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ABSTRACT

We use difference-in-differences models and individual-level data from the national and state Youth Risk Behavior Surveillance System (YRBSS) from 2005 to 2015 to examine the effects of e-cigarette Minimum Legal Sale Age (MLSA) laws on youth cigarette smoking, alcohol consumption, and marijuana use. Our results suggest that these laws increased youth smoking participation by about one percentage point, approximately half of which could be attributed to smoking initiation. We find little evidence of higher cigarette smoking persisting beyond the point at which youth age out of the law. Our results also show little effect of the law on youth drinking, binge drinking, and marijuana use. Taken together, our findings suggest a possible unintended effect of e-cigarette MLSA laws—rising cigarette use in the short term while youth are restricted from purchasing e-cigarettes.

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1. Introduction

Teenage substance use continues to be a major public health concern. Substance use has been linked with poor academic performance, impaired cognitive development, other mental and physical health problems, and motor-vehicle accidents (National Institute on Drug Abuse , National Institute on Alcohol Abuse and Alcoholism 2016). Tobacco, marijuana, and alcohol are among the most widely used substances by adolescents. Although rates of youth smoking are declining, each day more than 3,200 youths initiate cigarette consumption and more than 2,000 transition into daily smoking (US Department of Health Human Services 2014). Marijuana is the most commonly used illicit drug, with 22% of high school seniors reporting past month use. Moreover, alcohol use among youths is even more widespread than the use of tobacco or illicit drugs. Almost one out of three youths has consumed alcohol in the past month, and almost one out of five has participated in binge drinking (Centers for Disease Control and Prevention 2015).

Though a large economics literature has examined the cross-relationship between smoking, drinking and marijuana use (Dee 1999, Gruber, Sen, and Stabile 2003, Picone, Sloan, and Trogdon 2004, Chaloupka et al. 1999, Farrelly et al. 2001), the introduction of electronic cigarettes (e-cigarettes or e-cigs) presents youths with an alternative that could disrupt their use of these substances. E-cigarettes are a particular type of vaping device within the broader class of electronic nicotine delivery systems (ENDS), and differ primarily from conventional cigarettes by permitting the inhalation of nicotine that is heated rather than combusted, thereby substantially reducing the harm associated with combustion-related byproducts. Since their introduction into the U.S market, e-cigarettes have been advertised and positioned as alternatives to conventional cigarettes, and their popularity particularly among youths has risen exponentially.[1] Within a four-year period (2011-2015), e-cigarette use has increased from 1.5% to 16.0% among high school students and from 0.6% to 5.3% among middle school students,

[1] The Tobacco Control Act of 2009 gave the Food and Drug Administration (FDA) jurisdiction over tobacco products, and this "deeming" rule was finalized in 2016.

surpassing cigarettes as the most commonly used tobacco product among adolescents (Singh 2016).[2]

A heated policy debate concerning the regulation of e-cigarettes has ensued, at the heart of which are fundamental questions regarding the relative risks between e-cigarettes and conventional cigarettes and the potential for e-cigarettes to serve as a tool towards tobacco harm reduction. A recent report issued by the British government suggests that e-cigarettes are no more than five percent as harmful as conventional cigarettes (Tobacco Advisory Group of the Royal College of Physicians 2016). Other studies have suggested that e-cigarettes can direct smokers away from smoking and possibly help them quit (Hampton 2014, Abrams 2014, Brandon et al. 2015, McNeill et al. 2015). However, the 2016 Surgeon General's Report warns that e-cigarettes are dangerous to adolescents because they can interfere with cognitive development and can cause nicotine addiction (US Department of Health Human Services 2016). One particular concern is that e-cigarettes may act as a gateway towards the use of other addictive substances, such as cigarettes, alcohol, and marijuana (Gostin and Glasner 2014, Primack et al. 2015, Mammen, Rehm, and Rueda 2016). While the downward trend in youth smoking indicates a reduction in the number of new initiates, possibly because some of these youths are starting to use e-cigarettes instead, it is not clear that this trend is necessarily harm-reducing since youths who initiate nicotine with e-cigarettes may transition to smoking at some later point in time or transition to dual use. Polysubstance use is also quite prevalent among youths, which may lead to further spillovers from tobacco use into the use of other substances such as alcohol or marijuana.[3]

In response, state governments passed a wave of regulations limiting youth access to e-cigarettes. A popular initiative has been the adoption of Minimum Legal Sale Age (MLSA) laws on e-cigarettes analogous to those passed for conventional cigarettes decades ago. New Jersey became the first state to implement an e-cigarette MLSA law in March of 2010, followed by

[2] Among adults, the 2014 National Health Interview Survey shows that 12.6% had ever used e-cigarettes at least once and 3.7% currently use e-cigarettes (Schoenborn and Gindi, 2015).

[3] Data from Wave 4 of the Add Health Survey indicated that 34% of youth reported either early use of both alcohol and marijuana, or alcohol, marijuana, and cigarettes (Moss, Cen, and Yi, 2014).

four other states later within the same year.[4] Additional states adopted an e-cigarette MLSA law in each year subsequently, and by the time the Food and Drug Administration (FDA) mandated a federal e-cigarette MLSA law of 18 in August of 2016, all states but two had an e-cigarette MLSA law in place.[5]

Youth vaping is predicted to decline as costs and other components of the "full price" associated with the product rise due to restrictions on youth access. The effect of the e-cigarette MLSA law on smoking and the use of other addictive substances is a priori ambiguous. If e-cigarettes are economic substitutes with other tobacco products or other addictive substances, then e-cigarette restrictions may induce substitution toward smoking and other substance use, counteracting some of the intended public health gains. On the other hand, if these substances are economic complements, contemporaneously and intertemporally, then restricting e-cigarette access will additionally reduce smoking and the addictive stock of nicotine, and possibly drinking and marijuana use, among youth currently and as they transition into adulthood. Understanding such policy-driven spillovers and cross-price effects are integral towards informing the debate underlying e-cigarettes and designing optimal regulatory policy.

In this study we assess whether, and the extent to which, restricting youth access to e-cigarettes has affected their use of other addictive substances. We contribute to the limited literature on the effects of e-cigarette MLSA laws in several ways. First, the few studies that have explored the effect of e-cigarette MLSA laws on youth smoking have arrived at mixed conclusions (Friedman 2015, Pesko, Hughes, and Faisal 2016, Abouk and Adams 2017), and our study attempts to provide further clarity to this conflicting evidence base. Second, we extend the prior work and provide the first evidence on the intertemporal relationship between e-cigarette MLSA laws and youth smoking. In addition to any contemporaneous effects, by affecting the addictive nicotine stock, e-cigarette MLSA laws may also have dynamic effects. Our study informs whether a policy that makes vaping less attractive today makes future smoking more or less likely when youths are no longer subject to the MSLA-based restriction.

[4] Utah, New Hampshire, Minnesota, and California enforced the law on May 11, July 31, August 1, and September 27, all in 2010, respectively.

[5] Appendix Table 1 provides a list of states that have implemented the e-cigarette MLSA laws over our sample period spanning 2005-2015.

As noted above, this intertemporal transition from e-cigarette use to smoking among youths forms one of the key questions underlying the policy debate. Third, we broaden the lens to other addictive substances and provide some of the first evidence on potential spillover effects of e-cigarette MLSA laws on other substance use. Such spillover effects are plausible given the high co-occurrence of and transitions between alcohol, marijuana, and tobacco use among adolescents.[6]

The remainder of the study is organized as follows. Section 2 provides a brief background and a review of the relevant literature. Section 3 outlines a conceptual framework of the various channels through which e-cigarette MLSA laws may affect substance use, and motivates our empirical specifications. Section 4 describes the assembled data, followed by a description of the empirical approach in section 5. We present the findings in section 6, and the final section discusses some of the implications of these results.

2. Relevant Studies

Individual states have made several efforts in recent decades to tighten tobacco control regulations by prohibiting retailers from selling tobacco products to minors. Several studies have examined the efficacy of cigarette MLSA laws adopted between the 1980s and early 1990s in curbing youth smoking. Though many of these studies suggest that the laws have been effective in reducing youth smoking (Chaloupka and Pacula 1998, Gruber and Zinman 2001, Ahmad and Billimek 2007, DiFranza, Savageau, and Fletcher 2009), some find the law effects being limited. Chaloupka and Grossman (1996) find little effect of youth access restrictions on youth smoking, which they attribute to the weak enforcement of the laws. DeCicca and colleagues (2002), using indices of smoking restrictions that ranged from youth access restrictions to restrictions on smoking in public places, also find limited effects of the laws. A recent study by Yoruk and Yoruk (2015) revisits the effect of cigarette MLSA laws on youth smoking using a regression discontinuity design. They find that gaining legal access to tobacco

[6] Data from the 2014 National Survey of Drug Use and Health (NSDUH) suggest that, among youth ages 12-17 who have used tobacco products in the past year, 88% have also consumed alcohol and 56% have used marijuana over this period.

products once youths have aged out is associated with a 2 to 3 percentage point increase in the probability of smoking, though the effects are imprecisely estimated. By focusing on a subsample where youths had smoked in the prior wave, the authors find that cigarette MLSA laws lead to a statistically significant increase in the probability of smoking (five percentage points) and frequency of smoking (25% increase).

