Marijuana Legalization, Underage Marijuana Use, and Educational Outcomes: Evidence from Oregon[*]

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Abstract

Since 2012, 22 states have legalized recreational marijuana for adults 21 and older. This paper examines whether there are negative spillovers on underage use and educational outcomes. Using difference-in-differences and instrumental variables strategies, I exploit plausibly exogenous spatial and temporal variation in access to marijuana after legalization in Oregon. Overall, my estimates suggest that self-reported access to marijuana did not change, but that marijuana use increased, particularly for 11th-grade girls. Additionally, I find that high school chronic absenteeism increased, and that dropout rates and ELA achievement for high school girls rose and fell, respectively.

Keywords: marijuana legalization, substance use, underage marijuana use, educational attainment, dropouts, chronic absenteeism

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1 Introduction

The legal marijuana market has exploded in the past decade. 22 states have legalized recreational marijuana, and 20 of them have established retail markets that are currently operational or will become operational later this year. The other two, Virginia and Delaware, have plans to open recreational dispensaries in 2024. The Urban Institute estimates that marijuana excise taxes brought in around $3 billion in 2022 alone, which does not include local or general sales tax revenue. In the states that impose these excise taxes, marijuana tax revenue was 0.3-1.7% of their total state tax revenue.[1] As more states consider whether to legalize, it is important for policy makers to understand what other consequences may arise from legalization.

While marijuana laws differ considerably across states, they all have one thing in common: the legal age of consumption is 21. This does not mean, however, that legalization cannot affect people under 21. Underage use may either go up or down depending on how easily young people can access marijuana after it is legal or whether legalization changes the stigma associated with using it. Changes in marijuana use can affect a wide range of behaviors, including how well kids do in school.

Estimating the causal effect of marijuana legalization on underage use and educational outcomes is difficult for a few reasons. First, demand for marijuana is likely higher in places that decide to legalize it. Second, there could be unobserved heterogeneity in both attitudes toward underage use and schooling that are somehow related to the decision to legalize. Either of these would bias simple comparisons of underage marijuana use and educational outcomes across places where marijuana is legal and illegal.

[1] See Cannabis Taxes at Cannabis Taxes | Urban Institute.

To solve this endogeneity problem, I use two complementary identification strategies that rely on spatial and temporal variation in access to marijuana resulting from recreational marijuana legalization in Oregon. After Oregon legalized recreational marijuana in 2014, it allowed counties that voted against the legalization measure by at least 55% to opt out. I first use a difference-in-differences estimation strategy, where I compare the counties that opted out with those that did not before versus after legalization. The key identifying assumption is that legalization created plausibly exogenous variation in access to marijuana across the vote-share threshold that is unrelated to the latent demand for marijuana as well as unobserved attitudes toward underage use and education. As a robustness check, I assess for parallel trends and find that outcomes follow similar trends in counties above and below the 55% threshold in the pre-legalization period.

I find that self-reported access to marijuana from the Oregon Student Wellness and Oregon Healthy Teens surveys did not change in a statistically significant or economically meaningful way after legalization. However, I do find that marijuana use increased, specifically for 11th-grade girls. The probability that 11th-grade girls used marijuana in the past month increased by 4.1 percentage points (22%). In addition, the number of times they used marijuana in the past month increased by 0.27 (26%).

In line with the literature on substance use and educational outcomes, I find that legalization not only leads to more marijuana use, but also worse student behavior and academic performance, with larger effects for girls. Using data on high schools from the Oregon Department of Education, I find that chronic absenteeism increased by 2.92 percentage points (12%) across all students after legalization. I also find that dropout rates increased by about 1 percentage point for

girls, a one-third increase. Additionally, while proficiency in math did not change, the proportion of 11th-grade girls who are not proficient in ELA rose by 3.22 percentage points (12%).[2]

To complement these difference-in-difference models, I use a second identification strategy that takes into account *within*-county variation in access to marijuana. Specifically, I use an instrumental variable approach to estimate the effects of open marijuana dispensaries on marijuana use and educational outcomes, where the drive time to a pre-existing marijuana dispensary is my instrument for the time to an open one. Like the difference-in-differences estimates, the IV estimates suggest that underage marijuana use goes up and educational outcomes decline after recreational marijuana legalization.

There is a small but growing literature in economics examining the effects of both medical and recreational marijuana legalization on access to marijuana and underage use. These papers have found varying effects of legalization in both magnitude and sign. For instance, Anderson, et al. (2015) find a small, insignificant decrease in the probability of marijuana use after medical marijuana legalization, while Wen, et al. (2015) find an increase.[3] Cerda, Wall, et al. (2017) find an increase in marijuana use in Washington (but not Colorado) after recreational legalization, while Dilley, et al. (2019) show that teen marijuana use in Washington fell. Additionally, Rusby, et al. (2018) find that marijuana use in a small sample of Oregon schools increased after legalization.

These papers do not, however, attempt to estimate whether there are any subsequent effects of legalization on educational outcomes, despite the well-documented negative relationship between substance use and educational attainment. Following Grossman (1972), many empirical

[2] I do find a small, statistically significant effect on dropout rates for boys.

[3] There are also conflicting results about access, use, and perceived riskiness in work by Khatapoush & Hallfors (2004), Wall, et al. (2011), Lynne-Landsman, et al. (2013), Harper, et al. (2012), Choo, et al. (2014), Schuermeyer, et al. (2014), and Cerda, Sarvet, et al. (2018).

papers in economics and public health estimate the effects of alcohol, tobacco, and marijuana use on student outcomes. For example, Chatterji (2006) finds that past-month marijuana use in 10th and 12th grades decreases the number of years of education completed by age 26, and McCaffrey, et al. (2010) find that marijuana use is associated with higher dropout rates.[4] Other work includes Yamada, et al. (1996), Bray, et al. (2000), Register, et al. (2001), and Roebuck, et al. (2004), among others.[5]

There are several explanations for this negative relationship. One is that marijuana use leads to changes in brain chemistry and harms cognitive development. Studies like Pope, et al. (1995) and Lisdahl, et al. (2013) show that using marijuana in adolescence negatively impacts cognition, memory, attention, IQ, and abstract reasoning skills. Research in neuroscience, including Jacobus & Tapert (2014), Washington State University (2014), Weir (2015), and Frontiers (2018), shows that female brains are affected more by marijuana use than male brains, leading to short-term memory loss, anxiety, depression, and a greater probability of addiction, particularly for females. Another possible explanation is that marijuana use may indirectly affect educational outcomes by affecting other substance use and increasing criminal behavior, as shown in Ellickson, et al. (1992), Kandel, et al. (1992), DeSimone (1998), Brook, Balka, & Whiteman (1999), Green & Ritter (2000), Brook, Lee, Brown, et al. (2011), Brook, Lee, Finch et al. (2013), and Epstein, et al. (2015).

Both this paper and another I have written, Jarrold-Grapes (2023), seek to tackle the question of whether marijuana legalization affects educational outcomes. Jarrold-Grapes (2023)

[4] McCaffrey, et al. (2010), however, find that much of this effect is explained away by family influence and peer effects in grade 8-10, as well as cigarette use. Similarly, Mokrysz, et al. (2016) finds that cigarette use mitigates the effect of marijuana on the IQ and educational performance of English students.

[5] See also Lynskey & Hall (2000), Ryan (2010), and Beverly, et al. (2019) from the sociology and public health literatures.

exploits a lottery in Washington state that generated random variation in access to marijuana dispensaries and, like this paper, finds a negative effect on student behavioral outcomes. What sets this paper apart is that I can estimate first-stage effects on marijuana use instead of relying on an assumption that use changes after legalization. I can also say something about possible mechanisms driving changes in use because the Oregon Student Wellness and Healthy Teens surveys ask students where they typically get marijuana and the risk associated with using it. Additionally, it is important to study legalization in multiple states because states implement their laws quite differently. Unlike Washington, Oregon earmarks a large amount of marijuana tax revenues for education purposes. These tax revenues could offset some of the harm legalization does to students depending on how they are spent. I estimate the effects of legalization on school spending to shed some light on this question.

The rest of the paper is organized as follows. In the next section, I describe legalization in Oregon and the variation I leverage for identification. I discuss the data in section 3 and my empirical model in section 4. I present results in section 5, robustness in section 6, extensions in section 7, and discuss mechanisms in section 8. Finally, I conclude.

2 Background on Marijuana Legalization in Oregon

Oregon has a long legislative history related to marijuana. In 1973, Oregon decriminalized the possession of small amounts of marijuana. Then, in 1998, voters passed Measure 67, which legalized the cultivation, possession, and use (but not the sale) of marijuana for medical purposes and established the Oregon Medical Marijuana Program (OMMP). After a few failed attempts, Oregon lawmakers approved sales from medical dispensaries in 2012. Due to local moratoriums, however, the first medical marijuana dispensary licenses were approved in March of 2014. See the appendix for more details about the OMMP.

Oregonians originally voted to legalize marijuana for recreational use in 1986 (Measure 5) and again in 2012 (Measure 80), but both measures were unsuccessful. Then, in November of 2014, they passed Measure 91 with a 56% majority vote, thereby legalizing the possession, use, and sale of recreational marijuana for adults ages 21 and older. Beginning in July 2015, users could possess small amounts of marijuana in various forms.[6] Additionally, Measure 91 gave regulatory power to the Oregon Liquor Control Commission (OLCC).[7] I discuss the OLCC's responsibilities in the appendix.

Recreational marijuana sales began in October 2015 out of existing medical marijuana dispensaries and were subject to a 25% sales tax starting in January 2016. This tax only applied to recreational sales out of medical dispensaries; medical sales remained tax free. The OLCC began to accept applications for recreational dispensaries at the beginning of 2016, and sales out of these new dispensaries began in October 2016. Sales from recreational dispensaries are taxed at 17%. In addition, cities and counties can institute a 3% tax with voter approval. Beginning in December 2016, medical dispensaries were required to apply for recreational licenses if they intended to keep selling to recreational customers.

The state's tax revenue from marijuana sales is distributed to several entities: 40% of revenues are earmarked for education, 20% go to the Mental Health Alcoholism and Drug Services Account, 15% are for state law enforcement, 10% each to cities and counties based on their population and number of licensees, and 5% for alcohol and drug abuse prevention, intervention, and treatment services. The 40% for education goes to the State School Fund, which is distributed

[6] Specifically, eight ounces of usable (dried) marijuana, one ounce of cannabinoid extracts or concentrates, 16 ounces of cannabinoid products in solid form and 72 ounces in liquid form, ten marijuana seeds, and four plants at home. These limitations apply to public possession as well, though dried marijuana is limited to one ounce in public instead of eight.

[7] Now the Oregon Liquor and Cannabis Commission.

to school districts in the form of several grants: facility, transportation, high-cost disabilities, and general purpose. Grant amounts are calculated using the state's school funding formula. Marijuana tax revenues help fund the general-purpose grant, which flows into school districts' general funds and can be used for any legal purpose.[8]

Though Measure 91 legalized marijuana statewide, localities were given the option to ban licensed producers, processors, wholesalers, and retailers from operating within their borders. Before 2016, counties with at least 55% of votes against legalization could opt out without an additional vote, and cities within these counties could also implement bans. 15 of the 36 counties in Oregon opted out and 48 cities within these counties did so as well.[9] Figure 1 shows the counties that voted against legalization with at least 55% of votes and opted out in white. All counties that could opt out did so. The counties with a 50% majority against legalization, but that were not allowed to opt out, are in light green. Counties with less than 50% against legalization are in dark green. Starting in 2016, any locality, regardless of how it voted on Measure 91, could vote to opt out or opt back into legalization. Currently, there are 15 counties and 81 cities banning marijuana retail businesses.[10] Importantly, only localities that allow marijuana sales receive state tax revenues.

Total marijuana sales have steadily increased since legalization, which is shown by the dark green line in Figure 2. Sales were roughly $2.5 million in October of 2016 and peaked in July

[8] Information is from my correspondence with the Assistant Superintendent for Research for the Oregon Department of Education's Office of Child Nutrition, Research, Accountability, Fingerprinting, and Transportation.

[9] These counties are Baker, Crook, Gilliam, Grant, Harney, Jefferson, Klamath, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, and Wheeler. 48 cities within these counties banned as well (League of Oregon Cities, Local Government Regulation of Marijuana in Oregon).

[10] Marion and Douglas counties voted to ban in 2016, while Gilliam voted to remove its ban (Oregon Liquor Control Commission, Record of Cities/Counties Prohibiting Licensed Recreational Marijuana Facilities). 28 cities in counties that had voted in favor of Measure 91 decided to ban in 2016, and another 5 banned in 2018 (The Oregonian, Oregon Marijuana Measures; Withycombe, "Six Oregon Cities Vote to Allow Marijuana Business"). Grant County repealed its ban on marijuana in 2018 (Hanners, "Recreational Marijuana Industry to Expand in Grant County").

2020 at roughly $99 million.[11] Recreational sales follow a similar trend. The medium green line shows that recreational sales went from $2 million in October 2016 to over $88 million in April 2021. Medical sales are in light green.[12] These stayed relatively constant at about $5 million through 2019, increased to just over $10 million by June 2020, then slowly declined to about $7 million by September 2021. In addition to sales, Figure 2 shows the median price per gram of recreational, smokable marijuana in blue. The median price per gram was $10.50 in October 2016 and has declined over time to less than $4.50 in September 2021. Since prices are going down and sales are going up, the quantity of marijuana products sold must also be increasing. Assuming that people are actually using the marijuana they are buying, these data suggest that (legal) marijuana use has been increasing significantly since legalization. However, these trends are not necessarily indicative of *teen* marijuana use, nor do they capture use prior to legalization. I use data from two surveys of Oregon youth to shed light on their marijuana use both before and after legalization.

