age 18, in part through access to informal social sources of tobacco products. Our study complements Hansen et al. (2023) by examining a different survey data source, exploiting additional policy variation than has been examined in prior studies, empirically examining mechanisms related to risk beliefs and ID checks, and supplementing survey-based analyses with sales data.

3. Data and Empirical Strategy

3.1 Data

For this study, we primarily use restricted MTF survey data between the years 2012 and 2019.[8] 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). Data are collected in the MTF survey each spring (February to June)[9] by interviewing around 50,000 students in the 8th, 10th, and 12th grades across the nation. We use all students under age 21. 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 enacted at both local and state levels. The MTF data has been used in a number of economics studies previously (DiNardo and Lemieux, 2001; Abouk and Adams, 2017a; Abouk and Adams, 2017b; Feng and Pesko, 2019; Abouk et al., 2021). However, this survey does not include people that drop out of school, does not include respondents from all U.S. states each year (since the data is nationally-representative rather than state representative), and it does not survey youth from some locations adopting T21. We start the analysis in the year 2012 to provide a sufficient length of time before significant policy changes took effect, such as the New York City law in 2014 and state laws in Hawaii and California in 2016. However, we report additional estimates for cigarette use using 2010-2019 data in Table 8.

The survey 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 2019 dollars. Finally, five binary

[8] We use the 2019 as our final year in the analysis since the federal T21 law came into effect at the end of 2019.
[9] By extending through the end of the school year, we avoid possible confounding from the outbreak of e-cigarette, or vaping, product use-associated lung injury (EVALI) mostly occurring mid- to late-2019 (Pesko et al., 2023).

variables control for parental education categories: high school graduate, some college, college graduate, post-baccalaureate, and missing (separately for the mother and father, using education less than high school as the reference group). We also control for large Metropolitan Statistical Areas (MSAs), other MSAs, and non-MSAs [reference].

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 county-level);[10] standardized e-cigarette taxes as provided by Cotti et al. (2021) (at county-level); marijuana decriminalization laws (at state-level); medical marijuana laws (at state-level); recreational marijuana 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).[11]

Data on cigarette 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*. Data on smoke-free air laws and vaping bans are from the *American Non-Smokers' Rights Foundation* (ANRF). Data on marijuana laws are from the *Marijuana Policy Project*.

The primary policy variable is a binary variable equal to one if the state, county, or city has T21 and zero otherwise. The data on the effective dates of the policy in each state, county, or city is from the *Preventing Tobacco Addiction Foundation*. By the end of our sample period in

[10] Among the study's T21 adopters, the local cigarette taxes in the City of Chicago and Cook County changed during our study period.

[11] 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).

mid-2019, six states and 482 areas had passed Tobacco 21 (T21) laws (American Lung Association, 2019). Table 1 lists cities, counties, and states represented in the MTF survey, which adopted T21 along with the effective dates.

3.2 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) $$Y_{iam} = \alpha + \gamma_a + \delta_m + \omega Tob21_{am} + Z_{am}\beta + X_{iam}\theta + \epsilon_{iam}$$

where *i* indexes individuals, *a* indexes state or sub-state area (such as cities or counties), and *m* indexes year-by-month of the interview.

Variable *Tob21* is binary and equal to one if a state, county, or city had T21 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.

γ_a is a set of area dummies. Areas are generally defined as a state, except if there is a local T21 law in place at any point during the study period, then we separate out that local area from the rest of the state. For example, Chicago is considered an area independent from the state of Illinois since T21 was implemented there in 2016. Both Chicago and the rest of Illinois receive their own area fixed effect. This approach of separating localities with e-cigarette policies from the rest of the state has been used recently in other studies on e-cigarette taxation (Allcott and Rafkin 2021; Pesko et al. 2020; Abouk et al. 2019).

Matrix Z contains a set of policy variables at the state level (beer taxes, standardized e-cigarette taxes, and marijuana decriminalization, medical, and recreational laws) 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 state level (s) to address the non-independence of observations from the same state over time (Bertrand et al., 2004).

Recent DID literature highlights the potential bias due to dynamic treatment heterogeneity in conventional DID estimation in the presence of staggered policy adoption (Goodman-Bacon, 2021; Callaway and Sant'Anna, 2020; Gardner, 2021; Sun and Abraham, 2021) and provides some solutions (Callaway and Sant'Anna, 2020; Gardner, 2021, Sun and Abraham, 2021). We provide estimates based on Gardner (2021), which is a two-stage estimation process, to address this issue. In the first stage of the Gardner method, we run a regression of the outcome of interest on time-varying covariates, area, and time dummies for the pretreatment period. We then calculate the residualized outcome using the estimated parameters. In the second stage, the residualized outcome is regressed on T21 using all observations. Finally, a GMM estimator is used to estimate the standard errors, given that they were previously estimated in two stages. The advantage of the Gardner method over other methods designed to address dynamic treatment heterogeneity is its flexibility in working with individual-level analysis as opposed to aggregate-level analysis. We also report event study results based on Sun and Abraham method in the Appendix Figures A1 and A2.

The DID identification strategy relies on the assumption of parallel trends in the outcome variable in treated and control areas 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 use lag and lead variables capturing the time before and after the

implementation of the policy to test for potential violation of the parallel trends assumption. We discuss the event study results in detail in section 4.3.

4. Results

4.1. Descriptive statistics

Before presenting the regression results, we provide a summary of the data in Table 2. Columns 1-2 report the descriptive statistics for the key variables and their means for $8^{th}/10^{th}$ graders for the baseline 2012-2013 time period. Columns 3-4 of the same table report these statistics for 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). Results suggest that in the baseline period, areas adopting T21 had lower cigarette use and higher perceptions of the risk of cigarettes for all grades.[12] In addition, T21 areas are more likely to implement other tobacco policies such as smoke- and vape-free air laws and e-cigarette MLSAs. Cigarette taxes were also higher in T21 areas. Individual-level characteristics such as the respondent's age, gender, and parental education were similar for both groups. However, T21 areas had lower income, a higher Hispanic population, a lower Black population, and were more likely to be a large MSA compared to non-adopters. We control for all these differences in our regression models.

4.2. Identification

To isolate plausibly causal effects of T21 on smoking behavior from confounding trends, we estimate an event study using a two-stage DID approach. We estimate the effect of T21 four (or more) to one years before T21 takes effect, during the first year of the implementation, and

[12] E-cigarette use and e-cigarette risk perceptions were first collected in 2014, so are not included in this table despite being used as outcomes.

then two (or more) years after T21 is in effect. Specifically, we replace the *Tob21* variable in model (1) with six binary variables corresponding to the timing of T21's passage. These variables are set to zero for non-T21 areas. The estimated coefficient for the year before the implementation of T21 is normalized to zero. The e-cigarette event study analysis includes three lead effects due to the availability of e-cigarette use data beginning 2014 in the MTF survey.

The MTF event study results are reported in Figures 1-2 for cigarette and e-cigarette use, with Panel A and B illustrating the cases for $8^{th}/10^{th}$-grade students and 12^{th}-grade students, respectively. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis.

For cigarette use (Figure 1), all estimates for the periods preceding the adoption of T21 in the relevant area are close to zero and lack any consistent evidence of a trend. We also find statistically significant evidence of reductions in the post-period in several of these graphs. Post-period coefficients broadly match the DID results shown in Table 3 to be discussed below.

For e-cigarette use (Figure 2), there is some evidence that a decline in e-cigarette use in the post-T21 period may have started prior to T21 coming into effect for $8^{th}/10^{th}$ graders. For this reason, we suggest caution in interpreting e-cigarette use results for $8^{th}/10^{th}$ graders. However, for 12^{th} grades we also observe declines in e-cigarette use in the post-T21 period and without evidence of a pre-T21 trend, which suggests these results may be causal.

We also test the sensitivity of our results under the treatment heterogeneity assumption in the presence of the staggered policy adoption using the method proposed by Sun and Abraham (2021), for which we also report the corresponding event study graphs in Appendix Figure A1 and A2. These graphs show basically the same pattern as results shown using the two-stage DID

approach in Figures 1 and 2, with evidence supporting the parallel trends assumption except for cigarette and e-cigarette use among 8th/10th graders.[13]

Following Pei et al. (2018), we also conduct balancing tests to investigate the possibility of the correlation of T21 with other regressors used in the analysis. For this test, we aggregate the regressors at the year-area level. We then regress T21 on the remaining explanatory variables and control for year and area dummies. Results for 8th/10th graders and 12th graders are reported in Appendix Table A1. There are associations between T21 and some policy variables, such as e-cigarette MLSA (for both samples), e-cigarette taxes (for 8th/10th graders), and recreational cannabis laws (for both samples), suggesting that policymakers pass T21 and other policies simultaneously. This motivates controlling for these other policies in our regression model since T21 does not appear to be adopted completely at random.

4.3. DID estimates

Table 3 presents the adjusted DID estimates of the effect of T21 on any cigarette use (Panel A) and any e-cigarette use (Panel B) for the 8th/10th graders. E-cigarette use data became available in the MTF in 2014. Therefore, we have a shorter period to study the effect of T21 on this outcome. These results are presented in brief, given failed parallel trend tests for both outcomes for this age group. While T21 is generally estimated to have a statistically insignificant effect on cigarette use in this age group, the two-state DID model finds a 0.7 ppt decrease in cigarette use among 8th graders ($p<0.05$). For e-cigarette use, the OLS approach yields a statistically significant T21 coefficient estimate in the full sample of 8th/10th graders (Panel B, columns 1).

[13] Differences in event studies based on the Gardner and Sun and Abraham approaches may be due to the fact that the latter does not allow for conditioning on time-varying (i.e., other state and local policies) covariates (Sun and Abraham, 2021).

However, that estimate becomes statistically insignificant in separate subsamples for 8th and 10th graders, and when using the two-stage DID approach. Full results to accompany Table 3 are reported in Tables A2-A3 in the Appendix.

In Table 4, we report the effect of T21 on any cigarette use (Panel A) and e-cigarette use (Panel B) during the past 30 days among 12th graders. T21 was associated with a smoking reduction of 20.8 ppt, or 19.6 percent of the baseline smoking rate and 77.2 ppt, or 58.5 percent of the baseline vaping in T21 areas, according to the two-stage DID approach. Full results to accompany Table 4 are reported in Tables A4-A5 in the Appendix. We also report smoking and vaping intensity results for 12th graders (Panel B) in Appendix Table A6 and find no significant results at the intensive margins among the 12th graders.

In Table 5, we show evidence that T21 laws affect mostly light smokers or those who might be experimenting with cigarettes by estimating the effect of T21 on four outcomes constructed from a question about ever smoking cigarettes. Respondents have the option to provide the following four responses: 1) once or twice, 2) occasionally, 3) regularly in the past, and 4) regularly now. We create four binary outcomes based on these responses. Results suggest that T21 laws significantly reduce the likelihood of ever smoking cigarettes once or twice with no effect on other more regular forms of smoking. This suggests that the largest effect of T21 is on the experimentation margin.

Finally, we address the question of if the effect of T21 on cigarette and e-cigarette use is more pronounced among the older respondents that are newly bound by the law in most cases (absent a grandfathering provision) and that use tobacco at higher rates. Figure 3 shows T21 effects on current cigarette and e-cigarette use estimated using a two-stage DID analysis and stratified by

age. The sizably larger coefficient for individuals 19+ years of age suggests that the effects of T21 are more pronounced among older individuals, but confidence intervals overlap.

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 the responses to T21 for cigarette and e-cigarette use differ across sociodemographic categories.

Table 6 reports two-stage DID results for the effect of T21 on cigarette and e-cigarette use among 12th graders by gender and race/ethnicity. Results reported in Panel A suggest that the percentage change effect of T21 on cigarette use is more pronounced for males compared to females in relative terms. After the adoption of T21, cigarette use declined by 32.3 percent among males (Panel A). Investigating the effect by race and ethnicity, we find statistically significant declines in cigarette use only among respondents who identified themselves as not belonging to the three largest demographic groups. In Panel B, we find statistically significant evidence of changes in e-cigarette use for both males and females.

4.5. Sensitivity Analysis

In this section, we report results from several sensitivity analyses using alternative samples, specifications, and models. In Table 7, row 1, we report the main results (based on the

two-stage DID model) for cigarette and e-cigarette use for 12th graders to make it easier to compare estimates.[14]

The first robustness check extends our analysis period to 2010 to check the sensitivity of our cigarette use results to using a longer pre-period. The results are reported in row (2) of Table 7 and show that the effects are similar, although the estimated coefficients are smaller than those based on the 2012-2019 analysis. We also report the event study analysis corresponding to these estimates in Appendix Figure A3, suggesting similar result patterns.[15]

The second check excludes the state of Massachusetts because a large portion of the state was covered by local T21 regulations creating differences in the timeline within the state. Comparing the coefficient estimates between row (3), where these estimates are reported, and row (1), we see that the coefficients are similar.