Only three studies have focused specifically on the impact of e-cigarette MLSA laws. Friedman (2015) and Pesko et al. (2016), based on state-aggregated data spanning up to 2013, both find that e-cigarette MLSA laws have increased youth smoking by 0.8 to 0.9 percentage points.[7] These results are consistent with e-cigarettes and conventional cigarettes being economic substitutes, at least contemporaneously. In contrast, the results in Abouk and Adams (2017) suggest complementarity between e-cigarettes and cigarettes. Their study finds that e-cigarette MLSA laws have led to a reduction in smoking among high-school seniors, based on individual-level data spanning 2007-2014 from Monitoring the Future (MTF). It is unclear whether the divergence in findings stems from the use of more granular individual-level data or from the addition of one more study period.[8]

Our study extends this seminal work and contributes to this limited literature in three important ways. First, we add to the thin evidence base by incorporating micro-level data from both the national and the state YRBSS spanning up to 2015. This yields a substantially larger sample size (over 700,000 observations) relative to the only prior study based on individual-level data (Abouk and Adams 2017). Utilizing data up to 2015, just prior to the FDA's national ban on e-cigarette sales to minors, further maximizes policy variation (8 additional states had adopted these laws in 2015) and extends the post-policy window for the other states to disentangle the law's dynamic effects. Second-order policy responses on youth substance use (other than e-cigarettes) are likely to be small, and hence micro-level data with large sample

[7] Friedman (2015) is based on 2-year state aggregated data from the NSDUH (spanning 2002-2013) and Pesko et al. (2016) is based on the state-aggregated data from the Youth Risk Behavioral Surveillance System (YRBSS; spanning 2007-2013).

[8] Using Nielsen scanner data and changes in monetary prices as the mechanism to study whether e-cigarettes and cigarettes are economic substitutes or complements, Huang et al. (2014) find little evidence that consumers substitute toward cigarettes when e-cigarette prices increase.

sizes, more cleanly-defined affected groups, and longer time windows with greater policy variation may be necessary for maximizing precision. Second, prior work has focused only on the contemporaneous effects of e-cigarette MLSA laws on smoking behaviors. Our study is the first to consider how these laws may affect youth smoking rates once they have aged out of the restrictions and are able to purchase e-cigarettes. This is particularly relevant for assessing long-term effects on smoking rates and addressing public health concerns regarding the intertemporal transition from e-cigarettes to smoking. Finally, we also estimate whether e-cigarette MLSA laws have had any spillover effects into the use of other addictive substances. With the exception of Pesko et al. (2016), who studied and found no effects on marijuana use, prior work has mainly focused on cigarette smoking.

3. Conceptual Framework

The overall effect of e-cigarette MLSA laws on smoking, drinking, and marijuana use depends on the marginal direct and indirect costs of youth obtaining e-cigarettes, and the relationship between e-cigarettes and these other substances. Banning legal sales of e-cigarettes to minors is predicted to raise the indirect costs of obtaining the product through added inconvenience and/or associated time delays. The restrictions could also increase the direct costs of obtaining the product through additional markups or youth having to pay "friends" to purchase the product for them. E-cigarette MSLA laws will therefore raise the full price of e-cigarettes, leading to first-order effects in the form of a decline in e-cigarette consumption. However, the predicted decrease in e-cigarette consumption may be moderated to the extent that retailers do not abide by the law or that youths are able to bypass the law through online vendors.[9]

Any rise in the indirect or direct costs of purchasing e-cigarettes would cause a *relative* increase in the cost of e-cigarettes in comparison with conventional cigarettes, thereby affecting not just e-cigarette use but also potentially shifting smoking behaviors. E-cigarettes

[9] Data from the 2015 NYTS suggest however that only 1.1% of teens who used e-cigarettes in the past month obtained them through online vendors.

and conventional cigarettes are both alternate modes of delivering nicotine, and youths may substitute to smoking if e-cigarettes become relatively more difficult to procure. Additionally, the e-cigarette MLSA laws may raise smoking if e-cigarettes are being used for smoking cessation or for cutting down on cigarette consumption. Losing access to e-cigarettes could therefore reduce a smoker's propensity to attempt cessation. Though some studies have documented the success of e-cigarettes in helping smokers quit (Etter and Bullen 2011, Brown et al. 2014, Adkison et al. 2013), the cessation margin may be less salient when it comes to youths. As most smokers initiate smoking prior to age 18, this initiation margin may be more relevant for adolescents, and policies that restrict access to e-cigarettes may induce some youths to initiate tobacco use with cigarettes instead.

While these channels underscore substitutability between e-cigarettes and conventional cigarettes and predict an increase in smoking as a result of the e-cigarette MLSA laws, it is also possible that e-cigarette restrictions may lead to a reduction in smoking. As with adults, concurrent use of e-cigarettes and conventional cigarettes is high among youths (Dutra and Glantz 2014).[10] If this pattern is reflective of economic complementarity, then policy-induced reductions in e-cigarette use could reduce cigarette consumption. Furthermore, lower e-cigarette use may reduce nicotine dependence, ceteris paribus, and make it less likely that youths may turn to tobacco products in general to satisfy nicotine-induced cravings. E-cigarette MLSA laws could also raise youth interest in the motive underlying the legal change and encourage them to search for health information related to e-cigarettes and possibly other substances, which could in turn change their attitudes toward consumption.

The e-cigarette MLSA laws may also impact dynamic transitions between e-cigarette use and smoking along channels similar to those discussed above. As with the contemporaneous effects, these intertemporal effects of the e-cigarette restrictions on smoking, for instance what happens to their smoking behaviors once adolescents have aged out of the restrictions, are also a priori indeterminate. It should be noted that once a youth turns 18, he/she is able to purchase

[10] Dutra and Glantz (2014) report that 76.3% of current e-cigarette users also concurrently used conventional cigarettes, based on the 2012 National Youth Tobacco Survey.

both e-cigarettes and conventional cigarettes legally.[11] In states that have enacted an e-cigarette MLSA law, youths who age out of the laws will therefore experience a decrease in the *relative* cost of obtaining e-cigarettes, which could lead to an increase in e-cigarette use and a decrease in smoking. However, if youths had turned to smoking when exposed to e-cigarette MLSA laws, the accumulation of the addictive stock of nicotine may make it difficult to cut down on smoking even when they are able to purchase e-cigarettes legally.

While effects on smoking are perhaps most highly indicated given the proximity between e-cigarettes and conventional cigarettes, the e-cigarette MLSA laws may also have second-order effects on the use of other addictive substances. Many youths concurrently smoke, drink, and use marijuana (Moss, Chen, and Yi 2014), and changes in tobacco consumption can affect the marginal utility of consuming these other substances. A large literature has explored this relationship between smoking, drinking, and marijuana use, based on variation stemming from cigarette excise taxes, medical marijuana laws, minimum legal drinking age, and other policies, though there still lacks a strong consensus in this literature regarding whether these substances are economic substitutes or complements.[12] Ultimately the question of how e-cigarette MLSA laws impact smoking, drinking, and marijuana use cannot be settled based on theory alone, and we bring empirical evidence to bear on this issue.

4. Data

Our analyses draw on the pooled national and state Youth Risk Behavior Surveillance System (YRBSS). The national YRBSS is conducted by the Centers for Disease Control and Prevention (CDC) and the state YRBSS, while coordinated by the CDC, is usually administered by state health departments or education agencies.[13] Several studies note the advantages of using

[11] In most cases, youths aged 18 are old enough to legally purchase e-cigarettes and conventional cigarettes except for a few cases where states set the minimum age at 19 or 21.

[12] See, for instance, Chaloupka et al. (1999), Dee (1999), Farrelly et al. (2001), Gruber et al. (2003), and Picone et al. (2004).

[13] Many states have authorized the CDC to distribute their data for secondary analyses and for states that did not, we contacted each and received their permission to use the data.

such pooled data over the national YRBSS alone.[14] For one thing, the pooled YRBRSS leads to a substantially larger overall sample size, on the order of about six times larger relative to the national YRBSS. Moreover, it also maximizes the sample size for smaller states, thereby improving precision and state-trend controls, and adds some additional states to the identifying variation since not all states contributed data to the national YRBSS in every wave. The YRBSS is conducted biennially, and we utilize data from the most recent six waves spanning 2005 through 2015. As the first set of states implemented an e-cigarette MLSA in 2010, this ensures that our sample period includes a five-year pre-policy window at a minimum.[15] Appendix Table 2 shows the states that are represented in the pooled YRBSS for each wave over the course of our sample period. We follow prior studies (Anderson, Hansen, and Rees 2015) and use weights based on population, gender, race, and age at the state-year level retrieved from the National Cancer Institute's Surveillance Epidemiology and End Results Program for all analyses.[16]

The YRBSS data collection typically starts in March and ends in early June for each state. Our policy indicator for the e-cigarette MLSA law is therefore set to turn on (equal one) if the law has been enacted by the end of the February of the survey year in the respondent's state of residence and zero otherwise. A battery of questions relating to youth risky behaviors such as smoking, drinking, and other substance use is consistently available in each wave of the YRBSS. We define dichotomous indicators for past month participation in smoking, alcohol consumption, binge drinking (consuming 5 or more drinks of alcohol in a row), and marijuana use. We also define an indicator for smoking initiation based on the respondent's current age and the age they reported smoking a full cigarette for the first time; this indicator captures whether the respondent initiated smoking in a given wave if their current age matches their reported age of smoking onset.

[14] See, for instance, Carpenter and Cook (2008), Anderson et al. (2015), Sabia and Anderson (2016), and Hansen, Sabia, and Rees (2017).

[15] We do not extend our sample to previous years in order to minimize introducing confounding trends and trend breaks from periods prior to when e-cigarettes became available in the U.S. However, we note that our estimates are robust to utilizing all waves of the YRBSS (1991-2015) or to starting the analyses in 2007, the year when e-cigarettes entered the U.S. Results for these alternate sample periods are available upon request.

[16] Results from regressions without weights are very similar to the ones reported here and are available upon request.

