NBER WORKING PAPER SERIES

SMOKE GETS IN YOUR EYES:
MEDICAL MARIJUANA LAWS AND TOBACCO USE

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Working Paper 22554
http://www.nber.org/papers/w22554

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2016, Revised June 2017

The authors thank Timothy Young, Thanh Tam Nguyen, and Brandyn Churchill for excellent research assistance. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 22554
August 2016, Revised June 2017
JEL No. D1,I1

ABSTRACT

This study is the first to examine whether medical marijuana laws (MMLs) have affected the trajectory of a decades-long decline in adult tobacco use in the United States. First, using data from the National Survey of Drug Use and Health (NSDUH), we establish that MMLs are associated with a 0.7 to 2.4 percentage-point increase in adult marijuana consumption. Then, using data from the NSDUH, the Behavioral Risk Factor Surveillance System (BRFSS), and the Current Population Survey Tobacco Use Supplements (CPS-TUS), we find no evidence that MMLs increased tobacco use. Rather, we find that MMLs enacted between the early 1990s and 2015 are associated with a 0.4 to 0.7 percentage-point reduction in adult tobacco consumption. These findings suggest that tobacco and marijuana are substitutes for many users. We also uncover some evidence of heterogeneity in the effects of MMLs (i) across the age distribution, and (ii) across early and later-adopting states.

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1. INTRODUCTION

Cigarette consumption has been documented to be the number one cause of lung cancer and emphysema in the United States (CDC 2004). The annual public health costs of tobacco consumption have been estimated to be $96 billion (CDC 2009), with estimates of the external costs of secondhand smoke exposure ranging from $5 to $11 billion (Max et al. 2012; Behan et al. 2005). While a wide body of research has examined the effects of cigarette taxes (Callison and Kaestner 2014; Cebula et al. 2014; Hansen et al. 2017; Carpenter and Cook 2008), informational campaigns (Adams et al. 2011; Liu and Tan, 2009), and smoking bans (Bruderl and Ludwig 2011; Demperio, 2013; Sari 2013) on tobacco consumption, increased attention has been paid to how changes in the prices of related substances may generate spillover effects on tobacco use.[1] Understanding policy-driven cross-price effects is critical for designing optimal tax and regulatory policy (Pacula 1997).

Recent policy reforms liberalizing access to marijuana for medicinal purposes enjoys not only widespread public support (Bradford and Bradford 2017) but also endorsement of the American Public Health Association (APHA 1995) and American Medical Association (AMA 2015). Despite cross-sectional evidence that marijuana and tobacco consumption are positively related (Agrawal, Budney, and Lynskey 2012; Ramo, Liu, and Prochaska 2012), next to nothing is known about effects of medical marijuana laws (MMLs) on tobacco use. As of April 2017, 29 states and the District of Columbia had adopted MMLs, which legalize the possession, use, and cultivation of marijuana for allowable medical purposes. In addition, Alaska, California, Colorado, the District of Columbia, Maine, Massachusetts, Nevada, Oregon, and Washington have passed more expansive legislation that allow adults ages 21 and older to legally possess up

[1]See, for example, Cameron and Williams 2002; Farrelly et al. 2001; Yoruk and Yoruk, 2011, 2013.

to typically one ounce of marijuana (without intent to sell) for personal consumption, including for recreational use (Marijuana Policy Project 2017). Recent studies have documented that MMLs are associated with increased marijuana consumption among adults (Anderson and Rees 2011; Wen et al. 2015; Sabia and Nguyen 2017), which appear to occur not only for medicinal purposes, but also for recreational use through supply side-induced reductions in the street price of high-grade marijuana (Anderson et al. 2013).[2] While there is evidence that MMLs may generate other physical and mental health benefits[3], this study is the first to examine the effect of MMLs on tobacco use.

The effect of MMLs on tobacco consumption is theoretically ambiguous. MMLs may reduce tobacco use if marijuana and tobacco are substitutes. For example, if marijuana and tobacco are consumed to achieve a similar objective, such as alleviating anxiety (Bambico 2007) or enhancing the taste of food (Riggs et al. 2012; Soria-Gomez et al. 2014), then the enactment of MMLs may reduce tobacco consumption. In addition, if increases in marijuana use for medical purposes lead to improvements in physical mobility or psychological health (Sabia et al. 2016), these positive health effects could increase the gains to avoiding tobacco. Moreover, if alcohol and marijuana are substitutes (Anderson et al. 2013; Sabia et al. 2016; Crost and Guerrero 2012), and alcohol and tobacco are complements (Tauchmann et al. 2013), MMLs may reduce tobacco use via this channel. Finally, time spent consuming marijuana may crowd-out time spent smoking cigarettes.

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[2] There is also some evidence of heterogeneous effects of MMLs on marijuana consumption by type of MML (Pacula et al. 2015; Wen et al. 2015).

[3] For instance, recent studies have examined the effect of MMLs on alcohol consumption (Anderson et al. 2013; Wen et al. 2015), suicides (Anderson et al. 2014), obesity (Sabia et al. 2016), and prescription drugs (Bradford and Bradford 2017; Kim et al. 2016).

On the other hand, MMLs could increase tobacco consumption if marijuana and tobacco are complements. This could be the case if both substances are consumed together as a "spliff" (Hammersley and Leon 2006) or if marijuana acts as a "gateway" substance for other risky health behaviors, including drinking (Wen et al. 2015; Pacula et al. 2015; Yoruk and Yoruk 2011, 2013). Moreover, MML-induced improvements in health may cause individuals to indulge in compensatory unhealthy behaviors (Radtke et al. 2011). Taken together, the net effect of MMLs on tobacco use depends on the mechanisms at work, the purpose of consumption (e.g. recreational or medicinal), and the magnitudes of potentially competing effects.

Using nationally representative data available from three large surveys — the National Survey on Drug Use and Health (NSDUH), the Behavioral Risk Factor Surveillance Survey (BRFSS), and the Current Population Survey Tobacco Use Supplements (CPS-TUS) — this study examines the effects of MMLs on marijuana and tobacco consumption. First, using data from the NSDUH, we document that MMLs are associated with a 0.7 to 2.4 percentage-point increase in adult marijuana use. Turning to tobacco use, data from all three datasets provide no evidence that MMLs are associated with increased tobacco use among adults. Moreover, over the 1990 to 2015 period, results from the BRFSS and CPS-TUS show that MMLs are associated with a 0.2 to 0.7 percentage-point *reduction* in tobacco consumption, suggesting that MMLs generated an unintended health benefit. Our results are generally consistent with the hypothesis that marijuana and cigarettes are substitutes for the average adult. Finally, we uncover evidence that the average effect of MMLs on tobacco use may mask heterogeneity in MML effects (i) across early- versus later-adopting states, and (ii) over the age distribution.

2. BACKGROUND

2.1 Public Health Effects of Marijuana and Tobacco

Consumption of tobacco cigarettes has been causally linked to respiratory health problems, heart disease, stroke, and a variety of cancers, including lung cancer, liver cancer, and colorectal cancer (U.S. Department of Health and Human Services 2014). Tobacco smokers are 25 to 26 times more likely to suffer from lung cancer—the country's most fatal cancer— than their non-smoking counterparts (Thun et al. 1997a, b; Thun et al. 2013). Tobacco use has also been documented to increase Chronic Obstructive Pulmonary Disease (COPD), a rising cause of mortality in the United States. In addition, exposure to secondhand smoke is associated with a substantial increase in the probabilities of stroke and death from cardiovascular diseases (CDC 2014).

Studies on the health effects of marijuana use, which are often (though not always) based on smaller clinical trials, produce less consistent evidence of adverse health effects relative to tobacco use. The most consistent evidence for negative health effects comes from heavier, frequent marijuana use. For instance, there is evidence that heavy marijuana use is associated with diminished respiratory health (Joshi et al. 2014; Pletcher et al. 2012), increased risk of heart disease (Hodcroft et al. 2014; Jouanjus et al. 2014), higher likelihood of amotivational syndrome (Volkow et al. 2016), and increased risk of poor psychological health (Van Ours and Williams 2011; Degenhardt et al. 2003). However, in contrast to tobacco use, the link between marijuana use and risk of lung cancer has not yet been definitively established (Gates et al. 2014). Moreover, unlike tobacco use, there is evidence that marijuana consumption may generate some important health benefits. Marijuana consumption may be effective in treating psychological ailments (Bambico 2007), physical pain (Fiz et al. 2011), and side effects from cancer or HIV treatments (Hall et al. 2005; Doblin and Kleinman 1991; Vinciguerra et al. 1988). Together, the evidence suggests that the adverse health effects of tobacco use are likely larger than for marijuana use.