The next robustness check reported in row 4 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 2019 for the cigarette use outcome, and between 2014 and 2019 for the e-cigarette use outcome, which reduced the number of states from 45 to 21 for 12th graders, which resulted in dropping only one T21 state (Oregon). Again, the results are similar to our original estimates.

In rows 5-6, we drop areas with either local- (city- or county-) level (in row 5) or state-level (in row 6) T21 laws. Coefficients suggest that state-level laws have larger effects on

[14] These results were originally reported in Column 2 of Table 4.
[15] We cannot extend the data back further for e-cigarette use outcomes since these questions were only added to the MTF in 2014.

cigarette and e-cigarette use outcomes. State level laws could have larger effects than local laws because they are harder to evade by, for example, by traveling to a non-T21 jurisdiction.

In row 7, 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). Although using a Probit regression model may seem more appropriate when the outcome is binary, it is not comparable to a two-stage DID model as it is not designed to address the treatment heterogeneity assumption in the DID framework. Comparing the results, we see that the overall patterns are similar across the two models. The coefficient for cigarette use is statistically significant but slightly larger in magnitude while the estimated marginal effect for e-cigarette use is smaller and less precise.

4.6 Potential Mechanisms

Results reported in the previous section suggest that T21 reduces cigarette use among 12th graders. In this section, we expand our analysis by investigating the effect of these laws on youth cigarette and e-cigarette use risk perceptions. We define two binary variables measuring cigarette and e-cigarette risk perceptions. For cigarette risk perceptions, the variable is set to one (zero) if the respondent believes the risk of using one pack of cigarettes or more per day is high (zero, slight, or moderate). For e-cigarette risk perceptions, the variable is set to one (zero) if the respondent believes the risk of regularly using e-cigarettes is high (zero, slight, or moderate).[16]

[16] Between 2014 and 2019, there are increasing trends in proportion of respondents who believe the risk of regular e-cigarette use to be at least as high as the risk of using one or more pack of cigarettes daily, especially among the 12th graders. The unweighted average across all grades in the percent believing e-cigarettes to be at least equally as dangerous is 23.4% in 2014 (the first year the question was surveyed) and 27.3% in 2019. A survey of experts in contrast has found e-cigarettes to have approximately 33% of the risk of cigarettes (Allcott and Rafkin 2021).

Results presented in Table 8 for 12th graders suggest that, overall, respondents reassess the risk of using e-cigarettes after the T21 adoption. We also do not find consistent evidence that T21 adoption changes the daily cigarette use risk perception for either group. Interestingly, our subgroup analysis reveals that in most cases, the changes in risk perceptions (as defined above) match well with the observed changes in cigarette and e-cigarette use patterns, suggesting that any increased assessed risk of the product is generally followed by a decline in that particular substance. For example, among females in 12th grade, T21 led to a 9.8 ppt (40%) increase in believing regular e-cigarette use to be high risk (Table 8), followed by a 8.6 ppt (76%) decline in e-cigarette use (Table 6). Overall, comparing the tables, we see consistency between T21 raising perceptions of regular e-cigarette use risk *and* the incidence of e-cigarette use declining. We also present event study graphs for the 12th grader sample for cigarette and e-cigarette risk perception measures in Appendix Figure A4, providing evidence of parallel trends prior to the introduction of T21.

We also study retailer compliance with T21 laws. We empirically test this hypothesis using the 2012-2019 MTF survey. The MTF asks a subset of smokers who have tried purchasing cigarettes from a store or gas station whether they were asked for proof of age and the outcome of the attempt to purchase cigarettes the last time they attempted to buy cigarettes in a store or gas station using two separate questions. Based on these questions, we create a measure of retailer compliance using an indicator variable equal to one if respondents attempted to buy but were not sold cigarettes and zero if they were not asked and were sold cigarettes.

Table 9 reports the effect of T21 on the likelihood of retailer compliance among 1) overall sample, 2) underage respondents and 3) adults as defined in Tables 3 and 4. Interestingly, our results provide evidence that retailers comply with the new T21 law, with the likelihood of

adult smokers having an unsuccessful attempt to buy increasing by nearly 19 ppts. No changes were observed among underage smokers. These results provide evidence suggesting that the T21s are complied with, which could reduce both own-use and contribute to drying up secondary sources of tobacco for younger ages. Appendix Figure A5 illustrates event study analysis corresponding to Table 9 and suggests that the effect is not driven by pre-trends.

4.7. Extensions

So far, our analysis has used self-reported measures of cigarette and e-cigarette use, which are not completely objective and can be biased by, say, unease over admitting to activities that are now of questionable legal nature because of T21.[17] Our findings would be bolstered if we could find similar evidence in data not based on self-report. Accordingly, we now provide an extension based on the 2012-2019 Nielsen Retail Scanner Data (NRSD) provided by the Kilts Center at the University of Chicago. In 2017, the Nielsen Kilts Center data included 31,521 stores and captured 26% of food store purchases, 52% of drug store purchases, 21% of mass merchandise store purchases, 23% of dollar store purchases, and 2% of both convenience and liquor store purchases.[18] In 2018 and 2019, the number of stores expanded significantly. To compensate for that, we use a balanced panel of stores that are consistently in the data from 2012 to 2019 (N=26,269).[19] For cigarette sales, we aggregated packs sold at the quarter-by-area level, using a fraction of a county with T21 in place since the county is the lowest level of geographical information available in the NRSD. For e-cigarette sales, we converted to fluid milliliter using

[17] Technically, many T21 laws do not prohibit individuals under 21 years of age from purchasing tobacco, but all prohibit individuals selling to people under 21 years of age.
[18] One limitation of the NRSD is that it does not include online sales or vape shop sales.
[19] This does not include any stores in Hawaii or Alaska.

additional product characteristic information from hand-collected data as first used in Cotti et al. (2018).

Table 10 presents the estimated effect of T21 on cigarette and e-cigarette sales (in logs), suggesting a 7.1 percent decline in overall cigarette sales after T21 adoption. The coefficient estimate suggests a 24 percent reduction in e-cigarette fluid ml sales, but this relationship is not statistically significant. When focusing on the states and areas in the top quartile with the most people under age 21, we find a 12.4% reduction in cigarette use and a 69.3% reduction in e-cigarette use. Although they are not directly comparable, the magnitudes are similar. For example, for the 12 graders, the law reduces e-cigarette smoking by 52%, based on self-reporting measures according to the point estimates in Panel B and column 2 of Table 4. Our event studies in Figure 4 following the Gardner method suggest parallel trends and sizable declines in sales, especially 2+ years after T21 adoption. Collectively, this provides complementary evidence from objective sales data, not influenced by self-reporting, that T21 reduced tobacco product purchasing, particularly in the counties with the largest share of young people.

5. Conclusion

Overall, we find that T21 sizably reduces current cigarette use among 12th graders and we find evidence of modest reductions in cigarette use for younger grades. The directionality of effects that we find in this study are comparable to those found in Friedman et al. (2019) and Friedman and Wu (2020), but important differences in sample construction reduce our ability to make direct comparisons. Friedman et al. (2019) estimated a 39 percent decline in smoking participation for 18-20-year-olds *that had ever tried smoking or vaping* (compared to 21-22-year-olds that had ever tried smoking or vaping), which is almost double the estimated effect we find

of an 18.7 (-0.0226/0.121) percent reduction for adult 12th graders (Table 3). The larger effect found by Friedman et al. (2019) is likely attributable to their use of a sample of those who have smoked or vaped, who are more likely to respond to T21 than individuals who have not yet initiated use of either product by adulthood. Friedman and Wu (2019) meanwhile estimate a 3.1 ppt reduction in smoking from local T21 policies among a general population of 18-20-year-olds residing in metropolitan areas, which is larger than our estimate of 1.1 ppt reduction from local T21 policies (Table 8, row 6, column 3) for 12th graders. These differences may be due to the different samples studied (general population of 18-20 year olds in metropolitan areas only, versus 12th graders in all areas), or Friedman and Wu (2019) using data through 2016 in their study whereas we use data through 2019 in ours. Our results are also comparable with Hansen et al. (2023), which uses survey data for the 2009-2019 period.[20]

T21 seems to have had much larger effects on reducing tobacco use than previous MLSA laws (Yörük and Yörük, 2016; Meier et al., 2019). The reason for this should be subject to further research, but one possibility is that previous MLSA laws generally did not cover all school-aged children, which may have created more accessible avenues for distributing tobacco products to minors through secondary markets. Additionally, T21 has a much larger effect on reducing cigarette use than cigarette taxes in recent years (Hansen et al., 2017, Callison and Kaestner, 2014), suggesting that policymakers may wish to focus on implementing/improving age-based sales bans rather than raising taxes if the goal is singularly to reduce youth tobacco use (versus, for example, raising government revenue).

One possible unintended effect of T21 is that it causes a larger increase in perceptions of the risks of e-cigarettes than cigarettes. According to the 2020 Health Information National

[20] Please see a description of differences in our papers at the end of section 2.2.

Trends Survey, only 10.2% of U.S. adults correctly answered that e-cigarettes are either less harmful or much less harmful than cigarettes, which may in part be driven by the wrongful attribution of nicotine e-cigarettes to lung injuries at the end of 2019 (Dave et al., 2020). The pervasive misperception that e-cigarettes are equally or more harmful than combustible cigarettes is a barrier to current smokers switching to e-cigarettes (Svenson et al., 2021). Raising the MLSA to 21 for both cigarettes and smokeless products could have the unintended effect of causing some substitution to cigarette use compared to the counterfactual world in which T21 could be adopted without changing perceptions of risk. Other policies like Combustible Tobacco-21 could be better for public health than T21 by leading to more sizable reductions in cigarette use (Pesko, 2021), which is similar in concept to a law recently adopted in New Zealand banning the purchase of combustible tobacco for individuals born after a certain date but allowing the sale of e-cigarettes.

As of Nov. 2022, 41 states have adopted T21.[21] Therefore, our research continues to provide ongoing evidence for possible effects of T21 in states that do not yet have them. This effect could also be achieved if the FDA finalizes the promulgation of their T21 law and improves the effectiveness of their current underage compliance program, which, when last evaluated, was not found effective in reducing youth tobacco use (Feng and Pesko, 2019).

[21] https://tobacco21.org/

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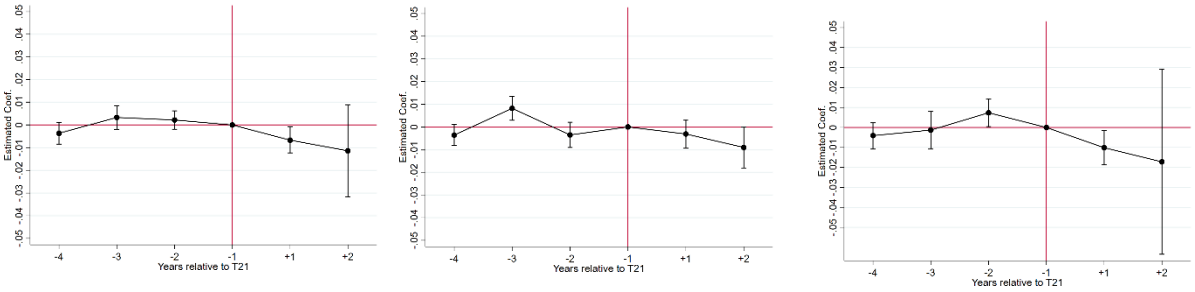
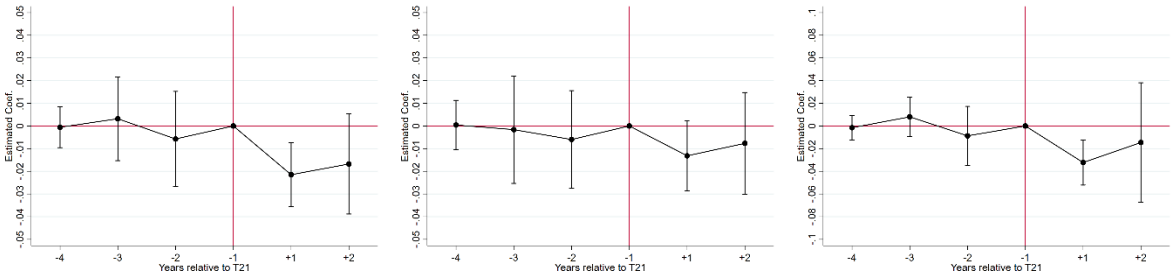
Figure 1. Event study of the effect of T21 on cigarette use past 30 days