To isolate the *ceteris paribus* relationship between e-cigarette MLSA laws and youth substance use, we control for an extensive set of confounding policy shifts over this period: federal and state cigarette excise taxes, state beer taxes, an index for medical marijuana laws (MML), state unemployment rates, and the natural logarithm of state per capita income.[17] Our index for MML is created using the law's three main provisions – overall legislative decision, home cultivation, and medical marijuana dispensary (Anderson, Hansen, and Rees 2015, Pacula et al. 2015, Choi, Dave, and Sabia 2016). The index equals one when states only grant the legal status of using marijuana for therapeutic purposes but not for home cultivation or marijuana dispensaries. It equals three when all dimensions are allowed.[18] To proxy for anti-smoking sentiment at the state level, we control for the comprehensiveness of smoking restrictions in indoor areas across four venues: government worksites, private worksites, restaurants, and bars. We also account for anti-vaping sentiment by using an indicator for whether vaping in private workplaces is banned.[19] We do not use e-cigarette taxes as a control because only Minnesota has levied taxes on e-cigarettes over our study period. We also control for zero-tolerance laws and Keg registration to account for a general social perception of teenage drinking at the state level.[20]

Table 1 reports the summary statistics for all key variables over our study period. Columns 1, 2, 3 present means for the full sample, and for youths under the age of 18 and for older youths, respectively. While four states (Alabama, Alaska, New Jersey, and Utah) set the purchasing age of e-cigarettes at 19 years during our study period, age in the YRBSS is top-

[17] The cigarette tax data comes from the CDC STATE System and the beer tax data comes from the National Institute on Alcohol Abuse and Alcoholism (NIAAA). We use the tax rates as of March for both variables to match the period of time over which the survey was conducted. Data for state's medical marijuana laws come from the National Conference of State Legislatures (NCSL) and National Organization for the Reform of Marijuana Laws (NORML). We obtain state unemployment rates and per capita income from Bureau of Labor Statistics (BLS). Both cigarette and beer taxes are inflation-adjusted to 2005 values using the Consumer Price Index for All Urban Consumers (CPI-U), and we transform the per capital income using a natural logarithm.

[18] We also experimented using a simple indicator for the medical marijuana legalization as in Anderson et al. (2015). Our results are not sensitive to the form of medical marijuana policy control.

[19] No partial bans on vaping in private workplaces exist. We have also experimented with including smoke-free air laws in bars and restaurants to further control for state anti-smoking sentiment, which are highly collinear with private workplace laws. Our estimate of the impact of e-cigarette MLSA laws was not materially affected by adding these additional proxy variables for anti-smoking sentiment.

[20] Information for zero-tolerance laws and Keg registration come from the Alcohol Policy Information System (APIS).

coded at "18 or above" and we are unable to separate out youths who are 19 years of age.[21] As shown in Table 1, 19% of the sample were past-month smokers, 20% were marijuana users, 39% were past-month drinkers, and 23% have participated in binge drinking. The proportion of current smokers, drinkers, and marijuana users among those who are 18 or above is expectedly and significantly higher than that among youths 17 or younger. Questions related to youth e-cigarette use are first included in the YRBSS in 2015. Based on the 2015 wave, 45% of high-school students have tried e-cigarettes in their lifetime, and 24% are current (past 30-day) users. The final two columns present means during the pre-policy periods, separately for states that enacted an e-cigarette MLSA law at any time over the sample period (treated states) and states that did not (control states). Baseline youth substance use is slightly higher among the control states (by about 2-4 percentage points, or about 10%), though the differences are not statistically significant. Youths in the treated states are significantly more likely to be white or black and less likely to be Hispanic, relative to those in the control states. All of the other differences are not significant.

5. Empirical Approach

Our baseline model employs the standard difference-in-differences (DD) framework, exploiting variation in the timing of policy adoption across states to identify the effects of the e-cigarette MLSA laws on youth substance use behaviors. Specifically, we estimate the following reduced-form demand function, relating substance use behaviors for youth i residing in state s and surveyed at time t directly to the e-cigarette MLSA laws.

$$P(DV_{i,s,t} > 0) = \sum_{i} \Gamma \mathbf{X}_{\mathrm{i,s,t}} + \mathbf{b_1}\mathrm{MLSA}_{\mathrm{s,t}} + \mathbf{b_2}\mathbf{Z}_{s,t} + \boldsymbol{\gamma}_s + \boldsymbol{\lambda}_t\,[+\boldsymbol{\gamma}_s t]\,[+\boldsymbol{\gamma}_s t_{Pre}] + \varepsilon_{i,s,t}, (1)$$

[21] This will result in some individuals "18 and above" being subject to the e-cigarette MLSA laws, that is, some individuals in the control group may be treated. We found that moving these youths into column 2 does not at all change the summary statistics. Based on the 2016 American Community Survey, among current high-school enrollees nationally between the ages of 12-19, only about 2% are aged 19, and only 4.3% (based on the share of the population of the affected states, AK, AL, NJ and UT) of these 19 year olds would be misclassified as being not treated. Hence, any attenuation bias from this misclassification is negligible. We show later that our results are not sensitive to dropping these four states from the analyses.

In specification (1), $DV_{i,s,t}$ is one of the four indicators for the youth's past month substance use. For instance, when $DV_{i,s,t}$ indicates smoking, $P(DV_{i,s,t} > 0)$ denotes the probability that the youth is a current smoker. Our key variable of interest, $\mathrm{MLSA}_{\mathrm{s,t}}$, is an indicator for whether the state had an e-cigarette MLSA law in place by the end of the February of the survey year and thereafter. The vector $\mathbf{X}_{\mathrm{i,s,t}}$ contains a full set of interactions across youth demographic characteristics, and the vector $\mathbf{Z}_{s,t}$ represents the time-varying, state level policy variables (inflation-adjusted cigarette and beer taxes expressed in dollars, a three-value index for the medical marijuana law, restrictions on vaping and smoking in private workplaces, an indicator for the existence of zero-tolerance laws, Keg registration, state unemployment rate, and the natural log transformed state per capita income). All specifications include state and year fixed effects, denoted by $\boldsymbol{\gamma}_s$ and $\boldsymbol{\lambda}_t$ respectively, to account for time-invariant state heterogeneity and unobserved national trends. All specifications are estimated as linear probability models via OLS.[22] Standard errors are clustered at the state level to account for correlated errors across individuals and over time within each state (Bertrand, Duflo, and Mullainathan 2004).

The parameter of interest $\mathbf{b_1}$ captures the average reduced-form effect of e-cigarette MLSA laws on youth smoking, drinking, or marijuana use, including through all reinforcing and/or competing pathways as discussed earlier. Identification in the DD framework comes from comparing changes in youth substance use within states that have implemented an e-cigarette MLSA law to changes in states have not yet done so. The DD estimate will yield a causal effect if the outcome trend for the control states (states that have not yet adopted the e-cigarette MLSA law) is a valid counterfactual to the outcome trend for the treatment states (those that have enacted the restrictions) in the absence of the policy (Colman and Dave 2015). We investigate this "parallel trends assumption" in Figure 1.

Figure 1 shows trends in youth smoking, drinking, binge drinking and marijuana use before and after the enactment of the e-cigarette MLSA law in the context of an unadjusted event study.[23] These figures suggest three things. First, the prevalence of youth smoking and

[22] Our results and conclusions are not materially affected if the specification is estimated via logit or probit regression.

[23] The different implementation dates of E-cigarette MLSA laws are normalized to time zero among states that have set the law in place by the end of February 2015. For states where e-cigarette MLSA laws have not yet been in

drinking have generally been declining over the past decade while youth marijuana use inched up (in the early 1990s), and then declined, before trending slightly upwards again. Second, pre-policy trends within both the treated states (solid line) and the control states (dashed line) have been broadly similar for smoking and marijuana use, though not so for drinking and binge drinking. Alcohol consumption appears to have been declining somewhat faster for the control states relative to the treated states even prior to the enactment of the e-cigarette MLSA law. Statistical tests however do not indicate significant differences in trends between the treated and non-treated states.[24] Third, there is limited graphical evidence of the impact of e-cigarette MLSA laws on youth smoking, drinking, or marijuana use, though if the treatment effects are small then it may be difficult to discern them in these unadjusted event study graphs. In the analyses that follow, we take care to account for a multitude of confounding factors (vector $\mathbf{Z}$), and, in alternate specifications, add state-specific linear time trends (denoted by $\boldsymbol{\gamma}_s t$) or state-specific pre-policy linear trends ($\boldsymbol{\gamma}_s t_{Pre}$) to adjust for the less than perfect nature of the natural experiment, and draw conclusions from the weight of the evidence.

We further extend the baseline specification of equation (1) in several ways to address other specific issues. First, to examine dynamic impacts of the policy on youth substance use and alternatively assess the parallel trends assumption between the reform and the non-reform states after conditioning on covariates, we transform specification (1) into a fully-specified event study design. In particular, we decompose $\mathrm{MLSA_{s,t}}$ in model (1) into a series of policy "leads", or "placebo" laws, and lags. The new specification takes the form:

$$P(DV_{i,s,t} > 0) = \sum_i \Gamma \mathbf{X}_{\mathrm{i,s,t}} + \boldsymbol{\alpha_1}\mathrm{MLSA_{s,-3}} + \boldsymbol{\alpha_2}\mathrm{MLSA_{s,0}} + \boldsymbol{\alpha_3}\mathrm{MLSA_{s,1}} + \mathbf{b_2}\mathbf{Z}_{s,t} + \boldsymbol{\gamma}_s + \boldsymbol{\lambda}_t\ [+\boldsymbol{\gamma}_s t] + \varepsilon_{i,s,t} \quad (2)$$

where all other variables besides the MLSA variable are defined as before. The reference group is the 1-2 years prior to the enactment of an e-cigarette MLSA law. The parameter $\boldsymbol{\alpha_2}$ captures the contemporaneous policy effect on teen substance use and $\boldsymbol{\alpha_3}$ captures the lagged policy effect one or more years after the law's implementation. Hence, $\boldsymbol{\alpha_1}$ provides evidence of

place by that time, we treat them as non-treated or control states. We then randomly assign each control state a pseudo-treatment date and normalize them to time zero.

