Marijuana Legalization and Educational Outcomes: Evidence from Oregon

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Abstract

In the past decade, 18 states have legalized recreational marijuana for adults ages 21 and older. This paper examines the extent to which there are negative spillovers on underage use and educational outcomes. I use two complementary identification strategies that rely on plausibly exogenous spatial and temporal variation in access to marijuana in Oregon. In November of 2014, Oregon passed Measure 91, a referendum to legalize recreational marijuana. Unlike other legal states, Oregon allowed counties that voted against the legalization measure by at least 55% to opt out. Difference-in-differences estimates suggest that self-reported access to marijuana from the Oregon Student Wellness and Oregon Healthy Teens surveys did not change in counties above versus below the vote-share threshold after legalization. However, use increased, particularly for 11th-grade girls. Girls were 4 percentage points more likely to use marijuana, and used it 0.3 more times, in the past month after legalization. Additionally, using data on high schools from the Oregon Department of Education, I find that chronic absenteeism increased by 3 percentage points across all students, dropout rates increased by 1 percentage point for girls, and the share of girls who are not proficient in ELA rose by over 3 percentage points. As an alternative method of identification that considers the within-county variation in access to marijuana, I estimate how the drive-time between high schools and marijuana dispensaries affects outcomes using an instrumental variable strategy. The results generally align with those from the difference-in-differences models.

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1 Introduction

In the past decade, a green wave began rolling over the nation. Colorado and Washington were the first states to legalize recreational marijuana in 2012, and since then, 16 other states have followed suit (see Figure 1).[1] Connecticut, New Mexico, New York, and Virginia passed measures legalizing marijuana for recreational use in 2021, and nine states will vote on measures this November. All legal states have established, or are planning to establish, a retail market for marijuana where sales are taxed, allowing them to tap into a new source of revenue and generate new employment opportunities. For instance, between 2013 and 2019, Colorado raised over 1.2 billion dollars in marijuana tax revenues. In 2019, these revenues accounted for roughly 2% of the state's total revenues and 1% of its budget. However, recreational marijuana legalization may also have negative spillovers on crime, traffic fatalities, workplace injuries, and substance use. From a policy perspective, it is important to know the magnitude of these spillovers to understand the effects of marijuana legalization.

This paper provides novel evidence on the effects of recreational marijuana legalization on educational outcomes. Existing studies on the relationship between substances and educational outcomes have primarily focused on alcohol and tobacco use. Given the rapid shift towards recreational marijuana legalization in the U.S., this paper fills an important knowledge gap by looking at the effects of recreational marijuana legalization on both underage marijuana use and educational outcomes.

The primary challenge in identifying the effects of marijuana legalization is that places that legalize potentially have a higher latent demand for marijuana than places that do not.

[1] South Dakota voters approved a measure for recreational marijuana legalization in 2020, but the state's supreme court struck it down after the fact. A new bill proposing the legalization of recreational marijuana was introduced in February 2022 but was not passed by lawmakers.

Additionally, there could be unobserved heterogeneity in attitudes toward underage use and education that are 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. Thus, I use two complementary identification strategies that rely on spatial and temporal variation in access to marijuana resulting from recreational marijuana legalization in Oregon.

Oregon passed Measure 91, a referendum to legalize recreational marijuana for adults ages 21 and older, in November of 2014. Oregon is unique because it allowed counties that voted against the legalization measure by at least 55% to opt out. Using a difference-in-differences estimation strategy, 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, particularly for 11^{th}-grade girls. The probability of past-month marijuana use increased by 4.1 percentage points for girls, which is a 22% increase from the pre-legalization average of 19%. Not only are girls more likely to use marijuana, but they also use it more frequently. The number of times they used marijuana in the past month increased by 0.27. This is a 26% increase from the average of 1.04.

One might expect the increase in marijuana use to feed into students' behavioral and performance outcomes, particularly for girls. This is largely the case. Using data on high schools

from the Oregon Department of Education, I find that chronic absenteeism increased by 2.92 percentage points across all students after legalization, which is a 12% increase from the pre-legalization average of 24%. I also find that dropout rates increased by about 1 percentage point for girls, a one-third increase from the base. 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. This is a 12% increase from the 28% average.[2]

