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High times: The effect of medical marijuana laws on student time use

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High Times: The Effect of Medical Marijuana Laws on Student Time Use

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Abstract

Medical marijuana laws (MMLs) represent a major change of marijuana policy in the U.S. Previous research shows that these laws increase marijuana use among adults. In this paper, we estimate the effects of MMLs on secondary and post-secondary students' time use using data from the American Time Use Survey. We apply a difference-in-differences research design and estimate flexible fixed effects models that condition on state fixed effects and state-specific time trends. We find no effect of MMLs on secondary students' time use. However, we find that college students in MML states spend approximately 20% less time on education-related activities and 20% more time on leisure activities than their counterparts in non-MML states. These behavioral responses largely occur during weekends and summer when students have more spare time. Finally, the impacts of MMLs are heterogeneous and stronger among part-time college students, who are more likely to be first-generation college goers and to come from underrepresented racial and ethnic groups.

JEL Codes: I18, K32, K42

Keywords: Time Use, Medical Marijuana, Education Unintended Consequences

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"I now have absolute proof that smoking even one marijuana cigarette is equal in brain damage to being on Bikini Island during an H-bomb blast."

- Ronald Reagan, 40th U.S. President.

1. Introduction

It is a popular belief that marijuana use harms educational performance and predicts school dropout and truancy. Marijuana use is highly correlated with low educational attainment and medical research suggests that marijuana can affect motivation, attention, and cognition. However, empirical evidence on the causal link between marijuana use and educational outcomes is limited. Despite significant policy implications, there are relatively few rigorous studies on the topic. Moreover, much of the extant literature relies on strong identification assumptions. Accordingly, it is unclear to what extent the findings in prior research are driven by unobserved confounders. A key difficulty in identifying the causal effects of marijuana use on educational outcomes is identifying arguably exogenous variation in marijuana consumption.

Over the past two decades, nearly thirty U.S. states have passed medical marijuana laws (MMLs) that allow patients to legally possess and use marijuana. Such laws are naturally controversial; while the number of legal medical marijuana patients was small until very recently, they have the potential to increase illicit marijuana use among non-patients. Large surveys such as the National Survey on Drug Use and Health (NSDUH) document a strong, positive correlation between MMLs and marijuana use (Cerdá et al. 2012; Wall et al. 2011). This correlation could be causal as MMLs lower non-patients' marginal cost of marijuana use through several channels. First, MMLs might increase non-patients' access to marijuana and lower the drug's real and shadow price. Some evidence suggests that medical marijuana commonly leaks from legally qualified patients or dispensaries to illegal users (Salomonsen-Sautel et al. 2012; Thurstone, Lieberman, and Schmiege 2011). Second, MMLs could shift social attitudes toward marijuana use and decrease stigma or the perceived harm associated with its use (Carliner et al. 2017; Khatapoush and Hallfors 2004). Finally, MMLs could cause law enforcement and the judicial system to take a more lenient approach to illegal marijuana use (Eddy 2010; GAO 2002).[1]

Several recent studies provide evidence of a causal relationship and show that MMLs cause roughly a 20% increase in marijuana use (Chu 2014, 2015; Wen, Hockenberry, and Cummings 2015). Nonmedical use likely constitutes most of the increase in marijuana use, as implied by the associated increases in marijuana possession arrests (Chu 2014). The effects of MMLs appear to be large especially on the intensive margin and on heavy marijuana use. For example, Chu (2014) finds an increase in marijuana treatment admissions that mostly consist of heavy users and Wen, Hockenberry, and Cummings (2015) show that nearly half of the increase in past-month marijuana use is due to increased daily marijuana use. Somewhat surprisingly, the increase in marijuana use is concentrated among adults, as MMLs do not affect marijuana usage among juveniles (Anderson, Hansen, and Rees 2015; Choo et al. 2014; Lynne-Landsman, Livingston, and Wagenaar 2013; Wen, Hockenberry, and Cummings 2015).[2] The general finding that MMLs affect non-patients' marijuana use suggests that MMLs might affect educational attainment because students may smoke more marijuana and therefore change their motivation and behaviors. Moreover, MMLs might affect educational attainment by causing students to shift to marijuana from other substances: Anderson, Hansen, and Rees (2013) find that MMLs reduce alcohol consumption and traffic fatalities involving alcohol, suggesting that marijuana and alcohol are substitutes, Chu (2015) finds evidence that marijuana and heroin are substitutes, and Bachhuber et al. (2014), Ozluk (2017), and Powell, Pacula, and Jacobson (2018) show that access to medical marijuana leads to a decrease in opioid-related overdose deaths.

In this paper, we provide novel evidence on the impact of MMLs on student behaviors both in and out of the classroom and contribute to our understanding of the causal relationship between marijuana use and behaviors associated with educational success.

[1] For example, cities like Denver, San Francisco, and Seattle, passed initiatives that either legalize marijuana or require authorities to make marijuana offenses 'the lowest law enforcement priority' (Eddy 2010).

[2] See Sarvet et al. (2018) for a thorough literature review and Chu (2018) for its commentary. However, some evidence suggests adolescent marijuana use among subgroups or on some margins might have increased. For example, Wen, Hockenberry, and Cummings (2015) find that MMLs increase first-time marijuana use but not regular use among ages 12–20; Smart (2015) finds that growth in the population shares of registered medical marijuana patients leads to an increase in adolescent marijuana use; Chu (2014) shows that MMLs increase marijuana use among treatment patients aged 15–17 in the online appendix.

Specifically, we estimate the effects of MMLs on students' time spent in education and leisure activities using time diary data from the American Time Use Survey (ATUS) for the years 2003–2016. We use a difference-in-differences research design and estimate fixed effects models that control for state and year fixed effects, state-specific time trends, and a variety of student and time-diary covariates. Both time spent in education and leisure activities can influence educational achievement and attainment (Jacob 2002; Kalenkoski and Pabilonia 2014). Educational activities such as attending class and doing homework and research are direct inputs to the education production function, while leisure activities such as watching television may crowd out time in more educationally productive activities such as reading (Schmidt and Anderson 2007).

Consistent with extant evidence that MMLs do not affect juvenile drug use, we find no effect of MMLs on high-school students' time use. In contrast, our results suggest that college students spend less time on education-related activities such as attending class and doing homework but more time on leisure activities such as watching television after the passage of MMLs. On average, college students' education time decreased by approximately 20–23% while their leisure time increased by 21–22%, both of which are roughly equivalent to 30 minutes on an average day. MMLs that provide broader access to marijuana appear to have stronger effects on education time than more restrictive MMLs. The decrease in education time occurs largely on the extensive margin, as college students are 16–19% less likely to spend any time on education activities. However, changes on the intensive margin contribute to the reduction in leisure time. Conditional on positive leisure time, time spent in leisure activities increased by 16–17% among college students.

These behavioral changes are not evenly distributed and largely occur during weekends and summer when students have more flexibility in allocating time. Interestingly, the effects of MMLs are heterogeneous: the changes in time use are driven mostly by part-time college students rather than full-time college students. Our findings indicate that marijuana use may harm educational outcomes, particularly among students who are only tenuously connected to schooling and provide evidence on potential behavioral channels through which these effects may operate.