[24] Appendix Table 3 shows the results of statistically testing for differential pre-policy trends by regressing youth substance use on an interaction of treatment status and time trends before policy enactment.

parallel or differential pre-treatment period time trends. If this coefficient is statistically distinguishable from zero, it would suggest that the treatment and control states had differential trends prior to policy adoption, which may undermine the interpretation of the DD effect as causal. Explicitly controlling for the lead effects as in the event study can also help to partly net out any non-parallel trends.

Next, we assess transitions into/out of smoking once youths are no longer subject to the e-cigarette purchase restrictions. Specifically, we estimate the inter-temporal associated with how being exposed to an e-cigarette MLSA law when youth were underage affects their smoking behaviors once they have aged out and are able to purchase e-cigarettes. We do so by restricting the sample to those who are currently 18 or older and thus not subject to the e-cigarette MLSA law, and then estimate the following specification:

$$P(Smk_{i,s,t} > 0) = \sum_{i} \Gamma \mathbf{X}_{\mathrm{i,s,t}} + \mathbf{b_1}\mathrm{MLSA\_Minor} + \mathbf{b_2}\mathbf{Z}_{s,t} + \boldsymbol{\gamma}_s + \boldsymbol{\lambda}_t\ [+\boldsymbol{\gamma}_s t] + \varepsilon_{i,s,t}\ , (3)$$

Here, MLSA_Minor is an indicator for whether an e-cigarette MLSA law was effective in the individual's state of residence at any point in time when the individual was underage.[25] For instance, an e-cigarette MLSA law was effective on January 1st, 2013 in the state of New York. Therefore, a youth aged 18 in 2014 from New York would have been exposed to the law in 2013. By the same analogy, a youth aged 18 or 19 in 2015 would have also been exposed to the law two years ago. Because age in the YRBSS is top-coded at 18, our strategy might erroneously subsume someone aged 19 or 20 in the treatment group who are in fact not subject to the law in our hypothetical examples. While this may possibly moderate the treatment effect, any attenuation bias is likely to be very small.[26] We confirm this by dropping the four states where the age limit of legally purchasing e-cigarettes is set at 19 and finding that the results are

[25] For states where no e-cigarette MLSA laws were enacted during the study period, this variable takes on a value of zero.

[26] Among current high-school enrollees nationwide between the ages of 12-21, only about 2% are 19, and less than 1% are 20 or 21 (based on the 2015 American Community Survey). Thus, at most 3% of the sample who may be untreated may be erroneously classified as being treated, and this would lead the treatment effect to be understated by at most a factor of 3% (for instance, an estimated treatment effect of 2.9 percentage points when the true treatment effect is 3 percentage points). This attenuation factor assumes that all 19 year olds are untreated, when most of them would have been treated if they lived in a state that had enacted an e-cigarette MLSA law in the past; hence in practice the attenuation bias is likely to be even smaller.

virtually unchanged. The parameter $\mathbf{b_1}$ captures how youth exposure to the e-cigarette purchase restrictions, at any point in time when the youth was underage, affects their substance use behavior once they have aged out of the restrictions.

We also build upon the above specifications and assess the margin at which smoking is potentially affected. Specifically, we consider whether, and to what extent, e-cigarette MLSA laws have impacted youth smoking initiation and take-up. In alternate specifications, we conduct additional checks to assess heterogeneous responses across gender and race. Finally, we implement a falsification check, assessing effects of the e-cigarette MLSA laws on youths who should not be constrained or affected by the policy.

6. Results

A. Effects on Smoking

Table 2 presents estimates of the effects of e-cigarette MLSA laws on youth smoking among those under-age adolescents. Panel A reports baseline effects from the difference-in-differences (DD) model specified in Equation (1). Model 1 suggests a significant 0.9 percentage point increase in smoking participation among youths exposed to an e-cigarette MLSA law, which translates to about a 4% increase relative to the baseline mean for the control states. We introduce state-specific linear pre-policy trends in Model 2, in order to net out any systematic differential trends in smoking across states prior to the enactment of the e-cigarette restrictions.[27] The effect magnitude remains significant, continuing to suggest about a one percentage point increase in smoking participation. The policy effect is also robust to controlling for a full set of state-specific linear trends in Model 3, allowing the trends to persist both pre- and post-policy enactment. State-specific time trends capture systematically time-varying state heterogeneity and adjust for the potential endogeneity of the e-cigarette MLSA restrictions. One possible limitation of using state-specific time trends is that it reduces the amount of identifying variation, which may be less credible (Neumark, Salas, and Wascher

[27] State-specific pre-trends allow only the pre-policy trends to differ and therefore attribute any potential break in trend at $t = 0$ to the policy.

2014). Furthermore, fitting such state-specific linear trends may exacerbate bias, particularly for sample periods and pre-policy windows where trends in smoking (or other substance use) are far from linear. Wolfers (2006) also cautions against adding state-specific linear trends in such timing analyses where the policy is modeled as pre-post implementation since such trends may confound both the state-specific time-varying unobservable as well as any dynamic effects of the policy itself. We therefore exercise care as the case warrants, though it is notable that adding state-specific trends has virtually no effect on our estimates, bolstering the plausibility of our research design.

Panel B decomposes the timing of the DD effects and presents estimates from a formal event study design as specified in Equation (2). In keeping with the biennial sampling scheme of the YRBSS, these models control for indicators for the full year of policy enactment, 1 or more years post-adoption, 1-2 years pre-adoption (reference category) and 3 or more years pre-adoption. The results from the event study design underscore three points. First, e-cigarette MLSA laws appear to have a significant "contemporaneous" effect during the full year of enactment, about one percentage point on average. Owing to YRBSS' biennial sampling frame, the enactment year indicator is defined such that it turns on if the policy took effect anytime since March of the previous wave and February of the current year.[28] This ensures that the policy was active for at least 12 months, though it would also pick up some lag in the policy effect for up to 2 years. Second, as the lag increases, there is some suggestive evidence that the response to policy becomes somewhat larger, on the order of 1-2 percentage points, though estimates in models with state trends are not significant and smaller.[29] This possible compounding of the policy effect over time is consistent with an interactive age response. Smoking participation generally increases with age among adolescents; current smoking participation among 16-year-olds is 10.2% compared to 5.0% among 14-year-olds. Hence, an e-cigarette MLSA law in effect when the adolescent was, for instance 14 years of age, would be expected to have a stronger "bite" as he/she ages and becomes more likely to contemplate

[28] For instance, for respondents interviewed in the 2013 YRBSS, the enactment indicator would equal 1 in 2013 if the state they lived in adopted the policy anytime between March 2011 and February 2013.
[29] As noted above, state trends may be picking up some of the dynamic effects of the policy.

smoking (or use other forms of tobacco) in the future. Third, the lead effects are generally small and insignificant, providing some validation of the research design and confirming that the policy is orthogonal to pre-adoption trends in smoking.

While our conceptual framework is agnostic about the direction of the effects given the potential for cigarette smoking to either substitute or complement e-cigarette use, the pattern of results that we find – suggesting an increase in smoking participation – is ex post validating when contrasted with unconditional declining trends in youth smoking over the sample period. As shown in Figure 1, unconditional trends suggest a decrease in youth smoking as e-cigarettes entered the market (2007) and e-cigarette MLSA laws proliferated across states (starting in 2010). Thus, if our models are simply reflecting this decline in smoking as states enacted more e-cigarette MLSA laws, then the DD effects would have suggested (possibly spuriously) that the laws have reduced youth smoking. However, finding increases in smoking from the policy, despite this declining secular trend, adds some confidence that these estimates are not just reflecting the falling smoking rates.