A substantial public health literature has documented a positive association between tobacco consumption and marijuana use (see, for example, Ramo et al. 2013, 2012; Beenstock and Tahov 2002; Bentler et al. 2002; Agrawal et al. 2007; Leatherdale et al. 2007). Young adults from ages 18 to 25 are nearly 10 times more likely to have used marijuana if they have also consumed cigarettes (Lai et al. 2000). There is also evidence that those who use marijuana in young adulthood are more likely to initiate smoking cigarettes (Agrawal et al. 2008; Behrendt et al. 2009; Okoli et al. 2008; Timberlake et al. 2007) and are less likely to quit smoking cigarettes (Richter et al. 2002) than their counterparts who have abstained from marijuana.

While the public health literature has tended to characterize this pattern of results as evidence that marijuana and tobacco are complements, caution should be taken with such an interpretation. Because tobacco and marijuana use are jointly determined, the positive association observed could be driven, in part or in whole, by difficult-to-measure characteristics such as personal discount rates, personality, family background characteristics, or reverse causality. Credibly establishing the complementarity or substitutability of tobacco and marijuana requires estimation of cross-price effects generated from plausibly exogenous shocks in prices.

A number of studies have relied on changes in cigarette taxes to identify such cross-price effects. Using data from the National Household Survey on Drug Abuse, Farrelly et al. (2001) find that increases in cigarette taxes are negatively related to (i) the probability of marijuana use for 12 to 20 year-old males and (ii) the quantity of marijuana consumed by marijuana users. Using a similar empirical approach with data from Monitoring the Future, Chaloupka et al.

(1999) find that cigarette tax hikes are negatively related to intensity of marijuana use among users.

There is mixed evidence on whether marijuana prices and decriminalization policies affect tobacco use. Using data from the Australian National Drug Strategy Household Surveys, Cameron and Williams (2002) find that higher cannabis prices are negatively related to tobacco use, but marijuana decriminalization laws have little effect on tobacco smoking behavior. Farrelly et al. (2001) find that larger marijuana possession penalties are essentially unrelated to tobacco consumption.

2.2. Medical Marijuana Laws, Marijuana Use, and Spillovers

There is generally consistent evidence that MMLs are associated with increased marijuana consumption among adults (Anderson and Rees 2011; Wen et al. 2015; Sabia and Nguyen 2017). Using data from the National Survey for Drug Use and Health, Wen et al. (2015) find that MMLs are associated with a 1 to 2 percentage-point increase in marijuana use among adults. Sabia and Nguyen (2017) and Anderson and Rees (2011) find a similar pattern of results in the NSDUH. The presence of MML-induced increases in marijuana use among demographic groups less likely to be using marijuana for medicinal purposes (those under age 30) suggests that there are recreational spillovers of MMLs. Such an interpretation is supported by Anderson et al. (2013), who find that MMLs are associated with a 10 percent reduction in the street price of marijuana and Chu (2014), who finds that MMLs are associated with 10 to 20 percent increases in marijuana possession arrests and marijuana-related admissions to rehabilitation centers.[4]

[4] These effects appear to be concentrated among adults. Using data from the Youth Risk Behavior Surveillance System (YRBSS), Anderson et al. (2014) find no evidence that MMLs affect high school students' marijuana use.

In addition to evidence that MMLs increase marijuana use, health economists have also begun to explore possible spillover effects of MMLs onto other health outcomes. A number of studies have examined the effects of MMLs on binge drinking (Pacula et al. 2015; Anderson et al. 2014; Wen et al. 2015) and hard drugs (Wen et al. 2015; Choi 2015), each of which could affect the demand for tobacco.[5] Evidence on the impact of MMLs on alcohol consumption is mixed. Anderson et al. (2013) and Sabia et al. (2016) find that MMLs are associated with a reduction in binge drinking, while Wen et al. (2015) find evidence of an increase in drinking. However, given that these studies examine different state MMLs, these findings could suggest that there are heterogeneous effects of MMLs across states (Pacula et al. 2015).

Finally, a newer set of studies have examined the impact of MMLs on prescription and non-prescription drug use, as well as broader measures of physical and mental health. Bradford and Bradford (2017) examine Medicare Part D patients and find that MMLs are associated with a reduction in use of prescription drugs for illnesses for which marijuana could serve as an alternative treatment. And Kim et al. (2016) find that MMLs are associated with a reduction in fatal accidents involving opioids, also consistent with the hypothesis that medical marijuana and opioids are substitutes. At the same time, there is little evidence that MMLs serve as a gateway to harder illicit drug use (Wen et al. 2015). In fact, MMLs have been linked to broader improvements in physical and mental health, including improved physical mobility and reduced obesity (Sabia et al. 2016), as well as diminished risk of suicide (Anderson et al. 2014). However, the impact of MMLs on tobacco use remains unexplored.

[5] For instance, Clements et al. (2010) note:

> "Empirical studies show that marijuana is closely related in consumption to at least two other goods, tobacco and alcohol…As argued by Pacula (1997)…such interrelations imply cross-commodity impacts of policy changes, so that changes in one drug market are likely to have spillover effects in related markets." (Clements, Lan, and Zhao 2010; p. 204)

3. DATA

Our analysis draws upon three national data sets with detailed information on tobacco consumption and provides the first evidence on how MMLs affect cigarette smoking. Each of the datasets, which we briefly discuss below, offers distinct advantages designed to complement the others.

3.1 NSDUH

The NSDUH is an annual cross-sectional survey available from the Substance Abuse and Mental Health Services Administration (SAMHSA) that collects data from about 70,000 individuals, age 12 and older, randomly selected from the U.S. civilian non-institutionalized population. The NSDUH collects data from residents of the households, and non-institutional group quarters (dorm, rooming houses, shelters, etc.), but does not include homeless individuals who do not use shelters or residents of institutional group quarters (jails and hospitals). This survey is a well-suited for this study because it contains detailed questionnaires about individuals' illicit drug use including marijuana and tobacco consumption. State-level NSDUH data, for two-year averages, are publicly available for the period from 2002 through 2015.[6] These state averages have been used by scholars in recent policy work examining the impact of state public health regulations on tobacco use (Friedman 2015). Our data on adult marijuana and tobacco use is generated from approximately 536,000 adult respondents (ages 18 and older) to the NSDUH from 2002 to 2015.

First, we measure current (prior month) *Marijuana Use* using state-level data compiled from the following NSDUH survey item:

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[6] At present, SAMHSA does not permit individual-level restricted-use data to be made available to scholars examining the impacts of medical marijuana laws.

"How many days did you use marijuana or hashish in the past 30 days?"

We set *Marijuana Use* equal to 1 if the respondent indicates a positive number of days of marijuana use and 0 otherwise. As shown in Table 1, we find that 6.8 percent of NSDUH respondents reported consuming marijuana or hashish on at least one day in the past month.

A comparable past-month state-level measure of *Tobacco Use* is generated from responses to the following questionnaire item:

"How many days did you smoke cigarettes in the past 30 days?"