This research makes several contributions. First, this paper leverages a new identification strategy—the exogenous shock of MMLs—for detecting the effects of marijuana use on intermediate educational outcomes. Previous studies either use instrumental variables that are largely based on cross-sectional variation, or try to model individual heterogeneity econometrically, with Marie and Zölitz (2017) being a notable exception. In contrast, the current study exploits a more plausible source of exogenous variation in marijuana consumption. Indeed, our findings are consistent with the results in Marie and Zölitz (2017), who find that university students' academic performance increased at Maastricht University after legal access to marijuana was removed, particularly for low-performing students. Second, students' behavioral responses to MMLs are of policy interest in their own right. The finding of stronger negative effects on the educationally productive activities of potentially disadvantaged groups is particularly relevant to discussions of inequality and the design of future education and health policies. Finally, while MMLs provide numerous benefits to patients, unintended negative externalities associated with increased access to marijuana exist. Identifying and quantifying unintended consequences of public policy is paramount to conducting careful cost-benefit analyses and to improving future iterations of policies.

The paper proceeds as follows: Section 2 briefly describes the history of MMLs and what is known about the relationship between marijuana use and educational outcomes. Sections 3 and 4 describe the data and empirical strategy, respectively. Section 5 presents the results and section 6 concludes.

2. Background and Literature Review

2.1 History of Medical Marijuana Laws

In the late 1970s, many states began passing legislation that allowed the use of medical marijuana through research programs, but only a handful of states' research programs became operable due to federal restrictions (Pacula et al. 2002). In 1986, the Food and Drug Administration (FDA) approved Marinol, a prescription drug containing the same active ingredient, Delta-9-THC, as marijuana. However, taking oral medications could be difficult for patients suffering from severe nausea, a common symptom among AIDS and cancer patients. In the late 1980s and early 1990s, smokable marijuana was discovered to benefit growing populations of AIDS and cancer patients. In 1996, California became the first state to pass a medical marijuana law allowing patients to legally use and possess marijuana. With growing positive medical evidence and lobbying by marijuana legalization advocacy groups, such as the National Organization for the Reform of Marijuana Laws (NORML), many states have since joined California in passing a new wave of medical marijuana legislation. As of 2017, 24 states and the District of Columbia have passed similar medical marijuana laws. Five other states, Minnesota, New York, Ohio, Pennsylvania, and West Virginia, passed medical marijuana laws that only allow non-smokable marijuana that is not dry leaf or in plant form (edibles are banned too). States with effective medical marijuana laws, including the five states with non-smokable laws, and the years they become legally effective, are summarized in Table 1 (Leafly 2018; MPP 2018; Powell, Pacula, and Jacobson 2018; ProCon.org 2017).

These laws permit patients with legally designated diseases and syndromes to use marijuana as a means of treatment. The designated symptoms and conditions typically include AIDS, anorexia, arthritis, cachexia, cancer, chronic pain, glaucoma, migraines, persistent muscle spasms, severe nausea, seizures, and sclerosis. Patients can legally possess marijuana up to a fixed amount that varies by state. Since MMLs do not change the criminal status of marijuana, only legal patients can be exempted from state penalties. To become a legal patient, individuals need a recommendation from a physician.[3] In most states, legal patients also need to register with the state medical marijuana program and obtain a medical marijuana card.[4] The number of registered patients was quite small before 2009 but has increased dramatically in recent years. For example, Colorado passed its medical marijuana law in 2001 and had only 5,051 registered patients in January 2009. By January 2010, however, the number of registered patients had increased more than 2,000 percent in just one year to 118,895. An estimate from ProCon.org (2016) suggests that the total number of legal patients in the U.S. increased from only 0.57 million in 2009 to 1.2 million legal patients in 2016, or about 0.8% of the total population of medical marijuana states.[5] There exist huge differences across medical marijuana states, even among recent adopted states. For example, both Arizona and New Jersey passed laws in 2010. More than

[3] Federal law does not allow physicians to 'prescribe' marijuana.
[4] California created a registration program in 2004, but registration is voluntary. Maine passed an amendment in November 2009 that created a registration program, but it remains voluntary. Washington does not have a registration program. In some states, such as Colorado and Nevada, patients who do not join the registry and are arrested for marijuana charges may argue an "affirmative defense of medical necessity."
[5] Smart (2015) provide a comparable estimate of a 0.49% registration rate for 2002–2013.

2% of Arizona residents are legal patients but only 0.2% of New Jersey residents are legal patients (ProCon.org 2018).

Medical marijuana laws passed prior to the Obama administration generally do not authorize marijuana dispensaries in order to conform to the federal classification of marijuana as a Schedule I drug. To overcome the supply issue, these laws allow for home cultivation. Patients can grow for their own and for other patients' use on a not-for-profit basis. Marijuana dispensaries with grey legal status still exist, however. [6] The prevalence of dispensaries largely depends on the attitude of local governments and the actions of local law enforcement, which could change from time to time. In 2007, New Mexico became the first state to pass a medical marijuana law with a provision to license production and distribution at the state level, but the first state-licensed marijuana provider in New Mexico was not approved until March 2009. In 2009, the Obama administration announced that the federal government would no longer seek to arrest medical marijuana users and suppliers so long as they conformed to state laws (Mikos 2011). This statement largely resolved the legal dispute between state and federal governments. As a result, laws and amendments now regulate dispensaries, and both the numbers of registered patients and dispensaries have increased significantly since then. Nevertheless, there is concern that the Trump administration may revert back to a more hostile stance towards marijuana. In 2018, Attorney General Jeff Sessions rescinded the Obama-era policy and encouraged federal prosecutors to use their their own discretion to crack down marijuana businesses in states where marijuana is legal (Khazan 2018). Table 1 lists the states that allow home cultivation, with legally protected dispensaries, and with active dispensaries (regardless of their legal status).

2.2 Marijuana Use and Educational Outcomes

[6] For example, dispensaries are considered to be legally protected in California (Senate Bill 420, 2003); the law does recognize the existence of dispensaries even though it is actually silent as to their legality (Pacula, Boustead, and Hunt 2014). Dispensaries in Colorado increased dramatically in 2008 after the court lifted the limit on the number of patients that a caregiver can provide (Johnson 2009; Spellman 2009), though their legal status is even greyer than those in California. More recent legislations and amendments generally seek to provide more legal protections and guidelines for dispensaries. One notable exception is that Montana passed SB423 in 2011 that effectively banned dispensaries by outlawing monetary transactions. In November 2016, Montana voters approved an initiative referendum (I-182) to repeal SB 423.

Strong correlations between marijuana use and educational outcomes such as school dropout and truancy are well documented (Lynskey and Hall 2000; Macleod et al. 2004). Such associations may be causal, owing to changes in motivation, cognitive ability, and other psychological effects of marijuana use. Numerous laboratory experiments find that marijuana users exhibit lower motivation and cognitive impairment (Foltin et al. 1989; Griffith-Lendering et al. 2012; Lane et al. 2005; Musty and Kaback 1995; Randolph et al. 2013; Shannon et al. 2010; Verdejo-Garcia et al. 2007; Wetherell et al. 2012; Whitlow et al. 2004). Heavy marijuana use is also associated with depression (Degenhardt, Hall, and Lynskey 2003). Moreover, many recent studies utilize magnetic resonance imaging (MRI) to show brain abnormalities among marijuana users (Batalla et al. 2014; Bolla et al. 2005; Filbey et al. 2014; Gilman et al. 2014; Price et al. 2015; Raver, Haughwout, and Keller 2013; Vaidya et al. 2012; Wesley, Hanlon, and Porrino 2011). Some evidence suggests that the impacts of marijuana use on the brain could be permanent, as brain abnormities can be found even among casual and abstinent users (Bolla et al. 2005; Gilman et al. 2014; Raver, Haughwout, and Keller 2013).