These difference-in-differences models do not take into account the within-county variation in access to marijuana, so I use an alternative identification strategy, an instrumental variable approach, to estimate the effect of open recreational marijuana dispensaries on marijuana use and educational outcomes. Specifically, I collect the addresses of public high schools and three groups of dispensaries: recreational marijuana dispensaries open between October 2016 and May 2019, medical marijuana dispensaries with licenses that were approved before Measure 91 was put on the ballot, and recreational dispensaries in Washington that were open before October 2015. Using the Google Distance-Matrix API, which computes the drive-time between two locations using Google Maps, I find the drive-time between each of these schools and dispensaries. For each school, I calculate the minimum time it takes to get to an open dispensary, and either a pre-existing medical or Washington dispensary, which serves as a proxy for marijuana accessibility. I estimate the effects on marijuana access and use and educational outcomes using the time to a pre-existing dispensary as an instrument for the time to an open one. The estimates suggest that being close to an open recreational marijuana dispensary makes marijuana more accessible, leads to greater use, worsens chronic absenteeism, and decreases girls' performance in both math and ELA.

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

Overall, the weight of the evidence suggests that the legalization of recreational marijuana in Oregon leads to greater marijuana use and worse educational outcomes for high school girls. Girls are more likely to use marijuana and use it more frequently after legalization. Chronic absenteeism and dropout rates rise, and more girls fail to reach proficiency levels in ELA. There is also some evidence suggesting that girls both find marijuana more accessible and perform worse in math after legalization.

The rest of the paper is organized as follows. In the next section, I discuss previous research and my conceptual framework. In section 3, I describe recreational marijuana legalization in Oregon and the variation I leverage for identification. I discuss the data on marijuana access and use and student outcomes in section 4. In section 5, I present my empirical model. Results are in section 6, robustness in section 7, and extensions in section 8. Section 9 discusses mechanisms. Finally, I end with a discussion of caveats and conclusions.

2 Literature and Conceptual Framework

2.1 Health, Human Capital, and Marijuana Legalization

Most research on health behaviors can be traced back to Grossman's model of health capital. The canonical model treats health as both a consumption and an investment good, where people enjoy good health directly and use time, goods, and services to produce more healthy days. The focus is typically on the investment component: individuals maximize utility where the marginal return on their investment in their health equals the marginal cost of their investment. Sometimes people choose to *negatively* invest in their health, i.e., participate in risky or unhealthy behaviors like substance use, unsafe sex, or binge eating. The returns on investing in unhealthy behaviors could be the instant gratification one feels or the social experience of participating. The

costs include both monetary costs of substances, food, etc., and non-monetary costs, like poorer health outcomes later in life or less success in the labor market.[3]

Indeed, there is a large body of empirical research on the relationships between risky behaviors and human capital accumulation and labor market outcomes. Most of this literature focuses on the effects of substance use, particularly cigarette smoking and alcohol use. A smaller section examines the effect of marijuana use. Relevant to this paper is the work on teen marijuana use and educational outcomes, which generally finds that smoking marijuana decreases educational attainment. 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, Kendix, and Yamada (1996), Bray, et al. (2000), Register, Williams, and Grimes (2001), and Roebuck, French, and Dennis (2004), among others.[5]

More recently, economists have started to examine the effects of medical and recreational marijuana legalization on access to marijuana and teen use. Findings are mixed. For instance, Anderson, Hansen, and Rees (2015) find a slight, insignificant decrease in the probability of marijuana use after medical marijuana legalization, while Wen, Hockenberry, and Cummings (2015) find an increase.[6] In regard to recreational marijuana legalization, Cerda, et al. (2017) find

[3] Grossman (1972) and Cawley and Ruhm (2011).
[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] A negative relationship is also documented in the sociology and public health literatures: Lynskey and Hall (2000) suggests that marijuana use is negatively related to grade point average, attitudes toward school, attendance, performance, and retention; Ryan (2010) finds that frequent use is associated with lower educational attainment; and Beverly, Castro, and Opara (2019) find that late marijuana users were 1.67 times more likely than early users to graduate from high school. International studies also find negative relationships between marijuana use and a variety of educational outcomes (Duarte, Escario, and Molina (2006); Fergusson and Boden (2008); Silins, et al. (2014); Thompson, et al. (2019)).
[6] There are also conflicting results about access, use, and perceived riskiness in work by Khatapoush and Hallfors (2004), Wall, et al. (2011), Lynne-Landsman, Livingston, and Wagenaar (2013), Harper, Strumpf, and Kaufman (2012), Choo, et al. (2014), Schuermeyer, et al. (2014), and Cerda, et al. (2018).

an increase in marijuana use in Washington (but not Colorado), while Dilley, et al. (2019) show that teen marijuana use fell after legalization in Washington. Additionally, Rusby, et al. (2018) find that marijuana use in a small sample of Oregon schools increased after legalization. I contribute to this literature by not just examining how recreational marijuana legalization effects underage marijuana use, but also how it effects kids' educational outcomes.