If the respondent reports a positive number of days smoking cigarettes during the prior 30 days, we set *Tobacco Use* equal to 1 and set it equal to 0 otherwise. When weighted by state population, we find that 31.7 percent of NSDUH respondents reported prior 30-day tobacco use. Note that this estimate of tobacco use is quite high relative to other nationally representative surveys, including the BRFSS and CPS-TUS (see below), but it is also much less precisely estimated.[7]

While a key advantage of the NSDUH data over other data sources is its inclusion of information on both marijuana and tobacco use, which allows us to estimate the size of the first-order effect of MMLs on marijuana use and gauge plausibly sized second-order spillover effects on tobacco use, there are a number of disadvantages. First, because NSDUH data are only

[7] See state-level tobacco estimates and the confidence intervals for the 2014-2015 here: http://samhda.s3-us-gov-west-1.amazonaws.com/s3fs-public/field-uploads/2k15StateFiles/NSDUHsaePercents2015.pdf

consistently available over the 2002 to 2015 period, early MML adopting states in the Pacific region do not contribute to identifying variation (see Table 2). These states include California, Colorado, Nevada, Oregon, and Washington, which disproportionately included "collective cultivation" provisions that have been found to generate important spillovers to recreational marijuana (Anderson and Rees 2014a,b). In addition, two-year state averages currently made available by SAMHSA may introduce measurement error and generate less precisely estimated policy impacts. Finally, the availability of broader state-aggregated measures do not permit finer data cuts by demographic characteristics of respondents. To address these limitations, we turn to two alternate national datasets.

3.2 BRFSS

The BRFSS is a nationally representative telephone survey conducted annually by the Centers for Disease Control and Prevention (CDC) since 1984. While the BRFSS was administered only via landline phones prior to 2011, beginning with the 2011 survey, the BRFSS began adding cellular phones to their sample and weighted these respondents accordingly. Respondents ages 18 and older are asked detailed questions about their health and health behaviors, including cigarette consumption. Our analysis sample consists of approximately seven million observations drawn from repeated cross-sections of the BRFSS from 1990 to 2015, a period that includes all states that have adopted MMLs. Second-order effects of the MMLs on cigarette use may be small, and such large sample sizes are important for maximizing precision. Furthermore, micro-level data from the BRFSS also allows us to assess heterogeneity in the policy effects based on demographic characteristics.

While the BRFSS do not contain information on adult marijuana use, these data do allow us to comparably measure *Tobacco Use*. To generate our indicator of smoking participation in the prior month, we must use survey responses from two sequentially asked survey items:

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

"Do you now smoke cigarettes everyday, some days, or not at all?"[8]

Following CDC guidelines (2009), we generate a dichotomous measure of current smoking participation set equal to 1 if the respondent reported smoking at least 100 cigarettes in his or her lifetime and smoking "everyday" or "some days" and equal to 0 if the respondent has not smoked 100 cigarettes in his/her lifetime or does not currently smoke. A limitation of this measure is that we cannot identify new current smokers because those who do not report smoking at least 100 cigarettes in their lifetimes are not asked about current smoking. In the weighted BRFSS sample, 20.8 percent of respondents report current tobacco use (see Table 1).

3.3 CPS-TUS

The Current Population Survey Tobacco Use Supplements (CPS-TUS) are sponsored by the National Cancer Institute and administered periodically as part of the Census Bureau's CPS since 1992. The CPS-TUS is based on a large nationally-representative sample containing information on about 240,000 individuals within a given survey period; it provides a key source of national, state, and sub-state level data regarding smoking and the use of other tobacco

[8]From 1990 to 1995, this item read simply, "Do you smoke cigarettes now?"

products among adults aged 18 and older. Our analysis sample consists of approximately two million adults ages 18 and older drawn from repeated cross-sections from 1992 to 2015.[9]

Smoking participation in the CPS-TUS is measured analogously to the BRFSS using responses to the following survey items:

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

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

Tobacco Use is set equal to 1 if respondents answered that they have smoked at least 100 cigarettes over their lifetime and either currently smoke every day or on somedays, and is set equal to 0 otherwise. In our weighted CPS sample, 19.3 percent of respondents reported smoking in the prior 30 days (see Table 1).

While the CPS-TUS have been used in a wide set of studies examining the effects of tobacco control policies on adult smoking (Colman and Remler 2008; Liu 2010) and offers large samples and consistent information on smoking behaviors, an important disadvantage is the staggered nature of the cross-sections; the waves are not fielded every year. In addition, like the BRFSS, the CPS surveys do not contain information on marijuana consumption.

4. METHODS

We begin by using state-level data from the NSDUH to estimate the "first-stage" effect of MMLs on adult marijuana use. We estimate the following difference-in-differences model:

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[9] We use the data from the following TUS fielded in July 2014, January 2015, and May 2015; in May 2010, August 2010 and January 2011; in May 2006, August 2006 and January 2007; in February, June and November 2003; in June 2001, November 2001 and February 2002; in September 1998, January 1999, and May 1999; in September 1995, January 1996, and May 1996; and in September 1992, January 1993, and May 1993. An abbreviated TUS was also conducted in January 2000 and May 2000.

$$\textit{Marijuana Use}_{st} = \beta_0 + \beta_1\text{MML}_{st} + \mathbf{X_{st}}\,\Phi + \nu_s + \omega_t + \varepsilon_{st} \qquad (1)$$

where *Marijuana Use*$_{st}$ measures marijuana use in state *s* at survey wave *t*, MML_{st} is an indicator for whether state *s* had enacted an MML in year *t*, and $\mathbf{X_{st}}$ is a vector of state-level time-varying controls. Included among these controls are state economic trends (unemployment rate and per capita income), state demographic characteristics (share non-white, male, and college graduates), state tobacco control policies (cigarette taxes, clean indoor air laws), other marijuana policies (marijuana decriminalization laws and laws that legalize marijuana use for recreational purposes), and state alcohol policies (state beer tax and blood alcohol content (BAC) 0.08 drunk driving laws). In addition, ν_s is a time-invariant state effect and ω_t is a state-invariant year effect. Equation (1) is estimated via ordinary lest squares (OLS).

Next, we turn to *Tobacco Use*. For our analysis using the NSDUH, we simply replace *Marijuana Use* in equation (1) with *Tobacco Use*. For analyses using the BRFSS and the CPS-TUS, for which we have individual-level data, we estimate the following:

$$\textit{Tobacco Use}_{ist} = \beta_0 + \beta_1\,\text{MML}_{st} + \mathbf{X_{st}}\,\Phi + \mathbf{Z_{ist}}\,\psi + \nu_s + \omega_t + \varepsilon_{ist} \qquad (2)$$

where *Tobacco Use*$_{ist}$ measures prior 30-day cigarette use of individual *i* residing in state *s* in year *t* and $\mathbf{Z_{ist}}$ is a vector of individual-level time-varying controls including age, gender, race/ethnicity, marital status, and indicators for educational attainment. Our coefficient of interest, β_1, is identified from state-specific changes in MMLs, as noted in Table 2. During the NSDUH sample period (2002-2015), 15 states and the District of Columbia (DC) adopted

MMLs. Over the sample for which we have BRFSS and CPS-TUS data, 23 states and DC had enacted MMLs. We estimate equation (2) via linear probability models, though estimated marginal effects are similar across probit and logit specifications.

We extend the baseline specification of equation (2) in several ways to address specific issues. Obtaining an unbiased estimate of β_1 requires that the common trends assumption of our difference-in-differences model be satisfied. This may be a concern if (i) marijuana (or tobacco) consumption was trending differently prior to the implementation of MMLs in "treatment" versus "control" states, (ii) state-specific time-varying unobservables are correlated with both the enactment of MMLs and tobacco use, and (iii) states implement MMLs in response to risky health behaviors related to tobacco use.

We undertake several strategies to try to address this concern. First, as noted above, we control for other substance use policies in the vector $\mathbf{X}_{st}$, including beer taxes, cigarette taxes, clean indoor air laws, and marijuana decriminalization and recreational legalization laws. Second, we explicitly decompose the timing of the effect based on an event study framework that controls for policy lags and leads. This specification allows us to assess whether marijuana use (and tobacco use) was trending differently prior to the adoption of MMLs and thus examine the robustness of estimated policy impacts to controls for MML leads.

Third, we use data from the General Social Survey (GSS) to construct a measure of state-level anti-marijuana legalization sentiment. Respondents to the GSS were asked:

"Do you think the use of marijuana should be made legal or not?"[10]

[10]One limitation of this measure is that it is only available for the calendar years 1990-1991, 1993, and even-numbered years between 1994 and 2000, and then 2001 through 2012. In those years, the data are non-missing in 79 percent of state-year cells. Anti-marijuana legalization sentiment is not measured in Nevada or Nebraska in the GSS. In total, our anti-marijuana legalization sentiment measure is available for 37 percent of our full BRFSS sample.