Estimates in Table 2 suggest that when faced with e-cigarette MLSA laws, underage youths may be more likely to turn to cigarette smoking. This may prima facie seem counter-intuitive since they are also restricted from purchasing cigarettes; hence, it would appear that underage youths are turning from one restricted substance to another. However, since all youths face purchase restrictions for cigarettes over the sample period, the implementation of e-cigarette MLSA laws would increase the *relative* costs of accessing e-cigarettes (relative to cigarettes), affecting the demand for these substances. Because cigarettes have been in the market for a long time, most youths who smoke may have found alternative ways to bypass the purchase restrictions and obtain their cigarettes through secondary sources, such as "bumming" or borrowing from a friend or adult (Katzman, Markowitz, and McGeary 2007, Hansen, Rees, and Sabia 2013).[30] Thus, it is conceivable that these youths are increasing their participation in the secondary cigarette market when purchasing e-cigarettes is prohibited. The

[30] A dollar increase in cigarette taxes is estimated to decrease the probability of youth getting cigarettes through a secondary market by 5 or 6 percent, but cigarette taxes had little impact on youth obtaining cigarettes through borrowing or taking from a store or family member. This may suggest that they have alternative ways to bypass the rising costs of cigarettes.

secondary market for e-cigarettes, however, may be less well-developed, particularly when recent estimates suggest that only 3.7% of adults vape (Schoenborn and Gindi 2015). That said, adults may be a less reliable source of e-cigarettes for teenagers in secondary markets than cigarettes.[31]

The smoking participation margin among adolescents in Table 2, columns 1-3 combines first-time smoking, smoking experimentation, regular smoking, and use of multiple tobacco products including cigarettes. Most smokers initiate smoking in their teens, and hence the initiation margin is the most salient for adolescents and also very relevant from a policy stance since it may determine future transitions and paths to nicotine dependence. Models 4-6 in Table 2 specifically look at how exposure to an e-cigarette MLSA law affects smoking initiation. For these analyses, we restrict the sample to youths who have initiated smoking in the given year and youths who are non-smokers; thus youths who are current smokers but had initiated their smoking habits in prior years are excluded. As noted earlier, a youth is defined as a first-time smoker if his/her age at the time of interview matches the reported age when he/she first tried smoking. These results should be interpreted with care since smoking initiation in the YRBSS is likely coupled with recall errors in the reported age at which smoking was initiated as well as the mismatch between age and wave year.[32] These estimates suggest that exposure to an e-cigarette MLSA law significantly increases the probability of initiating smoking, on the order of 0.5 to 0.6 percentage point. The event study models in Panel B also suggest similar magnitudes during the full year of enactment (0.6 to 0.7 percentage point, capturing significant effects within 12 months of enactment and possibly up to 24 months of enactment, as noted above) and some positive effects thereafter, though these lagged effects are not statistically significant. The magnitudes for smoking initiation represent a little over half of the smoking participation effect identified in models 1-3. Thus, the caveats regarding measurement error

[31] See https://www.cdc.gov/nchs/products/databriefs/db217.htm. Furthermore, while it may be relatively easier for a youth to borrow or "bum" a combustible cigarette from a friend or adult, which by definition is disposed after use, the long-lasting properties of e-cigarettes (e.g. even one disposable e-cigarette can last up to 400 puffs or equivalent to one pack of cigarettes) makes it more difficult to borrow or bum from another user.

[32] For instance, a 15-year-old surveyed in 2013 who reported that they initiated smoking at age 15 would be coded as having initiated smoking in 2013. However, the youth may have initiated smoking in 2012 while still 15 years of age.

notwithstanding, which is likely to bias the initiation effect downward, it appears that much of the positive effects of e-cigarette MLSA laws on smoking among underage youths may reflect an increase in initiation and remainder reflects movement across smoking and vaping in former initiates.[33]

In Table 3, we evaluate whether the increase in smoking persists after youths are no longer constrained by the e-cigarette purchasing restrictions. Thus, all models are estimated for youths, 18 and above, who have aged out of the e-cigarette MLSA laws. Since age in the YRBSS is top-coded as 18 or above and four states (AL, AK, NJ, and UT) set the age for legally purchasing e-cigarettes at 19, our sample may still include a few who are not old enough to buy e-cigarettes. We therefore present models for all states (models 1-3) and after excluding these four states (models 4-6). We discuss here the latter set of models that bypass the potential misclassification, though estimates remain virtually identical whether we include or exclude the states that had set the e-cigarette MLSA at age 19.

Models reported in Panel A are based on equation (3), where we define an indicator for whether a youth was exposed to an e-cigarette MLSA law at any time while he/she was underage.[34] There is little evidence from these specifications to suggest that exposure to an e-cigarette MLSA law when underage is associated with smoking behaviors when he/she has aged out. Hence, we do not find any strong evidence that the increase in smoking persists as youths age out of e-cigarette MLSA laws. These models suggest that any effects on underage smoking, among youths exposed to an e-cigarette MLSA law, fade when they aged out of the law and are able to purchase e-cigarettes legally.[35]

[33] It should be noted that adolescents aged 14-17 who are current smokers are likely to have initiated very recently; hence, any change in the smoking margin for this age group may still reflect initiation, experimentation, and trying out different substances.

[34] Since the YRBSS is not longitudinal, this requires the implicit assumption that the youth has not changed their state of residence. Data from the 2001-2015 American Community Surveys show that, on average, about 1.3% of high-school students ages 14-18 change state of residence from one year to the next. Thus, any measurement error from assuming stable state of residence will be minimal. Based on the average inter-state migration rate, only about 5% of 18 year olds may be misclassified when assigning a state of residence to when they were underage.

[35] Most smokers initiate smoking during adolescence, with 16 years of age being the mode among ever-smokers (based on the 2013 National Survey on Drug Use and Health). Hence, accumulation of the addictive smoking stock is still relatively low.

B. Magnitude of the Smoking Effect

Our estimates thus far suggest that when faced with e-cigarette MLSA laws, underage youths may be more likely to turn to cigarette smoking, at least until they age out of these laws. Models in Table 2 suggest about a 1.1 percentage point increase in smoking post-policy adoption, which is consistent with findings reported by Friedman (2015) and Pesko et al. (2016).[36] To place this magnitude in context, it should be noted that the DD effect we estimate is an intention-to-treat (ITT) effect. Most adolescents in the population would not be affected by e-cigarette MLSA laws, and thus the estimated reduced-form smoking response is an average across two groups – those who are potentially affected by e-cigarette MLSA laws and those who are not. It is unlikely that e-cigarette MLSA laws would have a direct effect on smoking behaviors, independent of their effect on e-cigarette use. If e-cigarette MLSA laws had no effect on e-cigarette use, we should expect no effects on other substance use behaviors as well.

Hence, establishing the first-stage effect of how e-cigarette MLSA laws may have impacted youth e-cigarette use can help frame what the maximal effect should be for spillover responses into smoking (and other substance use) given that these individuals represent the affected group. However, estimating effects on e-cigarette use due to these policies has been a challenge because of data limitations; youth-based surveys, including the YRBSS and the MTF, have only recently started asking respondents regarding their e-cigarette use, yielding only one wave of data. Abouk and Adams (2017), for instance, estimate that the e-cigarette MLSA law is associated with a significant 10 percentage point decline in e-cigarette use among high school seniors, which may be an upper bound estimate given that it is based on cross-sectional evidence from only the 2014 MTF wave out of necessity.

[36] Both studies find about a 0.9 percentage point increase in smoking among underage youth, based on data up to 2013. Our slightly larger estimate (up to 1.1 percentage points in some models) reflect two additional years of data (YRBSS spanning up to 2015) in conjunction with some evidence that the lagged policy response may be slightly larger over time.

The YRBSS started fielding questions on e-cigarette use in the latest 2015 wave. For suggestive evidence, we estimate a similar specification to equation (1) for outcomes related to e-cigarette use (ever use and current use) based only on the 2015 YRBSS.[37] Appendix Table 4 suggests that, among underage youths, e-cigarette MLSA laws reduced current use by about 1.2 percentage points (6% decline relative to the sample mean of 21% vaping participation), and ever use (as a proxy for initiation) by about 4.4 percentage points (10% decline relative to the sample mean of 40% ever vaping). Similar to Abouk and Adams (2017), the effects (not shown) are somewhat larger for older adolescents (11th and 12th graders). We previously found evidence that the laws increased youth smoking by about one percentage point, and so we calculate a back-of-the-envelope treatment-on-the-treated (TOT) effect of 0.25 using the law's impact on ever vaping. We use ever vaping for this calculation to better match the longer duration of data available for smoking. In other words, about 1 in 4 youths may have increased their smoking as they reduced their e-cigarette use in response to the e-cigarette MLSA laws. These estimates should be interpreted with caution and are meant to be suggestive due to the inherent difficulties in obtaining the first-stage effect of the laws on e-cigarette use. Nevertheless, they can prove useful in gauging the credibility of the magnitudes on the second-order effects.

C. Effects on Drinking and Marijuana Use

Next we examine whether exposure to e-cigarette MLSA laws has any spillover effects on other substance use behaviors among underage youths. In Table 4, baseline DD estimates and dynamic effects from the event study are presented separately for past month drinking and binge drinking, showing little evidence of any meaningful or consistent effect on alcohol use. There is some suggestive evidence of a lagged decrease in binge drinking (on the order of about 1-2 percentage points, 5-8% relative to the baseline mean) in the event study specifications (models 5 and 6). However, standard errors are large and we cannot reject the null. Table 5

[37] Given the single wave of data, we are not able to control for state fixed effects, and year fixed effects are not necessary. Instead, we include census region fixed effects to account for unobserved heterogeneity at this geographic level. Models are saturated with all other state-level policy controls.

presents estimates of the effect of e-cigarette MLSA laws on past month marijuana use, and here we do not find any statistically or economically significant effects.

We note that effects on substances other than tobacco are third-order effects, and so it is not surprising that they are quite weak. While some estimates in Tables 4 are suggestive of declines in binge drinking in association with e-cigarette MLSA laws, the weight of the evidence confirms that the effects are expectedly quite small or nil. Hence, while our results suggest that restricting the purchase of e-cigarettes among underage youths may have spilled over into higher smoking participation, we find little evidence of additional substitution into drinking or marijuana use.

D. Placebo Checks and Heterogeneous Effects

Given that e-cigarette MLSA laws are by definition binding only for underage youths, this presents a natural falsification test. The policy should have no causal effect on any addictive behaviors among youths who have aged out and who were not exposed to the policy while underage. That is, even if a state enacted an e-cigarette MLSA law of 18 in 2010, youths aged 18 or older in 2010 (19 years of age or older in 2011; etc.) should not be affected since they were never exposed to the restriction even when they were underage. Table 6 carries out this falsification for each specification and substance use outcome, defining the sample as youths that have aged out of e-cigarette MLSA laws and were never exposed while underage. All of these estimates, most notably for current smoking participation, which earlier models suggested a significant effect among affected underage youths, are generally statistically insignificant and small in magnitude.