2.2 Potential Mechanisms

There are numerous mechanisms that could lead to more marijuana use, and subsequently worse educational outcomes, after legalization. First, legalization could make marijuana easier for teens to access, which could increase the likelihood of use. In the following section I provide some context for Oregon's decision to legalize and discuss what, when, and where marijuana is potentially available to teens.

Second, a large body of research in cognitive development shows that using marijuana in adolescence has negative effects on cognition, short-term memory, attention, overall and verbal IQ, and abstract reasoning skills, and that the effects are more pronounced for those who start using earlier.[7] Additionally, neuroscientists have found that male and female brains have different reactions to tetrahydrocannabinol (THC), the psychoactive ingredient in marijuana that produces the drug's high. The amygdala, the part of the brain that regulates emotion, fear response, and memory, is shown to have a larger volume for female who use marijuana, but not males. This leads to increased anxiety, depression, and short-term memory loss, particularly for females. Estrogen also plays a role in how females react to THC. Females are more sensitive to the pain-relieving effects of THC and develop a tolerance to the drug faster than males, leading to a greater

[7] Pope, Gruber, and Yurgelun-Todd (1995) and Lisdahl, et al. (2013).

probability of addiction for females. The sensitivity to THC is particularly strong during ovulation when estrogen levels have peaked.[8]

Third, the peer effects literature suggests that teens with peers who use substances or approve of using substances are more likely to use than teens with disapproving peers. Whether girls and boys react differently to peer substance use is ambiguous.[9] Fourth, girls may be more likely to be rule-followers and boys more likely to be risk-takers, meaning that boys might decide to use marijuana before it is legal while girls might wait. Indeed, research in psychology shows that girls are more risk-averse than boys.[10] Fifth, legalization leads to higher quality marijuana products, which could lead to larger changes in use for girls but not boys. The legal marijuana market is highly regulated. As I describe in the following section, products are regularly tested for contaminants as well as THC concentration. If girls are more worried than boys about smoking marijuana that could be laced with contaminants or other drugs, then more girls than boys might decide to wait to use marijuana until after legalization when this is less likely to happen.

Finally, an increase in marijuana use after legalization could negatively affect educational outcomes not only directly, as discussed above, but also indirectly. Research suggests that marijuana is a gateway drug to alcohol and other illicit substances that are known to have negative effects on educational outcomes. In addition, there is evidence that marijuana use leads to worse mental health and greater participation in deviant and criminal behaviors.[11]

Lack of data leaves me unable to distinguish between these potential mechanisms, though I can comment somewhat on accessibility and risk-taking behavior, which I do in section 9. Thus,

[8] Jacobus, J. and Tapert, S. (2014), Washington State University (2014), Weir, K. (2015), and Frontiers (2018).
[9] Guo, J., Hill, K., Hawkins, J., Catalano, R., Abbott, R. (2002), Eisenberg, D. (2004), Kawaguchi, D. (2004), Lundborg, P. (2006), Moriarty, J., McVicar, D., and Higgins, K. (2012), Mason, M., Mennis, J., Linker, J., Bares, C., and Zaharakis, N. (2014), and Henneberger, A., Mushonga, D., and Preston, A. (2021).
[10] Byrnes, J., Miller, D., and Schafer, W. (1999) and Harris, C., Jenkins, M., and Glaser, D. (2006).
[11] Ellickson, Hays, and Bell (1992), Kandel, Yamaguchi, and Chen (1992), DeSimone (1998), Brook, et al. (1999), Green and Ritter (2000), Brook, et al. (2011), Brook, et al. (2013), and Epstein, et al. (2015).

in this paper, I identify the *net* effects of legalization on marijuana use and educational outcomes. Additionally, since evidence suggests that legalization could have different effects for girls and boys, I estimate the effects of legalization separately by student gender.

3 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. 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.

Like Oregon, Washington state, on Oregon's northern border, 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.

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.

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 recreational 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 sales tax revenue from marijuana 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 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.[12]

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 putting it on a ballot. 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.[13] Figure 2 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.[14] Importantly, only localities that allow marijuana sales receive state tax revenues.

[12] 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.

[13] 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).

[14] 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").