3 Data

3.1 Teen Marijuana Access and Use

Illegal substance use is notoriously difficult to measure. Before states decided to legalize marijuana, researchers had to rely solely on self-reported illicit marijuana use, which is subject to measurement error. People may not be truthful when answering questions about their drug use when the drug is illegal. After legalization, sales records can be used to proxy for marijuana use, though sales are not necessarily good measures of *underage* marijuana use, which remains illegal.

[11] Dispensaries were considered essential businesses during the Covid-19 pandemic.
[12] Medical sales are purchases made with medical marijuana cards issued through the OMMP. Note that distinguishing sales as recreational or medical does not necessarily indicate the purpose for which an individual consumer uses marijuana, i.e., marijuana purchased with a medical marijuana card could be used for recreational purposes and marijuana purchased without a medical marijuana card could be used for medical purposes.

Because I am examining the effects of legalization on underage marijuana use, I have to rely on self-reported data.

These data, which include measures of marijuana accessibility and use, come from the Oregon Student Wellness (OSWS) and Oregon Healthy Teens (OHTS) surveys. Both surveys are administered by the Oregon Department of Education (ODE) in conjunction with the Oregon Health Authority (OHA) to assess overall student health and school climate. They are given to students in school by their teachers in the spring semester. The OSWS is given in even years and the OHTS in odd years, so I pool the data to have a more continuous time series that includes the 2009-10 school year and the 2011-12 through the 2018-19 school years. Additionally, the OSWS is administered to 6^{th}, 8^{th}, and 11^{th} graders, while the OHTS is given to 8^{th} and 11^{th} graders. In this paper, I focus only on 11^{th} graders. Doing so allows me to better capture the cumulative effects of using marijuana. In addition, 11^{th}-grade marijuana use is probably more closely related to student drop-out decisions, one of my outcomes of interest, than use in 8^{th} grade. My sample includes about 126,000 11^{th} graders across the entire sample period.

Students are asked questions about how easy it is for them to get marijuana, whether they used marijuana in the past month, and how many times they used it in the past month.[13] They also record their ethnicity and gender, which I use as controls in my model. The questions about marijuana use are identical, and those about access are similar, to those used in the Monitoring the Future (MTF) survey sponsored by the National Institute on Drug Abuse (NIDA) and the questionnaires used in the Centers for Disease Control and Prevention's (CDC) Youth Risk Behavior Surveillance System (YRBSS). Numerous validation studies have been conducted to

[13] Table A1 in the appendix lists the specific questions from each survey.

assure that the questions in the YRBSS provide reliable information on teen substance use.[14] In addition to the YRBSS-specific validation studies, there are also many others that examine the relationship between adolescent self-reported marijuana use and clinical measures of use, like the amount of THC present in urine and hair samples. These studies generally show a moderate to high correlation between reported and clinical use.[15] Some also find stronger correlations when teens are asked about marijuana use in more recent periods, like the past few days rather than the past few weeks. However, this could be due to the frequency of use leading up to the test. THC is more likely to be detected by these tests for frequent users rather than, say, the person who smoked once or twice several weeks before the test.[16]

Additionally, each Oregon study conducts internal honesty and logic checks and discards surveys where students are likely not telling the truth. See the appendix for more detailed information on the survey methodologies, response rates, and honesty checks.

3.2 Educational Outcomes

The ODE provides publicly available, school-level data on dropout rates and chronic absenteeism. Dropouts are students who either dropped out of school and did not re-enroll at any point during the year or who completed the previous school year but did not enroll in the current year though they were expected to do so. The dropout rate is defined as the ratio of dropouts to the number of students enrolled in high school in the fall of the current school year. The chronic absenteeism rate is the percentage of students who missed 10% or more of the days they were

[14] Morbidity and Mortality Weekly Report: Methodology of the Youth Risk Behavior Surveillance System, Centers for Disease Control and Prevention.
[15] Folk, et al. (2022), Boykan, et al. (2019), Dembo, et al. (2015), and Buchan, et al. (2002).
[16] Folk, et al. (2022).

enrolled in school. Both outcomes are available from the 2012-13 through the 2018-19 school years, and dropout rates are available by gender.

Student test score data is also available at the school level from the ODE. The proportions of 11th-grade students who did not meet, nearly met, met, and exceeded standards in math and ELA are available by gender from 2014-15 through 2017-18. Specifically, I examine the effects on the proportions of girls and boys who score below proficient on these tests, i.e., those who nearly met or did not meet the proficiency standards. Additionally, the ODE has information on student race, ethnicity, disability status, and free-or-reduced-price lunch eligibility, which serves as a proxy for student economic disadvantage. I use these student characteristics to control for differences within schools over time.[17]

The analysis sample includes over 200 high schools each year. I exclude charter schools because they typically draw students from multiple counties, especially if they are virtual, which makes it unclear whether they were treated by legalization.

4 Empirical Methodology

If marijuana use among teens was randomly assigned, then its causal effect on student outcomes would be given by the OLS estimate of β_1 in the following equation:

$$Y_{it} = \beta_0 + \beta_1 M_{it} + \varepsilon_{it} \quad (1)$$

where i is students, t is time, Y is the student outcome of interest, M is marijuana use, and ε is a random error term. However, there is likely unobserved heterogeneity in marijuana use across students, potentially in terms of risk aversion and time preferences, that could be correlated with

[17] To preserve student confidentiality, some variables are suppressed for schools with fewer than ten students and are coded as "less than 1%," "less than 5%," "greater than 95%," or "greater than 99%." I recode these as exactly 1%, 5%, 95%, or 99%.

educational outcomes and yields $cov(M_{it}, \varepsilon_{it}) \neq 0$. The OLS estimate of β_1 in this case is biased and no longer has a causal interpretation.

One way to deal with this challenge to identification is to find a situation that creates random variation in marijuana use and use this as an instrument for *M* in equation (1). One such instrument is recreational marijuana legalization, assuming that this policy changes access to marijuana and thus use. Since legalization varies across counties and time in Oregon, I consider *Legal x Post* as an instrument for marijuana use. *Legal* is a binary variable equal to one for counties that voted in favor of Measure 91 by over 45%, and *Post* indicates years after the marijuana sales market opened.[18]

However, the data on marijuana use and educational outcomes come from two separate data sets that are at different units of analysis, so I cannot use this exact estimation method. Instead, I estimate the effects of legalization on marijuana use (the "first stage") and educational outcomes (the "reduced form"). The ratio of the reduced form to the first stage provides an approximation of the IV estimate of β_1 from equation (1).[19]

The first stage is given by the following equation:

$$M_{ict} = \delta_0 + \delta_1 (Legal\ x\ Post)_{ct} + \delta_2 X_{it} + \alpha_c + \theta_t + \mu_{ict} \qquad (2)$$

where *i*, *c*, and *t* index students, counties, and years, respectively. The dependent variable, *M*, is either a binary variable indicating whether the student thinks it is easy to access marijuana, a binary indicator for whether the student used marijuana in the past month, or the number of times a student

[18] Another strategy would be to use a regression discontinuity design and compare outcomes in counties just above and just below the 55% vote-share threshold. While I originally considered this method, I ultimately decided to use a difference-in-differences method because there is not enough variation to estimate local treatment effects. There are 36 counties in Oregon, and, if I consider a range of five percentage points on either side of the threshold, there are only five right below and five right above 55%. It would be difficult to test the assumptions needed for an RDD with so few observations, thus, I use the more global DiD approach.

[19] As an extension, I use a two-sample instrumental variables strategy to estimate the effects of marijuana use on educational outcomes in section 8.

used marijuana in the past month. *Legal* is 1 for counties with over 45% of votes in favor of legalization, and 0 for those with at least 55% against it. *Post* is 1 after marijuana sales began in October 2015 and 0 before. The interaction of *Legal* and *Post* is my variable of interest. *X* is a vector of time-varying student characteristics, which includes gender and ethnicity. α_c and θ_t are fixed effects to control for idiosyncrasies across counties and time, respectively, and μ_{ict} is the random student-by-county-by-year error term. Standard errors are clustered by county. Since I am pooling data from the OSW and OHT surveys, I use the provided county enrollment weights. Assuming that the $cov[\mu_{ict}, (Legal\ x\ Post)_{ct} | X_{it}, \alpha_c, \theta_t] = 0$, $\widehat{\delta_1}$ is the causal estimate of the effect of recreational marijuana legalization on 11th-grade marijuana access and use.

The reduced form regression of legalization on educational outcomes is the following:

$$Y_{sct} = \beta_0 + \beta_1 (Legal\ x\ Post)_{ct} + \beta_2 X_{st} + \gamma_s + \theta_t + \omega_{sct} \quad (3)$$

where *s*, *c*, and *t* index schools, counties, and years, respectively. *Y* represents dropout rates, chronic absenteeism, and non-proficiency rates. Again, *Legal* is 1 for counties with over 45% of votes in favor of legalization, and 0 for those with at least 55% against it, and *Post* is 1 after marijuana sales began in October 2015 and 0 before. *X* is a vector of school-level student characteristics that possibly change over time, such as the proportion of students who are considered disabled, economically disadvantaged, Hispanic, Black, or Asian. The fixed effects γ_s and θ_t control for unobserved differences across schools and time, respectively. ω_{sct} is the random school-by-county-by-year error term. Standard errors are clustered by county. Like equation (2), the interaction of *Legal* and *Post* is my variable of interest, and assuming that the $cov[\omega_{sct}, (Legal\ x\ Post)_{ct} | X_{st}, \gamma_s, \theta_t] = 0$, the estimate of β_1 is the causal effect of recreational marijuana legalization on student outcomes.

Given the new literature on difference-in-differences, I implement the Wooldridge (2021) method to check whether multiple time periods and time-varying covariates are biasing the two-way fixed effects estimates of equations (2) and (3). This method adds interactions to the standard two-way fixed effects model to control for heterogenous treatment effects across covariates and time. The results, in appendix Tables A2 and A3, show minimal changes to the estimates of equation (2) and large changes to the estimates of equation (3), specifically for girls' ELA scores and dropout rates. Despite these changes, the results from the Wooldridge method are qualitatively similar to the two-way fixed effects estimates.

The primary identifying assumption of these difference-in-differences models is that marijuana use and educational outcomes would have followed the same trends in counties that opted out and counties that did not if recreational marijuana had not been legalized. Though I cannot test this assumption directly because I do not observe outcomes in absence of legalization, I assess for parallel trends, conditional on covariates, prior to the sales market opening in my robustness checks. Parallel trends would allow that outcomes in counties above and below the 55% vote-share threshold could have continued along similar trends if Measure 91 had not been passed.

5 Main Results

It is well-documented in the public health literature that substance use varies by gender. Generally, more boys than girls tend to use substances, and this pattern holds true for teenage marijuana use.[20] In addition, male and female brains react differently to THC, as shown in the neuroscience literature I discussed previously. As such, I present my estimation results disaggregated by student gender.

[20] National Institute on Drug Abuse Report on Sex and Gender Differences in Substance Use (2021); Cuttler, et al. (2016), Schepis, et al. (2011); and Butters (2005).

The tables of results include marginal effects and standard errors clustered by county, as well as one-tailed p-values from the original estimation and one-tailed Romano-Wolf p-values. I implement the Romano-Wolf correction for multiple hypotheses because I use the same model to estimate the effects of legalization on several outcomes.

5.1 Marijuana Access and Use

When I estimate equation (2) separately by gender, I find that girls think it is somewhat easier to get marijuana after legalization while boys think it is slightly more difficult. The marginal effect for girls is 0.0248 (0.0222), and the one-sided p-value is 0.133, as shown in Table 1, column (1). This is an increase of about 4% from the pre-legalization average of 63%. For boys, the marginal effect is -0.0198 (0.0221) with a one-sided p-value of 0.185 (column (2)). Relative to the pre-legalization average, 67%, this is a decrease of 3%.

Though access to marijuana did not increase in a statistically significant or economically meaningful way after legalization, marijuana use did. The likelihood that 11th-grade girls used marijuana in the past month increased by 4.1 percentage points on a base of 19%, which is a 22% increase (Table 1, column (3)). For boys, the probability of past-month marijuana use only increased by 0.41 percentage points relative to the 22% average (column (4)). This is less than a 2% increase. I can reject the null hypothesis that marijuana use does not change after legalization in favor of the alternative that it increases at the 1.1% level for girls and the 41% level for boys. After accounting for multiple hypothesis testing, the effect on girls' marijuana use remains statistically significant at the 5% level.

Not only are 11th-grade girls more likely to use marijuana after it is legalized, but they also choose to use it more frequently. Column (5) of Table 1 shows that girls used marijuana 0.2749 (0.1232) more times after legalization, which is a 25% increase from the pre-period average of

1.04. Boys used it 0.0338 (0.1236) more times, which is a 2% increase relative to a base of 1.59 (column (6)). One-sided p-values are 0.013 and 0.392 for girls and boys, respectively. The former is significant at the 5% level after implementing the Romano-Wolf correction.[21] [22]

5.2 Student Behavior

Given that marijuana use increased after legalization, I examine whether legalization changed student behavior. Specifically, I estimate equation (3) for dropout rates and chronic absenteeism. Table 2 shows results for chronic absenteeism across all students, as absenteeism data is not available by gender, and dropout rates for boys and girls separately. Column (1) shows that the marginal effect of legalization on chronic absenteeism is 0.0292 (0.0134), which is statistically greater than zero at the 1.8% level and stays significant at the 5% level after correcting for multiple hypothesis testing. This is a 12% increase from the pre-period average of 24%. To put this in perspective, before legalization the average high school had 715 students, 171 of whom were chronically absent. A 12% increase means that an additional 20 students were chronically absent from school after legalization.