Panel A *8th/10th graders*



Overall 8th Graders 10th Graders

Panel B *12th graders*

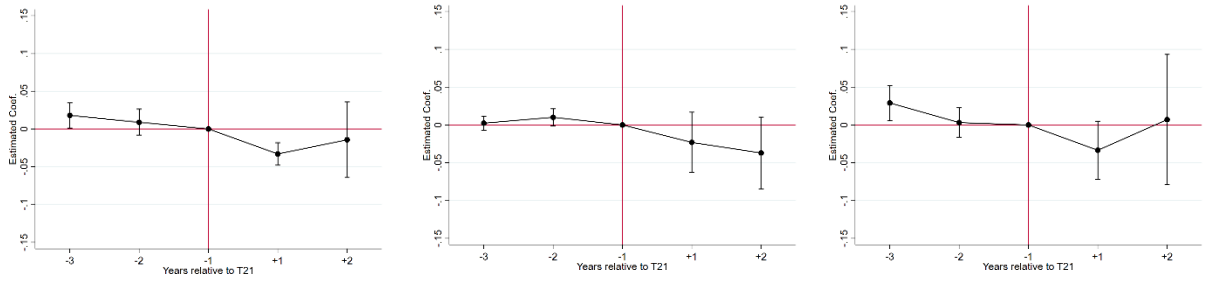


Overall Underage Adult

Notes: Each graph plots event study coefficients using a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

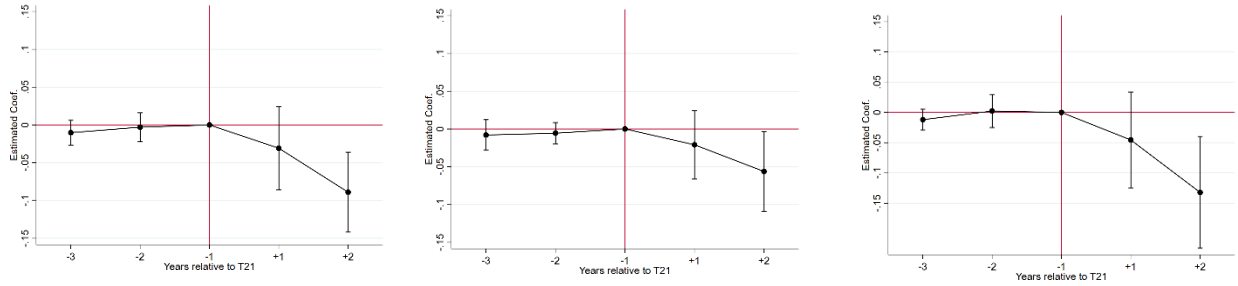
Figure 2. Event study of the effect of T21 on e-cigarette use past 30 days

Panel A *8th /10th Graders*



Overall 8th Graders 10th Graders

Panel B *12th Graders*

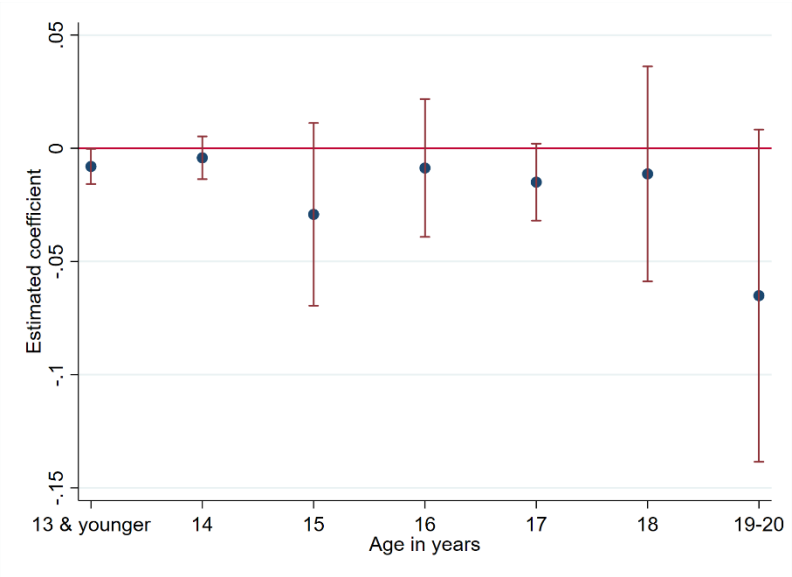


Overall Underage Adult

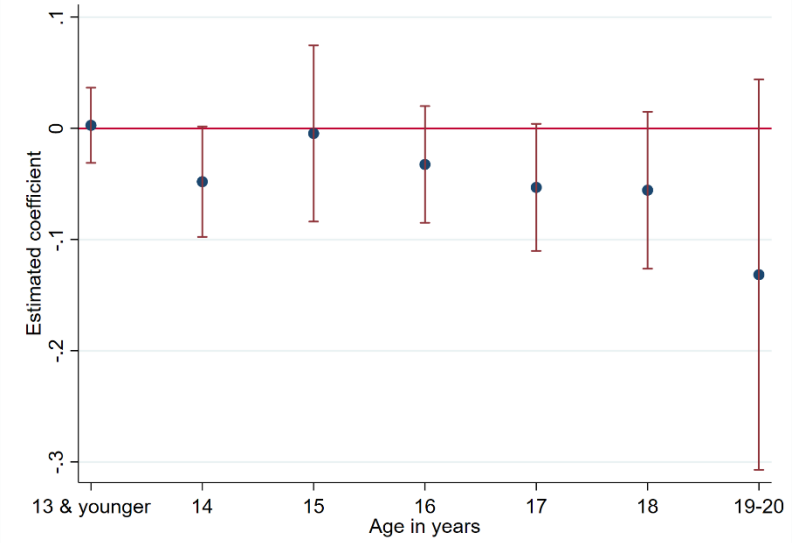
Notes: Each graph plots event study coefficients using a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Figure 3. Effect of T21 on cigarette and e-cigarette use past month by age

Panel A *Cigarette use past month*



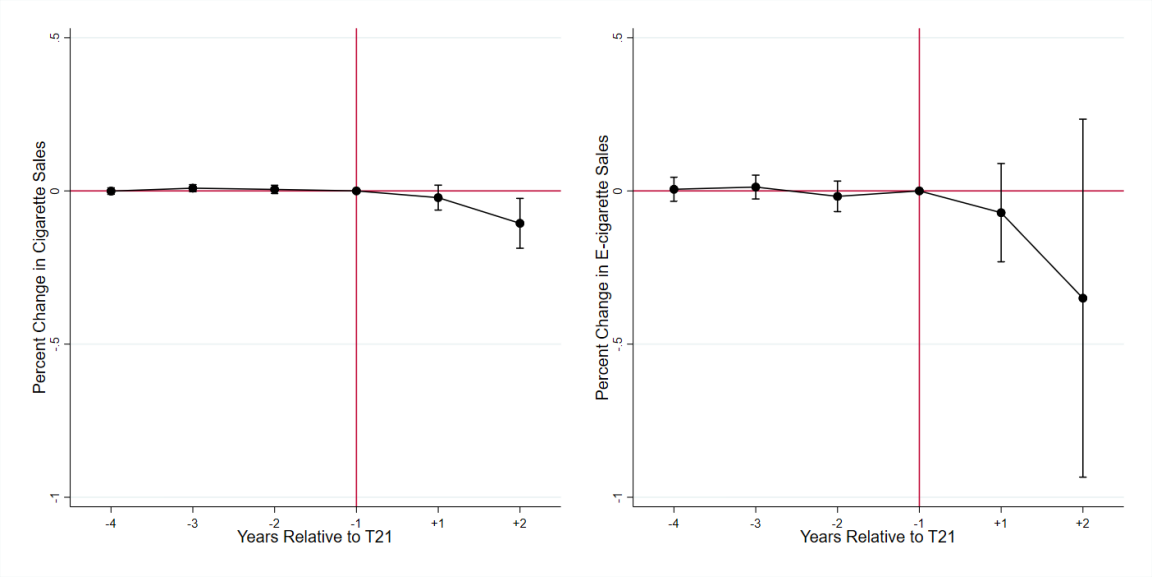
Panel B *E-cigarette use past month*



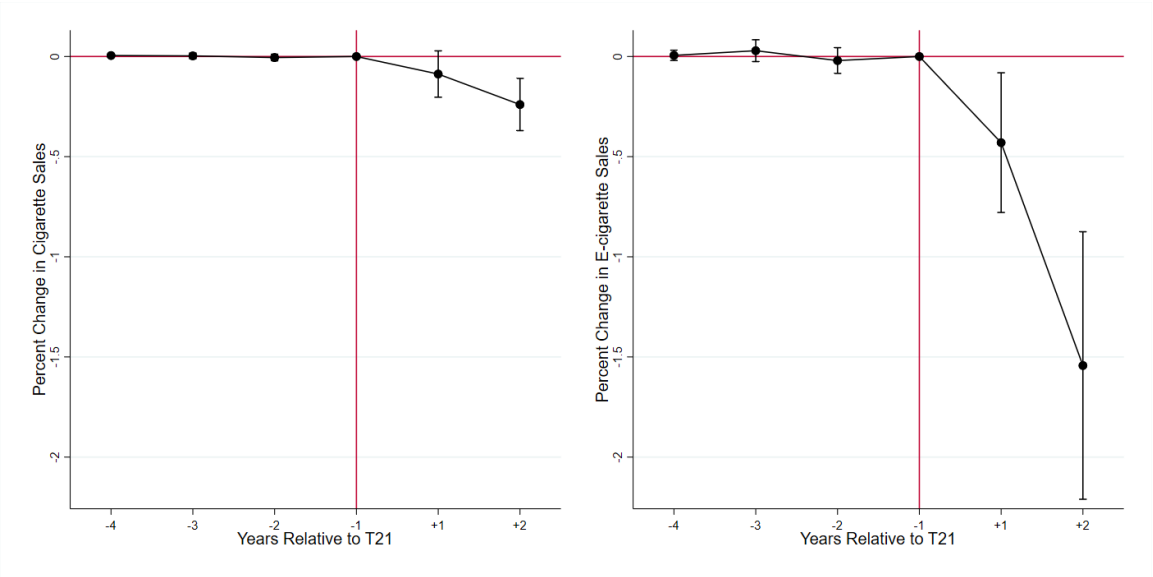
Notes: Each coefficient is the estimated effect of T21 on cigarette use (Panel A) and e-cigarette use (Panel B) for the reported age using pooled 8th/10th and 12th graders and a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. Capped spikes illustrate the 95% confidence intervals.