Total marijuana sales have steadily increased since legalization, which is shown by the dark green line in Figure 3. Sales were roughly $2.5 million in October of 2016 and peaked in July 2020 at roughly $99 million. 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 given by the light green line.[15] 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 3 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.

4 Data

4.1 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

[15] 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.

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. 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. 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

assure that the questions in the YRBSS provide reliable information on teen substance use.[16] 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.[17] 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.[18]

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.

4.2 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

[16] Morbidity and Mortality Weekly Report: Methodology of the Youth Risk Behavior Surveillance System, Centers for Disease Control and Prevention.
[17] Folk, Hirschtritt, McCrary, and Kalapatapu (2022), Boykan, et al. (2019), Dembo, et al. (2015), and Buchan, Dennis, Tims, and Diamond (2002).
[18] Folk, Hirschtritt, McCrary, and Kalapatapu (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.[19]

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.

5 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

[19] 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.[20]

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).[21]

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

[20] 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.

[21] 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.

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 prior to the sales market opening in my robustness checks. Parallel trends would suggest that outcomes in counties above and below the 55% vote-share threshold would have continued along similar trends if Measure 91 had not been passed.

6 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.[22] 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.

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.

6.1 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

[22] 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).

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.[23]

[23] I use the six specifications in Table 1, and 100 bootstrap replications, to calculate the Romano-Wolf p-values.

6.2 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.[24] Again, to put this in perspective, consider the average high school 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.

[24] 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.

6.3 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."

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.[25] 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.

7 Robustness

7.1 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

[25] 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.

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 4 shows average marijuana access and use for counties where marijuana businesses were banned (black) and allowed (green). For all outcomes, the figures indicate that counties followed similar trends in the pre-period. Figure 5 shows average dropout rates and chronic absenteeism over time. The trends before legalization were somewhat similar, though not as convincing as those in Figure 4, 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 11^{th}-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 the parallel trends assumption holds for high school girls.[26]

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. A statistically significant result far from zero would indicate that the placebo treatment explains the differences I see after legalization, suggesting that the effects I find could be attributed to underlying differences in opt-out and non-opt-out counties rather than legalization. The results of these placebo tests are in Table 4. Like the pseudo difference-in-differences results, I present the placebo test for all students in the first panel, and then separately for girls and boys in the remaining two panels. Panel A, columns (1) and (2) show that the marginal effects of the placebo treatment on marijuana access and use on the extensive margin across all students are small and not statistically significant. Column (3) in panel A shows that the effect on marijuana use on the intensive margin is a bit farther from zero but is still not significant. The effect on chronic absenteeism is similarly not very close to zero but is also not significant, as shown in column (4). Panel A, columns (5)-(7) show the effects, across all students, on dropout rates and the proportions of students not proficient in math or ELA. None are statistically significant, and the dropout rate and ELA results are near zero. The effects of the placebo on all outcomes for girls and boys separately yield similar results to those across all students, as shown in panels B and C, respectively.

Overall, 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.

[26] 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.

7.2 Potential Confounders

There are a few other things happening in Oregon around recreational marijuana legalization that could influence educational outcomes. First, the legislature passed Senate Bill 1532 in February 2016, which outlined annual minimum wage increases between July 2016 and July 2022. If the minimum wage changed uniformly across the state each year, then it would be picked up by the year fixed effect. However, the bill stated that the minimum wage would change at a different rate in different areas in the state: standard counties, the Portland metropolitan area, and non-urban counties. The goal was that, by 2023, the Portland metro would have a minimum wage $1.25 above the standard, and the non-urban counties would have a minimum wage $1 below the standard.[27] All of the counties that opted out after legalization, as well as Douglas, Coos, and Curry counties, fall under the non-urban category. The rest of the counties that did not opt out are either part of the Portland metro area or are considered standard counties.

Since the minimum wage generally went up more in the counties that did not opt out after legalization, it 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 educational outcomes 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 are presented in Table 5. Chronic absenteeism increases by a slightly smaller amount (2.5 compared to 2.9 percentage points) after accounting for the minimum wage, as shown in column (1). Similarly, dropout rates for both girls and boys increase less when I include the minimum wage. For girls, the dropout rate goes up by 0.81 percentage points compared to 0.97 in the main analysis (column (2)), and for boys it increases by 0.55 percentage points compared to

[27] A chart of the minimum wages over time is included in the appendix.