However, the correlation might be spurious and driven by individual heterogeneity. Most of the laboratory experiments mentioned above are not randomized control experiments. Due to ethical issues, researchers cannot randomly assign marijuana use to experiment subjects, and instead recruit volunteer marijuana users as experiment subjects. It is unclear to what extent the psychological effects found in the medical literature are causal. For example, Denson and Earleywine (2006) suggest that some marijuana use may be self-medication, and marijuana users generally have less depressed moods than nonusers. Weiland et al. (2015) point out that in many previous studies marijuana users are observably different from nonusers in terms of alcohol use and along several other dimensions, and the researchers find no association between marijuana use and standard MRI brain shape measurements after carefully controlling for alcohol use, gender, age, and other variables. Filbey et al. (2014) also point out that current MRI evidence is largely correlational, and longitudinal studies that can trace changes over time are needed to determine causality. In addition, peer behaviors appear to affect marijuana use (Duarte, Escario, and Molina 2009; Gaviria and Raphael 2001). Thus, poor academic performance among marijuana users could be a result of social interaction and self-selection into lowachieving peer groups. A final concern is reverse causality, as Sander (1998) and Zimmerman and Schmeelk-Cone (2003) suggest that school performance may affect marijuana initiation and usage.

Perhaps due to a general lack of plausible exogenous variation, only a handful of studies have attempted to determine the causal association between marijuana use and educational attainment. In addition to directly controlling for individual and family characteristics (Cobb-Clark et al. 2015), most research uses instrumental variables and simultaneous equation models to address endogeneity problems (Bray et al. 2000; Chatterji 2006; Duarte, Escario, and Molina 2006; Roebuck, French, and Dennis 2004; Yamada, Kendix, and Yamada 1996). State beer taxes, marijuana and cocaine prices, marijuana penalties, and de-penalization status have been used as instruments for marijuana use. Some research also relies on econometric modeling to control for individual heterogeneity (Duarte, Escario, and Molina 2006; Roebuck, French, and Dennis 2004; van Ours and Williams 2009). The literature finds evidence of a negative causal link between marijuana use and educational attainment. However, these conclusions should be interpreted cautiously, as the identification in these studies tends to rely on strong assumptions. For example, the instruments are generally weak and arguably endogenous (French and Popovici 2011). McCaffrey et al. (2010) show that estimates are sensitive to the specification of the conditioning set and propensity score weights, suggesting that unobserved heterogeneity remains an important factor. Moreover, medical research utilizing data on twins finds no causal effect of marijuana use on educational attainment (Bergen et al. 2008; Grant et al. 2012; Verweij et al. 2013). A recent exception to this critique is Marie and Zölitz (2017), who use a difference-in-differences strategy to estimate the effect of a policy that removed college students' legal access to marijuana. The authors find that student performance at Maastricht University increased after legal access was removed, that this effect was driven by younger university students, and provide suggestive evidence that these improvements were due to increased understanding of material rather than changes in students' effort provision.

We contribute to this literature by investigating the channels through which access to marijuana might affect educational achievement and attainment. Specifically, we provide reduced-form evidence on the causal effects of MMLs on student behaviors associated with educational success. Intuitively, MMLs might increase marijuana use among students by reducing the costs associated with procuring and using marijuana. We therefore estimate MMLs' effects on time in education and leisure activities, both of which might influence educational achievement and attainment (Jacob 2002; Kalenkoski and Pabilonia 2014).

3. ATUS Data

We examine the effects of medical marijuana laws on secondary and postsecondary students' time use. Behavioral responses to MMLs are of interest in their own right, but also constitute a potential mechanism through which marijuana use might affect educational achievement and attainment. Prevailing social attitudes towards how individuals spend their time likely influence responses to traditional survey questions, a phenomenon known as *social desirability bias* (Grimm 2010). Accordingly, retrospective time diaries likely yield more accurate measures of students' non-school time use (Juster and Stafford 1991). We therefore analyze time diaries collected by the American Time Use Survey (ATUS) for the years 2003–2016.

The ATUS is a nationally representative survey that has been administered annually since 2003 by the Bureau of Labor Statistics. The ATUS collects a 24-hour retrospective time diary from one individual aged 15 or over per household from a subset of the Current Population Survey (CPS) sampling frame and links each diary to socio-demographic household data from the CPS. The analytic sample of more than 18,000 time diaries is restricted to respondents who self-reported being enrolled in high school or college at the time of completing the time diary, for whom basic demographic variables are observed.

Table 2 summarizes the students who comprise the analytic samples of the two populations of interest: high school students and college students. The resulting sample sizes are 7,543 for high school students and 9,916 for college students. The first set of statistics summarize students' participation in education and leisure activities on both the intensive and extensive margins. The two most important education activities recorded in the ATUS are taking class and doing research or homework for class, and the most common leisure activity is watching television.[7] On average, college students spend 112 minutes on education activities per day, which is a bit more than half as much time spent by high school students.[8] Intuitively, these differences are due to systematic differences in the school schedules of the two types of students. On both the intensive and extensive margins, college students spend less time on education activities than high school students. 55 percent of high school students and 42 percent of college students engage in at least some education activity on the diary day. Conditional on participating in education activities on a given day, high school students spend about 348 minutes and college students spend about 270 minutes on these activities. In contrast, leisure habits are fairly similar across both student groups. Television watching is the most common form of leisure in the ATUS. Time spent on leisure is common, as more than 80 percent of students have some leisure time on their diary day. Conditional on spending some time on leisure activities in a given day, the average student spends more than 200 minutes on these activities.

The remainder of Table 2 summarizes the demographic composition of the analytic samples. Nearly all high school students are studying fulltime but only 61 percent of college students are fulltime students. The sexes are evenly represented in high school, but females outnumber males in college. The latter is consistent with the emerging gender gaps in college enrollment and completion that favor females (Bailey and Dynarski 2011).

In the last two columns, Table 2 presents summary statistics for college students by part-time and full-time enrollment status. As expected, full-time college students spend more time on education than part-time college students. Full-time college students also have a bit more leisure time than part-time college students. Unfortunately, we do not have data on students' socioeconomic status such as household income and parent's education, and thus cannot speak to socioeconomic-status-based differences. The reason is that when

[7] To create the variable for time spent on education-related activities, we sum over the following three categories in the ATUS: taking class (4-digit code: 0601), non-sport extracurricular school activities (4-digit code: 0602), and research and homework (4-digit code: 0603). The variable for time spent in leisure activities is from the "relaxing and leisure" category (4-digit code: 1203) in which the most common activity is non-religious television viewing (6-digit code: 120303). Among college (high school) students, the average time is 40 (140) minutes in taking class, 72 (46) minutes in research and homework, and 119 (135) minutes in watching television.