Figure 4. Nielsen Retail Scanner Data analysis

Panel A *Event study analysis*



Panel B *Event study analysis - top quartile*



Notes: Each graph plots event study coefficients using two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Table 1. States and areas adopting T21 laws in the MTF data

Locality	Effective Date
Kansas City, KS	11/26/2015
City of Andover, MA	02/01/2015
City of Belmont, MA	01/01/2015
City of Beverly, MA	11/01/2017
City of Dedham, MA	01/01/2014
City of Greenfield, MA	07/01/2015
City of North Andover, MA	09/01/2015
City of Gloucester, MA	06/01/2016
City of Randolph, MA	10/07/2016
City of Waltham, MA	03/01/2015
City of Poland, ME	07/20/2016
City of Chicago, IL	07/01/2016
City of Kansas City, MO	11/29/2015
City of St. Louis, MO	11/29/2015
City of Maplewood, NJ	08/18/2016
City of Union City, NJ	09/01/2015
City of Cleveland, OH	04/14/2016
City of Columbus, OH	10/01/2017
City of Lakewood, OH	04/18/2019
Kern County, CA	11/15/2015
St. Louis County, MO	12/01/2016
Genesee County, MI	05/17/2017
Albany County, NY	06/15/2016
Bronx County, NY	04/18/2014
Cattaraugus County, NY	11/01/2016
Kings County, NY	04/18/2014
Nassau County, NY	05/15/2017
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
Sullivan County, NY	09/01/2017
Westchester County, NY	07/16/2018
California	06/09/2016
Maine	07/01/2018
Massachusetts	12/31/2018
New Jersey	11/01/2017
Oregon	01/01/2018

Source: Tobacco21.org

Table 2. Summary statistics, 2012-2013 MTF

VARIABLES	8th/10th Graders		12th Graders	
	Non-T21 Localities	T21 Localities	Non-T21 Localities	T21 Localities
Cigarette past 30 days	0.0791	0.0492*	0.1768	0.1227*
	(0.2699)	(0.2163)	(0.3815)	(0.3281)
Average daily cigs half a pack or more	0.0121	0.0060*	0.0387	0.0174*
	(0.1094)	(0.0773)	(0.1930)	(0.1307)
T21	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Tobacco tax in 2019 $ city-county-state-federal	1.5092	2.2570	1.6325	2.1125*
	(0.8679)	(1.8778)	(0.9511)	(1.7833)
Beer tax in 2019 $	0.3322	0.1863	0.3013	0.1910*
	(0.2910)	(0.0524)	(0.2566)	(0.0427)
E-cigarette Sales Ban	0.1237	0.6948*	0.1417	0.7030*
	(0.3292)	(0.4605)	(0.3488)	(0.4570)
100% smoking ban in WRB (county-level)	0.2651	0.7269*	0.2400	0.7560*
	(0.4414)	(0.4456)	(0.4271)	(0.4295)
100% vaping ban in WRB (county-level)	0.0158	0.1512*	0.0016	0.1498*
	(0.1232)	(0.3467)	(0.0397)	(0.3251)
Standardized e-cig taxes in 2019 $	0.0295	0.0000*	0.0000	0.0000
	(0.1805)	(0.0000)	(0.0000)	(0.0000)
Marijuana decriminalization laws	0.1903	0.8349*	0.2040	0.9464*
	(0.3925)	(0.3713)	(0.4030)	(0.2253)
Medical marijuana laws	0.2138	0.6930*	0.2150	0.7337*
	(0.4100)	(0.4613)	(0.4108)	(0.4421)
Recreational marijuana laws	0.0327	0.0000*	0.0206	0.0000*
	(0.1779)	(0.0000)	(0.1419)	(0.0000)
Male	0.4971	0.4812	0.4710	0.4934
	(0.5000)	(0.4997)	(0.4992)	(0.5000)
Age in years	14.6255	14.6356*	18.4176	18.3216
	(1.1627)	(1.1332)	(7.9215)	(8.1165)
Black non-Hispanic	0.1234	0.0624*	0.1167	0.0701*
	(0.3289)	(0.2419)	(0.3211)	(0.2553)
Hispanic	0.1666	0.3085*	0.1462	0.2710*
	(0.3726)	(0.4619)	(0.3533)	(0.4445)
Others non-Hispanic	0.1187	0.1640*	0.0902	0.1669*
	(0.3234)	(0.3702)	(0.2864)	(0.3730)
Log weekly income in 2019 $	2.2944	2.1779*	3.3334	2.9612*
	(1.8490)	(1.7559)	(2.0799)	(2.0546)
Missing Income	0.0784	0.0838	0.0764	0.0971*
	(0.2689)	(0.2770)	(0.2657)	(0.2962)
Mother below high school	0.1018	0.1156*	0.1023	0.1172*
	(0.3024)	(0.3198)	(0.3030)	(0.3217)
Mother high school	0.1913	0.1682*	0.2333	0.2002*
	(0.3933)	(0.3741)	(0.4230)	(0.4002)
Mother some college	0.1544	0.1367*	0.2074	0.1937
	(0.3613)	(0.3436)	(0.4054)	(0.3952)
Mother college graduate	0.2893	0.2864*	0.2863	0.2810
	(0.4535)	(0.4521)	(0.4521)	(0.4495)
Mother graduate degree	0.1612	0.1774*	0.1227	0.1565*
	(0.3677)	(0.3820)	(0.3281)	(0.3634)
Mother educ. Missing	0.1020	0.1156*	0.0408	0.0412
	(0.3026)	(0.3197)	(0.1978)	(0.1989)
Father below high school	0.1208	0.1275	0.1343	0.1505*
	(0.3259)	(0.3336)	(0.3409)	(0.3576)
Father high school	0.2310	0.1886*	0.2790	0.2141*
	(0.4215)	(0.3912)	(0.4485)	(0.4102)
Father some college	0.1209	0.1159	0.1658	0.1601
	(0.3260)	(0.3201)	(0.3719)	(0.3668)
Father college graduate	0.2289	0.2374*	0.2227	0.2224
	(0.4201)	(0.4255)	(0.4161)	(0.4159)
Father graduate degree	0.1395	0.1647*	0.1162	0.1701*
	(0.3465)	(0.3709)	(0.3205)	(0.3758)
Father educ. Missing	0.1589	0.1660	0.0743	0.0737
	(0.3656)	(0.3721)	(0.2622)	(0.2613)
Large MSA	0.2534	0.6019*	0.2764	0.5511*

	(0.4350)	(0.4895)	(0.4472)	(0.4974)
Other MSA	0.5011	0.3499*	0.4562	0.4489
	(0.5000)	(0.4769)	(0.4981)	(0.4974)
Non-MSA	0.2455	0.0482*	0.2674	0.0000*
	(0.4304)	(0.2143)	(0.4426)	(0.0000)
Observations	40,249	15,651	17,756	6,619
Risk of 1+ pack of cigarette use per day high	0.7165	0.7608	0.7668	0.8361
	(0.4507)	(0.4266)	(0.4229)	(0.3702)
Observations	38,817	15,101	15,567	5,949

Notes: Each row reports the mean of the listed variable for different samples across columns using 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 and risk perception descriptive statistics are not available before 2014.

Table 3. Effects of adopting T21 on 8th/10th graders

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SDID	OLS	2SDID	OLS	2SDID
Panel A: Cigarette Use Past Month	Overall [0.040]		8th Graders [0.024]		10th Graders [0.052]	
T21	-0.0024	-0.0100	-0.0016	-0.0069**	-0.0100	-0.0175
	(0.0030)	(0.0071)	(0.0037)	(0.0035)	(0.0082)	(0.0180)
Observations	222,735	222,735	113,030	113,030	109,705	109,705
R-squared	0.0397	0.0475	0.0335	0.0393	0.0439	0.0506
Panel B: E-cigarette Use Past Month	Overall [0.092]		Underage [0.071]		Adult [0.108]	
T21	-0.0264***	-0.0192	-0.0123	-0.0316	-0.0253	-0.0545
	(0.0096)	(0.0183)	(0.0105)	(0.0227)	(0.0173)	(0.0418)
Observations	74,050	74,050	36,967	36,967	37,083	37,083
R-squared	0.0511	0.0532	0.0345	0.0365	0.0560	0.0592

Notes: Each column in each panel reports the results from a single regression using MTF weights and the 2012-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and two-stage DID model (Gardner 2021) in columns 2, 4, and 6. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 4. Effects of adopting T21 on 12th graders

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SDID	OLS	2SDID	OLS	2SDID
Panel A: Cigarette Use Past Month	Overall [0.106]		8th Graders [0.092]		10th Graders [0.121]	
T21	-0.0230***	-0.0208**	-0.0206**	-0.0133	-0.0230*	-0.0226
	(0.0086)	(0.0100)	(0.0088)	(0.0103)	(0.0122)	(0.0219)
Observations	103,940	103,940	45,714	45,714	58,226	58,226
R-squared	0.0534	0.0507	0.0532	0.0511	0.0530	0.0505
Panel B: E-cigarette Use Past Month	Overall [0.132]		Underage [0.125]		Adult [0.140]	
T21	-0.0224	-0.0772***	-0.0037	-0.0488**	-0.0457**	-0.1138**
	(0.0173)	(0.0266)	(0.0210)	(0.0249)	(0.0189)	(0.0467)
Observations	36,168	36,168	15,948	15,948	20,220	20,220
R-squared	0.0716	0.0716	0.0831	0.0847	0.0697	0.0682

Notes: Each column in each panel reports the results from a single regression using MTF weights and the 2012-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and a two-stage DID model (Gardner 2021) in columns 2, 4, and 6. Numbers in brackets are mean outcome variables in treated groups before the implementation of Tobacco 21. All individual-level and policy variables in addition to area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 5. Effect by categories of ever-smoking cigarettes, 12th graders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Once or twice		Occasionally		Regularly in the past		Regularly now	
	OLS	2SDID	OLS	2SDID	OLS	2SDID	OLS	2SDID
	[0.0161]		[0.074]		[0.030]		[0.033]	
T21	-0.0127	-0.0195*	-0.0023	-0.0121	-0.0035	0.0004	-0.0102**	-0.0043
	(0.0081)	(0.0106)	(0.0095)	(0.0190)	(0.0043)	(0.0040)	(0.0040)	(0.0104)
Observations	103,840	103,840	103,840	103,840	103,840	103,840	103,840	103,840
R-squared	0.0177	0.0162	0.0213	0.0201	0.0126	0.0122	0.0344	0.0336

Notes: Each column in each panel reports the results from a single regression using MTF weights and the 2012-2019 data. Results report the estimated effects from a linear regression model in columns 1 and 3 and a two-stage DID model (Gardner 2021) in columns 2 and 4. All individual-level and policy variables in addition to area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 6. Effects by gender, race and ethnicity, 12th graders

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Male	Female	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other
Panel A: Cigarette Use Past Month						
	[0.122]	[0.093]	[0.131]	[0.063]	[0.086]	[0.080]
T21	-0.0394***	-0.0080	-0.0122	-0.0024	-0.0317	-0.0681***
	(0.0136)	(0.0105)	(0.0203)	(0.0298)	(0.0209)	(0.0250)
Observations	47,424	56,516	55,091	11,488	21,986	11,521
R-squared	0.0545	0.0497	0.0601	0.0531	0.0407	0.0557
Panel B: E-cigarette Use Past Month						
	[0.157]	[0.113]	[0.160]	[0.083]	[0.117]	[0.117]
T21	-0.0594*	-0.0859***	-0.0124	-0.0885	0.0702	0.0280
	(0.0343)	(0.0265)	(0.0308)	(0.0576)	(0.0447)	(0.1063)
Observations	16,482	19,686	19,117	4,127	7,793	3,941
R-squared	0.0812	0.0605	0.0759	0.0730	0.0788	0.1126

Notes: Each column in each panel reports the estimated effects from a single two-stage DID regression model (Gardner 2021) using MTF weights and the 2012-2019 data in Panel A and 2014-2019 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 area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 7. Sensitivity analyses, 12th graders

T21 Estimated Effects	(1) Cigarette Use Past Month	(2) E-cigarette Use Past Month
	12th Graders	
(1) Main results	-0.0208**	-0.0772***
	(0.0100)	(0.0266)
Observations	103,940	36,168
(2) 2010-2019 period	-0.0141	---
	(0.0088)	---
Observations	132,920	---
(3) MA excluded	-0.0241*	-0.0813**
	(0.0124)	(0.0262)
Observations	100,441	35,241
(4) States surveyed all years	-0.0118	-0.0953***
	(0.0092)	(0.0297)
Observations	84,207	29,090
(5) State T21	-0.0288*	-0.0660*
	(0.0157)	(0.0367)
Observations	96,364	33,765
(6) Local T21	-0.0033	-0.0673
	(0.0140)	(0.0462)
Observations	72,156	22,678
(7) Probit regression	-0.0387***	-0.0199
	(0.0109)	(0.0208)
Observations	103,910	36,191

Notes: Each cell reports the estimated effect of raising MLSA to 21 using a two-stage DID regression model (except row 7) from a single regression. For cigarette use, the 2012-2019 MTF data are used and for e-cigarette use, the 2014-2019 data are used as 2014 was the first year in which questions about e-cigarettes were asked. Numbers in parentheses are standard errors clustered at the state level. All regressions are weighted using the MTF sampling weights. In each regression, all individual-level and policy covariates along with area and year-month dummies are included. *** p<0.01, ** p<0.05, * p<0.10.