Column (2) shows that the dropout rate for girls increased by 0.97 percentage points from the 3% average, which is a 32% increase. For boys, the dropout rate increased by 0.69 percentage points relative to the pre-legalization average of 4%, a 17% increase (column (3)). Both effects are statistically greater than zero at the 5% level of significance and remain so when I implement the Romano-Wolf correction.[23] Again, to put this in perspective, consider the average high school

[21] I use the six specifications in Table 1, and 100 bootstrap replications, to calculate the Romano-Wolf p-values.
[22] Dispensaries in Washington state opened in July 2014. Cross-border sales could bias the estimated effects of legalization in Oregon. When I exclude counties on the Oregon-Washington border, the effects on girls' marijuana use decrease but remain large and statistically significant. See table A6 in the appendix.
[23] I use the first three columns in Table 2 and 100 bootstrap replications to compute the Romano-Wolf p-values for chronic absenteeism and dropout rates.

cohort, which had about 170 students – 83 girls and 87 boys. On average, 2 girls and 3 boys dropped out prior to legalization. A 32% increase for girls and a 17% increase for boys means that at most 1 additional girl and 1 additional boy dropped out after legalization.

It is possible that legalization is not the only thing that affected student behavior during this time. The Oregon state legislature passed Senate Bill 1532 in February 2016, which outlined annual minimum wage increases between July 2016 and July 2022. Different areas in the state were subject to different minimum wage increases, and generally, the counties that did not opt out after legalization were those with more generous increases. This could mean that students in these counties, more so than those in the opt-out counties, might have decided to work instead of going to school. Thus, the changes in absenteeism and dropout rates could reflect these differential minimum wage changes instead of legalization. I check the robustness of my results to the minimum wage by including it as a regressor in equation (3). The results, as well as a chart of the wage changes, are in the appendix (Tables A4 and A5). The estimates fall slightly with the inclusion of the minimum wage, but the results are qualitatively the same: legalization leads to large increases in absenteeism and dropout rates for high school girls.[24]

5.3 Academic Performance

I also estimate the effect of legalization on student performance in math and ELA. Given the results for behavioral outcomes, I focus on students at the bottom of the test score distribution. These students either "did not meet" or "nearly met" grade-level standards on end-of-grade tests. In other words, they are "not proficient."[25]

[24] When I exclude counties on the Oregon-Washington border, the effects on chronic absenteeism and girls' and boys' dropout rates increase. See table A7 in the appendix.

[25] Statewide assessments changed in 2014-15. These changes do not affect my results because I use test score data from 2014-15 through 2017-18, the years the data is available by student gender.

Table 2, column (4) shows that the marginal effect of legalization on the proportion of 11th-grade girls who are not proficient in math is 0.0152 (0.0151). The one-sided p-value is 0.161 and I cannot reject the null hypothesis that the effect is zero. The proportion of 11th-grade boys who are not proficient in math fell by 0.0027 (0.0260), which is also statistically insignificant at the standard levels (column (5)). In column (6), the marginal effect on the proportion of 11th-grade girls who are not proficient in ELA is 0.0322 (0.0160). This is a 12% increase from the pre-legalization average of 28%. I can reject that the null is zero in favor of the alternative hypothesis that the effect is positive at the 2.6% level, and at the 5% level when I correct for multiple hypothesis testing.[26] For 11th-grade boys, the same proportion fell by 0.0136 (0.0296), which is a 4% decrease from the pre-period average of 38% (column (7)). The one-sided p-value is 0.324. Overall, performance in math did not change in a statistically significant way after legalization, while performance in ELA worsened, particularly for girls.[27]

6 Parallel Trends

The identifying assumption in these models is that the outcomes in counties that opted out and did not opt out would have followed parallel trends in absence of legalization. Though this is not directly testable, I can examine the outcomes across counties before legalization for parallel trends. If the outcomes did *not* follow similar trends in the pre-period, then my estimates may reflect differences in underlying characteristics across opt-out and non-opt-out counties instead of the effects of legalization. Figure 3 shows average marijuana access and use for counties where marijuana businesses were banned (black) and allowed (green). For all outcomes, the figures

[26] I use columns 4-7 in Table 2 and 100 bootstrap replications to calculate the Romano-Wolf p-values for the shares of students not proficient in math or ELA.
[27] When I exclude counties on the Oregon-Washington border, the effect on girls' proficiency in ELA does not change. See table A7 in the appendix.

indicate that counties followed similar trends in the pre-period. Figure 4 shows average dropout rates and chronic absenteeism over time. The trends before legalization were somewhat similar, though not as convincing as those in Figure 3, particularly for dropout rates. Since the proficiency data is only available in one year during the pre-period, I cannot check parallel trends visually for those outcomes.

In addition to this visual inspection, I do two more formal checks for pre-existing parallel trends. First, I perform a pseudo difference-in-differences using only the pre-period years. I make 2014 and 2015 the pseudo-post years and the years prior to, and including, 2013 the pseudo-pre years then re-estimate equations (2) and (3). If the parallel trends assumption holds, then the coefficient on *Legal x Post* should be statistically insignificant and near zero. In other words, I should find no effect of legalization prior to legalization. The results from this pseudo difference-in-differences are in Table 3. The first panel includes all students, and the second two panels break down the estimates by gender. Panel A, columns (1)-(3) show that marijuana access and use increase significantly in the pre-period, and panels B and C show that these effects are driven by 11th-grade boys. The effects on chronic absenteeism and dropout rates are not statistically significant, as shown in panel A, columns (4) and (5). Like marijuana access and use, there is an increase in boys' dropout rates before legalization (panel C, column (5)), but no change in girls' dropout rates (panel B, column (5)). These results indicate that there is potentially something confounding the estimates of legalization on the outcomes for high school boys, but that there is no evidence the parallel trends assumption is violated for high school girls.[28]

As a second check, I randomly assign vote-shares to counties and then re-estimate the models with *Legal* defined using these placebo vote-shares. I randomly assign vote-shares 100

[28] I cannot estimate a pseudo difference-in-differences for the shares of students not proficient in math or ELA because there is only one year of data available in the pre-period.

different times and estimate the models for each random draw. The averages of these effects are presented in Table 4, for all students and for girls and boys separately. A large, statistically significant result would indicate that the placebo treatment explains the differences I see after legalization, suggesting that the effects I find could instead be attributed to underlying differences in opt-out and non-opt-out counties. As Table 4 shows, most of the estimates are very small, with 95% confidence intervals that include zero.

Thus, the weight of the evidence suggests that the differences in marijuana use and educational outcomes after marijuana legalization are not due to underlying differences in the counties that opted out or did not opt out. The evidence is particularly strong for girls.

7 Extensions

I extend my analysis in several ways. First, I examine whether the effects of legalization change over time. Effects could increase as the marijuana market grows or dissipate as it becomes less novel. Generally, I find that the medium-run effects of legalization appear larger than the short-run effects (appendix Tables A8 and A9). Second, I estimate the effect of marijuana use on educational outcomes using a two-sample instrumental variables strategy. I find that chronic absenteeism increases with marijuana use, but that the effects on dropout rates and math and ELA performance are not statistically significant (appendix Table A10). Third, I examine whether legalization had different effects in poor and less poor schools, as measured by the percentage of free or reduced-price lunch eligible students, and in urban, suburban, and rural schools. I find that the effects of legalization appear to be concentrated in poor schools. It is less clear whether there are differential effects across school locations (appendix Tables A11 and A12). Finally, I estimate a drive-time model that takes into account more granularities in access to marijuana after legalization. The remainder of the section focuses on this model.

7.1 Drive-Time Model

For my analysis thus far, I have used a county-level measure of marijuana accessibility – the vote-share in favor of Measure 91 – to estimate the effects on marijuana use and educational outcomes. In doing so, I have treated everyone in a county that voted for legalization as having the same level of access to marijuana. However, this is not the case. Take Lane County for instance. As shown in Figure 1, Lane County voted for Measure 91. Map (a) in Figure 5 shows that Eugene, the county seat, has several marijuana dispensaries, making it easy for people who live in or near the city to get marijuana, but more difficult for those farther away. In this section, I develop a different measure of marijuana access that utilizes this within-county variation and estimate the effects on marijuana use and educational outcomes using this measure, as well as an instrumental variable identification strategy.

7.2 Drive-Time Data and Measures

Using the Google Distance-Matrix API, I find the drive-time between schools and marijuana dispensaries. The API allows me to input starting and ending addresses and it uses Google Maps to calculate seconds of drive-time and meters of drive-distance between the two locations. I use the API to find the drive-time between public high schools and the following three groups of marijuana dispensaries: recreational dispensaries open between October 2016 and May 2019, *pre-existing* medical dispensaries, and recreational dispensaries open in Washington prior to October 2015. Where dispensaries decide to open within a county is likely endogenous to unobserved demand for marijuana. Thus, I estimate the effect of open dispensaries on marijuana use and educational outcomes using the drive-time to a pre-existing medical dispensary or Washington dispensary as an instrument for the drive-time to one that opens.

The open dispensaries are those that opened at some point between October 2016 – when recreational licenses were first approved – and May 2019 – the last year in my sample – and stayed open throughout the entire period. Unfortunately, I do not have information on the dispensaries that opened and then closed within this timeframe, nor do I know the medical marijuana dispensaries that participated in early sales.[29]

The sample of medical marijuana dispensaries includes the 110 that had licenses approved prior to July 22, 2014, the day that Measure 91 was officially put on the ballot. These dispensaries were allowed to participate in the early sale of recreational marijuana beginning in October 2015 and could convert to selling recreational marijuana after October 2016, making them a relevant set of dispensaries to consider. Since they were established before Measure 91 was passed, their location choice is plausibly exogenous rather than a response to recreational legalization. Figure 5 shows the distribution of pre-existing dispensaries (pink squares) and public high schools (black circles) in map (a) relative to a snapshot of recreational dispensaries active at the start of 2020 in map (b). The maps show that there are fewer medical than recreational dispensaries, but they are concentrated in similar areas within counties.

In addition to the Oregon dispensaries, I include the 188 dispensaries that were open in Washington prior to the start of Oregon's early sales. According to Hansen, Miller, and Weber (2020), Oregonians bought marijuana in Washington before dispensaries opened in-state, and it is possible that teens in the counties bordering Washington had greater access to marijuana too.[30] While the drive-time to a Washington dispensary may not be a good predictor of the drive-time to

[29] I have requested this data from the OLCC and the OMMP.
[30] Hansen, et al. (2020) find that dispensaries in Washington had a 36% loss in sales after dispensaries began selling marijuana in Oregon.

an open dispensary in non-border counties, it likely is a good predictor for the border counties, especially around the Portland area, which is why I use them to construct my instrument.

For each school, I calculate the minimum amount of time it takes to get to an open dispensary, as well as the minimum time it takes to get to either a pre-existing medical dispensary or a dispensary in Washington. I use the minimum drive-time as a proxy for marijuana accessibility. While high schoolers are not necessarily driving themselves to dispensaries to purchase marijuana illegally, it is possible that they are able to get marijuana more easily from dealers, older friends, family members, etc. if their school is closer to one.

I keep the drive-time measures at the school level to estimate the effects on educational outcomes, but I have to aggregate up to the county level to estimate the effects on marijuana access and use. Specifically, I take the weighted average of the minimum drive-times across schools in a county, where the weights are 11^{th}-grade school enrollment. Figure 6 shows the weighted average of the minimum drive-time by county for open dispensaries (map (a)) and pre-existing ones (map (b)), where the darker shades of green indicate shorter drive-times. Not surprisingly, it generally takes less time to get to dispensaries, both pre-existing and open, in counties that did not opt out after legalization than in those that did.

7.3 Results

I estimate an instrumental variable model where the minimum drive-time to an open dispensary multiplied by a post-period indicator is instrumented for with the minimum drive-time to a pre-existing medical or Washington dispensary multiplied by the same post-period indicator. I exclude the 2015-16 school year from this analysis because recreational marijuana dispensaries opened in October 2016, and I do not have data on which medical marijuana dispensaries participated in early sales.

Instead of presenting the marginal effects, I present the marginal effects evaluated at the difference-in-means between counties that did and did not opt out. Specifically, I compute the weighted average of the minimum drive-time across counties above and below the 55% vote-share threshold and take the difference, then multiply this difference by the marginal effects. The weighted average in opt-out counties is 71.8 minutes while it is 9.3 minutes in non-opt-out counties, so I evaluate the marginal effects at the difference of 62.5 minutes. Tables 5 and 6 show the results. Note that a positive effect indicates an increase in the outcome when the drive-time *decreases* by 62.5 minutes. I interpret these results as what would have happened to marijuana use and educational outcomes in counties that opted out after legalization if the drive-time from schools to dispensaries was as short as that in counties that did not opt out.