Those respondents who report that they did not believe marijuana should be made legal are coded as 1, and 0 otherwise. Adding a control for anti-marijuana legalization sentiment should help to address the possibility that our MML measure is simply capturing within-state changes in sentiment, as well as reduce the possibility that cultural shifts can explain any MML effects observed.[11]

In addition, we also explore the robustness of our findings to controls for state-specific linear time trends by estimating:

$$\textit{Tobacco Use}_{ist} = \beta_0 + \beta_1 \text{MML}_{st} + \mathbf{X_{st}}\,\Phi + \mathbf{Z_{ist}}\,\psi + \nu_s + \omega_t + \nu_s{*}t + \varepsilon_{ist}, \quad (3)$$

where $\nu_s{*}t$ is a state-specific linear time trend.

Finally, we explore potential heterogeneity in the effects of the medical marijuana laws across two broad dimensions. First, given variation in tobacco use by age, we assess whether the effects of the MMLs differ along this dimension. Second, we examine whether the effects of the MMLs differ across particular provisions of these laws.

Table 2 shows the effective dates of MMLs enacted since 1990, as well as information on the date at which several provisions of MMLs were implemented. Specifically, following Wen et al. (2015) and Sabia and Nguyen (2017), we examine state provisions that allow for collective cultivation of marijuana for multiple patients (Anderson et al. 2013), the presence of at least one state-run dispensary (Pacula et al. 2015), MMLs that allow marijuana to be consumed for non-

[11] In unreported results, we also explore the robustness of our estimated MML effects to controls for per-capita state Master Settlement Agreement payments (see Jayawardhana et al. 2014 for a discussion of alternate indices of state anti-tobacco efforts) The findings are quantitatively similar.

specific pain (Sabia et al. 2016), and MML laws that require the maintenance of state registries of medical marijuana patients (Wen et al. 2015; Sabia and Nguyen 2017).

5. Results

Tables 3 through 9 below present our main findings. We focus on estimates of β_1 for ease of presentation, but estimates on the coefficients of controls are available upon request. All regressions are weighted and standard errors are clustered at the state level (Bertrand et al. 2004).

5.1 NSDUH Findings on Marijuana and Tobacco Use

In Panel I of Table 3, we use NSDUH data to estimate equation (1), and assess the first-order effects of the MMLs on marijuana use. Column (1) shows a parsimonious specification using only state and year fixed effects. We find that the enactment of an MML is associated with a 0.8 percentage-point increase in the rate of marijuana use. Relative to the mean value of marijuana use, this represents an approximately 12 percent increase. The inclusion of controls for socioeconomic and demographic controls (column 2) and state policy controls (column 3) has little impact on the magnitude of the estimated MML effect.

Could the findings observed in Panel I of Table 3 be driven by pre-existing differential trends in marijuana use? In Figure 1, we show an event study analysis of the impact of MMLs on marijuana use. Specifically, we show the 95 percent confidence interval around estimates of three years of leads up to MML adoptions, the year of the MML law change (year "0"), and one, two and three years or more after the enactment. The results provide no evidence that marijuana use was trending differently prior to the adoption of MMLs and increased only after the adoption of the law, with the largest impacts occurring one and three or more years after policy enactment.

In Panel II of Table 3, we present estimated coefficients on leads and lags of MMLs in two-way fixed effects models that include controls for the full set of observables. The pattern of findings confirms the results of the event study. We find no evidence of significantly differential marijuana use trends prior to the adoption of an MML (column 2) and the controls for leads has no impact on the estimated effect of MMLs on marijuana use. There is some evidence that the lagged impact of MMLs on marijuana use is relatively larger. That is, we find that while marijuana use does not increase instantaneously with the enactment of the law (year 0), the impact of the law takes some time to unfold, with relatively larger effects three or more years after policy adoption.

Overall, the estimates in Tables 3 are consistent with the findings reported in Wen et al. (2015), Anderson and Rees (2011), and Sabia and Nguyen (2017). These models suggest that MMLs are associated with about a one to two percentage point increase in marijuana use. The magnitudes of these "first-stage effects" are important for gauging the credibility of second-order spillover effects on other substances, including cigarette use. Because most adults are not affected by MMLs, the estimated reduced-form smoking response (an intent-to-treat or ITT response) is an average across two groups – those affected by the medicinal marijuana legislation and those who are not. It is unlikely that MMLs would have a direct effect on smoking behaviors, independent of their effect on marijuana consumption.[12]

Turning to tobacco use, the results shown in Table 4 suggest that marijuana and tobacco are weak substitutes. In Panel I, we find that the enactment of an MML is associated with a

[12] There could be a direct effect stemming from an income effect. That is, even if MMLs do not affect marijuana consumption, changes in the price of marijuana may lead to an income effect that in turn impacts the use of other substances. For instance, studies have documented supply side-induced reductions in the street price of high-grade marijuana associated with MMLs (Anderson et al. 2013). This may generate a positive income effect among marijuana users, which may raise (reduce) the demand for other substances that are normal (inferior) commodities. However, this effect is likely to be very weak and would not be the primary mechanism through which MMLs shift the demand for other substances.

statistically insignificant 0.2 to 0.3 percentage-point decline in prior 30-day tobacco use, representing about a one percent decline in the average rate of tobacco use. The precision of our estimates allows us to rule out, with 95 percent confidence, MML-induced increases in tobacco use greater than 0.6 percentage points and MML-induced declines in tobacco use exceeding about one percentage point.

In Figure 2 and Panel II of Table 4, we find little evidence that adult tobacco use trended differently in MML-adopting states relative to non-adopting states prior to MML adoption. Moreover, in the years following the passage of an MML, there is no evidence of an increase in tobacco use. While not statistically distinguishable from zero, there is some suggestive evidence of a small decline in tobacco use following MML adoption. Estimated longer-run effects of MMLs on tobacco use (based on fully-specified dynamic models in Panel II) are closer to about 0.6 to 1.7 percentage points. While remaining statistically indistinguishable from zero at conventional levels, there is some evidence that the effects of MMLs on tobacco use become more negative in the years after the enactment of the law, again providing some weak evidence that marijuana and tobacco may be substitutes for some users.

Together, the results from the NSDUH suggest that while MMLs have increased marijuana use, perhaps for both medical and recreational purposes, spillover effects to tobacco use are small and imprecisely estimated over the 2002 to 2015 period. However, as noted above, the NSDUH has several limitations, including the lack of identifying variation contributed by early-adopting states from the Pacific region with collective cultivation provisions and the two-year state aggregated nature of the data. Both of these limitations are especially salient for estimating the effects of MMLs on tobacco use. Any second-order policy responses on substance use other than marijuana are likely to be small and credibly no more than one to two percentage points, the magnitude of the first-order response on marijuana use. Thus, micro-level data with large sample sizes and longer time windows that include greater policy variation may be necessary for maximizing precision. We therefore turn to the BRFSS and the CPS-TUS.

5.2 BRFSS and CPS-TUS Results

Panels I and II of Table 5 present estimates of equation (2) from the BRFSS. Panel I limits the sample period to 2002-2015 to provide comparison with the NSDUH analyses and Panel II uses the full 1990-2015 analysis period. Estimates for this shorter time period suggest a small and statistically insignificant decline in smoking participation, on the order of 0.3 percentage-points, consistent with the NSDUH. When we expand the time period to 1990-2015, exploiting all of the policy variation in the MMLs including that from the earliest adopting states (Panel II), we find more consistent evidence of a significant MML-induced decline in tobacco use, with an estimated marginal effect of 0.7 percentage-points. The magnitude of the effect is remarkably stable with the addition of state-level economic and policy controls (columns 2 and 3), consistent with the hypothesis that MML adoption is unrelated to these characteristics.

In Panel III, we show corresponding estimates from the CPS-TUS. Largely consistent with the BRFSS estimates, we find that over the 1992-2015 period, MML enactment is associated with a 0.4 percentage-point decline in tobacco use. Again, this result is robust to the inclusion or exclusion of observable controls.[13]

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[13] Because of the staggered nature of the TUS waves and hence the limited variation over the shorter 2002-2015 time window, we omit results from the shorter period from the main table. Standard errors in the CPS-TUS analyses increase by about 50% when the sample is limited to the shorter time window, indicative of the limited policy variation owing to the CPS-TUS staggered sampling scheme. MML estimates are, not surprisingly, statistically indistinguishable from zero. Estimates from this shorter window are available in Appendix Table 1.