Table 8. Analysis of risk perceptions, 12th graders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All	Male	Female	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other
Panel A: Risk of 1+ pack of cigarette use per day high							
	[0.827]	[0.811]	[0.840]	[0.840]	[0.794]	[0.824]	[0.824]
T21	-0.0112	0.0031	-0.0215	0.0294**	0.0023	0.0513	-0.0770**
	(0.0139)	(0.0202)	(0.0171)	(0.0131)	(0.0295)	(0.0446)	(0.0357)
Observations	83,216	37,802	45,414	44,869	8,777	17,391	9,169
R-squared	0.0357	0.0338	0.0401	0.0424	0.0626	0.0306	0.0486
Panel B: Risk of regular e-cigarette use high							
	[0.218]	[0.181]	[0.245]	[0.202]	[0.265]	[0.209]	[0.223]
T21	0.0719*	0.0441	0.0976**	0.0683	0.0290	0.1077	0.0317
	(0.0431)	(0.0512)	(0.0497)	(0.0517)	(0.1854)	(0.1572)	(0.0776)
Observations	25,131	11,103	14,028	13,317	2,526	5,352	2,700
R-squared	0.0695	0.0613	0.0766	0.0778	0.1261	0.1091	0.1116

Notes: Each column in each panel reports the estimated effects from a single two-stage DID regression model using MTF weights and the 2012-2019 data in Panel A and 2014-2019 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 area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 9. Effect of T21 on the MLSA retailer compliance, 2012-2019 MTF

VARIABLES	(2) Overall [0.143]	(4) Underage [0.185]	(6) Adult [0.054]
T21	0.0806	-0.0223	0.1901**
	(0.0565)	(0.0962)	(0.0942)
Observations	3,879	2,170	1,709
R-squared	0.1422	0.1106	0.1005

Notes: Each column reports the estimated effects from a two-stage DID regression model using the MTF weights and the 2012-2019 data. The outcome is a binary variable indicating no sales to the respondent in a store or a gas station. The small number of observations is due to asking this question from a subset of respondents who use cigarettes and have tried purchasing them from a store or gas station. Numbers in brackets are mean outcome variables in treated groups before implementation of Tobacco 21. All individual-level and policy variables in addition to area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table 10. Results from Nielsen point-of-sales data, 2012-2019

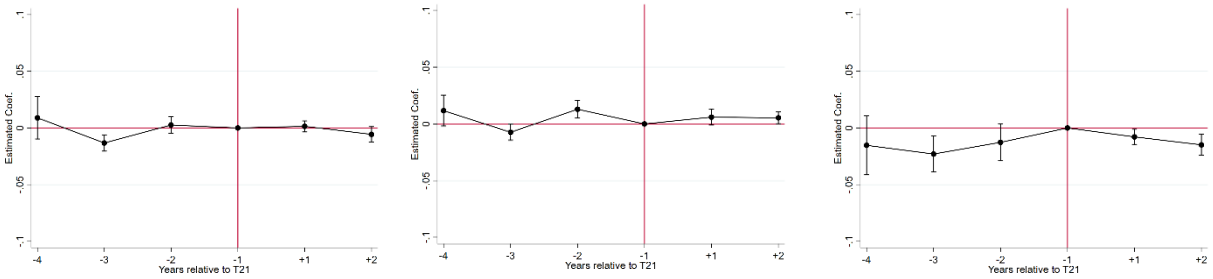
	(1) Cigarette Sales	(2) E-cigarette Sales
Panel A: Overall		
T21	-0.0714**	-0.2356
	(0.0334)	(0.2024)
Observations	2,816	2,816
Panel B: States and areas with top quartile under 21 population ratio		
T21	-0.1236*	-0.6934**
	(0.0648)	(0.2576)
Observations	1,220	1,220

Notes: Each column reports the result from a single two-stage DID regression model weighted by the area population. The outcomes are log sales in 2019 dollars. The unit of observation is the quarterly sales in each area. The analysis includes data for 32 quarters and 49 states (including 39 states or sub-states that adopted T21). Area and year-quarter fixed effects are included. Policy variables included in the model are tobacco excise taxes, beer taxes, e-cigarette MLSA laws, indoor smoking and vaping laws, e-cigarette taxes, marijuana decriminalization laws, medical marijuana laws, and recreational marijuana laws. The numbers in parentheses are standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Appendix

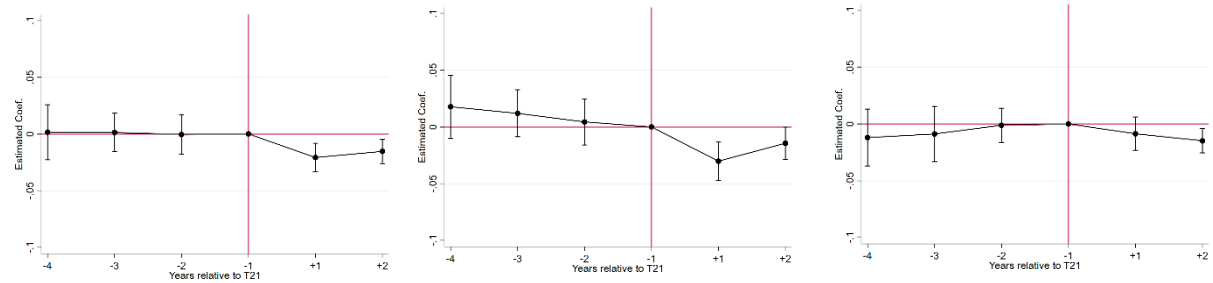
Figure A1. Event study of the effect of T21 on cigarette use past month
Sun and Abraham (2021)

Panel A 8th/10th graders



Overall | 8th Graders | 10th Graders

Panel B 12th graders

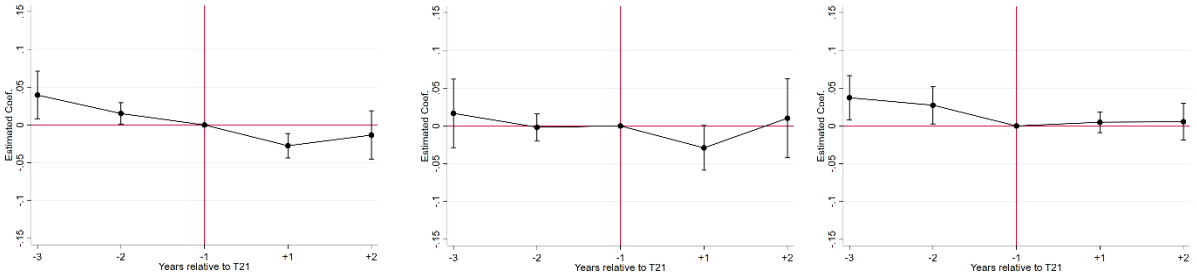


Overall | Underage | Adult

Notes: Each graph plots event study coefficients using the approach proposed by Sun and Abraham (2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

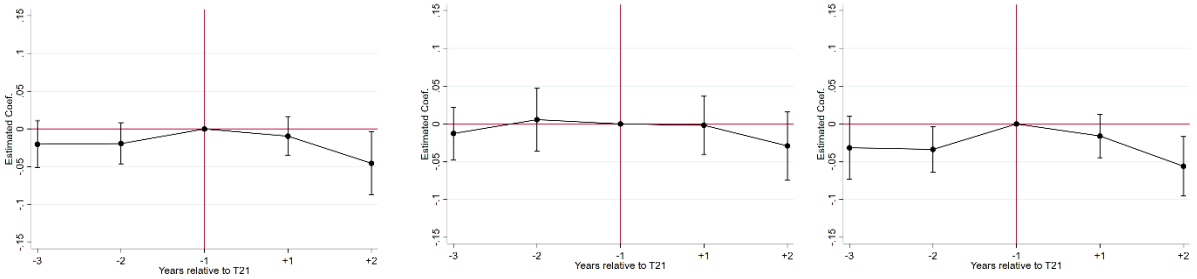
Figure A2. Event study of the effect of T21 on e-cigarette use past month
Sun and Abraham (2021)

Panel A 8th/10th graders



Overall 8th Graders 10th Graders

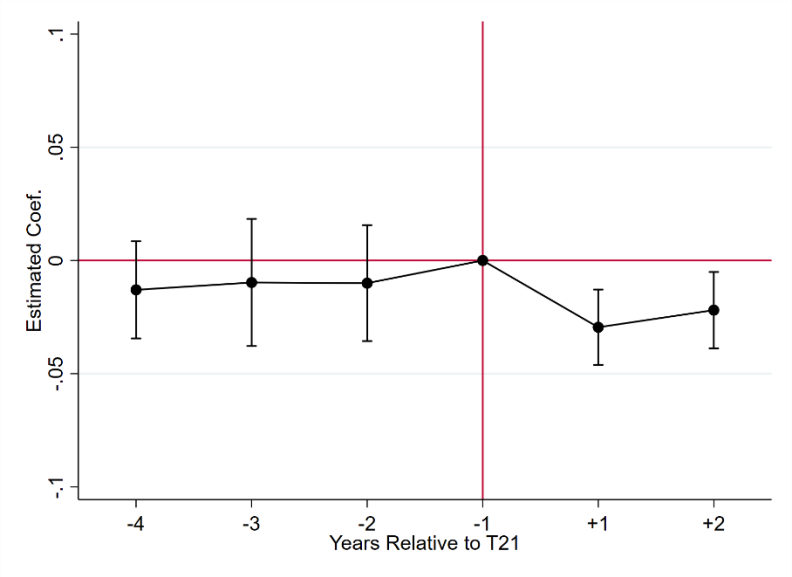
Panel B 12th graders



Overall Underage Adult

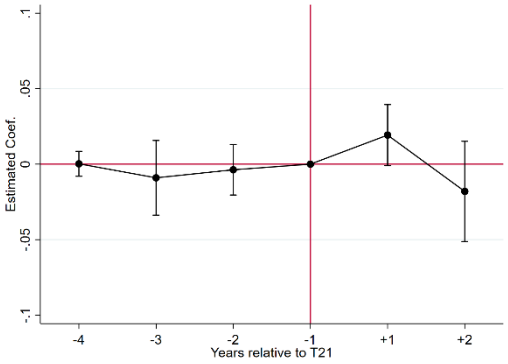
Notes: Each graph plots event study coefficients using the approach proposed by Sun and Abraham (2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Figure A3. Event study of the effect of T21 on cigarette use past month among 12th graders, MTF 2010-2019

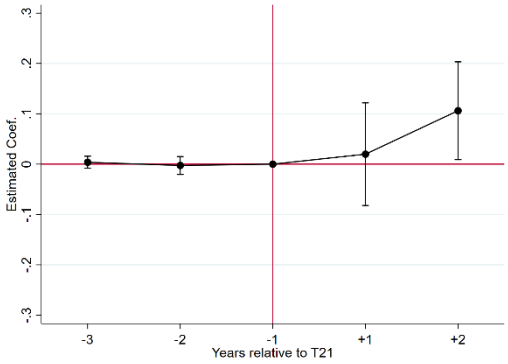


Notes: Each graph plots event study coefficients using a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Figure A4. Event study of the effect of T21 on cigarette and e-cigarette risk perceptions among 12th graders, MTF



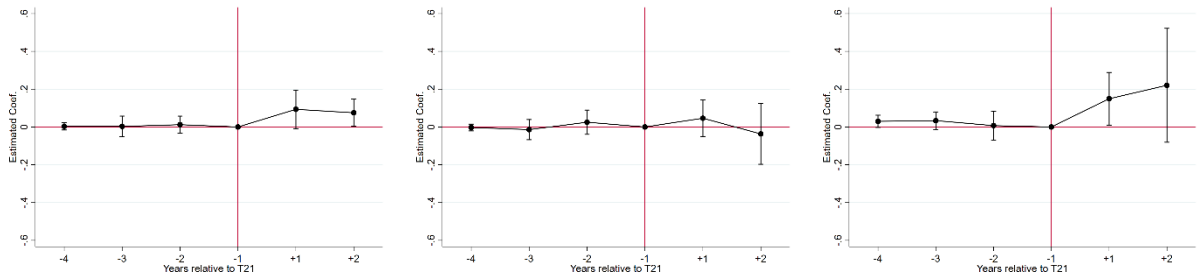
Risk of 1+ pack of cigarette use per day high



Risk of regular e-cigarette use high

Notes: Each graph plots event study coefficients using a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Figure A5. Event study of the effect of T21 on the MLSA retailer compliance, 2012-2019 MTF



Overall Underage Adult

Notes: Each graph plots event study coefficients using a two-stage DID model (Gardner 2021). Regressions are weighted by MTF sampling weight and standard errors are clustered at the state level. In each of the diagrams, the estimated changes are presented on the vertical axis, and years relative to the implementation of T21 are presented on the horizontal axis. Capped spikes illustrate the 95% confidence intervals. The estimated coefficient for the year before the implementation of T21 is normalized to zero.