[8] We use diaries from the full calendar year as students report substantial time spent on education-related activities even in summer months (June – August). The average education time is 70 (94) minutes in summer months and 124 (207) minutes in the academic months among college (high school) students.

household income is reported for students, it is unclear whether the income being reported is of the student's or of the student's parents' households.

4. Econometric Model

We implement a difference-in-differences style identification strategy by estimating the following model:

$$Time_{ist} = f(\tau MML_{st} + \gamma ML_{st} + \lambda C_i + \beta X_{ist} + \delta_t + \theta_s + \theta_s t + \theta_s t^2 + \varepsilon_{ist}), \qquad (1)$$

where *Time* is a measure (in minutes) of the time that respondent *i* spent on a particular activity on the diary day; MML_{st} is a binary indicator equal to one if state *s* had a medical marijuana law in effect in year *t*, and zero otherwise;[9] ML_{st} is a vector of binary indicators for other state-level marijuana policies: non-smokable medical marijuana laws, marijuana legalization (also in Table 1), and marijuana decriminalization;[10] C_i is a vector of controls for the timing of respondent i's diary including diary-month fixed effects, days-of-week fixed effects, and a dummy variable indicating whether the diary was taken on a holiday; X_{ist} is a vector of observed respondent characteristics as reported in Table 2; θ and δ are state and year fixed effects (FE), respectively; and ε is an idiosyncratic error term. We first estimate equation (1) as a linear model in which $f(\cdot)$ is an identity function. As the dependent variables contain many zeros (especially education time) and are discrete count variables of non-negative integers measured in minutes, we also estimate equation (1) as a fixed-effect Poisson model, that is, $f(\cdot)$ is an exponential function. The parameter of interest is τ, which represents the impact of state MMLs on student time use in terms of minutes per day in a linear model and in terms of percentage changes in a Poisson model. Throughout this paper, standard errors are clustered by state, to make statistical inference robust to heteroskedasticity and serial correlation within states over time, as the treatment occurs at the state level.

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[9] All policy indicators such as MML_{st} equal one in the first *full year* of a policy being effective and thereafter. Note that there often is a one-to-two-year time lag between the law being legally effective and the marijuana program starting to accept patient applications. There often are further delays for dispensaries starting to operate. Table 1 lists the years when dispensaries are known to be operational (Powell, Pacula, and Jacobson 2018). Interested readers can see MPP (2018) for some of the political hurdles causing delays of MML implementation in each state.

[10] In our sample period, states that remove criminal status of marijuana possession are California (2011), Connecticut (2012), Delaware (2016), Maryland (2015), Massachusetts (2009), Rhode Island (2014), Vermont (2014), and Washington D.C. (2015). (The first full years that these laws become effective are in the parenthesis.)

The critical identifying assumption necessary to give estimates from a difference-in-difference research design a causal interpretation is the parallel trends (i.e., common slopes) assumption. Intuitively, this means that after controlling for level differences between states with state FE, time use in both treated (MML) and control (non-MML) states was trending similarly. However, if unobserved within-state secular trends jointly determined both time use and states' adoptions of MMLs, the estimates from a fixed effects regression will be biased. We explicitly relax the parallel trends assumption by allowing each state, regardless of treatment status, to follow its own time trend. Accordingly, equation (1) conditions on state-specific quadratic time trends ($\theta_s t$ and $\theta_s t^2$). The resulting estimator identifies state-specific departures from trends in response to the passage of MMLs and is robust to any smoothly trending unobservables at the state level.

5. Effects of MMLs on Time Use

5.1 Main Results

Tables 3 and 4 present baseline estimates of τ from equation (1) separately for high school and college students, respectively. The estimated impacts of MMLs on time spent in education activities are reported in the upper panel. Corresponding effects on leisure activities are reported in the lower panel. We first present estimates from linear models in columns (1) – (3) and then from Poisson models in columns (4) – (6). For both models, we estimate three specifications with linear, quadratic, or cubic state-specific time trends. Thus, each cell of tables 3 and 4 report the estimated effect of MMLs from a unique regression.

Most of the estimates in Table 3 suggest negative effects of MMLs on high school students' education time and positive effects of MMLs on leisure time. However, the estimates tend to be small in magnitude with large standard errors and are sensitive to time trend specifications. All estimates (except for one) are not statistically significant at traditional confidence levels. This is unsurprising, given that the extant literature finds little evidence that MMLs affect high school students' marijuana use. We therefore restrict attention to college students in all subsequent analyses.[11]

[11] Student migration could be a potential concern, especially for full-time college students who leave their home state to attend college. For example, college students in nonmedical marijuana states may be from

In contrast, the estimates in Table 4 suggest statistically significant effects of MMLs on college students' time spent in education and leisure activities. While the estimates are smaller and insignificant in the specification with linear time trends (column 1 and 4), they become economically and statistically significant in the specification with quadratic time trends (columns 2 and 5). Importantly, the estimates are robust to augmenting the model to account for cubic state-specific time trends (columns 3 and 6) and the point estimates remain approximately the same size, although the estimated standard errors increase as expected.

In the upper panel of Table 4, the OLS estimates in columns 2 and 3 suggest a decrease of 25 minutes in education-related activities such as attending class and doing research or homework after the passage of MMLs, or equivalently, a 23% (25/107) decrease relative to the pre-MML average. The Poisson estimates in columns 5 and 6 suggest that college students spend 20% ($e^{-0.221} - 1$) less time on education activities. In terms of the average partial effects, the Poisson estimates are nearly identical to OLS estimates and indicate a decrease of 25 (0.221 × 112) fewer minutes in education activities. (The average partial effects of a Poisson model are obtained by multiplying the point estimates by the sample average of the dependent variable). Interestingly, decreases in time spent in educationally productive activities are entirely offset by increases in leisure time.

In the lower panel of Table 4, the OLS estimates suggest an increase of approximately 30 minutes in leisure activities after the passage of MMLs. The Poisson estimates are strongly statistically significant and indicate that college students spend 17–22% more time on leisure activities, or equivalently, an average partial effect of approximately 30 more minutes. In the ATUS, watching television accounts for most of the leisure time in the survey. Television viewing is unlikely an educationally productive activity because entertainment programming constitutes the majority of young adults' television viewing and most educational programming is aimed at children less than 5 years of age (Huston et al. 2007; Schmidt and Anderson 2007). Therefore, our finding here

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medical marijuana states and therefore were affected by MMLs when they were in high school. However, the literature finds that MMLs do not affect high school student marijuana use, student migration should not play an important role in determining the results for college students.

is consistent with the hypothesis that television viewing could harm education attainment by displacing time spent reading (Schmidt and Anderson 2007).