The results for marijuana access and use are presented in Table 5. Column (1) shows that the probability that girls think getting marijuana is easy after legalization increases by 0.0212 (0.0005) when the drive-time to a dispensary decreases by 62.5 minutes. The probability that boys think getting marijuana is easy increases by 0.0089 (0.0006), as shown in column (2). Neither effect is statistically significant at the standard levels. Decreasing the average minimum drive-time increases the likelihood of past-month marijuana use by 0.0182 for girls and 0.0304 for boys, as shown in columns (3) and (4). The one-sided p-value is 0.242 for girls and 0.130 for boys. Column (5) shows that girls use marijuana 0.0412 (0.0009) more times in the past month when the drive-time falls, but this not statistically significant. Column (6) shows that boys use marijuana 0.0808 (0.0010) more times in the past month. The one-sided p-value is 0.094.[31]

Table 6 shows the results for educational outcomes. Note that I correct for spatial correlation of the errors using the Conley method. Column (1) shows that chronic absenteeism

[31] I cluster my standard errors by county. I cannot implement the Conley correction for spatial correlation because I do not have data on school location as part of the OSWS and OHTS data-use agreements.

increases by 0.0465 (0.0004) when average minimum drive-time between schools and dispensaries decreases by 62.5 minutes. This effect is statistically greater than zero at the 5% level. In columns (2) and (3), dropout rates for girls fall by 0.0017 and increase by 0.0005 for boys. Neither effect is statistically significant at the standard levels.

Column (4) shows that girls perform worse in math when the drive-time decreases. Specifically, the proportion of girls not reaching proficiency levels in math increases by 0.0453 (0.0008) when the drive-time falls by 62.5 minutes. The one-sided p-value is 0.182. The effect on math proficiency for boys is -0.0131 and not significant, as shown in column (5). The proportion of girls who do not reach proficiency in ELA increases by 0.0302 (0.0007) while the same proportion for boys decreases for boys by 0.0568 (0.0008), as shown in columns (6) and (7), respectively. The one-sided p-value for the former is 0.230 and is 0.122 for the latter.

While most of these estimates are not statistically significant, they do suggest that being closer to a marijuana dispensary makes marijuana more accessible, leads to greater use, worsens chronic absenteeism, and decreases girls' proficiency in math and ELA. With better data on the dispensaries that opened in Oregon (i.e., those that participated in early sales and a more complete set of dispensaries open over time), these results should be more precise and indicative of the full picture of legalization in Oregon.

8 Mechanisms

While I cannot test every possible mechanism that could be contributing to the changes in marijuana use and educational outcomes after recreational marijuana legalization, I can examine student risk-taking behavior, where students acquire marijuana, and school spending.

8.1 Risk-Taking Behavior

Previous research in psychology suggests that boys are more prone to taking risks than girls, which could help explain why boys are typically more likely to use substances than girls.[32] Indeed, the data from the OSWS and OHTS show that boys are less likely to perceive marijuana as risky and more likely to use marijuana, while girls are more likely to perceive it as risky and less likely to use it. Legalization could change how teens perceive the risk associated with using marijuana. If girls think using marijuana is less risky after legalization while boys' perceptions do not change, then this could explain why marijuana use increases for girls but not boys after legalization.

To test this hypothesis, I use data on the perceived risk of marijuana from the OSW and OHT surveys. Specifically, the surveys ask students how much they think people risk harming themselves (physically or in other ways) if they use marijuana at least once or twice a week.[33] I create a binary variable equal to zero if students say using marijuana regularly is not risky or slightly risky and one if students say it is moderately or greatly risky. Before legalization, the average probability that girls thought using marijuana was moderately or greatly risky was 56%, while it was 46% for boys. To determine whether risk perceptions changed after legalization in non-opt-out counties, I re-estimate equation (2) with the risk measure as the dependent variable. The results are in Table 7. Column (1) shows that legalization leads to a decrease in the probability of perceived riskiness of 0.0365 for girls, which is about a 7% decrease from the pre-legalization average. This is statistically different from zero at the 10% level of significance. Column (2), however, shows that boys' risk perceptions do not change. The coefficient on *Legal x Post* is

[32] Byrnes, et al. (1999) and Harris, et al. (2006).
[33] The SWS asks about smoking specifically, while the HTS asks about *using* marijuana. I treat these as the same questions for this analysis.

0.0037 and the two-tailed p-value is 0.864. These findings suggest that changing perceptions of risk are contributing to the differential changes in marijuana use for girls and boys after legalization.

8.2 Acquisition and Product Safety

It is possible that girls are less comfortable buying marijuana on the black market prior to legalization than boys. Buying from a dealer could be less safe than, say, getting marijuana from an older sibling after legalization, particularly for girls. Not only could the act of getting marijuana be safer after legalization, but the product itself is almost certainly better. Marijuana products are required to be tested for contaminants and are much less likely to be laced with other drugs and harmful substances, like alcohols, acetone, pesticides, and other chemicals, after legalization (see the appendix for more details). If girls are more concerned than boys about the possibility of smoking marijuana that is laced with contaminants, then it might be the case that they wait to use marijuana until this possibility is much lower, i.e., after legalization. Boys, however, might not wait. If this is the case, then it could partly explain why girls, but not boys, use more marijuana after legalization.

I cannot test this hypothesis directly because I do not have information on whether teens think getting marijuana is safe or whether they think the products they use are high-quality. However, starting in 2012, the OSWS asked the students who used marijuana in the past month where they got it. The choices given in the survey include the following: a public event like a sporting event or concert, a party, friends 18 or older, friends under 18, a family member, a medical marijuana cardholder or grower, I gave someone money to buy it for me, I grew it, I got it some other way. They are allowed to choose more than one option. On average, prior to legalization, girls and boys were most likely to get marijuana from their friends and at parties. I re-estimate

equation (2) for each source separately to see where girls and boys get marijuana after it is legal. The results are in Table 8. There are no statistically significant changes in where girls get marijuana after legalization, and only a couple significant changes for boys. Column (4) shows that boys are about 4 percentage points more likely to get marijuana from a public event and 12 percentage points less likely to get marijuana from older friends after legalization. Overall, it does not appear that differences in where boys and girls get marijuana after legalization are contributing to the differential changes in marijuana use.

8.3 Marijuana Tax Revenue for Schools

As I discussed earlier in the paper, early marijuana sales out of medical marijuana dispensaries were taxed at 25% by the state. Sales out of new recreational dispensaries are taxed at 17% by the state and can be taxed another 3% by counties and cities. Figure 7 shows marijuana tax receipts over time. The solid green line represents revenues from the state tax, while the green dashed line represents revenues from local taxes that are collected by the state on behalf of localities. Tax revenues increased from $2.5 to $8 million between February 2016 and October 2016, when the 25% tax rate was in place. Revenues dipped at the end of 2016 when the 17% tax was applied. Since then, revenues have steadily climbed and reached almost $16 million by August 2021.

Part of the sales tax revenues are allocated to schools located in places that did not opt out after legalization. Specifically, 40% of revenues from the state tax flow into the State School Fund, where it is then used to fund general purpose grants. This money goes into school district general funds, where it is spent on a number of items. Most of the general fund is spent on instruction and support services, like classroom support, special education programs, and counseling services, but

some is also spent on enterprise and community services, facilities acquisition and construction, and other services.

I estimate the effect of legalization on total general fund expenditures, as well as spending from each of these five categories separately to see if marijuana tax revenue is being used for a particular purpose. The data come from the ODE at the school-district-level and are available from the 2012-13 through the 2018-19 school years. There are 1,358 school districts across the sample period. The model is analogous to the reduced form given in equation (3) except I include school district fixed effects in the place of school fixed effects. The dependent variables are the natural logarithms of per pupil expenditures, so the marginal effects are interpreted as percentage changes. The results are in Table 9.

Column (1) shows that spending from the general fund increased by about 5.6% after legalization. This is about a $700 increase in per pupil spending from the pre-legalization average of $12,508. I can reject the null hypothesis that the effect is equal to zero at the 10.8% level. In column (2), legalization leads to a 7% increase in instructional spending, though this is not a statistically significant effect (two-sided p-value is 0.209). This is a $466 increase in per pupil spending relative to the average. Spending on support services goes up by 3.8%, as shown in column (3), but the effect is not statistically different from zero (two-sided p-value is 0.321). Enterprise and community services spending, facilities spending, and spending on other things, including debt service, do not change in statistically significant ways after legalization, as shown in columns (4)-(6).

To put these results in perspective, I compare them to estimates in the education production function and school finance literatures. The meta-analysis in Greenwald, et al. (1996) finds that the median effect of a one dollar increase in per pupil expenditures on reading and math

achievement is 0.0001-0.0003 standard deviations. The $700 increase in per pupil spending from the general fund that I find translates to about a 0.07-0.21 standard deviation increase in achievement using these estimates. Card & Krueger (1996) summarize the estimated effects on earnings and wages: a 10% increase in per pupil spending leads to a 1.3% increase in adult earnings and a 0.7% increase in wages. My estimates thus suggest that earnings will increase by 0.73% and wages by 0.39% when per pupil general fund expenditures increases after legalization. More recently, Jackson, et al. (2015) estimate the effects of increasing spending during each year of public-school education. They find that a 10% increase in per pupil spending for twelve years results in 0.31 more years of education completed, a 7-percentage-point increase in the probability of graduating from high school, and a 7.7% increase in wages. If spending from the general fund were to increase by 5.6% each year for twelve years, then the number of years of completed schooling would increase by 0.17, the probability of high school graduation would increase by 3.92 percentage points, and wages would increase by 4.3%.

Given that increasing school spending likely leads to better educational outcomes, it is possible that my estimated effects of legalization on chronic absenteeism, dropout rates, and non-proficiency rates are lower bounds of the true effects. In other words, if schools had not received tax revenues from marijuana, then their students might have been even worse off after legalization.

9 Conclusion

This paper examines the effects of recreational marijuana legalization on underage marijuana use and educational outcomes in Oregon. Overall, the results suggest that legalization leads to an increase in marijuana use for 11th-grade girls, which subsequently leads to higher rates of high school chronic absenteeism, higher dropout rates for high school girls, and worse performance in math and ELA for 11th-grade girls.

These results are tempered by the following three caveats. First, since cities and counties can hold local elections to ban marijuana businesses every two years, the difference-in-differences estimates in this paper should be thought of as intention-to-treat rather than total average treatment effects. Second, since I only have data on marijuana use for 11th graders, the first stage estimates may not be representative of high schoolers in general. Thus, the reduced form effects can only be explained by the change in marijuana use from the first stage to the extent that a change in 11th-grade use is indicative of a change in marijuana use across all high school grades.

Finally, these findings cannot necessarily be generalized to other states that have legalized recreational marijuana because they have different regulatory structures, taxes, and ways of distributing revenue. Washington, for instance, put a quota on the number of retail licenses that it would distribute and used a lottery system to determine which potential businesses would receive a license. I examine the effect of legalization on educational outcomes using this exogenous variation in dispensary location in Jarrold-Grapes (2023). In addition, Colorado differs from Oregon in how it utilizes marijuana tax revenues. Schools still receive revenues, but Colorado uses them to help fund school construction grants instead of general grants.

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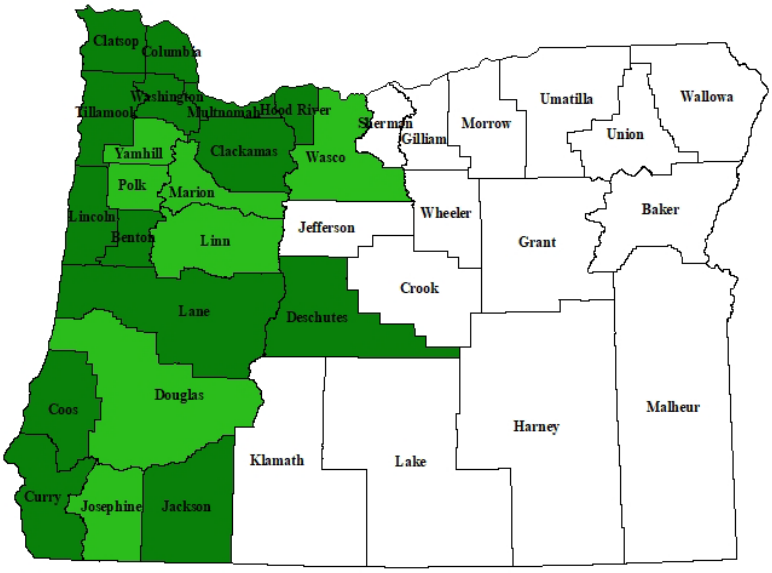
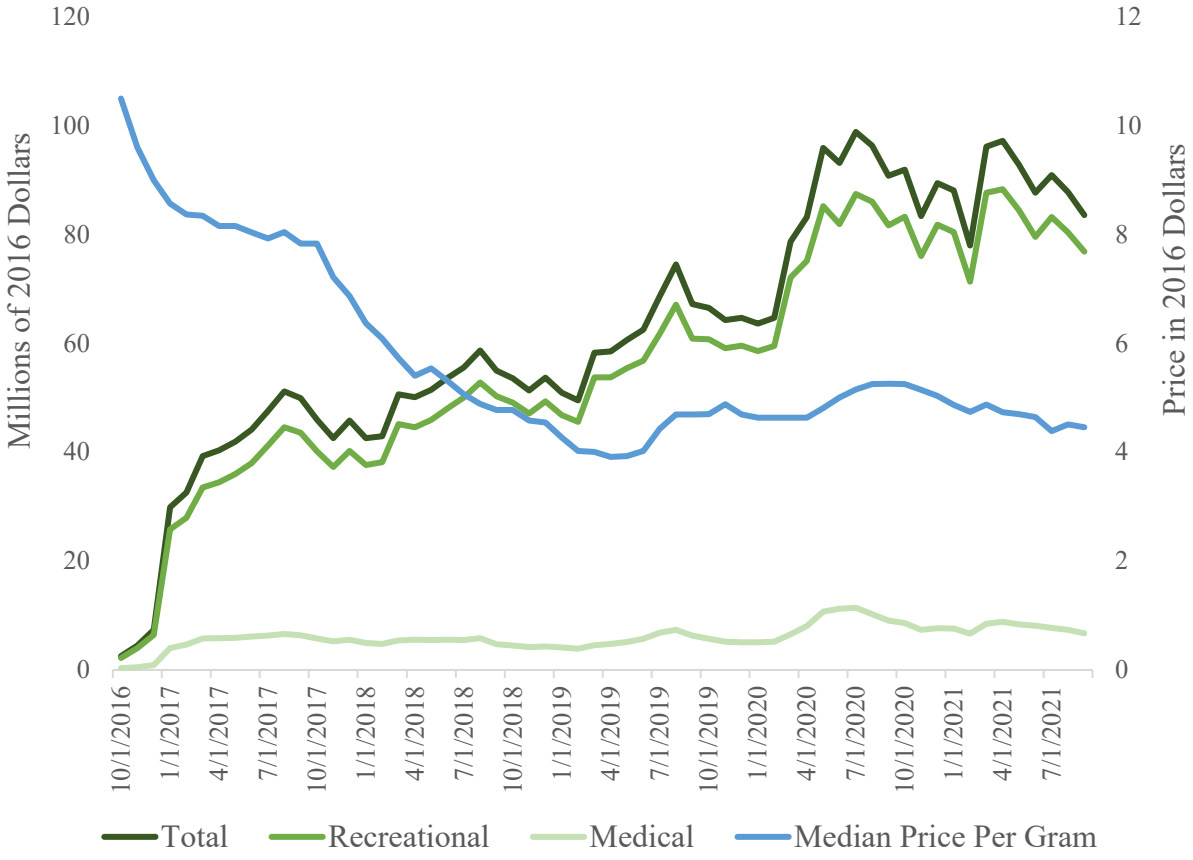
Figures