Together, these estimates from the BRFSS and the CPS-TUS translate into effect sizes of approximately two to three percent relative to sample means. These findings are consistent with the hypothesis that marijuana and tobacco are substitutes. In principle, the MML-induced cigarette smoking effects we observe could reflect shifts on either the initiation or cessation margin. However, given that the vast majority of ever smokers (84 percent) initiate tobacco use at age 18 or earlier and virtually no one initiates after age 21, our estimates likely reflects shifts on the cessation margin.[14]

Table 6 examines the sensitivity of the above estimates to state-specific time-varying characteristics that could be correlated with the enactment of MMLs and tobacco consumption. First, column (1) adds controls for policy leads to address the concern that our estimated policy impacts could have captured pre-treatment tobacco use trends. After controlling for differential pre-treatment trends, the estimated association between MMLs and cigarette consumption actually *increase* slightly in absolute magnitude. However, the estimated declines remain small, about 0.6 to 1 percentage point, representing an effect size of 3.1 to 4.8 percent relative to the mean.

Column (2) adds controls for anti-marijuana legalization sentiment from the GSS, in addition to the policy leads and the state time trends. Estimates remain robust and continue to point to evidence that MMLs are associated a small reduction in the probability of smoking

[14] In Appendix Table 1, we estimate the effects of MMLs on other margins of cigarette consumption. Effects on being a daily smoker are similar to those for any smoking participation over the past month (reported in Tables 5 and 6), suggesting a decrease in the probability of being an everyday smoker of about 0.4 percentage points. This is not surprising since the majority (about 60%) of current smokers are everyday smokers. CPS-TUS estimates also suggest a significant MML-induced decline in smoking at the intensive margin. Specifically, MMLs are associated with about a 4% reduction in the number of cigarettes smoked among current smokers. Results from the BRFSS are statistically insignificant, in part because measures of everyday smoking and cigarettes smoked are not available in all waves and this reduces the sample size.

participation, suggesting that shifts in marijuana legalization sentiment cannot fully explain our findings.

Finally, in column (3), we control for state-specific time-varying unobservables by adding state-specific linear time trends to the right hand side of equation (2). Estimated MML effects from the BRFSS and CPS-TUS fall by approximately 50 percent, but continue to show that MMLs are associated with a 0.2 to 0.5 percentage-point decline in tobacco use. However, caution should be taken given that the inclusion of state-specific time trends will reduce identifying variation available to estimate policy impacts.[15]

5.3 Heterogeneity in Effects of MMLs

In Table 7, we explore heterogeneity in the effects of MMLs on tobacco use by age and gender. This may be important given that (i) MMLs have been found to have larger effects on both younger adults under 30 (Anderson et al. 2013) and older adults over 50 (Sabia et al. 2016), and (ii) consumption of tobacco and marijuana together as a spliff is much more common among males than females (Ramo et al. 2013).

Models in Table 7 specifically consider differential effects across different age groups, pooling both genders. Comparing patterns across age groups, there is some suggestive evidence of stronger effects among young adults of ages 18 to 25, particularly in the BRFSS, which may reflect the relatively high prevalence of marijuana use for this age group. We also find relatively stronger negative effects on smoking among older adults ages 55 and up across both datasets, a population for whom MML-induced increases in marijuana use have been observed (Sabia and

[15] The addition of state linear trends substantially reduces the identifying variation in the policy measure by almost 60%. In addition, Wolfers (2006) cautions against adding state-specific linear trends since such trends may confound both the state-specific time-varying unobservable as well as any dynamic effects of the policy itself.

Nguyen 2017). The larger effects among older adults may be consistent with MML-induced marijuana consumption for medical purposes potentially improving physical mobility (Sabia et al. 2016) or mental health (Anderson et al. 2013), and in turn reducing patients' reliance on cigarettes as a form of self-medication (Saffer and Dave 2005). In unreported results, we also experiment with testing whether there are differential effects of MMLs by gender, but find no evidence that policy impacts are statistically significantly different.

Finally, in Table 8, we assess heterogeneity in the average MML response we uncover above across differing types of state MMLs. Potential heterogeneity across different MML provisions may also explain some of the discrepancy in the estimates across the shorter- vs. longer time horizons. As shown in Table 2, 15 states and DC enacted MMLs during the 2002 to 2015 period. One reason why MMLs might have different spillover effects on tobacco use across different periods may be due to early and later adopting states implementing different types of MMLs. For example, as shown in Table 2, states that adopted MMLs earlier were somewhat less likely to legally permit dispensaries, but more likely to allow prescriptions for non-specific (general) pain, relative to later-adopting states. We therefore return to our full sample period and alternately assess differential effects across specific types of MMLs.

Table 9 presents estimates for four particular dimensions of the MMLs: whether a state (i) has specific allowances for medical marijuana use for general pain rather than particular medical conditions; (ii) allows home or collective cultivation of marijuana for multiple patients; (iii) legally permits dispensaries to operate (effective date of first dispensary opening); and (iv) mandates the maintenance of a state-run patient registry for eligible patients.

Panel I presents estimates based on the BRFSS, and Panel II presents estimates from the CPS-TUS. Columns (1) through (4) separately include effective state implementation of the four specific dimensions of the MMLs noted above. These models suggest that all four components of the MMLs are generally associated with reduced smoking participation, though to varying degrees. Models based on both datasets suggest that specific allowances for medical marijuana for general pain are associated with a significant 0.4 to 0.5 percentage point decline in the likelihood of being a current smoker. Models based on the CPS-TUS also suggest similar significant declines associated with collective cultivation and permissible dispensaries, though the BRFSS estimates for these provisions are smaller and insignificant. Mandated MML registry is also associated with a decline in smoking participation, though the effect is meaningful and significant only for the BRFSS.

The model shown in column (5) jointly controls for all four dimensions of the MMLs. While there is some consistency in the effects of provisions that allow for non-specific pain (both datasets suggesting about a 0.4 to 0.5 percentage decline in smoking participation), there is some divergence in the estimates for the other provisions. However, these provision-specific estimates are quite imprecise due to a high degree of collinearity among different policy components (see the discussion in Wen et al. 2015). Thus, estimates from column (5) should be interpreted with caution, though we cannot reject the hypothesis that these estimates are statistically equivalent across datasets at conventional levels. Despite these differences, we conclude, conservatively, that none of our key MML provisions appears to induce greater tobacco consumption.

6. Conclusions

With the proliferation of state laws allowing for medical marijuana use and several states considering similar legislation, public health professionals and policymakers have expressed concerns that these policies may have unintended spillovers that adversely affect health.[16] Previous work has considered outcomes related to problematic alcohol use (Anderson and Rees 2011, 2013; Wen et al. 2015), illicit drug use (Wen et al. 2015), and body weight (Sabia et al. 2016), but this study is the first to examine the tobacco-related effects of MMLs.

First, using data from the NSDUH, we document that MMLs are associated with a 0.7 to 2.4 percentage-point increase in marijuana use. Then, using data from the BRFSS and the CPS-TUS, we find that the enactment of MMLs is associated with a 0.4 to 0.7 percentage point reduction in cigarette consumption. The magnitude of these effects is relatively small, representing generally less than a 3% decline relative to the mean. Where we find negative effects on smoking, these are generally driven by both young adults (ages 18-25) as well as adults ages 55 and older, suggesting that there may be both recreational and medicinal reasons for such substitution. We find the strongest evidence for tobacco-reducing effects of MMLs when early adopting MML states in the Pacific region contribute to identifying variation.