In Tables 7 and 8, we assess whether the response in smoking behaviors is different across gender and grade in school. Models 1-3 in Table 7 present estimates of being exposed to an e-cigarette MLSA law on smoking participation among underage boys, and Models 4-6 present estimates for underage girls. We find that most of the positive effects on smoking is being driven by boys; specifically, these models suggest a significant 1.2 to 1.4 percentage point increase in smoking participation among boys who are exposed to an e-cigarette MLSA law,

which translates to about a 8% increase relative to their baseline mean. Use of e-cigarettes and conventional cigarettes is significantly lower among adolescent girls relative to boys, and hence it is not altogether surprising that the policy effects are substantially larger among boys. Models in Table 8 present differential effects across 9th and 10th graders vs. 11th and 12th graders. We generally find significant and positive effects of the e-cigarette access restrictions on smoking participation for both groups. The event study analyses with state trends are somewhat suggestive of a slightly larger response among the older adolescents (about 1.1 to 1.9 percentage points) relative to the younger adolescents (about 0.7 to 1.1 percentage points). However, standard errors are relatively large, and we are not able to reject the null that these effects are similar across both groups.

7. Conclusion:

Economic theory suggests that e-cigarette MLSA laws may reduce e-cigarette use, and we find suggestive evidence of this using a single cross-section of data. Using MTF data, Abouk and Adams (2017) reached a similar conclusion. We also find strong evidence that e-cigarette MLSA laws increased the probability of youth smoking conventional cigarettes by approximately 1.1 percentage points (5% relative to the mean smoking rate). In particular, youths who have not smoked in the past but initiated their first cigarettes due to the e-cigarette MLSA laws may have contributed to more than half of the increase in smoking participation. Our estimates of the effect of the laws on youth smoking are slightly larger than estimates from Friedman (2015) and Pesko et al. (2016), who both found that the laws increased smoking participation by roughly 0.9 percentage points. Our slightly larger estimate reflects two additional years of data in conjunction with some evidence of a lagged policy response. However, our finding that e-cigarette MLSA laws increased cigarette use contrasts from findings by Abouk and Adams (2017). Given that both our study and Abouk and Adams (2017) use individual-level data, this alone does not appear to account for the differences in results. Our study employs one additional year of data, and utilizes data from the pooled YRBSS which yields a sample size approximately 14 times that of the Monitoring the Future (MTF) sample employed by Abouk and Adams (2017). Restricting our analyses to the same periods as

their study does not materially alter our results or conclusions. Hence, it is possible that differences between the MTF and the YRBSS sampling schemes and their respective sample sizes may underlie some of the differences in our results. Further research exploring these difference is warranted.

Our models also suggest that the positive effect of e-cigarette MLSA laws on youth smoking appear to fade once youths have aged out of the law, with estimates indicating that these youths reduced their smoking once they could legally buy e-cigarettes. We do not find any strong evidence of either positive or negative spillovers into the use of other addictive substances such as alcohol or marijuana use.

While federal regulations require all states to have a cigarette MLSA law of at least 18, some states have made the age limit for purchasing both cigarettes and e-cigarettes higher. As of the 4th quarter of 2016, four states had an MLSA law of 19 and three states (California, D.C., and Hawaii) had MLSA laws of 21. Our results suggest some caution in raising MLSA laws for both cigarettes and e-cigarettes to 21. It may be preferable to raise cigarette MLSA laws to 21, but maintain e-cigarette MLSA laws at 18 to encourage youths to quit smoking using e-cigarettes. Preventing youths from legally buying e-cigarettes until age 21 may harden preferences for cigarettes and make quitting at that age more difficult.

In sum, results from our study suggest that it is unclear if e-cigarette MLSA laws have a positive impact on public health. It appears that some portion of the decrease in e-cigarette use, about 25% based on crude TOT estimates, may come at the cost of higher conventional cigarette use, at least in the short-term until the youth has aged out of the restrictions. If e-cigarettes are only 5% as harmful as traditional cigarettes (Tobacco Advisory Group of the Royal College of Physicians 2016), then e-cigarette MLSA laws leading to increased smoking may cause greater harm than benefits. However, such net costs need to be balanced against other considerations such as the potential use of e-cigarettes for smoking cessation among older youths and among longer-term smokers.

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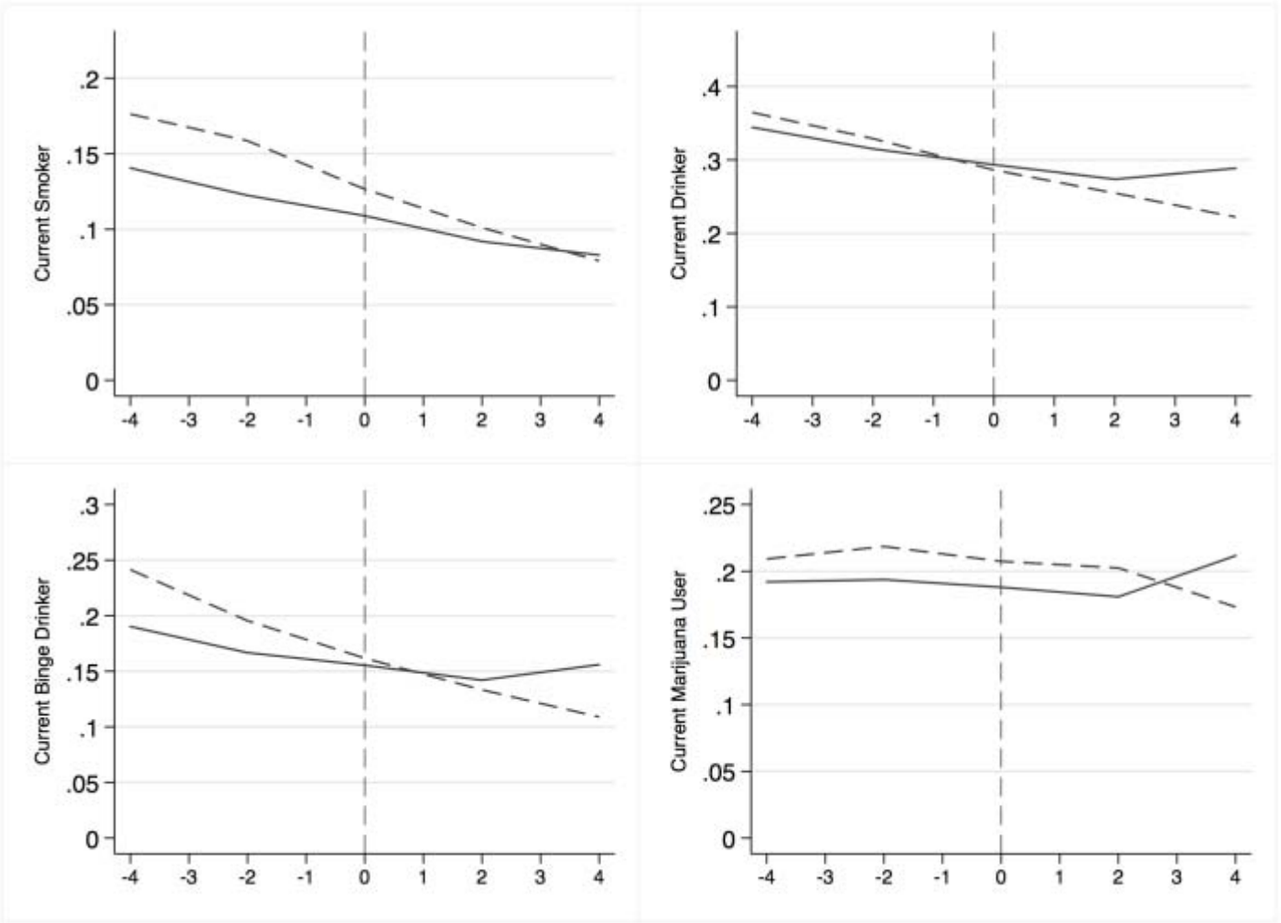

Figure 1. Pre- and Post-E-Cigarette MLSA Law Trends in Youth Substance Use

Note: Based on unweighted data from the national and state YRBSS. The solid line represents the treated states and the dashed line represents the non-treated states. The horizontal axis represents the year of law change. The different dates of E-Cigarette MLSA law have been normalized to time point 0. Pseudo treatment dates are first randomly assigned to the non-treated states and then normalized to time 0.