Figure 1: Legality of Recreational Marijuana by County in Oregon



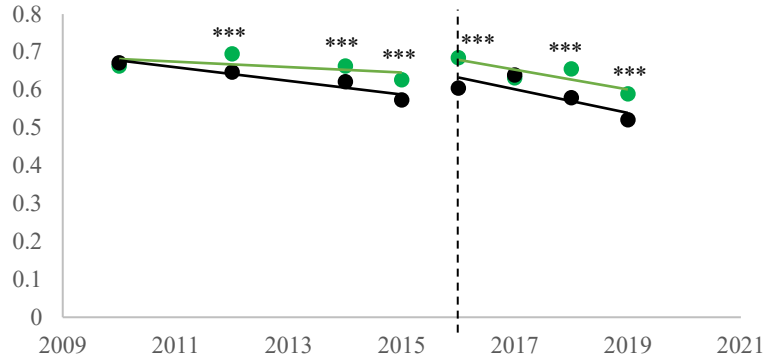
Notes: This figure shows which counties in Oregon were able to opt-out after legalization. The counties in white had a 55% majority against Measure 91 and were allowed to (and did) opt out. Those in light green had a 50% majority against legalization but were not allowed to opt out. Counties in dark green had less than 45% of votes against marijuana and were unable to opt out.

Figure 2: Monthly Marijuana Sales and Prices in Oregon



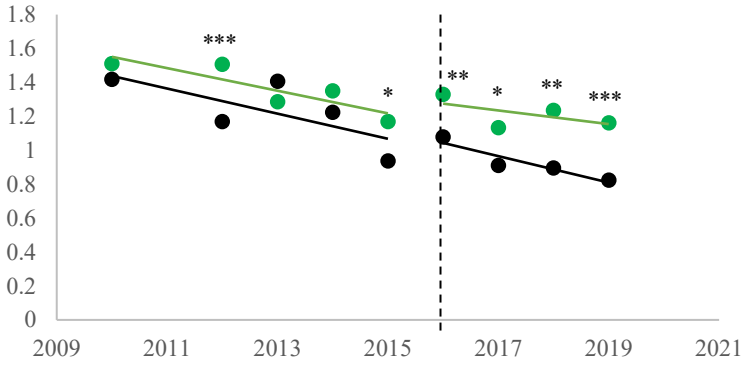
Notes: This figure shows trends in total, recreational, and medical marijuana sales, as well as the median price per gram of recreational, smokable marijuana, in Oregon from October 2016 through September 2021. Sales and prices are in 2016 dollars. The data was extracted from the Oregon Liquor and Cannabis Commission's Metric Cannabis Tracking System.

Figure 3: Trends in Average Marijuana Access and Use in Oregon for Opt-Out (Black) and Non-Opt-Out (Green) Counties



(a) Marijuana Access

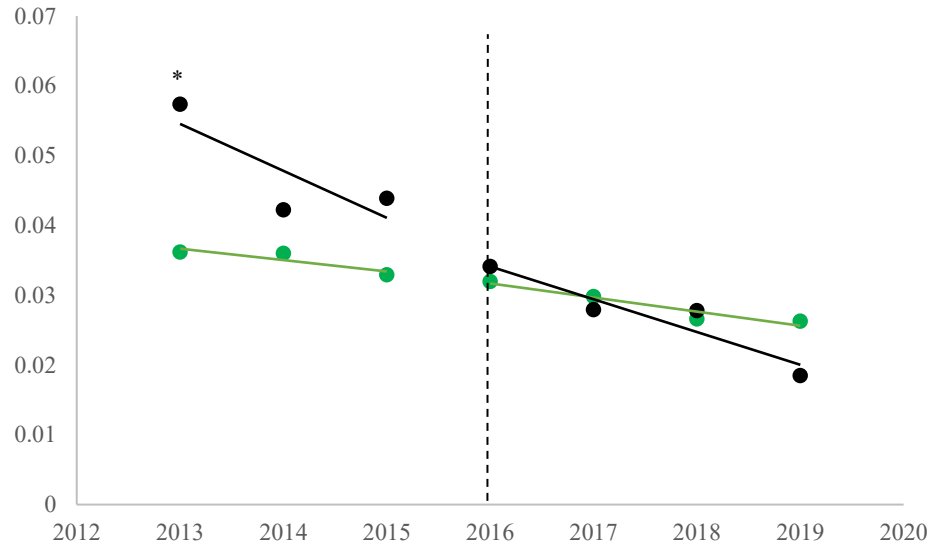
(b) Marijuana Use (Extensive)



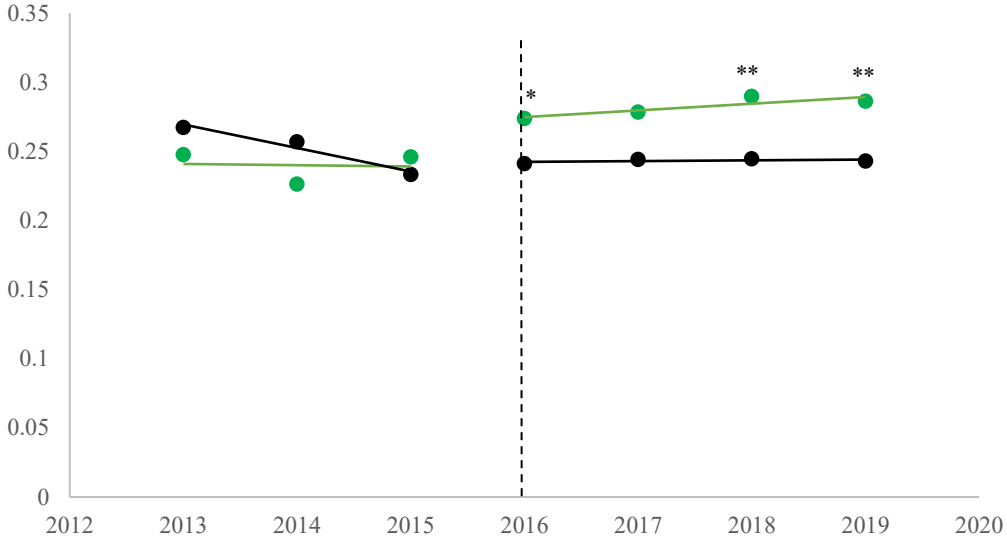
(c) Marijuana Use (Intensive)

Notes: This figure shows trends in 11th-grade average marijuana access (a), marijuana use on the extensive margin (b), and marijuana use on the intensive margin (c) from the OSWS and OHTS. The years on the x-axis are spring semesters. Linear trendlines are fitted to the average outcomes before and after marijuana sales began in the 2015-16 school year (marked by the vertical dashed line). The green lines show trends across counties that did not opt out after legalization, and the black lines show trends across counties that opted out after legalization. Statistically significant differences are indicated by stars: * is 10%, ** is 5%, and *** is 1%.

Figure 4: Trends in the Average Dropout Rate and Chronic Absenteeism in Oregon for Opt-Out (Black) and Non-Opt-Out (Green) Counties



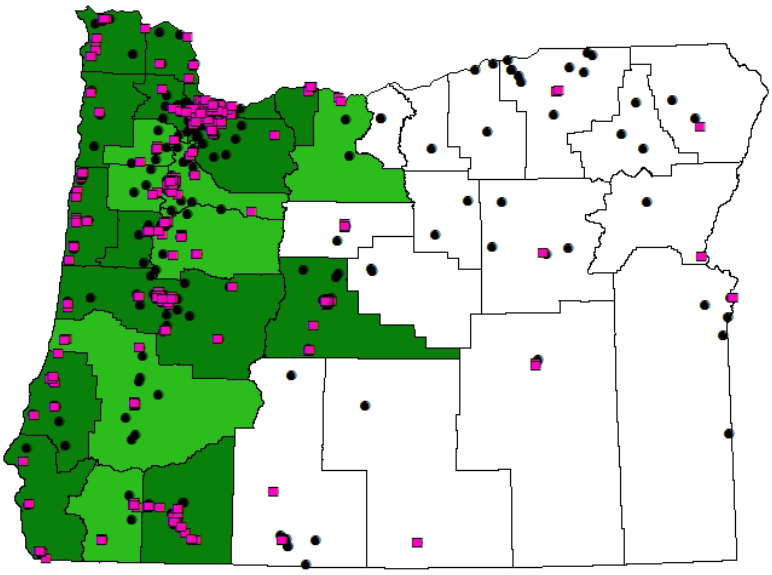
(a) Dropout Rate



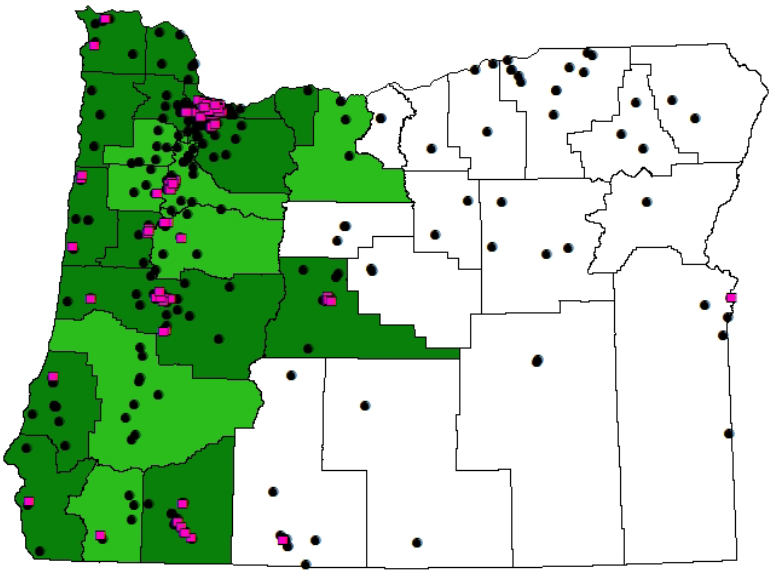
(b) Chronic Absenteeism

Notes: This figure shows the average high school dropout rate (a) and proportion of chronically absent high school students (b) over time. The years on the x-axis are spring semesters. Linear trendlines are fitted to the average outcomes before and after marijuana sales began in the 2015-16 school year (marked by the vertical dashed line). The green lines show trends across counties that did not opt out after legalization, and the black lines show trends across counties that opted out after legalization. Statistically significant differences are indicated by stars: * is 10%, ** is 5%, and *** is 1%.