In Table 5, we estimate the effects of MMLs on time use using different definitions of time use. A substantial proportion of college students in the survey report zero time in education (58%) and leisure (16%) activities. One natural question is whether changes in time use are due to changes at the extensive margin or the intensive margin. To address this question, we estimate the effects of MMLs on the likelihood that a college student participated in education or leisure activities on the diary day. If there is no effect of MMLs on participation, then the results presented in Table 4 suggest that MMLs primarily change students' time use on the intensive margin; otherwise, the extensive margin plays an important role. These results are reported in the upper panel of Table 5 and suggest that behavioral changes on the extensive margin are an important channel through which total education time decreased. In column 1, the OLS estimate indicates that MMLs decrease the likelihood of spending any time on education activities by 7.5 percentage points (19%). In column 2, the Poisson estimate is quantitatively similar and indicates a decrease of 16%. In contrast, the estimates in columns 3 and 4 are small and insignificant, suggesting that the increase in leisure time among college students shown in Table 4 is primarily driven by behavioral changes on the intensive margin.

In the lower panel of Table 5, we estimate the effects of MMLs strictly on the intensive margin and restrict the samples to students reporting positive time on education and leisure activities. The estimates in columns 1 and 2 suggest a decrease of 8% (24 minutes) in education time on the intensive margin. However, as the sample size is quite small for positive education time, these estimates are imprecise. The estimates in columns 3 and 4 show an increase of 17% (33 minutes) in leisure time and are significant at the 5% level, which together with the null effect on the extensive margin suggests that the positive effect on leisure time among college students in Table 4 is driven by behavioral changes on the intensive margin. We focus on the Poisson model hereafter because its estimates can be easily interpreted in terms of both level and percentage changes and the estimates from Poisson and OLS regressions are nearly identical.

In Table 6, we estimate an event-study version of equation (1) that includes binary indicators for policy leads and lags. We replace the MML indicator in equation (1) with a series of binary indicators for each full year (and a dummy for year 6 and above) after the MML was passed to estimate the dynamic effects of MMLs on student time use.[12] To test for policy endogeneity, we also estimate a specification with an indicator for years prior to the MML. Intuitively, this allows us to test for "effects" of MMLs before they were passed. Should such "effects" be observed, this is evidence of differential, pre-existing trends in MML states. In column 1, the impacts of MMLs on education time appear to increase over time. We find no evidence of policy endogeneity, as the estimate for the pre-treatment indicator in column 2 is small and statistically insignificant. The estimates for post-law dummies in column 2 display the same patterns and magnitudes observed in column 1, although they are less precisely estimated. Similarly, the estimates in columns 3 and 4 suggest positive effects of MMLs on leisure time that appear to increase over time and offer no evidence of pre-existing differential trends. The estimates in Table 6 are broadly consistent with a causal interpretation of our earlier results suggesting that MML laws affected time use, as the effect of MMLs on marijuana use also appears to increase over time (Chu 2014, 2015). However, as this exercise asks a lot of the data, and is underpowered in the sense that splitting the pre- and post- periods into year-specific cells yields some small state-by-year cells, the estimates for dynamic effects are noisy and imprecisely estimated. In fact, in Table 6, these estimates for dynamic effects are not statistically different from each other. Consequently, we prefer a single post-treatment dummy that averages MMLs' effects that arguably better approximates the true policy effects.

5.2 Heterogeneous Effects of MMLs

Another interesting question is when these behavioral changes occur. If marijuana use indeed causes college students to substitute their education activities with leisure activities, intuitively, these marginal changes would likely occur during the period when students have more spare time. The rich information in the ATUS allows us to address this question. In particular, one advantage of the ATUS is that it oversamples Saturdays and

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[12] Since the ATUS data are available since 2003, medical marijuana states passing law before 2003 do not directly contribute to identifying the estimates for MMLs in Tables 4 and 5. To be consistent with the main results, the binary indicators in Table 6 are defined using only MMLs passed after 2003.

Sundays when there is more spare time for various activities.[13,14] In Table 7, columns 1–2, we split the sample and estimate the effects of MMLs on time use separately on weekdays and weekends. Consistent with the above expectation, the decrease in education time is mostly driven by changes in weekend time use. The estimate in column 1 suggests that college students spend 38% less time on education activities on weekends after the passage of MMLs, or equivalently an average partial effect of 38 fewer minutes.[15] In contrast, the estimate in column 2 is small and statistically insignificant and thus the time spent in education activities does not change substantially during weekdays after the passage of MMLs. In the lower panel, the increase in leisure time is also greater on weekends than on weekdays, but the difference is small. The estimates show that leisure time among college students increases by 26% during weekends and by 20% during weekdays. In columns 3–4, by similar logic, we estimate the effects of MMLs on time use separately in summer (June to August) and during academic year (September to May). The estimates suggest that behavioral responses during summer can account for most of the changes in education and leisure time. The reduction in education time is mostly driven by changes in summer time use, although the large magnitude (61%) is likely imprecisely estimated due to the small sample size. A similar pattern emerges for leisure time. The increase in leisure time during summer is more than twice as large as during the academic year. Overall, the estimates in Table 7 show that the behavioral responses occur during the time when students have more flexibility in time allocation and thus are consistent with our causal interpretation that MMLs affect college students' time use.

[13] Note that we do not use the ATUS sampling weights to estimate our regressions. Ideally, our research design would use representative samples for college students in each state-year as the treatment varies at the state-year level. Since the ATUS sampling weights do not help to recover either the representativeness of students or the representativeness of states, we follow Solon, Haider, and Wooldridge (2015) to use unweighted regressions. The weighted estimates remain quantitatively similar in the subsamples of weekends and of part-time college students but they tend to be small and insignificant in the pooled sample.

[14] We further conduct two analyses to address potential issues related to weighting as suggested by Solon, Haider, and Wooldridge (2015). First, we explore the heterogeneity in the policy effects between weekdays and weekend in Table 6 because the ATUS weights mainly affect the relative weighting of weekdays and weekends. Second, to be conceptually more consistent with the research design, we average the individual-level data to the state-level and re-run the regressions at the state-level so each state receives equal weight. The results are reported in Appendix Table A1. While the estimates are nosier as expected, they are quantitatively similar to those reported in Table 4, suggesting that our results are not driven by one or two MML states with large populations.

[15] The average education (leisure) time is 78 (194) minutes in weekends and 146 (143) minutes in weekdays. The average education (leisure) time is 70 (175) minutes in summer and 124 (167) minutes in academic year.

In Table 8, we further probe potential heterogeneity in the effects of MMLs on college students' time use by part-time and full-time enrollment status (Appendix Table A2 reports the OLS estimates). Compared to full-time college students, part-time college students tend to be lower performing and of lower socioeconomic status. Data from the National Center for Education Statistics (NCES) suggest that part-time college students are more likely to be Hispanic, first-generation college goers, and to come from low-income families (Chen 2007). If marijuana usage indeed has negative effects on educational outcomes that are larger for lower-performing students, as found in Marie and Zölitz (2017), we would expect that the academically weaker, socioeconomically disadvantaged, first generation, and historically underrepresented students who are more likely to be part-time college students are more susceptible to the harmful effects of marijuana use and of increased access to marijuana.

Columns 1, 3, and 5 present the effects of MMLs on part-time college students' time use. In the upper panel, the estimates suggest a large decrease of 58% in time spent in education activities that is largely driven by the extensive margin (a 41% decrease). That is, part-time college students are less likely to spend any time on education-related activities like taking class and homework. In the lower panel, the estimates suggest that part-time college students spend 48% more time on leisure activities after the passage of MMLs. The estimates also indicate an 8% increase on the extensive margin and a 36% increase on the intensive margin. Therefore, most of the increase in leisure time appears to be driven by part-time college students spending more time on leisure activities. However, as the sample size is relatively small, and there are many zeros especially in education time, interpretation of these estimates requires caution. The estimates may suffer finite sample bias and some of the magnitudes seem implausibly large.