Table A1. Balancing test, MTF 2012-2019

Outcome Variable: Tobacco 21	(1) **8th/10th Graders**	(2) **12th Graders**
Tobacco tax in 2019 $ city-county-state-federal	-0.0593	-0.0798
	(0.0566)	(0.1158)
Beer tax in 2019 $	-0.0385*	0.0000
	(0.0202)	(0.0401)
E-cigarette MLSA	-0.0760**	-0.0719*
	(0.0322)	(0.0335)
100% smoking ban in WRB (county-level)	-0.1540	-0.0706
	(0.0875)	(0.0548)
100% vaping ban in WRB (county-level)	0.3137**	0.0098
	(0.1212)	(0.1322)
Standardized e-cigarette tax (state/quarter)	0.1306**	0.2451
	(0.0566)	(0.1255)
Cannabis decriminalization	0.0405	-0.0506
	(0.1046)	(0.0815)
Medical cannabis laws	0.0790	0.1823
	(0.1269)	(0.2168)
Recreational cannabis laws	0.2137**	0.1874***
	(0.0675)	(0.0351)
Male	-0.1024	0.0097
	(0.2056)	(0.1038)
Age in years	0.0002	0.0155
	(0.0170)	(0.0171)
White non-Hispanic	0.7783	1.7769
	(0.6399)	(1.5683)
Black non-Hispanic	0.8797	2.0989
	(0.5940)	(1.7656)
Hispanic	1.0533	2.1991
	(0.8024)	(1.6718)
Others non-Hispanic	0.9254	1.5891
	(0.8844)	(1.3927)
Log weekly income in 2019 $	0.0380	0.0023
	(0.0716)	(0.0576)
Mother high school	-0.2579	0.2125
	(0.4254)	(0.2484)
Mother some college	-0.1188	0.6765
	(0.4323)	(0.4742)
Mother college graduate	0.2964	-0.0694
	(0.3788)	(0.3993)
Mother graduate degree	-0.1838	0.2642
	(0.4861)	(0.6268)
Father high school	0.0171	-0.4936
	(0.2188)	(0.3432)
Father some college	0.4887	-0.0278
	(0.3911)	(0.5172)
Father college graduate	0.1427	0.2735
	(0.1647)	(0.4432)
Father graduate degree	0.2499	-0.1449
	(0.1733)	(0.5908)
Large MSA	-0.0049	-0.0313
	(0.0574)	(0.0382)
Other MSA	0.0491	-0.0254
	(0.0292)	(0.0205)
Observations	436	330
R-squared	0.6254	0.7130

Notes: results are based on a linear regression model. In addition to the listed variables, we control for the area and year dummies. The unit of observation is each area in each year. Numbers in parentheses report cluster-robust standard errors at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table A2. Effect of T21 on cigarette use past month, 2012-2019, 8th/10th graders (full)

	(1)	(2)	(3)	(4)	(5)	(6)
	Cigarette Use Past Month					
	Overall		8th Graders		10th Graders	
VARIABLES	OLS	2SDID	OLS	2SDID	OLS	2SDID
T21	-0.0024	-0.0100	-0.0016	-0.0069**	-0.0100	-0.0175
	(0.0030)	(0.0071)	(0.0037)	(0.0035)	(0.0082)	(0.0180)
Tobacco tax in 2019 $ city-county-state-federal	0.0035*	0.0045**	0.0010	0.0025	0.0046	0.0026
	(0.0019)	(0.0021)	(0.0022)	(0.0020)	(0.0035)	(0.0031)
Beer tax in 2019 $	-0.0168***	-0.0109	-0.0153***	-0.0114**	-0.0199***	-0.0083*
	(0.0054)	(0.0073)	(0.0046)	(0.0052)	(0.0068)	(0.0070)
E-cigarette Sales Ban	-0.0083**	-0.0069*	-0.0072	-0.0059	-0.0103*	-0.0103*
	(0.0040)	(0.0036)	(0.0043)	(0.0038)	(0.0060)	(0.0056)
100% smoking ban in WRB (county-level)	-0.0034	-0.0042	0.0037	0.0017	-0.0094	-0.0076
	(0.0034)	(0.0032)	(0.0033)	(0.0034)	(0.0058)	(0.0049)
100% vaping ban in WRB (county-level)	0.0031	0.0064	0.0002	-0.0008	0.0003	0.0108
	(0.0062)	(0.0075)	(0.0056)	(0.0049)	(0.0071)	(0.0110)
Standardized e-cig taxes in 2019 $	-0.0002	-0.0036	0.0024	0.0008	-0.0006	-0.0031
	(0.0017)	(0.0024)	(0.0022)	(0.0032)	(0.0039)	(0.0032)
Marijuana Decriminalization Laws	0.0019	0.0007	0.0114*	0.0121**	-0.0032	-0.0091
	(0.0046)	(0.0062)	(0.0058)	(0.0059)	(0.0073)	(0.0084)
Medical Marijuana Laws	0.0023	0.0013	-0.0045	-0.0040	0.0107	0.0103
	(0.0037)	(0.0037)	(0.0033)	(0.0041)	(0.0089)	(0.0074)
Recreational Marijuana Laws	0.0082*	0.0128*	0.0024	0.0077	0.0205**	0.0157
	(0.0042)	(0.0066)	(0.0036)	(0.0050)	(0.0081)	(0.0123)
Male	0.0008	0.0036**	-0.0056***	-0.0048***	0.0075**	0.0118**
	(0.0016)	(0.0017)	(0.0014)	(0.0017)	(0.0028)	(0.0026)
Age 11	-0.2300***	-0.2060***	-0.4461***	-0.3932**	-0.1045	-0.0698
	(0.0789)	(0.0683)	(0.1660)	(0.1611)	(0.0823)	(0.1120)
Age 12	-0.2911***	-0.3124***	-0.4932***	-0.4319***	-0.1181	-0.1079
	(0.0695)	(0.0691)	(0.1524)	(0.1472)	(0.1067)	(0.1525)
Age 13	-0.3115***	-0.3294***	-0.5028***	-0.4316***	-0.0703	-0.0784
	(0.0711)	(0.0664)	(0.1525)	(0.1472)	(0.1119)	(0.0953)
Age 14	-0.3067***	-0.3231***	-0.4963***	-0.4242***	-0.1629**	-0.2123**
	(0.0708)	(0.0662)	(0.1521)	(0.1469)	(0.0667)	(0.0815)
Age 15	-0.2843***	-0.2943***	-0.4601***	-0.3784**	-0.1895***	-0.2451***
	(0.0699)	(0.0656)	(0.1522)	(0.1468)	(0.0696)	(0.0789)
Age 16	-0.2771***	-0.2868***	-0.3989**	-0.3163***	-0.1830**	-0.2379**
	(0.0699)	(0.0657)	(0.1585)	(0.1510)	(0.0698)	(0.0790)
Age 17	-0.2350***	-0.2414***	-0.3907**	-0.2913**	-0.1436**	-0.1955**
	(0.0693)	(0.0640)	(0.1490)	(0.1397)	(0.0696)	(0.0782)
Age 18	-0.1612**	-0.1699**	-0.4093***	-0.3376**	-0.0558	-0.1067
	(0.0759)	(0.0688)	(0.1514)	(0.1476)	(0.0760)	(0.0804)
Age 19	-0.1956***	-0.1928***	-0.3796**	-0.3277***	-0.1048	-0.1137
	(0.0727)	(0.0692)	(0.1565)	(0.1459)	(0.1051)	(0.1149)
Black non-Hispanic	-0.0412***	-0.0506***	-0.0220***	-0.0299**	-0.0591***	-0.0699***
	(0.0036)	(0.0037)	(0.0027)	(0.0032)	(0.0058)	(0.0051)
Hispanic	-0.0237***	-0.0282***	-0.0085***	-0.0120***	-0.0387***	-0.0440***
	(0.0026)	(0.0030)	(0.0025)	(0.0027)	(0.0041)	(0.0044)
Others non-Hispanic	-0.0048	-0.0076	0.0029	0.0002	-0.0134***	-0.0152***
	(0.0028)	(0.0032)	(0.0033)	(0.0034)	(0.0035)	(0.0038)
Missing race	-0.0155**	-0.0181**	-0.0000	-0.0052	-0.0377***	-0.0349***
	(0.0058)	(0.0058)	(0.0070)	(0.0072)	(0.0082)	(0.0079)
Log weekly income in 2019 $	0.0091***	0.0113***	0.0067***	0.0086***	0.0110***	0.0136***
	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0008)	(0.0007)
Missing Income	0.0299***	0.0381***	0.0156***	0.0206***	0.0441***	0.0557***
	(0.0024)	(0.0027)	(0.0020)	(0.0025)	(0.0042)	(0.0043)
Mother high school	-0.0079**	-0.0091**	-0.0061**	-0.0064**	-0.0101**	-0.0119**
	(0.0032)	(0.0036)	(0.0029)	(0.0028)	(0.0050)	(0.0058)
Mother some college	-0.0100***	-0.0143***	-0.0053*	-0.0081**	-0.0143***	-0.0196***
	(0.0031)	(0.0032)	(0.0031)	(0.0034)	(0.0051)	(0.0051)

Mother college graduate	-0.0209***	-0.0264***	-0.0135***	-0.0170***	-0.0275***	-0.0345***
	(0.0039)	(0.0041)	(0.0034)	(0.0034)	(0.0058)	(0.0064)
Mother graduate degree	-0.0167***	-0.0234***	-0.0089**	-0.0131**	-0.0232***	-0.0320***
	(0.0040)	(0.0042)	(0.0035)	(0.0041)	(0.0061)	(0.0063)
Mother educ. Missing	-0.0158***	-0.0208***	-0.0072**	-0.0111**	-0.0255***	-0.0309***
	(0.0043)	(0.0035)	(0.0035)	(0.0032)	(0.0070)	(0.0065)
Father high school	-0.0161***	-0.0212***	-0.0130***	-0.0188***	-0.0196***	-0.0239***
	(0.0037)	(0.0044)	(0.0041)	(0.0043)	(0.0043)	(0.0054)
Father some college	-0.0262***	-0.0324***	-0.0197***	-0.0263***	-0.0323***	-0.0379***
	(0.0043)	(0.0044)	(0.0047)	(0.0042)	(0.0051)	(0.0057)
Father college graduate	-0.0359***	-0.0458***	-0.0270***	-0.0359***	-0.0444***	-0.0550***
	(0.0043)	(0.0049)	(0.0046)	(0.0045)	(0.0053)	(0.0064)
Father graduate degree	-0.0370***	-0.0475***	-0.0282***	-0.0386***	-0.0450***	-0.0555***
	(0.0045)	(0.0055)	(0.0048)	(0.0047)	(0.0061)	(0.0076)
Father educ. Missing	-0.0121***	-0.0166***	-0.0120***	-0.0161***	-0.0119**	-0.0171**
	(0.0035)	(0.0048)	(0.0037)	(0.0038)	(0.0049)	(0.0069)
Large MSA	-0.0193***	-0.0199***	-0.0142***	-0.0116**	-0.0208***	-0.0218***
	(0.0042)	(0.0038)	(0.0041)	(0.0051)	(0.0052)	(0.0052)
Other MSA	-0.0147***	-0.0126***	-0.0102**	-0.0054	-0.0211***	-0.0181***
	(0.0052)	(0.0043)	(0.0048)	(0.0046)	(0.0063)	(0.0055)
Observations	222,735	222,735	113,030	113,030	109,705	109,705
R-squared	0.0397	0.0475	0.0335	0.0393	0.0439	0.0506

Notes: Each column reports the results from a single regression using MTF weights and the 2012-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and a two-stage DID model (Gardner 2021) in columns 2, 4, and 6. All area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table A3. Effect of T21 on e-cigarette use past month, 2014-2019, 8th/10th graders (full)