Figure 5: Distribution of Schools and Marijuana Dispensaries Across Oregon



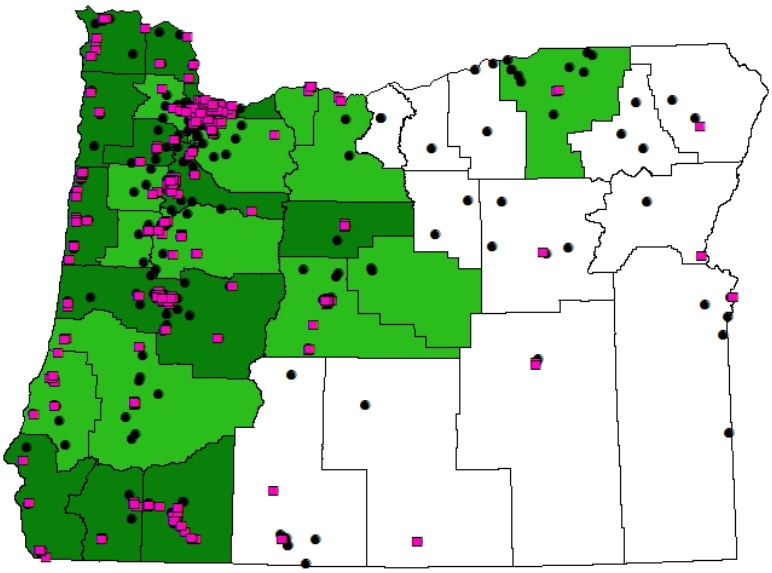
(a) Public High Schools and Recreational Marijuana Dispensaries



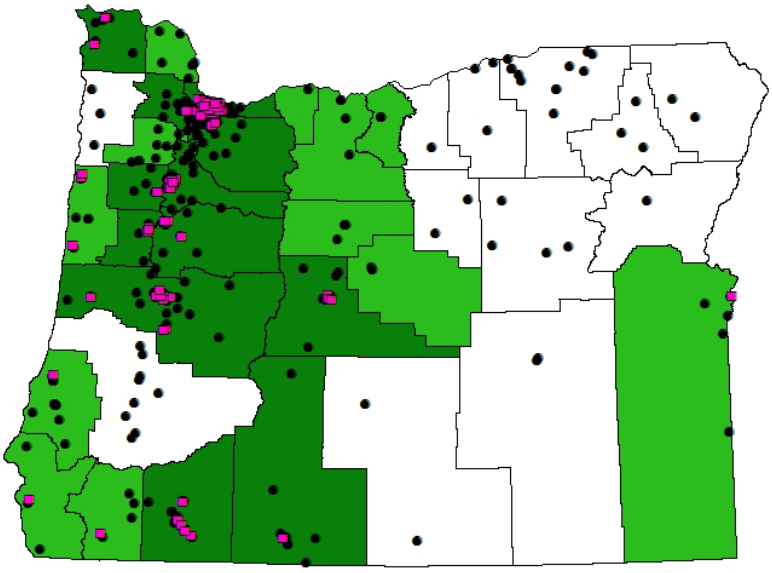
(b) Public High Schools and Pre-Existing Medical Marijuana Dispensaries

Notes: This figure shows the distribution of public high schools and marijuana dispensaries across Oregon. Map (a) shows public high schools (black circles) and recreational marijuana dispensaries (pink squares) active at the beginning of 2020. Map (b) shows public high schools (black circles) and medical marijuana dispensaries (pink squares) licensed before Measure 91 was put on the ballot. The counties in white had a 55% majority against Measure 91 and banned marijuana businesses. Those in light green had a 50% majority against legalization but were not given the option to ban. Counties in dark green were unable to ban. There are some dispensaries located in the white counties because of elections at the county and city levels that subsequently allowed the operation of retail marijuana businesses.

Figure 6: Variation in the Minimum Drive-Time Between Schools and Dispensaries Across Counties in Oregon



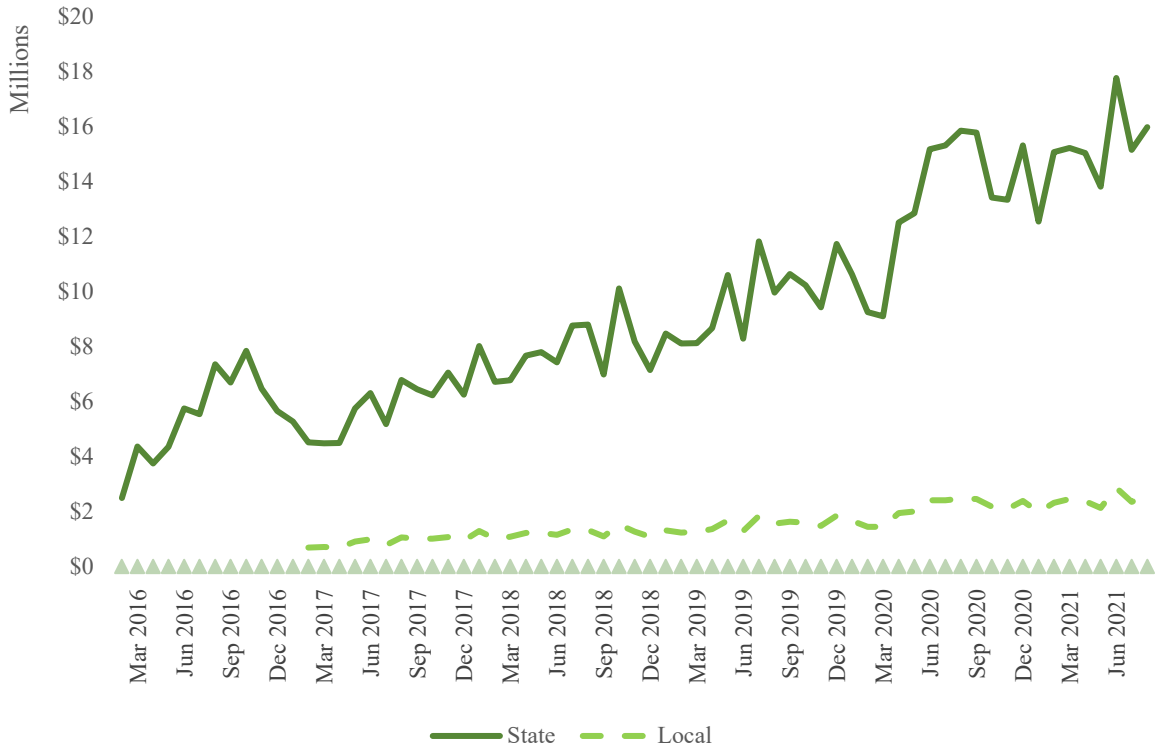
(a) Public High Schools and Recreational Marijuana Dispensaries



(b) Public High Schools and Pre-Existing Medical Marijuana Dispensaries

Notes: This figure shows the average minimum drive-time between public high schools (black circles) and marijuana dispensaries (pink squares) weighted by 11th-grade enrollment for each county in Oregon. Map (a) shows public high schools and recreational marijuana dispensaries active at the beginning of 2020. Dark green counties have an average minimum drive-time to an open dispensary of 4-6 minutes; light green counties 6-36 minutes; and white counties 36-159 minutes. Map (b) shows public high schools and medical marijuana dispensaries licensed before Measure 91 was put on the ballot. Dark green counties have an average minimum drive-time to a pre-existing medical dispensary or a dispensary in Washington of 7-14 minutes; light green counties 14-48 minutes; and white counties 48-144 minutes.

Figure 7: Monthly Marijuana Tax Receipts in Oregon



Notes: This figure shows monthly marijuana tax receipts in Oregon from February 2016 through August 2021. The data come from the Oregon Department of Revenue. Starting in 2017, counties and cities can tax marijuana sales at 3%. The dashed line shows the tax receipts from these local taxes that were collected by the state on behalf of localities. The dip in state tax receipts at the end of 2016 reflects the decrease in the tax rate from 25% to 17% as recreational sales transitioned from medical dispensaries to new recreational dispensaries.

Tables

Table 1: Marginal Effects of Recreational Marijuana Legalization in Oregon on 11th-Grade Marijuana Access and Use by Student Gender

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x Post	0.0248	-0.0198	0.0409	0.0041	0.2749	0.0338
	(0.0222)	(0.0221)	(0.0178)	(0.0174)	(0.1232)	(0.1236)
	[0.133]	[0.185]	[0.011]	[0.407]	[0.013]	[0.392]
	{0.297}	{0.307}	{0.035}	{0.455}	{0.045}	{0.455}
Dependent Mean	0.63	0.67	0.19	0.22	1.04	1.59
Observations	53,277	52,199	60,541	59,594	60,140	58,950

Notes: This table reports marginal effects from the estimation of equation (2). Probit models are used in columns (1)-(4), while interval regression models are used in columns (5) and (6). There are fewer observations in columns (1) and (2) because data on marijuana access is not available in 2013. All specifications control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses. One-tailed p-values are shown in square brackets and Romano-Wolf p-values correcting for multiple hypothesis testing are in curly brackets.

Table 2: Marginal Effects of Recreational Marijuana Legalization in Oregon on High School Chronic Absenteeism, Dropout Rates, and 11th-Grade Math and ELA Test Scores

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Legal x Post	0.0292	0.0097	0.0069	0.0152	-0.0027	0.0322	-0.0136
	(0.0134)	(0.0044)	(0.0035)	(0.0151)	(0.0260)	(0.0160)	(0.0296)
	[0.018]	[0.018]	[0.028]	[0.161]	[0.459]	[0.026]	[0.324]
	{0.030}	{0.030}	{0.030}	{0.243}	{0.431}	{0.050}	{0.391}
Dependent Mean	0.24	0.03	0.04	0.71	0.70	0.28	0.38
Observations	1,550	1,553	1,553	766	777	777	814

Notes: This table reports marginal effects from the estimation of equation (3). Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses. One-tailed p-values are shown in square brackets and Romano-Wolf p-values correcting for multiple hypothesis testing are in curly brackets.

Table 3: Pseudo Difference-in-Differences

	Marijuana Access	Marijuana Use (Extensive)	Marijuana Use (Intensive)	Chronic Absenteeism	Dropout Rate
	(1)	(2)	(3)	(4)	(5)
Panel A: All					
Legal x Pseudo Post	0.0579	0.0251	0.2050	-0.0123	0.0083
	(0.0179)	(0.0160)	(0.1203)	(0.0186)	(0.0068)
	[0.001]	[0.059]	[0.044]	[0.257]	[0.116]
Observations	56,995	70,095	69,416	696	699
Panel B: Female					
Legal x Pseudo Post	0.0327	-0.0035	0.0621		0.0014
	(0.0253)	(0.0218)	(0.1617)		(0.0076)
	[0.098]	[0.435]	[0.350]		[0.429]
Observations	28,661	35,196	34,954		699
Panel C: Male					
Legal x Pseudo Post	0.0844	0.0642	0.3730		0.0132
	(0.0252)	(0.0229)	(0.1772)		(0.0074)
	[0.0004]	[0.003]	[0.018]		[0.042]
Observations	28,334	34,889	34,462		699

Notes: This table shows marginal effects of the estimation of equations (2) and (3) using only pre-period years. Pseudo Post equals 1 for the 2013-14 and 2014-15 school years, and 0 for school years up to and including 2012-13. Columns (1)-(3) control for student ethnicity and year and county fixed effects. Columns (4) and (5) control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. In all columns, standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table 4: Placebo Test with Random Assignment of Vote-Share Across Counties

	Marijuana Access	Marijuana Use (Extensive)	Marijuana Use (Intensive)	Chronic Absenteeism	Dropout Rate	Not Proficient in Math	Not Proficient in ELA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: All							
Placebo x Post	-0.003	-0.0004	-0.0051	0.0004	-0.0001	-0.0003	-0.001
	(0.0009)	(0.0007)	(0.0054)	(0.0013)	(0.0003)	(0.0016)	(0.0015)
	[-0.0048, -0.0012]	[-0.0018, 0.0009]	[-0.0157, 0.0055]	[-0.0022, 0.003]	[-0.0006, 0.0004]	[-0.0034, 0.0027]	[-0.004, 0.002]
Panel B: Female							
Placebo x Post	-0.004	-0.001	-0.0101		-0.0001	0.0004	-0.0012
	(0.0013)	(0.001)	(0.0069)		(0.0003)	(0.0019)	(0.0018)
	[-0.0065, -0.0015]	[-0.003, 0.0009]	[-0.0236, 0.0034]		[-0.0006, 0.0004]	[-0.0033, 0.0041]	[-0.0046, 0.0023]
Panel C: Male							
Placebo x Post	-0.002	0.0003	-0.0004		-0.0002	0.0023	0.0006
	(0.0013)	(0.001)	(0.0084)		(0.0003)	(0.0018)	(0.0019)
	[-0.0045, 0.0005]	[-0.0017, 0.0023]	[-0.0168, 0.0161]		[-0.0008, 0.0005]	[-0.0013, 0.0059]	[-0.0032, 0.0043]

Notes: This table reports marginal effects from the estimation of equations (2) and (3) where *Legal* is replaced with a binary variable *Placebo* that equals 1 if the randomly assigned vote-share against legalization is less than 55% and 0 if it is greater than or equal to 55%. Vote shares are randomly assigned 100 different times, so the marginal effects in the table are averages of the 100 different estimates. Columns (1)-(3) control for student gender and ethnicity and include county and year fixed effects. Columns (4)-(7) control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and 95% confidence intervals are shown in square brackets.