In contrast, in columns 2, 4, and 6, the estimates are quite noisy and not statistically significant, suggesting that MMLs do not affect full-time college students' education or leisure time, on either the extensive or intensive margins. The differences between full-time and part-time college students are intuitive. As Chu (2014, 2015) suggests, the impact of MMLs on marijuana usage is probably concentrated among heavy users. Therefore, MMLs likely affect a small proportion of full-time college students (compliers) who are perhaps struggling academically, but they may have little impact on average students. Indeed, marijuana use rates, especially heavy usage rates, are lower among full-time college students than among their similarly aged peers.[16] Given the nature of the survey, the ATUS data probably do not have sufficient statistical power to detect such heterogeneous policy effects among full-time college students.

In Table 9, we explore heterogeneity in marijuana provision of MMLs and its effects on time use. In addition to shifting marijuana demand by lowering people's perceived health and legal risks, MMLs shift marijuana supply by making marijuana more easily accessible. Anderson, Hansen, and Rees (2013) show that marijuana prices decrease significantly after the passage of MMLs. However, there is substantial heterogeneity in medical marijuana provision across states, and great care is required when distinguishing between different types of MMLs as the practice could be divorced from written laws (Anderson and Rees 2014; Powell, Pacula, and Jacobson 2018). Earlier legislations allow home cultivation and dispensaries with grey legal status. In contrast, later legislations provide legal protection for dispensaries but require them to be state licensed and generally prohibit home cultivation in order to regulate the supply more strictly. The process could take a few years after the passage of a MML for state licensed dispensaries to open. Because the MMLs that allow home cultivation and the MMLs that license dispensaries are almost mutually exclusive and dispensaries can operate semi-legally without a state license, we focus on the effects of home cultivation and the effects of active dispensaries regardless of their legality.[17] Both home cultivation and the presence of marijuana dispensaries likely increase marijuana supply and therefore marijuana use.

Consistent with the above intuition, columns 1–3 of Table 9 suggest that education time in MML states allowing home cultivation and MML states with active dispensaries decreases even more than in other MML states. In column 1, college students spend 25% ($e^{-0.155 - 0.131} - 1$) less time in education-related activities in MML states allowing home cultivation, while students only spend 14% less time in education-related activities in other MML states. Similarly, in column 2, college students in MML states spend 19% less time on education-related activities, and the education time reduced by an additional 12% after

[16] For example, the Monitoring the Future survey shows that in 2014, among people who were one to four years beyond high school, the rate of daily marijuana use was about twice as high for non-college goers (10.8%) as for full-time college students (5.9%) (Johnston et al. 2015).

[17] Notice that there is time variation in *Active Dispensary* × *MML* (see Table 1) conditional on *MML*. As in Table 6 (see Note 12), to be consistent with the main results, *Active Dispensary* × *MML* equals to zero for MMLs passed before 2003.

marijuana dispensaries began operations. The results are quantitatively similar in column 3 when both home cultivation and active dispensaries are controlled for in the regression. However, these differences are imprecisely estimated and statistically insignificant.

Somewhat surprisingly, in columns 4–6, we do not find a similar pattern for leisure time. College students in MML states allowing home cultivation do not increase their leisure time as much as in other MML states. Also, leisure time increases slightly less after marijuana dispensaries start to operate, though the difference is small and not statistically significant.[18] However, one problem rarely acknowledged in empirical work is that fixed effects estimates and their standard errors could contain substantial bias when the number of treatment groups is small (Conley and Taber 2011). Because only a handful of states enacted any specific type of MMLs at a given time, the estimates in Table 9 could suffer from finite sample bias and therefore should be interpreted with caution. Moreover, these estimates may not necessarily reflect differences in marijuana provision since most MMLs allowing for home cultivation were passed before 2009 and therefore it is difficult to distinguish differences in laws from regime/time effects. Overall, perhaps because of the relatively small sample size, we only find limited evidence of heterogeneity by the type of MMLs.

7. Conclusion

The current study uses a difference-in-differences strategy to estimate the effect of medical marijuana laws (MMLs) on students' time use. Consistent with the extant literature that shows no change in marijuana use among adolescents, we do not find any substantial change in secondary students' time use. In contrast, we find robust, arguably causal evidence that the passage of MMLs affected post-secondary students' time use. Specifically, on average, college students in MML states spent approximately 20% less time on education activities such as taking class and doing homework and 20% more time

[18] Interestingly, the estimates for (recreational) marijuana legalization exhibit the same pattern and similar magnitudes as the estimates for home cultivation and active dispensaries. These results are presented in Appendix Table A3. It is possible that people who are more responsive to changes in marijuana supply (e.g., heavy users) tend to substitute education-related activities with non-leisure activities so their leisure time does not increase as much. Unfortunately, since only a small number of states legalize marijuana and these laws were passed very recently, the estimates may also suffer from the finite sample bias described by Conley and Taber (2011).

on leisure activities such as watching television than those in non-MML states after the passage of MMLs.[19] Changes on the extensive margin contribute to most of the decrease in education time, while the increase in leisure time occurs almost entirely on the intensive margin. Importantly, the effects of MMLs on students' time use appear to be heterogeneous across time and across student groups and mostly come from behavioral changes during weekend and summer days and among part-time college students. As part-time college students are more likely to be academically weaker students, our results imply that lower-performing students are more susceptible to the harmful effects of marijuana usage and are thus consistent with the findings in Marie and Zölitz (2017).

These results provide indirect evidence that marijuana use induced by increased access to marijuana affects relatively disadvantaged, marginally connected students' educational outcomes. They also provide suggestive evidence on the mechanisms through which marijuana use affects academic achievement. Still, a caveat of the current study is that we lack data on individual students' drug use, so these estimates represent reduced-form impacts of policies that affect access to marijuana. Similarly, the ATUS data do not contain direct measures of academic achievement or persistence in postsecondary education. Still, these results identify a potentially important, and costly, unintended consequence of MMLs that might perpetuate socioeconomic inequities by delaying, or limiting, the postsecondary educational success of students from certain socio-demographic backgrounds and of nontraditional students who enroll part time or not immediately after high school completion.

[19] The main findings are robust to a variety of modeling choices. The results are quantitatively similar if time use is measured in terms of ratios of education or leisure time to sleeping time; if states that passed MMLs before 2003 and therefore are effectively part of the control group are dropped. These results are available upon request.