To place the magnitudes of our tobacco use estimates in context, the effect we estimate is an intention-to-treat effect. Most adults are not affected by MMLs and therefore the reduced-form smoking effect we estimate is an average effect across those who are affected by MMLs and those who are not impacted. It is unlikely MMLs would have a direct effect on smoking behaviors, independent of their effect on marijuana consumption. If we assume that any effect of MMLs on other substance use necessarily must involve a change in marijuana consumption, then second-order effects on smoking cannot be larger than the first-order effects on marijuana consumption. The prior literature and our own NSDUH analyses has established small first-

[16] Twelve states (IN, IA, KY, MO, NE, NC, OK, SC, TN, TX, UT, WI) have pending legislation or amended ballot measures in 2017; WV passed legislation in 2017; and similar legislation failed in three states in 2017 (KS, MS, VA). See: http://medicalmarijuana.procon.org/view.resource.php?resourceID=002481

stage effects of the MMLs on marijuana consumption, on the order of 1 to 2 percentage-points for all adults. Thus, credible smoking effects would be an order of magnitude lower than this (either in the positive or negative direction).[17]

We can roughly gauge the size of the smoking effect by imputing the "treatment-on-the-treated" (TOT) effect of marijuana consumption on smoking. This is the Wald estimate, computed as the ratio of the two reduced-form estimates of the effects of MMLs on smoking to the effects of MMLs on marijuana use, which translates into a TOT of about -0.3.[18,19] This estimate implies that, while the MMLs had a relatively small effect on marijuana use among adults and the "treated" population is thereby small, among those who were impacted about 1 out of 3 may have reduced their smoking as they increased their marijuana consumption.

Together, our results suggest very little evidence that MMLs have impeded the U.S. trend of declining tobacco use. While the average tobacco use response to MMLs is likely small and negative, our results also point to considerable heterogeneity in the effects of the laws, both across later-adopters vs. the early adopters of MMLs, as well as across different dimensions of the laws, echoing work by Anderson and Rees (2014a; 2014b), Pacula et al. (2015) and Wen et

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[17] Data from the 2011 NSDUH suggest that about 90% of current or former marijuana users had also used cigarettes (either currently or in the past). Wen et al. (2015) and the NSDUH analyses in this study find that the MMLs on average raised current marijuana use among adults by about 1.5 percentage points (taking average of short- and longer-run estimates). Thus the potential "treated" adult population, who would be "at risk" of being impacted by the MMLs in terms of their smoking behaviors is 1.4% (0.90*1.5) of the population; the remaining 98.6% of adults would not be impacted, either because they were not impacted in terms of their marijuana consumption from the MMLs or because they never smoked cigarettes. Conditional on the first-stage effect, this also helps to bound the potential effect sizes for cigarette consumption. Even if all of the "treated" population changes their smoking behaviors, then the maximal predicted average MML impact on smoking would be between -1.4 to 1.4 percentage points within the adult population, which is consistent with the estimates from this study.

[18] Utilizing the lower CPS-TUS estimate of -0.004 and dividing by the average first-stage effect of 0.015 (found in both studies by Anderson and Rees 2011 and Wen et al. 2014 and the NSDUH analyses in this study) yields -0.27. Utilizing the slightly larger BRFSS estimate of -0.008 and dividing by the average first-stage effect of 0.015 yields a TOT of -0.53.

[19] Implicit TOT effects rescaled in this manner should be interpreted with caution because small changes in the denominator (in this case the first-order effect of the MMLs on marijuana use) and the underlying estimates can lead to large differences.

al. (2015). Our study adds to a growing body of evidence showing that the spillover public health effects of MMLs generally improve health outcomes.

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Figure 1. Event-Study Analysis, Marijuana Use, NSDUH