	(1)	(2)	(3)	(4)	(5)	(6)
	E-cigarette Use Past Month					
	Overall		8th Graders		10th Graders	
VARIABLES	OLS	2SDID	OLS	2SDID	OLS	2SDID
T21	-0.0264***	-0.0192	-0.0123	-0.0316	-0.0253	-0.0545
	(0.0096)	(0.0183)	(0.0105)	(0.0227)	(0.0173)	(0.0418)
Tobacco tax in 2019 $ city-county-state-federal	0.0037	-0.0018	0.0185	0.0124	-0.0024	-0.0135
	(0.0119)	(0.0138)	(0.0129)	(0.0140)	(0.0167)	(0.0168)
Beer tax in 2019 $	0.0150	0.0151	0.0176*	0.0171*	0.0288	0.0315
	(0.0162)	(0.0153)	(0.0090)	(0.0086)	(0.0211)	(0.0223)
E-cigarette Sales Ban	-0.0015	-0.0002	0.0042	0.0013	0.0001	0.0057
	(0.0117)	(0.0128)	(0.0114)	(0.0109)	(0.0143)	(0.0150)
100% smoking ban in WRB (county-level)	0.0046	-0.0021	0.0100	0.0082	0.0089	0.0001
	(0.0080)	(0.0082)	(0.0084)	(0.0093)	(0.0141)	(0.0150)
100% vaping ban in WRB (county-level)	-0.0273	-0.0224	-0.0165	-0.0158	-0.0385	-0.0161
	(0.0186)	(0.0230)	(0.0146)	(0.0175)	(0.0325)	(0.0308)
Standardized e-cig taxes in 2019 $	-0.0052	0.0039	-0.0197	0.0105	-0.0058	-0.0045
	(0.0136)	(0.0226)	(0.0119)	(0.0137)	(0.0191)	(0.0378)
Marijuana Decriminalization Laws	0.0462**	0.0472**	0.0428***	0.0398***	0.0506	0.0491
	(0.0176)	(0.0209)	(0.0123)	(0.0136)	(0.0324)	(0.0337)
Medical Marijuana Laws	-0.0061	-0.0075	-0.0072	-0.0118	-0.0070	-0.0052
	(0.0162)	(0.0187)	(0.0113)	(0.0114)	(0.0273)	(0.0299)
Recreational Marijuana Laws	0.0044	-0.0025	-0.0218**	-0.0209**	0.0221	0.0225
	(0.0098)	(0.0117)	(0.0094)	(0.0094)	(0.0190)	(0.0215)
Male	0.0099***	0.0111***	0.0024	0.0033	0.0191***	0.0204***
	(0.0029)	(0.0029)	(0.0029)	(0.0032)	(0.0052)	(0.0057)
Age11	-0.2189*	-0.3167**	-0.2155	-0.2662*	-0.1954	-0.3256
	(0.1196)	(0.1343)	(0.1366)	(0.1553)	(0.1803)	(0.2027)
Age12	-0.1654	-0.2173	-0.1659	-0.1973	0.1449	0.1135
	(0.1180)	(0.1400)	(0.1389)	(0.1618)	(0.3002)	(0.3337)
Age13	-0.2075*	-0.2795**	-0.1706	-0.2193	-0.2210	-0.4436**
	(0.1126)	(0.1293)	(0.1339)	(0.1554)	(0.2382)	(0.1970)
Age14	-0.1971*	-0.2681**	-0.1596	-0.2072	-0.1665	-0.2892
	(0.1131)	(0.1298)	(0.1341)	(0.1555)	(0.1774)	(0.1945)
Age15	-0.1446	-0.2174*	-0.1429	-0.1903	-0.1666	-0.2668
	(0.1120)	(0.1290)	(0.1336)	(0.1551)	(0.1789)	(0.1999)
Age16	-0.1440	-0.2141	-0.1035	-0.1446	-0.1722	-0.2703
	(0.1122)	(0.1294)	(0.1393)	(0.1601)	(0.1791)	(0.2002)
Age17	-0.1453	-0.2227*	-0.1493	-0.2006	-0.1725	-0.2790
	(0.1155)	(0.1310)	(0.1359)	(0.1602)	(0.1832)	(0.2021)
Age18	-0.0784	-0.1407	-0.1975	-0.2569	-0.0779	-0.1678
	(0.1196)	(0.1414)	(0.1458)	(0.1632)	(0.1798)	(0.2069)
Age19	-0.2490**	-0.3414**	-0.1795	-0.2823*	-0.2932	-0.4007*
	(0.1187)	(0.1312)	(0.1467)	(0.1559)	(0.1838)	(0.2043)
Black non-Hispanic	-0.0832***	-0.0842***	-0.0494***	-0.0542***	-0.1067***	-0.1041***
	(0.0060)	(0.0059)	(0.0075)	(0.0069)	(0.0093)	(0.0095)
Hispanic	-0.0365***	-0.0335***	-0.0070	-0.0083	-0.0627***	-0.0558***
	(0.0038)	(0.0047)	(0.0062)	(0.0070)	(0.0068)	(0.0073)
Others non-Hispanic	-0.0273***	-0.0228***	-0.0078	-0.0074	-0.0396***	-0.0305***
	(0.0057)	(0.0050)	(0.0047)	(0.0050)	(0.0103)	(0.0081)
Missing race	-0.0594***	-0.0441***	-0.0422***	-0.0425***	-0.0720***	-0.0354
	(0.0110)	(0.0137)	(0.0079)	(0.0082)	(0.0260)	(0.0301)
Log weekly income in 2019 $	0.0207***	0.0214***	0.0161***	0.0168***	0.0244***	0.0249***
	(0.0012)	(0.0012)	(0.0014)	(0.0015)	(0.0015)	(0.0016)
Missing Income	0.0577***	0.0614***	0.0386***	0.0419***	0.0767***	0.0806***
	(0.0069)	(0.0076)	(0.0056)	(0.0062)	(0.0131)	(0.0143)
Mother high school	-0.0023	-0.0032	0.0065	0.0058	-0.0129	-0.0142
	(0.0060)	(0.0067)	(0.0084)	(0.0085)	(0.0092)	(0.0106)
Mother some college	0.0044	0.0012	0.0096	0.0115	-0.0046	-0.0129
	(0.0056)	(0.0055)	(0.0062)	(0.0072)	(0.0102)	(0.0100)
Mother college graduate	-0.0099*	-0.0122*	-0.0075	-0.0080	-0.0169*	-0.0215**
	(0.0056)	(0.0062)	(0.0077)	(0.0088)	(0.0087)	(0.0097)
Mother graduate degree	-0.0012	-0.0046	-0.0008	-0.0006	-0.0040	-0.0117
	(0.0070)	(0.0074)	(0.0085)	(0.0096)	(0.0115)	(0.0124)
Mother educ. Missing	-0.0165*	-0.0226***	-0.0043	-0.0081	-0.0340***	-0.0413***

	(0.0082)	(0.0065)	(0.0100)	(0.0096)	(0.0110)	(0.0105)
Father high school	-0.0126*	-0.0105	-0.0198**	-0.0200**	-0.0094	-0.0056
	(0.0068)	(0.0071)	(0.0089)	(0.0099)	(0.0078)	(0.0083)
Father some college	-0.0209***	-0.0184**	-0.0221***	-0.0207**	-0.0229***	-0.0197**
	(0.0063)	(0.0070)	(0.0072)	(0.0079)	(0.0084)	(0.0096)
Father college graduate	-0.0390***	-0.0370***	-0.0402***	-0.0403***	-0.0421***	-0.0384***
	(0.0062)	(0.0069)	(0.0072)	(0.0081)	(0.0074)	(0.0086)
Father graduate degree	-0.0454***	-0.0430***	-0.0487***	-0.0505***	-0.0453***	-0.0405***
	(0.0067)	(0.0071)	(0.0074)	(0.0086)	(0.0094)	(0.0102)
Father educ. Missing	-0.0262***	-0.0226***	-0.0318***	-0.0310***	-0.0210***	-0.0156*
	(0.0052)	(0.0061)	(0.0071)	(0.0082)	(0.0067)	(0.0081)
Large MSA	0.0092	0.0137	-0.0015	0.0002	0.0238	0.0347*
	(0.0097)	(0.0092)	(0.0127)	(0.0135)	(0.0189)	(0.0176)
Other MSA	0.0029	0.0024	0.0014	-0.0002	-0.0017	-0.0021
	(0.0058)	(0.0064)	(0.0072)	(0.0075)	(0.0092)	(0.0099)
Observations	74,050	74,050	36,967	36,967	37,083	37,083
R-squared	0.0511		0.0345		0.0560	

Notes: Each column reports the results from a single regression using MTF weights and the 2014-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and a two-stage DID model (Gardner 2021) in columns 2, 4, and 6. All area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table A4. Effect of T21 on cigarette use past month, 2012-2019, 12th graders (full)

	(1)	(2)	(3)	(4)	(5)	(6)
	Cigarette Use Past Month					
	Overall		Underage		Of Age	
VARIABLES	OLS	2SDID	OLS	2SDID	OLS	2SDID
T21	-0.0230**	-0.0208**	-0.0206**	-0.0133	-0.0230*	-0.0226
	(0.0086)	(0.0100)	(0.0088)	(0.0103)	(0.0122)	(0.0219)
Tobacco tax in 2019 $ city-county-state-federal	-0.0029	-0.0010	-0.0018	-0.0015	-0.0034	0.0001
	(0.0041)	(0.0052)	(0.0048)	(0.0056)	(0.0049)	(0.0064)
Beer tax in 2019 $	-0.0231	-0.0239	-0.0155	-0.0171	-0.0443**	-0.0466**
	(0.0180)	(0.0182)	(0.0147)	(0.0147)	(0.0193)	(0.0193)
E-cigarette Sales Ban	-0.0182***	-0.0195**	-0.0169*	-0.0159	-0.0205*	-0.0237**
	(0.0067)	(0.0074)	(0.0094)	(0.0099)	(0.0103)	(0.0107)
100% smoking ban in WRB (county-level)	-0.0092	-0.0079	-0.0141	-0.0107	-0.0053	-0.0058
	(0.0087)	(0.0101)	(0.0092)	(0.0115)	(0.0091)	(0.0098)
100% vaping ban in WRB (county-level)	-0.0031	-0.0029	-0.0011	0.0027	-0.0065	-0.0101
	(0.0127)	(0.0125)	(0.0121)	(0.0131)	(0.0164)	(0.0156)
Standardized e-cig taxes in 2019 $	0.0054	0.0004	0.0035	-0.0075	0.0064	0.0070
	(0.0051)	(0.0072)	(0.0055)	(0.0074)	(0.0058)	(0.0106)
Marijuana Decriminalization Laws	-0.0249	-0.0248	-0.0045	-0.0036	-0.0414*	-0.0423
	(0.0181)	(0.0194)	(0.0110)	(0.0118)	(0.0243)	(0.0259)
Medical Marijuana Laws	-0.0190***	-0.0193***	-0.0109	-0.0097	-0.0261***	-0.0278***
	(0.0057)	(0.0062)	(0.0074)	(0.0077)	(0.0072)	(0.0085)
Recreational Marijuana Laws	0.0010	0.0012	0.0081	-0.0014	-0.0092	-0.0006
	(0.0087)	(0.0129)	(0.0101)	(0.0148)	(0.0097)	(0.0120)
Male	0.0306***	0.0322***	0.0235***	0.0257***	0.0354***	0.0366***
	(0.0036)	(0.0040)	(0.0046)	(0.0049)	(0.0042)	(0.0047)
Age 15	-0.0706	-0.0651	-0.0635	-0.0573		
	(0.1168)	(0.1235)	(0.1151)	(0.1210)		
Age 16	-0.1581	-0.1587	-0.1564	-0.1579		
	(0.1076)	(0.1116)	(0.1048)	(0.1079)		
Age 17	-0.1763	-0.1830	-0.1729	-0.1808		
	(0.1088)	(0.1123)	(0.1063)	(0.1090)		
Age 18	-0.1550	-0.1607	-0.1546	-0.1618		
	(0.1089)	(0.1124)	(0.1067)	(0.1096)		
Age 19	-0.1418	-0.1451			0.0133	0.0157
	(0.1103)	(0.1142)			(0.0091)	(0.0095)
Age 20	-0.1062	-0.1082			0.0477**	0.0516**
	(0.1149)	(0.1191)			(0.0229)	(0.0236)
Age missing	-0.1014	-0.1088	-0.0995	-0.1046	0.0525***	0.0495***
	(0.1109)	(0.1149)	(0.1030)	(0.1060)	(0.0134)	(0.0151)
Black non-Hispanic	-0.0894***	-0.0935***	-0.0904***	-0.0944***	-0.0869***	-0.0911***
	(0.0072)	(0.0071)	(0.0076)	(0.0078)	(0.0076)	(0.0076)
Hispanic	-0.0514***	-0.0516***	-0.0593***	-0.0600***	-0.0441***	-0.0446***
	(0.0055)	(0.0062)	(0.0056)	(0.0065)	(0.0068)	(0.0076)
Others non-Hispanic	-0.0242***	-0.0244***	-0.0252***	-0.0259***	-0.0234***	-0.0232***
	(0.0055)	(0.0061)	(0.0063)	(0.0075)	(0.0073)	(0.0077)
Missing race	-0.0444***	-0.0395***	-0.0439**	-0.0422**	-0.0419***	-0.0340**
	(0.0084)	(0.0089)	(0.0175)	(0.0208)	(0.0120)	(0.0130)
Log weekly income in 2019 $	0.0150***	0.0158***	0.0134***	0.0145***	0.0161***	0.0166***
	(0.0009)	(0.0011)	(0.0009)	(0.0013)	(0.0011)	(0.0013)
Missing Income	0.0632***	0.0685***	0.0550***	0.0613***	0.0691***	0.0728***
	(0.0051)	(0.0063)	(0.0063)	(0.0074)	(0.0056)	(0.0069)
Mother high school	-0.0095*	-0.0096*	-0.0137**	-0.0161**	-0.0065	-0.0053
	(0.0050)	(0.0056)	(0.0062)	(0.0074)	(0.0072)	(0.0076)
Mother some college	-0.0099*	-0.0087	-0.0156**	-0.0178**	-0.0060	-0.0031
	(0.0055)	(0.0063)	(0.0061)	(0.0073)	(0.0079)	(0.0085)
Mother college graduate	-0.0211***	-0.0218***	-0.0272***	-0.0302***	-0.0164*	-0.0162*
	(0.0073)	(0.0077)	(0.0084)	(0.0097)	(0.0084)	(0.0084)
Mother graduate degree	-0.0173**	-0.0180**	-0.0260***	-0.0310***	-0.0106	-0.0087
	(0.0066)	(0.0074)	(0.0075)	(0.0099)	(0.0093)	(0.0096)