Table 1 — Summary Statistics

	Full Sample	Youths younger than 18	Youths 18 or older	States W/ E-Cig MLSA Law in the pre-policy period	States W/O E-Cig MLSA Law in the pre-policy period
Youth substance use					
Current smoker	0.19 [0.40]	0.18 [0.39]	0.28 [0.45]	0.22 [0.41]	0.24 [0.43]
Current drinker	0.39 [0.49]	0.38 [0.48]	0.50 [0.50]	0.41 [0.49]	0.45 [0.50]
Current binge drinker	0.23 [0.42]	0.22 [0.41]	0.33 [0.47]	0.25 [0.43]	0.28 [0.45]
Current marijuana user	0.20 [0.40]	0.19 [0.40]	0.25 [0.44]	0.20 [0.40]	0.22 [0.41]
Youth demographic characteristics					
Females	0.51 [0.50]	0.52 [0.50]	0.45 [0.50]	0.51 [0.50]	0.51 [0.50]
White	0.58 [0.49]	0.58 [0.49]	0.57 [0.49]	0.61 [0.49]	0.53 [0.50]
Black	0.15 [0.36]	0.15 [0.36]	0.17 [0.38]	0.17 [0.38]	0.11 [0.31]
Hispanics	0.14 [0.35]	0.14 [0.35]	0.15 [0.35]	0.12 [0.33]	0.21 [0.41]
Other races	0.12 [0.33]	0.12 [0.33]	0.11 [0.31]	0.10 [0.30]	0.15 [0.36]
Grade = 9^{th}	0.28 [0.45]	0.32 [0.47]	0.01 [0.08]	0.28 [0.45]	0.27 [0.45]
Grade = 10^{th}	0.27 [0.44]	0.30 [0.46]	0.01 [0.11]	0.27 [0.44]	0.27 [0.43]
Grade = 11^{th}	0.24 [0.43]	0.26 [0.44]	0.11 [0.31]	0.24 [0.43]	0.24 [0.43]
Grade = 12^{th}	0.21 [0.41]	0.12 [0.32]	0.87 [0.33]	0.21 [0.40]	0.21 [0.40]
Merged state-level policies					
E-cigarette MLSA Laws	0.20 [0.40]	0.21 [0.41]	0.15 [0.36]	0.00 [0.00]	0.00 [0.00]
Cigarette taxes	1.75 [1.04]	1.78 [1.05]	1.59 [0.98]	1.43 [0.99]	1.55 [0.80]
Beer taxes	0.29 [0.25]	0.29 [0.25]	0.31 [0.26]	0.33 [0.28]	0.29 [0.22]
Medical Marijuana Law	0.57 [1.04]	0.59 [1.04]	0.50 [1.00]	0.21 [0.67]	0.74 [1.15]
State unemployment rate	5.92 [1.92]	5.91 [1.91]	5.95 [1.98]	6.02 [2.09]	5.96 [2.00]
Natural log of per capita income	10.43 [0.19]	10.44 [0.19]	10.40 [0.18]	10.39 [0.18]	10.34 [0.12]
Comprehensive indoor smoking restrictions	0.43 [0.46]	0.44 [0.46]	0.36 [0.44]	0.30 [0.42]	0.30 [0.42]
Indoor E-cigarette restrictions in private workplaces	0.01 [0.09]	0.01 [0.09]	0.01 [0.10]	0.00 [0.00]	0.00 [0.00]
Keg registration	0.62 [0.49]	0.63 [0.48]	0.57 [0.50]	0.35 [0.48]	0.33 [0.47]
Zero-tolerance law	0.30 [0.46]	0.30 [0.46]	0.28 [0.45]	0.16 [0.37]	0.39 [0.49]

Note: Means and standard deviation (in bracket) are reported. Youth substance use variables are defined in the text. E-cigarette MLSA laws and cigarette tax data come from CDC STATE System. Beer taxes and keg registrations come from NIAAA. State unemployment rate and per capita income data come from Bureau of Labor Statistics. Comprehensive indoor smoking restrictions consist of four venues: government workplaces, private workplaces, restaurants, and bars. Each venue is coded as a binary indicator with 1 denoting full restriction and 0 otherwise. Comprehensive indoor smoking restrictions are the averages of these four binary indicators. Indoor e-cig restrictions in private workplaces, zero-tolerance law, and keg registrations are created as binary indicators. Both cigarette and beer taxes are inflation-adjusted using CPI-U.

Table 2 — E-cigarette MLSA Laws and Youth Smoking

National and State YRBSS

	DV: Youth is a current smoker			*DV: Youth is a first-time smoker*		
Panel A:	1	2	3	4	5	6
E-cigarette MLSA Law	0.009*	0.011*	0.011*	0.005*	0.006†	0.006*
	(0.004)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)
Panel B:	1	2	3	4	5	6
E-cigarette MLSA Law 3 Year Prior	-0.008	-0.003	-0.005	-0.002	-0.002	-0.002
	(0.005)	(0.005)	(0.004)	(0.002)	(0.004)	(0.003)
E-cigarette MLSA Law	0.009*	0.009	0.011+	0.005	0.007†	0.006*
	(0.004)	(0.006)	(0.006)	(0.003)	(0.004)	(0.003)
E-cigarette MLSA Law 1 Year Post	0.021**	0.008	0.009	0.002	0.002	0.007
	(0.007)	(0.012)	(0.013)	(0.004)	(0.008)	(0.009)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No	No	Yes	No
State-specific linear trend	No	No	Yes	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.14	0.14	0.14	0.08	0.08	0.08
Observations	724,413	724,413	724,413	530,574	530,574	530,574

Note: Standard errors, clustered at the state level, are shown in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.

In columns 1 to 3, youths are defined as current smokers if any days of smoking over the past month are reported. The sample has been restricted to youths younger than 18.

In columns 4 to 6, youths are defined as first time smokers if their age at the time of the survey match their age of first-time smoking cigarettes. Youths who never smoked cigarettes are coded zero and youths who initiated smoking when they were younger than the time of the survey were excluded. Age≤ 12 and ≥18 are dropped due to perfect collinearity.

The key regressors of interest are defined in the text.

Table 3 — Intertemporal Relationship Between E-cigarette MLSA Laws and Youth Smoking

National and State YRBSS

DV: Youth is a current smoker	1	2	3	4	5	6
MLSA_Minor	0.001	-0.004	-0.001	-0.000	-0.004	-0.001
	(0.013)	(0.013)	(0.013)	(0.014)	(0.013)	(0.014)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No	No	Yes	No
State-specific linear trend	No	No	Yes	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.23	0.23	0.23	0.23	0.23	0.23
Observations	89,728	89,728	89,728	86,517	86,517	86,517

Note: Standard errors, clustered at the state level, are shown in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.

The sample has been restricted to youths ages 18 and above.

In columns 1 to 3, Alabama, Alaska, New Jersey, and Utah where E-cigarette MLSA Law set the age limit at 19 are **included**.

In columns 4 to 6, Alabama, Alaska, New Jersey, and Utah where E-cigarette MLSA Law set the age limit at 19 are **excluded**.

The key regressors of interest are defined in the text.

Table 4 — E-cigarette MLSA Laws and Youth Drinking

National and State YRBSS

	DV: Youth is a current drinker			*DV: Youth is a current binge drinker*		
Panel A:	1	2	3	4	5	6
E-cigarette MLSA Law	0.002	-0.002	0.009	0.001	-0.003	0.001
	(0.009)	(0.007)	(0.008)	(0.006)	(0.006)	(0.005)
Panel B:	1	2	3	4	5	6
E-cigarette MLSA Law 3 Year Prior	-0.008	-0.010	-0.014^{+}	-0.003	0.002	0.001
	(0.007)	(0.009)	(0.008)	(0.004)	(0.008)	(0.007)
E-cigarette MLSA Law	-0.001	0.004	0.008	0.001	-0.004	-0.003
	(0.009)	(0.010)	(0.009)	(0.005)	(0.009)	(0.006)
E-cigarette MLSA Law 1 Year Post	-0.015	-0.003	0.002	0.005	-0.018	-0.012
	(0.013)	(0.017)	(0.017)	(0.008)	(0.012)	(0.012)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No	No	Yes	No
State-specific linear trend	No	No	Yes	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.34	0.34	0.34	0.19	0.19	0.19
Observations	683,964	683,964	683,964	683,964	683,964	683,964

Note: Standard errors, clustered at the state level, are shown in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.

In columns 1 to 3, youths are defined as current drinker if any days of drinking over the past month are reported. The sample has been restricted to youths younger than 18.

In columns 4 to 6, youths are defined as current binge drinker if any days of binge drinking (drank 5 or more drinks of alcohol in a row within a couple of hours) over the past month are reported. The sample has been restricted to youths younger than 18.

The key regressors of interest are defined in the text.

Table 5 — E-cigarette MLSA Laws and Youth Marijuana Use

National and State YRBSS

Panel A:			
DV: Youth is a current marijuana user	1	2	3
E-cigarette MLSA Law	-0.002	-0.011	-0.005
	(0.008)	(0.008)	(0.007)
Panel B:			
DV: Youth is a current marijuana user	1	2	3
E-cigarette MLSA Law 3 Year Prior	-0.010^{+}	-0.006	-0.010
	(0.005)	(0.008)	(0.008)
E-cigarette MLSA Law	-0.001	-0.007	-0.003
	(0.008)	(0.011)	(0.010)
E-cigarette MLSA Law 1 Year Post	0.011	-0.000	0.001
	(0.014)	(0.015)	(0.021)
Full Controls	Yes	Yes	Yes
State FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No
State-specific linear trend	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.19	0.19	0.19
Observations	731,805	731,805	731,805

Note: Standard errors, clustered at the state level, are shown in parentheses.

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.

Youths are defined as current marijuana users if any days of marijuana use over the past month are reported.

The sample has been restricted to youths younger than 18.

The key regressors of interest are defined in the text.

Table 6 — Falsification Tests
National and State YRBSS

Panel A:			
DV: Youth is a current smoker	1	2	3
E-cigarette MLSA Law	0.012	0.007	0.010
	(0.013)	(0.016)	(0.013)
Mean of DV	0.23	0.23	0.23
N	89,728	89,728	89,728
Panel B:			
DV: Youth is a current drinker	1	2	3
E-cigarette MLSA Law	-0.011	-0.025	-0.010
	(0.018)	(0.024)	(0.024)
Mean of DV	0.47	0.47	0.47
N	72,924	72,924	72,924
Panel C:			
DV: Youth is a current binge drinker	1	2	3
E-cigarette MLSA Law	0.001	-0.010	-0.003
	(0.014)	(0.017)	(0.017)
Mean of DV	0.31	0.31	0.31
N	72,924	72,924	72,924
Panel D:			
DV: Youth is a current marijuana user	1	2	3
E-cigarette MLSA Law	-0.001	-0.030	-0.023
	(0.015)	(0.022)	(0.018)
Mean of DV	0.26	0.26	0.26
N	74,812	74,812	74,812
Full Controls	Yes	Yes	Yes
State FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No
State-specific linear trend	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015

Note: Standard errors, clustered at the state level, are shown in parentheses.
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.
The sample has been restricted to youths ages 18 or above
The definitions of youths being current smokers, current drinkers, current binge drinkers, and current marijuana users are the same as in Table 2–5.
The key regressors of interest are defined in the text.