0.69 (column (3)). Column (6) shows that the share of 11th-grade girls who are not proficient in ELA increases by 2.4 percentage points, which is about 0.8 percentage points less than the original estimate. The effects on the shares of girls and boys not proficient in math, and the share of boys not proficient in ELA, also decline, and they remain statistically insignificant. Overall, while the increasing minimum wage does explain some of the variation in educational outcomes after marijuana legalization, legalization stills lead to large increases in absenteeism, dropout rates, and non-proficiency in ELA.[28]

Second, statewide assessments changed starting in the 2014-15 school year. The data on math and ELA proficiency are only available between 2014-15 and 2017-18 by student gender, so I only use years the new tests are in place for my analysis. In addition, the test scores required for students to receive a diploma changed to reflect the new tests in the 2015-16 school year, which is picked up by the year fixed effect. [29]

7.3 Washington Border Counties

As I briefly mentioned in the background section, Washington state, along Oregon's northern border, legalized recreational marijuana in 2012. The first dispensaries opened in Washington in July 2014, just over a year before early sales began out of medical dispensaries in Oregon. While Oregonians were waiting for dispensaries to open in-state, it is possible that they traveled to Washington to buy marijuana. In fact, Hansen, Miller, and Weber (2020) find that dispensaries in Washington had a 36% loss in sales after dispensaries began selling marijuana in Oregon. The authors do not track underage marijuana use, but it is plausible that teens, especially

[28] While it does not seem intuitive that changes in the minimum wage would impact marijuana use, I do estimate equation (2) with the minimum wage as a regressor. The estimates are a bit smaller but are generally robust to minimum wage changes. The results are presented in Table A3 in the appendix.

[29] Another potential confounder is changes in alcohol policies over the sample period that would make alcohol more or less attractive than marijuana for teens. I am not aware of any such changes.

those in the counties bordering Washington, were able to access marijuana easier after Washington's dispensaries opened, making use go up in Oregon before dispensaries opened in-state. If this is the case, then I could be underestimating the effects of legalization in Oregon. To test this, I re-estimate equations (2) and (3) without the ten counties bordering Washington, i.e., without Clatsop, Columbia, Multnomah, Wasco, Hood River, Sherman, Gilliam, Morrow, Umatilla, and Wallowa. The results are presented in Tables 6 and 7.

When I remove the border counties, the effects on girls' marijuana use fall. Column (3) of Table 6 shows that the probability of past-month use increased by 3.66 percentage points after legalization in non-border counties compared to the 4.09 percentage point increase when I include all counties. The number of times 11th-grade girls used marijuana in the past month went up by 0.18 in this sample compared to the 0.27 increase with all counties. The effects on boys' marijuana use remain statistically insignificant.[30]

Table 7 includes results for both behavioral and academic performance outcomes. The effect on chronic absenteeism is a little larger when I remove the border counties. Column (1) shows that the effect is 3.11 percentage points compared to 2.92 from the analysis with all counties. Columns (2) and (3) show that dropout rates increase more for both girls and boys after legalization when the border counties are removed. Dropout rates increase by 1.44 and 0.93 percentage points for girls and boys, respectively, relative to 0.97 and 0.69 percentage points from the main analysis. The effect on the proportion of girls who are not proficient in ELA stays the same after removing the border counties, as shown in column (6). As before, the shares of girls and boys not proficient in math, as well as the share of boys not proficient in ELA, do not change after legalization in statistically significant ways.

[30] Column (2) shows that 11th-grade boys find it more difficult to get marijuana after legalization in the non-border counties.

It appears that my original estimates are overestimating the effects on marijuana use but underestimating the effects on educational outcomes. As I mentioned above, I hypothesized that the opening of Washington's market would induce more teens to use marijuana before legalization in Oregon, driving average use in the pre-period up, making the effects of legalization on both use and educational outcomes appear smaller than the true effects. It is unclear to me why the original estimates on marijuana use would be upward biased while the estimates on educational outcomes would be downward biased. This deserves further scrutiny.

7.4 New Difference-in-Differences Literature

The difference-in-differences literature has been rapidly evolving over the past few years. Econometricians have determined that the traditional implementation of the DiD design with two-way fixed effects can be problematic when there are multiple treatment groups, a continuous treatment, differential treatment timing, or covariates. In my setting, I have a binary treatment, only one treatment group, and no variation in treatment timing, but I do include time-varying covariates, specifically in equation (3), to control for differences in schools over time that could affect educational outcomes. In this case, the parallel trends assumption must hold *conditional* on covariates. The pseudo DiD and placebo test I do in section 7.1 include controls, and as I explained there, the parallel trends assumption appears to hold across all outcomes, particularly for girls.