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Table 1: State Medical Marijuana Laws

State	Legally Effective Date	Home Cultivation	Dispensaries Legally Protected	Dispensary is Known to be Active	Recreational Use Legally Effective Date
Alaska	03/04/1999	Yes	No	n/a	02/24/2015
Arizona	11/29/2010	Yes	Yes	2012	n/a
Arkansas	11/09/2016	No	Yes	?	n/a
California	11/06/1996	Yes	Yes (2003)	1996	11/09/2016
Colorado	06/01/2001	Yes	Yes (2010)	2005	12/10/2012
Connecticut	10/01/2012	No	Yes	2014	n/a
Delaware	07/01/2011	No	Yes	2015	n/a
Florida	01/03/2017	No	Yes	2017	n/a
Hawaii	06/16/2000	Yes	No	n/a	n/a
Illinois	01/01/2014	No	Yes	2015	n/a
Maine	12/22/1999	Yes	Yes (2009)	2011	01/30/2017
Maryland	06/01/2014	No	Yes	2017	n/a
Massachusetts	01/01/2013	Yes	Yes	2015	12/15/2016
Michigan	12/04/2008	Yes	No	2009	n/a
Minnesota*	05/29/2014	n/a	n/a	n/a	n/a
Montana	11/02/2004	Yes	No	2009	n/a
Nevada	10/01/2001	Yes	Yes (2013)	2009	01/01/2017
New Hampshire	07/23/2013	No	Yes	2016	n/a
New Jersey	06/01/2010	No	Yes	2012	n/a
New Mexico	07/01/2007	Yes	Yes	2009	n/a
New York*	07/05/2014	n/a	n/a	n/a	n/a
North Dakota	04/18/2017	No	Yes	?	n/a
Ohio*	09/08/2016	n/a	n/a	n/a	n/a
Oregon	12/03/1998	Yes	Yes (2013)	2009	07/01/2015
Pennsylvania*	04/17/2016	n/a	n/a	n/a	n/a
Rhode Island	01/03/2006	Yes	Yes (2009)	2013	n/a
Vermont	07/01/2004	Yes	Yes (2011)	2013	07/01/2018
Washington	12/03/1998	Yes	No	2009	12/06/2012
Washington, D.C.	07/27/2010	No	Yes	2013	02/26/2015
West Virginia*	04/19/2017	n/a	n/a	n/a	n/a

Notes: Only states with effective laws before 2016 are coded as medical marijuana states in the paper.

*: The laws in Minnesota, New York, Ohio, Pennsylvania, and West Virginia do not allow smokable and edible marijuana and exclude dry leaf or plant form.

?: Dispensaries are legally protected but do not yet exist as of July 2018.

The information in collected by the authors from the following sources: (Leafly 2018; MPP 2018; Powell, Pacula, and Jacobson 2018; ProCon.org 2017, 2018b)

Table 2: Summary Statistics

	High School	College	Part-time College	Full-time College
Time Spent on Education	190.7	112.1	69.1	139.8
	(221.3)	(179.8)	(133.0)	(199.5)
Pr (Time Spent on Education > 0)	0.55	0.42	0.32	0.48
	(0.50)	(0.49)	(0.47)	(0.50)
Time Spent on Education (if > 0)	347.7	269.5	214.1	293.7
	(186.2)	(187.8)	(154.2)	(195.9)
Time Spent on Leisure	217.0	168.7	160.2	174.2
	(179.9)	(162.1)	(154.3)	(166.7)
Pr (Time Spent on Leisure > 0)	0.90	0.84	0.85	0.84
	(0.30)	(0.36)	(0.36)	(0.37)
Time Spent on Leisure (if > 0)	240.4	200.4	188.7	208.1
	(173.9)	(157.7)	(150.6)	(161.7)
Full-time	0.95	0.61		
	(0.22)	(0.49)		
Age	16.7	28.7	32.5	26.3
	(3.1)	(8.7)	(8.6)	(7.9)
Male	0.51	0.37	0.35	0.39
	(0.50)	(0.48)	(0.48)	(0.49)
White	0.80	0.75	0.78	0.74
	(0.40)	(0.43)	(0.42)	(0.44)
Black	0.12	0.17	0.15	0.17
	(0.33)	(0.37)	(0.36)	(0.38)
Hispanic	0.19	0.15	0.16	0.14
	(0.39)	(0.36)	(0.37)	(0.35)
Metropolitan	0.83	0.87	0.88	0.86
	(0.38)	(0.34)	(0.32)	(0.35)
Observations	7,543	9,916	3,886	6,030

Notes: Time spent on education and leisure activities is measured in minutes.

Table 3: Estimates of Effects of MMLs on High School Students' Time Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)					
	OLS			Poisson		
MML	3.12 (7.73)	-7.53 (12.44)	-18.74 (18.32)	0.052 (0.043)	-0.018 (0.072)	-0.042 (0.112)
pre-*MML* avg.	187.8					
	Time Spent on Leisure (Minutes)					
	OLS			Poisson		
MML	-0.69 (10.65)	14.72 (14.79)	35.56 (22.15)	0.001 (0.046)	0.076 (0.067)	0.170* (0.097)
pre-*MML* avg.	223.2					
Time Trends	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Observations	7,543	7,543	7,543	7,543	7,543	7,543

Notes: The dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Table 4: Estimates of Effects of MMLs on College Students' Time Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)					
	OLS			Poisson		
MML	-2.06	-24.67*	-25.27	0.010	-0.221**	-0.214
	(9.00)	(13.60)	(17.72)	(0.070)	(0.109)	(0.137)
pre-*MML* avg.	107.2					
	Time Spent on Leisure (Minutes)					
	OLS			Poisson		
MML	6.57	35.76***	29.15**	0.029	0.197***	0.158***
	(11.66)	(6.96)	(11.07)	(0.065)	(0.042)	(0.059)
pre-*MML* avg.	167.0					
Time Trends	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Observations	9,916	9,916	9,916	9,916	9,916	9,916

Notes: The dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Table 5: Estimates of Effects of MMLs on the Extensive and Intensive Margins of College Students' Time Use

	(1)	(2)	(3)	(4)
	Pr (Time Spent on Education > 0)		**Pr (Time Spent on Leisure > 0)**	
	OLS	Poisson	OLS	Poisson
MML	-0.075* (0.041)	-0.174* (0.093)	0.044 (0.031)	0.050 (0.036)
pre-*MML* avg.	0.403		0.837	
Observations	9,916	9,916	9,916	9,916
	Time Spent on Education > 0 (Minutes)		**Time Spent on Leisure >0 (Minutes)**	
	OLS	Poisson	OLS	Poisson
MML	-23.56 (24.79)	-0.085 (0.095)	32.76** (13.07)	0.153** (0.065)
pre-*MML* avg.	266.2		199.7	
Observations	4,125	4,125	8,347	8,347

Notes: In the upper panel, the dependent variables are dummy variables indicating any positive time spent in education-related activities or any positive time spent in leisure activities. In the lower panel, the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities conditional on positive time spent in these activities. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Table 6: Estimates of Dynamic Effects of MMLs on College Students' Time Use

	(1)	(2)	(3)	(4)
	Time Spent on Education (Minutes)		**Time Spent on Leisure (Minutes)**	
Year -1 & -2		0.036		-0.011
		(0.102)		(0.076)
Year 1	-0.328**	-0.282*	0.266***	0.252**
	(0.145)	(0.158)	(0.057)	(0.118)
Year 2	-0.319**	-0.264	0.159	0.142
	(0.144)	(0.176)	(0.121)	(0.205)
Year 3	-0.482**	-0.414*	0.357***	0.336
	(0.188)	(0.241)	(0.122)	(0.211)
Year 4	-0.537**	-0.460*	0.291*	0.266
	(0.243)	(0.262)	(0.150)	(0.271)
Year 5	-0.961**	-0.872**	0.379	0.350
	(0.381)	(0.359)	(0.233)	(0.371)
Year 6+	-0.984***	-0.879**	0.512**	0.478
	(0.375)	(0.412)	(0.232)	(0.387)
Observations	9,916	9,916	9,916	9,916