Table 7 — E-cigarette MLSA Laws and Youth Smoking (Stratified By Gender)

National and State YRBSS

DV: Youth is a current smoker	Boys			Girls		
Panel A:	1	2	3	4	5	6
E-cigarette MLSA Law	0.012*	0.014*	0.014***	0.005	0.001	0.008
	(0.005)	(0.006)	(0.004)	(0.004)	(0.007)	(0.007)
Panel B:	1	2	3	4	5	6
E-cigarette MLSA Law 3 Year Prior	-0.011	-0.010	-0.008+	-0.003	0.005	-0.001
	(0.007)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
E-cigarette MLSA Law	0.012*	0.019*	0.016*	0.005	-0.001	0.006
	(0.006)	(0.007)	(0.006)	(0.004)	(0.008)	(0.007)
E-cigarette MLSA Law 1 Year Post	0.029**	0.006	0.019	0.011	0.011	-0.000
	(0.010)	(0.012)	(0.015)	(0.009)	(0.014)	(0.014)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No	No	Yes	No
State-specific linear trend	No	No	Yes	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.15	0.15	0.15	0.13	0.13	0.13
Observations	378,818	378,818	378,818	345,595	345,595	345,595

Note: Standard errors, clustered at the state level, are shown in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for race, age, and grade. State level policy variables shown in Table 1 are also included.

Youths are defined as current smokers if any days of smoking over the past month are reported. The sample has been restricted to youths younger than 18.

The key regressors of interest are defined in the text.

Table 8 — E-cigarette MLSA Laws and Youth Smoking (Stratified By Grade)

National and State YRBSS

DV: Youth is a current smoker	9 & 10 grade			11 & 12 grade		
Panel A:	1	2	3	4	5	6
E-cigarette MLSA Law	0.011*	0.008	0.012*	0.006	0.010	0.011
	(0.005)	(0.007)	(0.005)	(0.006)	(0.008)	(0.007)
Panel B:	1	2	3	4	5	6
E-cigarette MLSA Law 3 Year Prior	-0.008	-0.002	-0.003	-0.006	-0.007	-0.008
	(0.006)	(0.005)	(0.004)	(0.008)	(0.010)	(0.008)
E-cigarette MLSA Law	0.012*	0.009	0.011	0.007	0.014	0.014+
	(0.006)	(0.008)	(0.007)	(0.005)	(0.009)	(0.008)
E-cigarette MLSA Law 1 Year Post	0.026*	0.010	0.007	0.017*	0.011	0.019
	(0.010)	(0.013)	(0.015)	(0.008)	(0.014)	(0.016)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear pre-trends	No	Yes	No	No	Yes	No
State-specific linear trend	No	No	Yes	No	No	Yes
Time span	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015	2005 – 2015
Mean of DV	0.12	0.12	0.12	0.16	0.16	0.16
Observations	444,531	444,531	444,531	279,882	279,882	279,882

Note: Standard errors, clustered at the state level, are shown in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

All models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.

Youths are defined as current smokers if any days of smoking over the past month are reported. The sample has been restricted to youths younger than 18.

The key regressors of interest are defined in the text.

Appendix Table 1 — E-Cigarette Minimum Legal Sales Age Laws, 2005–2015

	Effective Date
Alabama	August 1, 2013
Alaska	August 22, 2012
Arizona	September 13, 2013
Arkansas	August 16, 2013
California	September 27, 2010
California	June 9, 2016
Colorado	March 25, 2011
Connecticut	October 1, 2014
Delaware	June 12, 2014
District of Columbia	October 1, 2015
Florida	July 1, 2014
Georgia	July 1, 2014
Hawaii	June 27, 2013
Hawaii	January 1, 2016
Idaho	July 1, 2012
Illinois	January 1, 2014
Indiana	July 1, 2013
Iowa	July 1, 2014
Kansas	July 1, 2012
Kentucky	April 10, 2014
Louisiana	May 28, 2014
Maine	July 4, 2015
Maryland	October 1, 2012
Massachusetts	September 25, 2015
Minnesota	August 1, 2010
Mississippi	July 1, 2013
Missouri	October 10, 2014
Montana	January 1, 2016
Nebraska	April 9, 2014
Nevada	October 1, 2015
New Hampshire	July 31, 2010
New Jersey	March 12, 2010
New Mexico	June 9, 2015
New York	January 1, 2013
North Carolina	August 1, 2013
North Dakota	August 1, 2015
Ohio	August 2, 2014
Oklahoma	November 1, 2014
Oregon	January 1, 2016
Rhode Island	January 1, 2015
South Carolina	June 7, 2013
South Dakota	July 1, 2014
Tennessee	July 1, 2011
Texas	October 1, 2015
Utah	May 11, 2010
Vermont	July 1, 2013
Virginia	July 1, 2014
Washington	July 28, 2013
West Virginia	June 6, 2014
Wisconsin	April 20, 2012
Wyoming	March 13, 2013

Note: By the end of August 2016, all states except Pennsylvania and Michigan have implemented E-Cigarettes MLSA Laws.

Appendix Table 2 — State Contribution

National and State YRBSS

State	2005	2007	2009	2011	2013	2015
Alabama	✓	✓	✓	✓	✓	✓
Alaska		✓	✓	✓	✓	✓
Arizona	✓	✓	✓	✓	✓	✓
Arkansas	✓	✓	✓	✓	✓	✓
California	✓	✓	✓	✓	✓	✓
Colorado			✓	✓	✓	✓
Connecticut	✓	✓	✓	✓	✓	✓
Delaware	✓	✓	✓	✓	✓	✓
D.C				✓		
Florida	✓	✓	✓	✓	✓	✓
Georgia	✓	✓	✓	✓	✓	✓
Hawaii	✓	✓	✓	✓	✓	
Idaho	✓	✓	✓	✓	✓	✓
Illinois	✓	✓	✓	✓	✓	✓
Indiana	✓	✓	✓	✓	✓	✓
Iowa	✓	✓		✓		
Kansas	✓	✓	✓	✓	✓	
Kentucky	✓	✓	✓	✓	✓	✓
Louisiana	✓	✓	✓	✓	✓	
Maine	✓	✓	✓	✓	✓	✓
Maryland	✓	✓	✓	✓	✓	✓
Massachusetts	✓	✓		✓		✓
Michigan	✓	✓	✓	✓	✓	✓
Minnesota	✓		✓		✓	✓
Mississippi		✓	✓	✓	✓	✓
Missouri	✓	✓	✓	✓	✓	✓
Montana	✓	✓	✓	✓	✓	✓
Nebraska	✓			✓	✓	✓
Nevada	✓	✓	✓	✓	✓	✓
New Hampshire	✓	✓	✓	✓	✓	✓
New Jersey	✓	✓	✓	✓	✓	✓
New Mexico	✓	✓	✓	✓	✓	✓
New York	✓	✓	✓	✓	✓	✓
North Carolina	✓	✓	✓	✓	✓	✓
North Dakota	✓	✓	✓	✓	✓	✓
Ohio	✓				✓	✓
Oklahoma	✓	✓	✓	✓	✓	✓
Oregon	✓		✓			
Pennsylvania	✓	✓	✓	✓	✓	✓
Rhode Island	✓	✓	✓	✓	✓	✓
South Carolina	✓	✓	✓	✓	✓	✓
South Dakota	✓	✓	✓	✓	✓	✓
Tennessee	✓	✓	✓	✓	✓	✓
Texas	✓	✓	✓	✓	✓	✓
Utah	✓	✓	✓	✓	✓	
Vermont	✓	✓	✓	✓		✓
Virginia	✓	✓	✓	✓	✓	✓
Washington	✓		✓	✓	✓	✓
West Virginia	✓	✓	✓	✓	✓	✓
Wisconsin	✓	✓	✓	✓	✓	
Wyoming	✓	✓	✓	✓	✓	✓

Appendix Table 3 – Parallel Trends Test

National and State YRBSS

	Current Smoker	Current Drinker	Current Binge Drinker	Current Marijuana User
Treated × Pre-trends	0.005	0.001	-0.001	0.001
	(0.003)	(0.002)	(0.002)	(0.002)
Full Controls	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
N	429,037	405,944	405,944	436,046

Note: Standard errors, clustered at the state level, are shown in parenthesis.
Pre-trends refer to time periods before point zero in Figure 1. Negatives are converted to positives by multiply -1.
Full controls include dummy variables for the individual demographic characteristics and the state-level covariates.
Youths 18 or older are excluded.

Appendix Table 4 – Relationship Between E-cigarette MLSA Laws and Youth Use of E-cigarettes

National and State YRBSS

	Ever Used E-cigarettes	Current Vapor
E-cigarette MLSA Law	-0.044**	-0.012
	(0.016)	(0.015)
Mean of DV	0.40	0.21
Full controls	Yes	Yes
Census Region FEs	Yes	Yes
Year	2015	2015
N	145,950	178,444

Note: Standard errors, clustered at the state level, are shown in parentheses.
† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Both models include dummy variables for gender, race, age, and grade. State level policy variables shown in Table 1 are also included.
The sample has been restricted to youths younger than 18.
The key regressors of interest are defined in the text.