Table 5: IV Estimates of the Effects of the Minimum Drive-Time Between Public High Schools and Open Marijuana Dispensaries on 11th-Grade Marijuana Access and Use by Student Gender

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Minimum Drive-Time x Post	0.0212	0.0089	0.0182	0.0304	0.0412	0.0808
(Evaluated at 62.5 Minutes)	(0.0005)	(0.0006)	(0.0004)	(0.0004)	(0.0009)	(0.0010)
	[0.260]	[0.400]	[0.242]	[0.130]	[0.238]	[0.094]
Observations	46,150	45,008	52,980	51,771	52,866	51,577

Notes: This table reports the effects of the minimum-drive time between public high schools and open marijuana dispensaries on marijuana access and use, where the drive-time to an open dispensary is instrumented with the minimum time to either a pre-existing medical marijuana dispensary in Oregon or an open marijuana dispensary in Washington. The minimum drive-time is a weighted average across schools in a county. These are not marginal effects, rather the marginal effects evaluated at the difference-in-means of the drive-time measure between counties that did and did not opt-out after legalization (62.5 minutes). There are fewer observations in columns (1) and (2) because data on marijuana access is not available in 2013. All specifications control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table 6: IV Estimates of the Effects of the Minimum Drive-Time Between Public High Schools and Open Marijuana Dispensaries on High School Chronic Absenteeism, Dropout Rates, and 11th-Grade Math and ELA Test Scores

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Minimum Drive-Time x Post	0.0465	-0.0017	0.0005	0.0453	-0.0131	0.0302	-0.0568
(Evaluated at 62.5 Minutes)	(0.0004)	(0.0001)	(0.0001)	(0.0008)	(0.0008)	(0.0007)	(0.0008)
	[0.020]	[0.361]	[0.469]	[0.182]	[0.398]	[0.230]	[0.122]
Observations	1,319	1,322	1,322	569	572	581	599

Notes: This table reports the effects of the minimum-drive time between public high schools and open marijuana dispensaries on marijuana access and use, where the drive-time to an open dispensary is instrumented with the minimum time to either a pre-existing medical marijuana dispensary in Oregon or an open marijuana dispensary in Washington. These are not marginal effects, rather the marginal effects evaluated at the difference-in-means of the drive-time measure between counties that did and did not opt-out after legalization (62.5 minutes). Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Conley standard errors that adjust for spatial correlation are in parentheses, and one-tailed p-values are shown in square brackets.

Table 7: Marginal Effects of Recreational Marijuana Legalization in Oregon on the Perceived Risk of Using Marijuana for 11th-Grade Students by Gender

	Perceived Risk of Marijuana Use	
	Female	Male
	(1)	(2)
Legal x Post	-0.0365	0.0037
	(0.0214)	(0.0214)
	[0.087]	[0.864]
Dependent Mean	0.56	0.46
Observations	58,423	56,932

Notes: This table reports marginal effects from the estimation of equation (2) where the dependent variable is a binary indicator for whether a student thinks using marijuana regularly is moderately or greatly risky. Probit models are used in both columns. Both specifications control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and two-tailed p-values are shown in square brackets.

Table 8: Marginal Effects of Recreational Marijuana Legalization in Oregon on the Place of Marijuana Acquisition for 11th-Grade Students by Gender

	Female		Male	
	Mean	Marginal Effect	Mean	Marginal Effect
Dependent Variable	(1)	(2)	(3)	(4)
Public Event	0.053	-0.0209	0.046	0.0404
		(0.0265)		(0.0242)
		[0.431]		[0.095]
Party	0.316	-0.0143	0.234	-0.0373
		(0.0658)		(0.0589)
		[0.828]		[0.526]
Friends 18 or Older	0.384	-0.0840	0.344	-0.1232
		(0.0653)		(0.0587)
		[0.198]		[0.036]
Friends Under 18	0.498	0.0540	0.481	-0.0054
		(0.0660)		(0.0576)
		[0.413]		[0.926]
Family Member	0.160	0.0241	0.204	0.0148
		(0.0551)		(0.0423)
		[0.662]		[0.726]
Medical Marijuana Cardholder or Grower	0.123	0.0391	0.102	-0.0172
		(0.0387)		(0.0365)
		[0.312]		[0.638]
Gave Someone Money to Buy It	0.174	0.0521	0.145	-0.0063
		(0.0380)		(0.0388)
		[0.171]		[0.871]
Grew It	0.025	0.0102	0.030	0.0172
		(0.0252)		(0.0299)
		[0.686]		[0.565]
Other Way	0.202	-0.0481	0.189	0.0059
		(0.0520)		(0.0497)
		[0.356]		[0.905]

Notes: This table reports marginal effects from the estimation of equation (2) where the dependent variables are dummies indicating where or how students acquired marijuana. The data come only from the OSWS and include the following years (spring semesters): 2012, 2014, 2016, and 2018. Pre-legalization averages of the dependent variables are in columns (1) and (3). Probit models are used in columns (2) and (4), and both columns control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and two-tailed p-values are shown in square brackets.

Table 9: Marginal Effects of Recreational Marijuana Legalization in Oregon on School District Expenditures from the General Fund

	Total General Fund Expenditures	Instruction	Support Services	Enterprise and Community Services	Facilities Acquisition and Construction	Other Uses
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x Post	0.0559	0.0696	0.0381	0.0961	-0.0028	0.1736
	(0.0339)	(0.0543)	(0.0379)	(0.1543)	(0.1592)	(0.1968)
	[0.108]	[0.209]	[0.321]	[0.537]	[0.986]	[0.384]
Dependent Mean	$12,508	$6,698	$5,239	$27	$94	$451
Observations	1,358	1,358	1,358	1,358	1,358	1,358

Notes: This table reports marginal effects of legalization on the natural logarithm of per pupil school district expenditures from the general fund. Column (1) shows total general fund expenditures, and the remaining columns are categories of spending within the general fund. Standard errors clustered by county are in parentheses and two-tailed p-values are shown in square brackets.

Appendix

Additional Background on Marijuana Laws

Oregon has a long legislative history related to marijuana. In 1973, Oregon decriminalized the possession of small amounts of marijuana. Namely, it removed the felony charge associated with public possession of one ounce and at-home possession of eight ounces of marijuana. Then, in 1998, voters passed Measure 67, a referendum to legalize the cultivation, possession, and use of marijuana for medical purposes statewide. Under this new law, people could use marijuana if recommended by their doctor to alleviate symptoms from the following conditions: cancer; glaucoma; degenerative or pervasive neurological conditions; HIV/AIDS; post-traumatic stress disorder (PTSD); and any medical condition that produces cachexia, severe pain, severe nausea, seizures, and/or persistent muscle spasms. Measure 67 also established the Oregon Medical Marijuana Program (OMMP). People could apply for permits from the OMMP to grow marijuana for medicinal use and were allowed to have seven plants (only three mature) and possess one ounce of dried marijuana.

While Measure 67 legalized possession, use, and cultivation, it did not legalize the *sale* of medical marijuana. As such, Oregonians tried to legalize the sale of medical marijuana twice in the early 2000s and 2010s. In 2004, they voted on Measure 33, which would have established marijuana distribution centers, and in 2010, they voted on Measure 74, which would have created medical marijuana dispensaries. Neither of these measures passed. Then, in 2012, Oregon lawmakers approved medical marijuana sales out of medical dispensaries, though they also passed a law the following year allowing localities to put moratoriums on dispensaries for a year. Thus, the first medical marijuana dispensary licenses were approved in March of 2014. Only medical marijuana card holders could make purchases from these dispensaries. Patients over the age of 18

could apply for medical marijuana cards through the OMMP as long as they supplied proof of a qualifying medical condition from their physician. Effective June 30, 2015, people under 18 years old could apply for medical marijuana cards with parental consent. Parents or legal guardians are required to be primary caregivers and speak to their child's physician about the possible side effects of using marijuana and are responsible for the acquisition and administration of marijuana to their child. The number of medical marijuana patients under 18 years old in Oregon was 214 in January 2015, which was about 0.3% of all patients. This number peaked at 298 (0.4%) in January 2017 and has since been declining. As of July 2021, there were 123 (0.5%) patients under 18. Most young patients use medical marijuana for severe pain and/or seizure disorders, though the number using marijuana for neurological disorders has steadily increased over the past two years.

Oregonians originally voted to legalize marijuana for recreational use in 1986 (Measure 5) and again in 2012 (Measure 80), but the measures were unsuccessful. Then, in November of 2014, they voted on Measure 91, a referendum for recreational marijuana legalization, that passed with a 56% majority vote. Measure 91 legalized the possession, use, and sale of recreational marijuana for adults ages 21 and older. Beginning in July 2015, users could possess eight ounces of usable (dried) marijuana, one ounce of cannabinoid extracts or concentrates, 16 ounces of cannabinoid products in solid form and 72 ounces in liquid form, ten marijuana seeds, and four plants at home. These limitations apply to public possession as well, though dried marijuana is limited to one ounce in public instead of eight.

Measure 91 also gave regulatory power to the Oregon Liquor Control Commission, which has since been renamed the Oregon Liquor and Cannabis Commission (OLCC). The OLCC is responsible for the running the OMMP; distributing licenses to recreational producers, processers, wholesalers, and retailers; developing a taxing structure and tracking sales; developing packaging

for products that discourage use by minors; and ensuring product quality. All marijuana products undergo testing for microbiological contaminants, pesticides, solvents, and THC and cannabidiol concentration. The amount of THC allowed in a serving size or a container depends on the product. For instance, the maximum concentration of THC per serving of edible marijuana is 5mg and the maximum concentration per container is 50mg.

The background section in the main text has information about marijuana taxes, the differences in legality across localities, and marijuana sales over time. As a small aside, Washington state, on Oregon's northern border, also legalized medical marijuana in 1998 and did not allow sales until later. Medical marijuana was first sold out of dispensaries in Washington in 2016. Additionally, Washington legalized marijuana for recreational use in 2012 and opened its first recreational dispensaries in July of 2014.

Survey Data

Oregon Healthy Teens Survey

The OHTS is a voluntary, anonymous survey administered to 8th and 11th grade students in the spring of odd-numbered years. The initial survey was done in 2001, and its final year was 2019. The survey was proctored by teachers within schools and was available in both English and Spanish. Students who chose not to participate in the survey or whose parents did not give them permission to participate were given another activity to do outside the classroom during survey completion.

From 2013-2019, it was conducted by county in the following way. Eligible schools were stratified by county, randomly sampled, and their students were sampled in proportion to the number of same-grade students in the county. Schools that could not be associated with a single school district, virtual charter schools, and schools with less than ten 11th graders were not eligible

to participate. County enrollment weights are provided for each grade. Roughly 15,000 8th graders and 13,000 11th graders are in the sample each year 2013-2019. Some counties did not participate in the 11th-grade survey: Wallowa (2013, 2015, 2017, 2019), Josephine (2015), Wheeler (2015), Crook (2017), Gilliam (2019). Additionally, Sherman, Gilliam, Wasco, Grant, Harney, and Lake counties had small sample sizes each year.

The following honesty checks were performed for internal validity. First, students reporting excessive use, early initiation, or discrepancies on questions about alcohol and marijuana use, smoking, sexual behavior, gambling, or fruit, vegetable, and beverage intake were removed. Second, students who surpassed a given threshold of exaggerated or conflicting responses were removed. Third, if a student reported that they were dishonest on the survey then they were excluded.

Oregon Student Wellness Survey

The OSWS is a voluntary, anonymous survey administered to 6th, 8th, and 11th graders in the spring of even-numbered years. The first survey was conducted in 2010 and the final in 2018. It was open to all traditional public and charter schools and was administered by teachers within schools. Paper and pencil, as well as online, versions were available in both English and Spanish. Grade specific county enrollment weights are included in the data. Around 20,000 6th graders, 22,000 8th graders, and 16,000 11th graders are in the sample each year.

Observations were removed if the student's school or grade could not be identified, and the following honesty checks were performed for internal validity. First, students who reported that in the past 30 days they had used six or more of marijuana, cocaine, ecstasy, heroin, hallucinogens, methamphetamines, and steroids were marked as dishonest and removed. Second, students who responded that they had never used a substance when asked the age of first use but

then responded that they had used the substance in the past 30 days were marked as dishonest and were removed. The substances checked were alcohol, cigarettes, other tobacco products, and marijuana. Third, students who reported excessively high amounts (averaging 10 or more times in the past 12 months) of physical fights, fighting at school, bullying, having been suspended and threatening with a weapon were marked as dishonest and removed. Finally, students whose reported age was more than two years less or more than two years more than would be expected for the reported grade level were marked as dishonest and removed. Additionally, students who reported that they were dishonest on the survey were excluded.

Item Non-Response

In the pooled dataset, 7% of the 11th-grade sample across all years are missing responses for the question on marijuana access; 4% are missing responses for the question on extensive margin marijuana use; and 5% are missing responses for the question on intensive margin marijuana use.