Note: The estimates are from Poisson models in which the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Table 7: Estimates of Effects of MMLs on College Students' Time Use by Weekend and Summer

	(1)	(2)	(3)	(4)
	Time Spent on Education (Minutes)			
	Weekend	Weekday	Summer	Fall to Spring
MML	-0.485**	-0.097	-0.929***	-0.098
	(0.209)	(0.162)	(0.348)	(0.128)
	Time Spent on Leisure (Minutes)			
	Weekend	Weekday	Summer	Fall to Spring
MML	0.232***	0.185*	0.375**	0.140***
	(0.057)	(0.108)	(0.188)	(0.053)
Obs.	4,985	4,931	2,223	7,693

Notes: The estimates are from Poisson models in which the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** p < 0.01. ** p < 0.05. * p < 0.10.

Table 8: Estimates of Effects of MMLs Impact on College Students' Time Use by Enrollment

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)		**Pr (Time Spent on Education > 0)**		**Time Spent on Education > 0 (Minutes)**	
	Part-time	Full-time	Part-time	Full-time	Part-time	Full-time
MML	-0.856***	0.000	-0.534***	0.033	-0.260	-0.005
	(0.142)	(0.141)	(0.112)	(0.111)	(0.161)	(0.090)
Obs.	3,886	6,030	3,886	6,030	1,254	2,870
	Time Spent on Leisure (Minutes)		**Pr (Time Spent on Leisure > 0)**		**Time Spent on Leisure > 0 (Minutes)**	
	Part-time	Full-time	Part-time	Full-time	Part-time	Full-time
MML	0.391***	0.041	0.074*	0.037	0.304***	0.020
	(0.087)	(0.100)	(0.042)	(0.047)	(0.090)	(0.126)
Obs.	3,886	6,030	3,886	6,030	3,299	5,048

Notes: The estimates are from Poisson models in which the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities in columns (1) – (2), dummy variables indicating any positive time spent in these activities in columns (3) – (4), and minutes spent in these activities conditional on positive time. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Table 9: Estimates of Effects of Home Cultivation and Active Dispensary on College Students' Time Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)			**Time Spent on Leisure (Minutes)**		
MML	-0.155 (0.112)	-0.215* (0.111)	-0.158 (0.111)	0.278*** (0.050)	0.199*** (0.038)	0.276*** (0.050)
Home Cultivation × *MML*	-0.131 (0.218)		-0.113 (0.228)	-0.161*** (0.061)		-0.154** (0.060)
Active Dispensary × *MML*		-0.123 (0.129)	-0.119 (0.129)		-0.063 (0.096)	-0.058 (0.095)
Obs.	9,916	9,916	9,916	9,916	9,916	9,916

Notes: The estimates are from Poisson models in which the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** p < 0.01. ** p < 0.05. * p < 0.10.

Appendix Table A1: State-level Estimates of Effects of MMLs on College Students' Time Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)					
	OLS			Poisson		
MML	-23.51 (15.63)	-46.45* (26.62)	-56.30* (31.10)	-0.151 (0.096)	-0.429* (0.228)	-0.500** (0.236)
pre-*MML* avg.	106.4					
	Time Spent on Leisure (Minutes)					
	OLS			Poisson		
MML	-7.63 (18.80)	24.67 (24.24)	24.06 (29.00)	-0.046 (0.106)	0.152 (0.126)	0.137 (0.147)
pre-*MML* avg.	170.0					
Time Trends	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Observations	9,916	9,916	9,916	9,916	9,916	9,916

Notes: The estimates are from OLS regressions in which the dependent variables are state-level average minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific time trends, and policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization. Control variables include age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and metropolitan status. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

Appendix Table A2: OLS Estimates of MMLs' Impact on College Students' Time Use by Enrollment

	(1)	(2)	(3)	(4)	(5)	(6)
	Time Spent on Education (Minutes)		**Pr (Time Spent on Education > 0)**		**Time Spent on Education > 0 (Minutes)**	
	Part-time	Full-time	Part-time	Full-time	Part-time	Full-time
MML	-58.04***	0.92	-0.174***	0.017	-50.83	-3.09
	(11.06)	(21.92)	(0.048)	(0.055)	(35.28)	(27.59)
pre-*MML* avg.	66.7	136.8	0.31	0.47	212.9	292.4
Observations	3,886	6,030	3,886	6,030	1,254	2,870
	Time Spent on Leisure (Minutes)		**Pr (Time Spent on Leisure > 0)**		**Time Spent on Leisure > 0 (Minutes)**	
	Part-time	Full-time	Part-time	Full-time	Part-time	Full-time
MML	66.77***	7.16	0.066*	0.031	58.60***	6.01
	(15.22)	(17.91)	(0.037)	(0.040)	(17.29)	(27.61)
pre-*MML* avg.	155.2	174.6	0.84	0.83	184.0	209.7
Observations	3,886	6,030	3,886	6,030	3,299	5,048

Notes: The dependent variables are minutes spent in education-related activities and minutes spent in leisure activities in columns (1) – (2), dummy variables indicating any positive time spent in these activities in columns (3) – (4), and minutes spent in these activities conditional on positive time. All models contain state and year fixed effects, state-specific time trends, month and day of week fixed effects, an indicator for holidays, and policy indicators for non-smokable medical marijuana laws, marijuana decriminalization, and marijuana legalization. Control variables include age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and metropolitan status. Standard errors in parenthesis are clustered by state. *** p < 0.01. ** p < 0.05. * p < 0.10.

Appendix Table A3: Estimates of Effects of Marijuana Legalization on College Students' Time Use

	(1)	(2)	(3)	(4)
	Time Spent on Education (Minutes)		**Time Spent on Leisure (Minutes)**	
MML	-0.221** (0.109)	-0.158 (0.111)	0.197*** (0.042)	0.276*** (0.050)
Legalization	-0.078 (0.367)	-0.074 (0.370)	-0.240* (0.125)	-0.234* (0.124)
Home Cultivation × MML		-0.113 (0.228)		-0.154** (0.060)
Active Dispensary × MML		-0.119 (0.129)		-0.058 (0.095)
Observations	9,916	9,916	9,916	9,916

Notes: The estimates in columns 1 and 3 are from the same regressions as column 5 of Table 4, and the estimates in columns 2 and 4 are from the same regressions as columns 3 and 6 of Table 9. The estimates are from Poisson models in which the dependent variables are minutes spent in education-related activities and minutes spent in leisure activities. All models contain state and year fixed effects, state-specific quadratic time trends, diary-month and days-of-week fixed effects, an indicator for holidays, policy indicators for non-smokable medical marijuana laws and marijuana decriminalization, and student characteristics: age, gender, race (Whites, Blacks, Hispanics), fulltime enrollment, and living in metropolitan. Standard errors in parenthesis are clustered by state. *** $p < 0.01$. ** $p < 0.05$. * $p < 0.10$.

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

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