Mother educ. Missing	-0.0089	-0.0085	-0.0142*	-0.0181*	-0.0059	-0.0033
	(0.0063)	(0.0071)	(0.0080)	(0.0104)	(0.0084)	(0.0095)
Father high school	-0.0198***	-0.0225***	-0.0161*	-0.0183*	-0.0229***	-0.0256***
	(0.0060)	(0.0062)	(0.0086)	(0.0095)	(0.0064)	(0.0065)
Father some college	-0.0298***	-0.0342***	-0.0323***	-0.0362***	-0.0278***	-0.0325***
	(0.0067)	(0.0063)	(0.0096)	(0.0096)	(0.0070)	(0.0068)
Father college graduate	-0.0508***	-0.0576***	-0.0443***	-0.0495***	-0.0562***	-0.0639***
	(0.0072)	(0.0064)	(0.0104)	(0.0105)	(0.0076)	(0.0069)
Father graduate degree	-0.0526***	-0.0596***	-0.0462***	-0.0528***	-0.0583***	-0.0652***
	(0.0095)	(0.0091)	(0.0118)	(0.0119)	(0.0106)	(0.0106)
Father educ. Missing	-0.0129**	-0.0164***	-0.0070	-0.0075	-0.0165*	-0.0215**
	(0.0056)	(0.0055)	(0.0078)	(0.0093)	(0.0088)	(0.0084)
Large MSA	-0.0303***	-0.0290***	-0.0176**	-0.0165*	-0.0396***	-0.0377***
	(0.0099)	(0.0102)	(0.0086)	(0.0087)	(0.0129)	(0.0131)
Other MSA	-0.0309***	-0.0303***	-0.0256***	-0.0252***	-0.0337***	-0.0331***
	(0.0079)	(0.0082)	(0.0081)	(0.0085)	(0.0094)	(0.0096)
Observations	103,940	103,940	45,714	45,714	58,226	58,226
R-squared	0.0534	0.0507	0.0532	0.0511	0.0530	0.0505

Notes: Each column reports the results from a single regression using MTF weights and the 2012-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and a two-stage DID model (Gardner 2021) in columns 2, 4, and 6. All area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table A5. Effect of T21 on e-cigarette use past month, 2014-2019, 12th graders (full)

	(1)	(2)	(3)	(4)	(5)	(6)
	E-cigarette Use Past Month					
	Overall		Underage		Of Age	
VARIABLES	OLS	2SDID	OLS	2SDID	OLS	2SDID
T21	-0.0224	-0.0772***	-0.0037	-0.0488**	-0.0457**	-0.1138**
	(0.0173)	(0.0266)	(0.0210)	(0.0249)	(0.0189)	(0.0467)
Tobacco tax in 2019 $ city-county-state-federal	0.0159	0.0162	0.0146	0.0200	0.0184	0.0157
	(0.0114)	(0.0166)	(0.0117)	(0.0125)	(0.0187)	(0.0244)
Beer tax in 2019 $	0.0453***	0.0520***	0.0479***	0.0571***	0.1048**	0.1129**
	(0.0107)	(0.0108)	(0.0123)	(0.0131)	(0.0493)	(0.0502)
E-cigarette Sales Ban	-0.0125	-0.0176	-0.0191	-0.0256	-0.0127	-0.0161
	(0.0190)	(0.0190)	(0.0220)	(0.0223)	(0.0197)	(0.0197)
100% smoking ban in WRB (county-level)	-0.0211	-0.0317*	-0.0375	-0.0548**	-0.0079	-0.0148
	(0.0196)	(0.0170)	(0.0258)	(0.0212)	(0.0192)	(0.0186)
100% vaping ban in WRB (county-level)	-0.0290	-0.0321	-0.0213	-0.0283	-0.0374*	-0.0367
	(0.0181)	(0.0200)	(0.0231)	(0.0247)	(0.0217)	(0.0223)
Standardized e-cig taxes in 2019 $	-0.0182	0.0163	-0.0339**	0.0010	-0.0069	0.0207
	(0.0164)	(0.0179)	(0.0154)	(0.0213)	(0.0229)	(0.0306)
Marijuana Decriminalization Laws	0.0412***	0.0385**	0.0530***	0.0518***	0.0301*	0.0294
	(0.0140)	(0.0168)	(0.0143)	(0.0187)	(0.0171)	(0.0185)
Medical Marijuana Laws	-0.0166	-0.0249	-0.0274*	-0.0336*	-0.0075	-0.0170
	(0.0166)	(0.0170)	(0.0146)	(0.0183)	(0.0235)	(0.0247)
Recreational Marijuana Laws	-0.0254	-0.0134	-0.0229	-0.0203	-0.0257	-0.0148
	(0.0178)	(0.0229)	(0.0180)	(0.0206)	(0.0226)	(0.0321)
Male	0.0687***	0.0701***	0.0675***	0.0696***	0.0695***	0.0700***
	(0.0059)	(0.0066)	(0.0063)	(0.0070)	(0.0093)	(0.0099)
Age 15	-0.1186	-0.1493	-0.0984	-0.1329		
	(0.2177)	(0.2448)	(0.2155)	(0.2415)		
Age 16	-0.0888	-0.1030	-0.0778	-0.0918		
	(0.2214)	(0.2483)	(0.2187)	(0.2441)		
Age 17	-0.0767	-0.1098	-0.0604	-0.0924		
	(0.2126)	(0.2340)	(0.2092)	(0.2293)		
Age 18	-0.0625	-0.0937	-0.0435	-0.0964		
	(0.2133)	(0.2349)	(0.2095)	(0.2294)		
Age 19	-0.0832	-0.1120			-0.0208*	-0.0193*
	(0.2128)	(0.2352)			(0.0104)	(0.0108)
Age 20	-0.0897	-0.1179			-0.0259	-0.0256
	(0.2152)	(0.2368)			(0.0547)	(0.0590)
Age missing	0.0214	-0.0250	0.1151	0.0622	0.0568*	0.0502
	(0.2117)	(0.2333)	(0.2227)	(0.2419)	(0.0282)	(0.0300)
Black non-Hispanic	-0.1301***	-0.1293***	-0.1196***	-0.1191***	-0.1358***	-0.1356***
	(0.0116)	(0.0118)	(0.0164)	(0.0176)	(0.0128)	(0.0130)
Hispanic	-0.0685***	-0.0570***	-0.0734***	-0.0556***	-0.0624***	-0.0566***
	(0.0100)	(0.0120)	(0.0091)	(0.0134)	(0.0144)	(0.0152)
Others non-Hispanic	-0.0438***	-0.0432***	-0.0343***	-0.0357***	-0.0503***	-0.0475***
	(0.0101)	(0.0103)	(0.0112)	(0.0122)	(0.0126)	(0.0130)
Missing race	-0.0532**	-0.0335	-0.0482	-0.0222	-0.0416*	-0.0286
	(0.0228)	(0.0257)	(0.0570)	(0.0663)	(0.0217)	(0.0247)
Log weekly income in 2019 $	0.0237***	0.0235***	0.0234***	0.0232***	0.0236***	0.0235***
	(0.0014)	(0.0015)	(0.0021)	(0.0024)	(0.0015)	(0.0016)
Missing Income	0.0916***	0.0885***	0.1051***	0.1033***	0.0832***	0.0804***
	(0.0086)	(0.0096)	(0.0140)	(0.0151)	(0.0119)	(0.0129)
Mother high school	0.0014	0.0022	-0.0049	-0.0059	0.0074	0.0096
	(0.0076)	(0.0092)	(0.0144)	(0.0163)	(0.0095)	(0.0100)
Mother some college	0.0152**	0.0179**	0.0078	0.0114	0.0231**	0.0246**
	(0.0074)	(0.0081)	(0.0146)	(0.0153)	(0.0099)	(0.0112)
Mother college graduate	0.0018	0.0012	-0.0072	-0.0069	0.0103	0.0088
	(0.0102)	(0.0115)	(0.0185)	(0.0214)	(0.0103)	(0.0113)
Mother graduate degree	0.0126	0.0103	-0.0009	-0.0084	0.0246	0.0254
	(0.0124)	(0.0146)	(0.0169)	(0.0204)	(0.0153)	(0.0163)
Mother educ. Missing	-0.0393***	-0.0418***	-0.0483***	-0.0503***	-0.0353***	-0.0366***
	(0.0107)	(0.0111)	(0.0172)	(0.0182)	(0.0119)	(0.0129)
Father high school	-0.0232***	-0.0221**	-0.0165	-0.0119	-0.0298***	-0.0310***
	(0.0075)	(0.0087)	(0.0123)	(0.0140)	(0.0078)	(0.0090)
Father some college	-0.0211***	-0.0197**	-0.0137	-0.0097	-0.0287***	-0.0280***

	(0.0071)	(0.0076)	(0.0125)	(0.0129)	(0.0089)	(0.0100)
Father college graduate	-0.0385***	-0.0395***	-0.0413***	-0.0397**	-0.0378***	-0.0399***
	(0.0080)	(0.0091)	(0.0131)	(0.0155)	(0.0103)	(0.0116)
Father graduate degree	-0.0369***	-0.0346***	-0.0406***	-0.0281*	-0.0339***	-0.0387***
	(0.0087)	(0.0090)	(0.0136)	(0.0142)	(0.0119)	(0.0128)
Father educ. Missing	-0.0080	-0.0103	-0.0154	-0.0106	-0.0024	-0.0098
	(0.0120)	(0.0117)	(0.0210)	(0.0195)	(0.0114)	(0.0132)
Large MSA	-0.0054	0.0025	-0.0031	0.0055	-0.0105	-0.0031
	(0.0177)	(0.0142)	(0.0223)	(0.0190)	(0.0176)	(0.0145)
Other MSA	0.0242*	0.0279**	0.0155	0.0219	0.0294*	0.0315*
	(0.0123)	(0.0126)	(0.0131)	(0.0134)	(0.0154)	(0.0157)
Observations	36,168	36,168	15,948	15,948	20,220	20,220
R-squared	0.0716	0.0716	0.0831	0.0847	0.0697	0.0682

Notes: Each column reports the results from a single regression using MTF weights and the 2014-2019 data. Results report the estimated effects from a linear regression model in columns 1, 3, and 5 and a two-stage DID model (Gardner 2021) in columns 2, 44, and 6. All area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.

Table A6. Effect of T21 at the intensive margin, 12th graders, MTF

	(1)	(2)	(3)	(4)
	Daily no. of cigarette use past 30 days if smoked		No. of Days Vaped Past Month if Vaped	
	OLS	2SDID	OLS	2SDID
T21	-0.8917	-0.8067	0.1248	0.2305
	(0.8256)	(0.7028)	(0.2847)	(0.2400)
Observations	11,685	11,685	6,554	6,554
R-squared	0.0517	0.0527	0.1434	0.1476
Period	2012-2019	2012-2019	2014-2019	2014-2019

Notes: Each column in each panel reports the results from a single regression using MTF weights and the 2012-2019 data for cigarette use and the 2014-2019 data for the e-cigarette use measures. Results report the estimated effects from a linear regression model in columns 1 and 3 and a two-stage DID model (Gardner 2021) in columns 2 and 4. All individual-level and policy variables in addition to area and year-month dummies are included in each regression. Numbers in parentheses are robust standard errors clustered at the state level. *** p<0.01, ** p<0.05, * p<0.10.