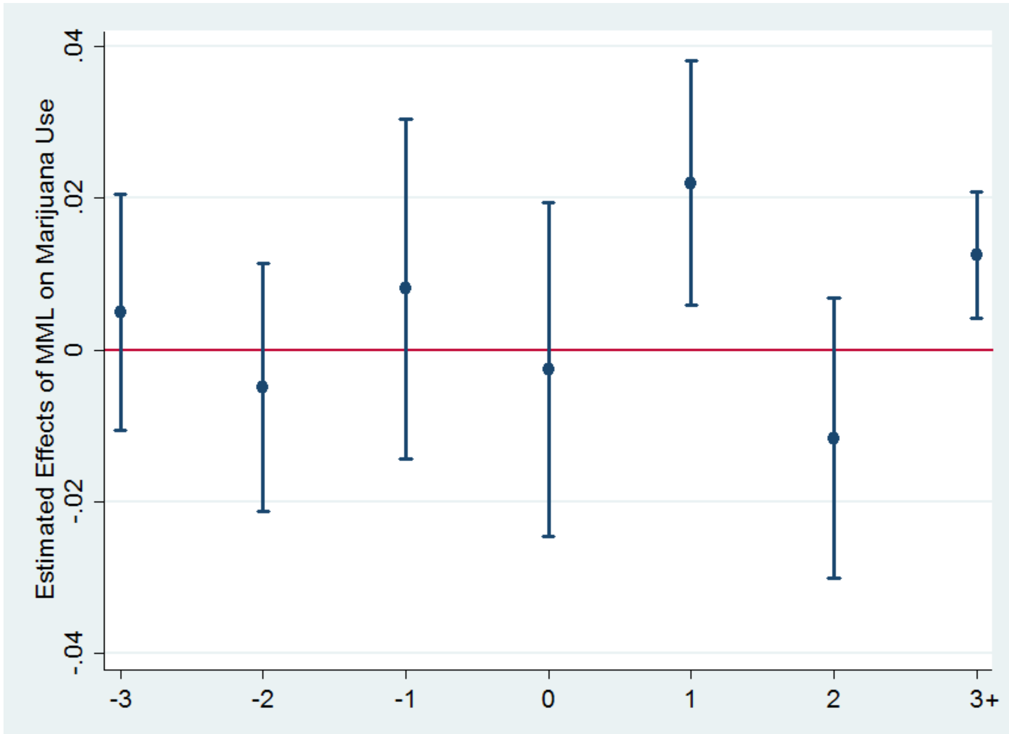

Figure 2. Event-Study Analysis, Tobacco Use, NSDUH

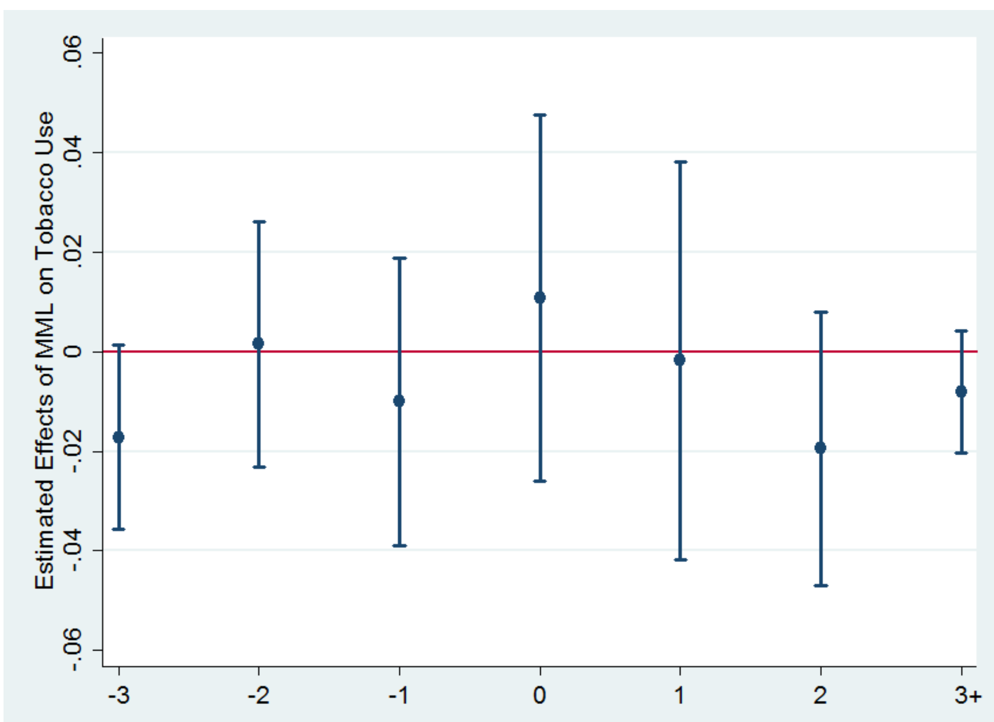

Table 1. Means of Tobacco Use and Selected Controls, NSDUH, BRFSS, CPS-TUS

	NSDUH (2002-2015)	BRFSS (1990-2015)	CPS-TUS (1992-2015)
Marijuana and Tobacco Measures			
Marijuana Use (Past 30 days)	0.068 (0.022)	.	.
Tobacco (Past 30 days)	0.317 (0.051)	0.208 (0.406)	0.193 (0.394)
Selected Controls			
Medical Marijuana Law	0.250 (0.442)	0.178 (0.382)	0.180 (0.384)
Cigarette Taxes (2015 $)	1.25 (0.892)	0.964 (0.813)	0.910 (0.760)
Beer Taxes (2015 $)	0.299 (0.248)	0.312 (0.236)	0.311 (0.231)
Marijuana Decriminalization Law	0.295 (0.454)	0.339 (0.473)	0.335 (0.472)
Marijuana Legalization Law	0.011 (0.093)	0.005 (0.074)	0.005 (0.071)
Zero Tolerance Law	1.00 (0.00)	0.819 (0.378)	0.849 (0.352)
BAC08 Law	0.950 (0.197)	0.677 (0.461)	0.630 (0.469)
Clean Indoor Air Law – Government Buildings	0.882 (0.320)	0.804 (0.397)	0.801 (0.399)
Clean Indoor Air Law – Private Sector Buildings	0.692 (0.457)	0.600 (0.490)	0.585 (0.493)
Clean Indoor Air Law -- Restaurants	0.750 (0.428)	0.665 (0.472)	0.659 (0.474)
Clean Indoor Air Law – Shopping Center	0.573 (0.487)	0.403 (0.490)	0.372 (0.483)
Clean Indoor Air Law – Public Schools	0.953 (0.207)	0.924 (0.265)	0.925 (0.363)
Clean Indoor Air Law – Private Schools	0.756 (0.427)	0.704 (0.456)	0.698 (0.459)
Per capita income (2015 $)	43,963.10 (6,777.31)	41,827.13 (6,725.96)	41,778.22 (6,573.62)
Unemployment Rate	6.36 (1.87)	6.16 (1.93)	5.81 (1.93)
Male	0.492 (0.007)	0.483 (0.500)	0.476 (0.499)
Education (HS/College)	0.294 (0.056)	0.286 (0.452)	0.318 (0.466)
Black	0.125 (0.095)	0.109 (0.311)	0.113 (0.316)
N	357*	6,970,691	2,044,577

*Data are available at the state-level in two-year averages.
Notes: Weighted means obtained using state-level data drawn from the National Survey for Drug Use and Health (2002 to 2013), individual-level data drawn from the Behavioral Risk Factor Surveillance System (1990 to 2015), and the Current Population Survey Tobacco Use Supplements (1992 to 2015).

Table 2. Effective Dates of Medical Marijuana Laws

State	MML	MML Provisions			
		Collective cultivation	Dispensary	Non-specific pain	Registry
	(1)	(2)	(3)	(4)	(5)
Alaska	03/1999	n/a	n/a	03/1999	03/1999
Arizona	04/2011	04/2011	12/2012	04/2011	04/2011
Arkansas	11/2016	n/a	n/a	11/2016	11/2016
California	11/1996	11/1996	11/1996	11/1996	n/a
Colorado	06/2001	06/2001	07/2005	06/2001	06/2001
Connecticut	05/2012	n/a	08/2014	n/a	05/2012
Delaware	07/2011	n/a	06/2015	07/2011	07/2011
Washington, D.C.	07/2010	n/a	07/2013	n/a	07/2010
Florida	01/2017	n/a	n/a	n/a	01/2017
Hawaii	12/2000	n/a	n/a	12/2000	12/2000
Illinois	01/2014	n/a	11/2015	n/a	01/2014
Maine	12/1999	n/a	04/2011	n/a	12/2009
Maryland	06/2014	n/a	n/a	06/2014	06/2014
Massachusetts	01/2013	n/a	06/2015	n/a	01/2013
Michigan	12/2008	12/2008	12/2009	12/2008	n/a
Minnesota	05/2014	n/a	07/2015	n/a	05/2014
Montana	11/2004	11/2004	04/2009	11/2004	n/a
Nevada	10/2001	10/2001	08/2015	10/2001	10/2001
New Hampshire	07/2013	n/a	04/2016	07/2013	07/2013
New Jersey	10/2010	n/a	12/2012	10/2010	10/2010
New Mexico	07/2007	n/a	06/2009	n/a	07/2007
New York	07/2014	n/a	01/2016	n/a	07/2014
North Dakota	12/2016	n/a	n/a	12/2016	12/2016
Oregon	12/1998	12/1998	11/2009	12/1998	01/2007
Ohio	08/2016	n/a	n/a	08/2016	08/2016
Pennsylvania	05/2016	n/a	n/a	05/2016	05/2016
Rhode Island	01/2006	01/2006	04/2013	01/2006	01/2006
Vermont	07/2004	n/a	06/2013	07/2007	07/2004
Washington	11/1998	07/2011	04/2009	11/1998	n/a

Notes: Dates of effective MMLs are updated using Table 1 and Appendix Table 2A of Anderson et al. (2013) and Table 1 on p. 69 of Wen et al. (2015) using Elliott (2009, 2011); Marijuana Policy Project (2015b; 2016); Ritter (2010); Saker (2009); Schwartz (2011) and Stucke (2009).

Table 3. The Effects of Medical Marijuana Laws on Adult Marijuana Use, NSDUH

	Panel I: Baseline Estimates		
MML	0.008**	0.007**	0.008**
	(0.003)	(0.003)	(0.002)
State & year FEs?	Yes	Yes	Yes
Demographic controls?	No	Yes	Yes
State economic controls?	No	Yes	Yes
State policy controls?	No	No	Yes
N	357	357	357
	Panel II: MML Leads and Lags		
Three Years Prior	-0.002		-0.001
	(0.006)		(0.008)
Two Years Prior	0.002		-0.001
	(0.005)		(0.008)
One Year Prior	-0.004		0.001
	(0.006)		(0.012)
MML	0.008**		
	(0.003)		
Year of Law Change		0.002	0.0004
		(0.005)	(0.011)
One Year After		0.020***	0.021**
		(0.007)	(0.009)
Two Years After		-0.009	-0.010
		(0.006)	(0.007)
Three Years After+		0.011***	0.011**
		(0.003)	(0.004)
Sum of Year of Law Change,		*0.024****	*0.022**
1, 2, 3+ Years		*F = 7.34*	*F = 2.91*
F-test (p-value)		*(p = 0.01)*	*(p = 0.09)*
State & year FEs?	Yes	Yes	Yes
Demographic controls?	Yes	Yes	Yes
State economic controls?	Yes	Yes	Yes
State policy controls?	Yes	Yes	Yes
N	357	357	357

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

Notes: Weighted OLS estimates obtained using data from the National Survey of Drug Use and Health from 2002-2015. State-level demographic controls include share non-white, male, and college educated. State economic controls include state per capita income and the state unemployment rate. State policy controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, and marijuana decriminalization and legalization laws. Standard errors corrected for clustering at the state-level are in parentheses.

Table 4. The Effects of Medical Marijuana Laws on Adult Tobacco Use, NSDUH

		Panel I: Baseline Estimates	
MML	-0.002	-0.002	-0.003
	(0.005)	(0.005)	(0.008)
State & year FEs?	Yes	Yes	Yes
Demographic controls?	No	Yes	Yes
State economic controls?	No	Yes	Yes
State policy controls?	No	No	Yes
N	357	357	357
		Panel II: MML Leads and Lags	
Three Years Prior	0.032		0.030
	(0.021)		(0.021)
Two Years Prior	-0.021		-0.019
	(0.017)		(0.027)
One Year Prior	0.005		0.0003
	(0.012)		(0.039)
MML	-0.0003		
	(0.005)		
Year of Law Change		-0.006	-0.0001
		(0.017)	(0.033)
One Year After		0.011	0.009
		(0.019)	(0.026)
Two Years After		-0.017	-0.012
		(0.016)	(0.016)
Three Years After+		-0.005	-0.003
		(0.005)	(0.006)
Sum of Year of Law Change,		*-0.017*	*-0.006*
1, 2, 3+ Years		*F = 0.59*	*F = 0.04*
F-test (p-value)		*(p = 0.45)*	*(p = 0.85)*
State & year FEs?	Yes	Yes	Yes
Demographic controls?	Yes	Yes	Yes
State economic controls?	Yes	Yes	Yes
State policy controls?	Yes	Yes	Yes
N	357	357	357

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

Notes: Weighted OLS estimates obtained using data from the National Survey of Drug Use and Health from 2002-2015. State-level demographic controls include share non-white, male, and college educated. State economic controls include state per capita income and the state unemployment rate. State policy controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, and marijuana decriminalization and legalization laws. Standard errors corrected for clustering at the state-level are in parentheses.