Table A1: Questions from the Oregon Student Wellness and Oregon Healthy Teens Surveys

	Oregon Student Wellness Survey		Oregon Healthy Teens Survey	
Outcome	Question	Years	Question	Years
Marijuana Access	If you wanted to get some, how easy would it be for you to marijuana? (0 – somewhat or very hard, 1 – sort of or very easy)	All	If you wanted to get some marijuana, how easy would it be for you to get some? (0 – sort of or very hard, 1 – sort of or very easy)	2015, 2017, 2019
Current Marijuana Use (Extensive Margin)	Which of the following illicit drugs did you use during the past 30 days? (Marijuana)	All	During the past 30 days, how many times did you use marijuana? (0 times)	All
Current Marijuana Use (Intensive Margin)	During the past 30 days, how many times did you use marijuana? (0, 1-2, 3-9, 10-19, 20-39, 40+ times)	All	During the past 30 days, how many times did you use marijuana? (0, 1-2, 3-9, 10-19, 20-39, 40+ times)	All
Source of Marijuana	During the past 30 days, from which of the following sources did you get marijuana? (I did not use marijuana, public event like a sporting event or concert, party, friends 18 or older, friends under 18, family member, medical marijuana cardholder or grower, I gave someone money to buy it for me, grew it, other way)	2012, 2014, 2016, 2018	-	-
Risk of Smoking/Using Marijuana	How much do you think people risk harming themselves (physically or in other ways) if they: Smoke marijuana regularly (at least once or twice a week)? (0 – no or slight risk, 1 – moderate or great risk)	All	How much do you think people risk harming themselves (physically or in other ways) if they: Use marijuana regularly (at least once or twice a week)? (0 – no or slight risk, 1 – moderate or great risk)	All

Table A2: Marginal Effects of Recreational Marijuana Legalization in Oregon on Marijuana Access and Use Controlling for Heterogenous Effects Across Covariates and Time

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x Post	0.0249	-0.0172	0.0406	0.0002	0.2641	0.0017
	(0.0222)	(0.0221)	(0.0178)	(0.0174)	(0.1234)	(0.1254)
	[0.131]	[0.217]	[0.012]	[0.496]	[0.016]	[0.495]
Observations	53,277	52,199	60,541	59,594	60,140	58,950

Notes: This table reports marginal effects from the estimation of equation (2) with post-year dummy variables, interactions between student ethnicity and the post-year dummies, as well as triple interactions between student ethnicity, the post-year dummies, and Legal x Post. Student ethnicity is demeaned by the average across non-opt-out counties for either boys or girls. Probit models are used in columns (1)-(4), while interval regression models are used in columns (5) and (6). There are fewer observations in columns (1) and (2) because data on marijuana access is not available in 2013. All specifications include county fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A3: Marginal Effects of Recreational Marijuana Legalization in Oregon on Educational Outcomes Controlling for Heterogenous Effects Across Covariates and Time

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Legal x Post	0.0269	0.0191	-0.0012	-0.0029	-0.0458	0.2020	0.0996
	(0.0217)	(0.0101)	(0.0173)	(0.0747)	(0.0904)	(0.0789)	(0.0953)
	[0.112]	[0.033]	[0.472]	[0.485]	[0.308]	[0.008]	[0.152]
Observations	1,550	1,553	1,553	766	777	777	814

Notes: This table reports marginal effects from the estimation of equation (3) with post-year dummy variables, interactions between covariates and the post-year dummies, as well as triple interactions between the covariates, the post-year dummies, and Legal x Post. Covariates are demeaned by the average across non-opt-out counties for all students, girls, or boys, and include the proportions of students who are Asian, Hispanic, Black, disabled, or receive free-or-reduced-price lunch. Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications include school fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A4: Minimum Wage Changes Over Time

Date	Standard Counties	Portland Metro	Non-Urban Counties
July 2016	$9.75	$9.75	$9.50
July 2017	$10.25	$11.25	$10.00
July 2018	$10.75	$12.00	$10.50
July 2019	$11.25	$12.50	$11.00
July 2020	$12.00	$13.25	$11.50
July 2021	$12.75	$14.00	$12.00
July 2022	$13.50	$14.75	$12.50

Notes: This table shows the annual changes to the minimum wage in Oregon outlined in Senate Bill 1532. Prior to July 2016, the minimum wage was $9.25 across the state. Starting in July 2023, the standard minimum wage rate is to be adjusted annually for inflation and the wage in the Portland metro is to remain $1.25 above the standard while the wage in non-urban counties is to stay $1 below the standard.

Table A5: Robustness to Changes in the Minimum Wage

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Legal x Post	0.0249	0.0081	0.0055	0.0095	0.0005	0.0239	-0.0127
	(0.0132)	(0.0043)	(0.0036)	(0.0147)	(0.0255)	(0.0169)	(0.0298)
	[0.034]	[0.035]	[0.067]	[0.262]	[0.492]	[0.084]	[0.336]
Observations	1,550	1,553	1,553	766	777	777	814

Notes: This table reports marginal effects from the estimation of equation (3) with the minimum wage included as a control. See appendix table A4 for the minimum wage rate over time. Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A6: Marginal Effects of Recreational Marijuana Legalization in Oregon on Marijuana Access and Use without the Counties Bordering Washington

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x Post	0.0138	-0.0464	0.0366	-0.0040	0.1834	-0.0855
	(0.0230)	(0.0231)	(0.0185)	(0.0178)	(0.1300)	(0.1189)
	[0.275]	[0.022]	[0.024]	[0.412]	[0.079]	[0.236]
Observations	42,033	40,951	47,550	46,620	47,222	46,112

Notes: This table reports marginal effects from the estimation of equation (2). The counties bordering Washington state are removed from the sample. Probit models are used in columns (1)-(4), while interval regression models are used in columns (5) and (6). There are fewer observations in columns (1) and (2) because data on marijuana access is not available in 2013. All specifications control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A7: Marginal Effects of Recreational Marijuana Legalization in Oregon on Educational Outcomes without the Counties Bordering Washington

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Legal x Post	0.0311	0.0144	0.0093	0.0116	-0.0252	0.0320	-0.0388
	(0.0153)	(0.0046)	(0.0034)	(0.0145)	(0.0215)	(0.0227)	(0.0386)
	[0.027]	[0.002]	[0.006]	[0.217]	[0.126]	[0.086]	[0.162]
Observations	1,207	1,210	1,210	596	607	605	639

Notes: This table reports marginal effects from the estimation of equation (3). Schools in counties bordering Washington state are removed from the sample. Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A8: Short- and Medium-Run Effects of Recreational Marijuana Legalization in Oregon on 11th-Grade Marijuana Access and Use by Student Gender

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x (2016 or 2017)	-0.0156	-0.0409	0.0109	-0.0242	0.2377	-0.0795
	(0.0272)	(0.0274)	(0.0226)	(0.0229)	(0.1545)	(0.1640)
	[0.284]	[0.068]	[0.316]	[0.146]	[0.062]	[0.314]
Legal x (2018 or 2019)	0.062	-0.0011	0.0727	0.0319	0.3102	0.1384
	(0.0269)	(0.0265)	(0.0221)	(0.0205)	(0.1493)	(0.1320)
	[0.011]	[0.484]	[0.001]	[0.061]	[0.019]	[0.147]
Dependent Mean	0.63	0.67	0.19	0.22	1.04	1.59
Observations	53,277	52,199	60,541	59,594	60,140	58,950

Notes: This table reports marginal effects from the estimation of equation (2) with interactions of *Legal* and dummy variables for different post-legalization years. Probit models are used in columns (1)-(4), while interval regression models are used in columns (5) and (6). There are fewer observations in columns (1) and (2) because data on marijuana access is not available in 2013. All specifications control for student ethnicity and include county and year fixed effects. County-level school enrollment weights are applied in each model. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A9: Short- and Medium-Run Effects of Recreational Marijuana Legalization in Oregon on High School Chronic Absenteeism, Dropout Rates, and 11th-Grade Math and ELA Test Scores

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Legal x (2016 or 2017)	0.0274	0.0093	0.0081	0.0077	0.0082	0.0152	-0.0289
	(0.0133)	(0.0053)	(0.0037)	(0.0158)	(0.0246)	(0.0227)	(0.0353)
	[0.023]	[0.044]	[0.018]	[0.313]	[0.371]	[0.254]	[0.210]
Legal x (2018 or 2019)	0.0313	0.0100	0.0055				
	(0.0175)	(0.0072)	(0.0047)				
	[0.041]	[0.088]	[0.123]				
Legal x (2018)				0.0302	-0.0229	0.0671	0.0163
				(0.0252)	(0.0309)	(0.0254)	(0.0310)
				[0.120]	[0.232]	[0.006]	[0.301]
Dependent Mean	0.24	0.03	0.04	0.71	0.70	0.28	0.38
Observations	1,550	1,553	1,553	766	777	777	814

Notes: This table reports marginal effects from the estimation of equation (3) with interactions of *Legal* and dummy variables for different post-legalization years. Chronic absenteeism is not available by gender. There are fewer observations in columns (4)-(7) because proficiency rates are only available between 2014-15 and 2017-18. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A10: Two-Sample Instrumental Variable Estimates of the Effect of Marijuana Use on High School Chronic Absenteeism, Dropout Rates, and 11th-Grade Math and ELA Test Scores

	Chronic Absenteeism	Dropout Rate		Not Proficient in Math		Not Proficient in ELA	
	All	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A:							
Marijuana Use	0.8022	-0.0773	-0.1058	-0.3242	-0.5571	-0.4146	-0.2269
(Extensive)	(0.2387)	(0.0505)	(0.0772)	(0.2913)	(0.4172)	(0.3134)	(0.3751)
	[0.332, 1.273]	[-0.177, 0.022]	[-0.258, 0.046]	[-0.901, 0.253]	[-1.383, 0.269]	[-1.035, 0.206]	[-0.969, 0.515]
	{0.377, 1.643}	{-0.259, 0.049}	{-0.408, 0.087}	{-1.466, 0.518}	{-2.192, 0.517}	{-1.643, 0.367}	{-1.697, 1.036}
Panel B:							
Marijuana Use	0.1373	-0.0141	-0.0160	-0.0371	-0.0568	-0.0475	-0.0232
(Intensive)	(0.0486)	(0.0095)	(0.0122)	(0.0307)	(0.0410)	(0.0318)	(0.0380)
	[0.042, 0.233]	[-0.033, 0.005]	[-0.040, 0.008]	[-0.098, 0.024]	[-0.138, 0.024]	[-0.110, 0.015]	[-0.098, 0.052]
	{0.062, 0.328}	{-0.051, 0.009}	{-0.064, 0.014}	{-0.150, 0.047]	{-0.218, 0.049}	{-0.167, 0.034}	{-0.169, 0.096}
Observations	230	230	230	125	127	124	127

Notes: This table reports two-sample instrumental variables estimates of the effects of marijuana use on educational outcomes. Marginal effects of marijuana use on the extensive margin for each educational outcome are in *Panel A*, while effects of marijuana use on the intensive margin for each outcome are presented in *Panel B*. Columns (1)-(3) include the years 2012-13 through 2018-19, while columns (4)-(7) include 2014-15 through 2017-18. Standard errors clustered by county are in parentheses. Standard 95% confidence intervals are in square brackets, while 95% confidence intervals assuming that *Legal x Post* is a weak IV are in curly brackets.

Table A11: Effects of Recreational Marijuana Legalization in Oregon on Student Behavioral and Performance Outcomes for Schools with Different Levels of Student Disadvantage

Dependent Variable	Less Poor (1)	Poor (2)	More Poor (3)
Panel A:			
Chronic Absenteeism	0.0140	0.0115	0.0381
	(0.0236)	(0.0228)	(0.0239)
	[0.278]	[0.309]	[0.060]
Dropout Rate (Female)	-0.0029	-0.0017	0.0329
	(0.0045)	(0.0065)	(0.0115)
	[0.262]	[0.397]	[0.004]
Dropout Rate (Male)	-0.0046	0.0014	0.0234
	(0.0064)	(0.0052)	(0.0069)
	[0.239]	[0.397]	[0.001]
Panel B:			
Not Proficient in Math (Female)	0.0432	-0.0197	0.0216
	(0.0866)	(0.0470)	(0.0240)
	[0.311]	[0.339]	[0.188]
Not Proficient in Math (Male)	0.0416	-0.0072	0.0070
	(0.0608)	(0.0719)	(0.0334)
	[0.250]	[0.461]	[0.418]
Not Proficient in ELA (Female)	-0.0480	0.0182	0.0488
	(0.0391)	(0.0487)	(0.0278)
	[0.116]	[0.355]	[0.0457]
Not Proficient in ELA (Male)	0.0400	-0.0683	0.0071
	(0.1014)	(0.0675)	(0.0504)
	[0.348]	[0.159]	[0.444]

Notes: This table reports marginal effects from the estimation of equation (3) for three groups of schools: less poor, poor, and more poor. These groups are terciles of the proportion of students eligible for free-or-reduced-price lunch. *Panel A* shows results for student behavioral outcomes and includes the 2012-13 through 2018-19 school years, while *Panel B* shows results for student academic performance and includes the 2014-15 through 2017-18 school years. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.

Table A12: Effects of Recreational Marijuana Legalization in Oregon on Student Behavioral and Performance Outcomes for City, Suburban or Town, and Rural Schools

Dependent Variable	City (1)	Suburb or Town (2)	Rural (3)
Panel A:			
Chronic Absenteeism	0.0596	0.0371	0.0200
	(0.0207)	(0.0186)	(0.0133)
	[0.009]	[0.028]	[0.071]
Dropout Rate (Female)	-0.0020	0.0113	0.0059
	(0.0041)	(0.0068)	(0.0049)
	[0.320]	[0.053]	[0.117]
Dropout Rate (Male)	-0.0010	0.0084	0.0004
	(0.0042)	(0.0057)	(0.0052)
	[0.411]	[0.073]	[0.473]
Panel B:			
Not Proficient in Math (Female)	0.0399	0.0002	-0.0115
	(0.0539)	(0.0205)	(0.0273)
	[0.239]	[0.496]	[0.339]
Not Proficient in Math (Male)	-0.0121	-0.0154	-0.0191
	(0.0270)	(0.0337)	(0.0344)
	[0.332]	[0.326]	[0.292]
Not Proficient in ELA (Female)	-0.0066	0.0313	0.0158
	(0.0083)	(0.0327)	(0.0436)
	[0.221]	[0.173]	[0.360]
Not Proficient in ELA (Male)	-0.0524	-0.0062	-0.0252
	(0.0250)	(0.0483)	(0.0505)
	[0.033]	[0.450]	[0.310]
Number of Schools	48	123	84

Notes: This table reports marginal effects from the estimation of equation (3) for three groups of schools: city, suburban or town, and rural schools (defined using the Common Core of Data and U.S. Census Bureau classifications). *Panel A* shows results for student behavioral outcomes and includes the 2012-13 through 2018-19 school years, while *Panel B* shows results for student academic performance and includes the 2014-15 through 2017-18 school years. All specifications control for the proportions of students who are Asian, Hispanic, Black, disabled, and receive free-or-reduced-price lunch, and include school and year fixed effects. Standard errors clustered by county are in parentheses and one-tailed p-values are shown in square brackets.