Table 5. The Effect of Medical Marijuana Laws on Tobacco Use, BRFSS and CPS-TUS

	(1)	**(2)**	**(3)**
		Panel I: BRFSS (2002-2015)	
MML	-0.003	-0.003	-0.003
	(0.002)	(0.002)	(0.002)
N	5,442,879	5,442,879	5,442,879
		Panel II: BRFSS (1990-2015)	
MML	-0.007***	-0.007***	-0.006***
	(0.002)	(0.002)	(0.002)
N	6,970,691	6,970,691	6,970,691
		Panel III: CPS-TUS (1990-2015)	
MML	-0.004**	-0.004**	-0.004**
	(0.002)	(0.002)	(0.002)
N	2,044,577	2,044,577	2,044,577
State & year FEs?	Yes	Yes	Yes
Demographic controls?	Yes	Yes	Yes
State economic controls?	No	Yes	Yes
State policy controls?	No	No	Yes

***Significant at 1% level **at 5% level *at 10% level
Notes: All estimates are weighted. State-specific time-varying controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, marijuana decriminalization and legalization laws, state per capita income, the unemployment rate, share of non-white population, and share of population graduating from college. Demographic controls include age, educational attainment, race/ethnicity, and marital status. All regressions include state fixed effects and year fixed effects.

Table 6. Sensitivity of Estimates of Relationship Between MMLs and Tobacco Use to Controls for Policy Leads, State-Specific Linear Time Trends, and Anti-Marijuana Legalization Sentiment, BRFSS and CPS-TUS

	Added Controls for Policy Leads **(1)**	*Column (1) + State Sentiment* **(2)**	*Column (2) + State Linear Trend* **(3)**
		Panel I: BRFSS, 1990-2015	
MML	-0.010***	-0.010***	-0.005**
	(0.002)	(0.002)	(0.002)
N	6,970,691	6,676,665	6,676,665
		Panel II: CPS-TUS, 1992-2015	
MML	-0.006**	-0.005**	-0.002
	(0.002)	(0.002)	(0.003)
N	2,044,577	1,984,074	1,984,074

***Significant at 1% level **at 5% level *at 10% level
Notes: Weighted difference-in-difference estimates obtained from the Behavioral Risk Factor Surveillance Survey and the Current Population Survey Tobacco Use Supplements. State-specific time-varying controls include beer taxes, cigarette taxes, zero tolerance laws, blood alcohol content (.08) driving laws, marijuana decriminalization and legalization laws, state per capita income, the unemployment rate, share of non-white population, and share of population graduating from college. Demographic controls include age, educational attainment, race/ethnicity, and marital status. All regressions include state fixed effects and year fixed effects.

Table 7. Age-Specific Estimates of the Effect of MMLs on Tobacco Use, BRFSS and NSDUH

	Ages 18-to-25 (1)	**Ages 26-to-54** (2)	**Ages 55+** (3)
		Panel I: BRFSS	
MML	-0.013*** (0.005)	-0.004 (0.004)	-0.007*** (0.002)
N	470,712	3,231,447	3,221,534
		Panel III: CPS-TUS	
MML	0.000 (0.004)	-0.001 (0.003)	-0.010*** (0.002)
N	265,089	1,128,283	651,205

***Significant at 1% level **at 5% level *at 10% level
Notes: Weighted difference-in-difference estimates obtained from the Behavioral Risk Factor Surveillance Survey and the Current Population Survey Tobacco Use Supplements. -specific time-varying controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, marijuana decriminalization and legalization laws, state per capita income, the unemployment rate, share of non-white population, and share of population graduating from college. Demographic controls include age, educational attainment, race/ethnicity, and marital status. All regressions include state fixed effects and year fixed effects.

Table 8. Exploring Heterogeneity in Effects of Tobacco Use by Different Types of Medical Marijuana Laws

	(1)	(2)	(3)	(4)	(5)
	Panel I: BRFSS, 1990-2015				
MML-Pain	-0.004*				-0.005
	(0.003)				(0.005)
MML-Collective Cultivation		-0.003			0.002
		(0.003)			(0.005)
MML-Dispensaries			-0.001		0.002
			(0.002)		(0.002)
MML-Registry				-0.006**	-0.005
				(0.002)	(0.003)
N	6,970,691	6,970,691	6,970,691	6,970,691	6,970,691
	Panel II: CPS-TUS, 1992-2015				
MML-Pain	-0.005**				-0.004
	(0.002)				(0.003)
MML-Collective Cultivation		-0.006***			-0.003
		(0.002)			(0.004)
MML-Dispensaries			-0.004*		0.000
			(0.002)		(0.003)
MML-Registry				-0.001	0.001
				(0.002)	(0.002)
N	2,130,058	2,130,058	2,130,058	2,130,058	2,130,058

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

Notes: Weighted difference-in-difference estimates obtained from the Behavioral Risk Factor Surveillance Survey and the Current Population Survey Tobacco Use Supplements. The full period includes the years 1990 through 2015. State-specific time-varying controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, marijuana decriminalization and legalization laws, state per capita income, the unemployment rate, share of non-white population, and share of population graduating from college. Demographic controls include age, educational attainment, race/ethnicity, and marital status. All regressions include state fixed effects and year fixed effects.

Appendix Table 1. The Effects of Medical Marijuana Laws on Everyday Smoking and Log Cigarettes Smoked, BRFSS and CPS-TUS

	(1)	(2)	(3)
	Panel I: Everyday Smoking, BRFSS (1996-2015)		
MML	-0.004	-0.003	-0.002
	(0.002)	(0.002)	(0.002)
N	6,153,550	6,153,550	6,153,550
	Panel II: Log Cigarettes, BRFSS (1990-2000)		
MML	0.027	0.028	0.014
	(0.018)	(0.017)	(0.018)
N	262,382	262,382	262,382
	Panel III: Everyday Smoking, CPS (1992-2015)		
MML	-0.004**	-0.004**	-0.004**
	(0.002)	(0.002)	(0.002)
N	2,044,577	2,044,577	2,044,577
	Panel IV: Log Cigarettes, CPS (1992-2015)		
MML	-0.040***	-0.040***	-0.036***
	(0.006)	(0.006)	(0.006)
N	235,172	235,172	235,172
	Panel V: Tobacco Use, CPS (2002-2015)		
MML	0.001	0.000	0.000
	(0.003)	(0.003)	(0.003)
N	983,418	983,418	983,418
State & year FEs?	Yes	Yes	Yes
Demographic controls?	Yes	Yes	Yes
State economic controls?	No	Yes	Yes
State policy controls?	No	No	Yes

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

Notes: Weighted difference-in-difference estimates obtained from the Behavioral Risk Factor Surveillance Survey and the Current Population Survey Tobacco Use Supplements. Log cigarette regressions are run on the sample of current smokers in the BRFSS and everyday smokers in the CPS-TUS due to the respective survey skip patterns. In the CPS-TUS, daily cigarettes smoked are top-coded at 40 to be consistent over the full sample period. State-specific time-varying controls include beer taxes, cigarette taxes, clean indoor air laws, zero tolerance laws, blood alcohol content (.08) driving laws, marijuana decriminalization and legalization laws, state per capita income, the unemployment rate, share of non-white population, and share of population graduating from college. Demographic controls include age, educational attainment, race/ethnicity, and marital status. All regressions include state fixed effects and year fixed effects.