Additionally, two-way fixed effects assumes that treatment effects are homogenous across all groups, which is unlikely in this setting. In fact, in section 8, I show that there are differential effects of legalization across schools in different locations and with different levels of student economic disadvantage. Also, two-way fixed effects requires that the trends in covariates must be the same in the treatment and control groups, which is difficult to test because not all counterfactual groups can be observed.

Wooldridge (2021) proposes using a two-way fixed effects estimator with interactions that control for heterogenous treatment effects across covariates and time. I implement this method and present the results in Tables 8 and 9. Each column includes *Legal x Post*, county or school fixed effects, post-year indicators, interactions of covariates with each post-period year, and interactions of covariates with each post-period year and *Legal x Post*. Note that the covariates included are demeaned by the average across treated units. The estimated effects of legalization on marijuana access and use on both the extensive and intensive margins barely change for 11th-grade girls, as shown in Table 8. The effects on boys' marijuana use fall substantially and are closer to zero, as shown in columns (4) and (6), and they remain statistically insignificant. In Table 9, column (1), the effect on chronic absenteeism stays about the same (2.7 compared to 2.9 percentage points). Column (2) shows that the effect on girls' dropout rates almost doubles with this specification. The estimate goes from 0.97 to 1.91 percentage points. The effect on boys' dropout rates is much smaller and no longer statistically significant (column (3)). In column (6), the effect on the share of girls not proficient in ELA is 20.2 percentage points, over six times as large as the original estimated effect. Like the original estimates, those for the shares of girls and boys not proficient in math are not significant, and neither is the effect on the share of boys not proficient in ELA.

It appears that the standard two-way fixed effect approach does a pretty good job with estimating the effects on marijuana use but is biased in estimating the effects on the educational outcomes, which makes sense given I include more time-varying controls in equation (3). The story, however, remains the same: recreational marijuana legalization has a negative effect on high school girls' educational outcomes and leaves boys largely unaffected.

7.5 County Time Trends

It is possible that there are underlying trends in marijuana use within individual counties that my model is attributing to legalization. For example, marijuana use might be increasing over the sample period within counties generally, and not have anything to do with legalization. One way to test this is to include a county-specific linear time trend and see if the results remain the same. However, when I do this, there is too little variation left to identify the effect of legalization. The R-squared from a regression of *Legal x Post* on the other covariates in equation (2) and the time trend is 0.9819, indicating that there is only $1 - 0.9819 = 0.0181$ residual variation left for identification.

8 Extensions of the Main Analysis

8.1 Effects of Legalization Over Time

The effects of legalization could either increase over time as the marijuana market grows, or they could dissipate as the market becomes less novel. To examine whether the effects are concentrated in the short run or the medium run, I re-estimate equations (2) and (3) without *Legal x Post*, but with interactions of the post-legalization years with *Legal*. Specifically, I interact *Legal* with two indicators: a dummy variable equal to one if the year is either 2016 or 2017, and a dummy variable equal to one if the year is either 2018 or 2019. I include both interaction terms when I estimate the models. I interpret the coefficients on the interaction of *Legal* with the 2016-17 indicator as short-run effects and the coefficients on the interaction of *Legal* with the 2018-19 indicator as medium-run effects. The results are presented in Tables 10 and 11.

For girls, access to marijuana did not change right after legalization, but increased by 6.2 percentage points in the medium run (Table 10, column (1)). Boys found it harder to get marijuana in the short run (4.09 percentage point decrease), but not in the medium run (column (2)). The

probability of using marijuana in the past month did not change for anyone in the earlier years but increased in the later years: in column (3), girls were 7.27 percentage points more likely to use marijuana in the medium run, and in column (4), boys were 3.19 percentage points more likely to do so. Finally, girls used marijuana more days in both the earlier and later years after legalization. They used 0.2377 more days in the short run and 0.3102 more days in the medium run (column (5)).

The effects on educational outcomes over time are given in Table 11. In column (1), the marginal effect on chronic absenteeism is 0.0274 (0.0133) right after legalization and 0.0313 (0.0175) in the medium run. For girls, the effect on dropout rates is about 1 percentage point in both the short and medium runs, while the effect is concentrated in the short run for boys, as shown in columns (2) and (3).

The proportion of 11^{th}-grade girls who are not proficient in math increased by 0.0077 (0.0158) in the short run and by 0.0302 (0.0252) in the medium run (column (4)). Similarly, the effect for boys is concentrated in the medium run. As shown in column (5), the marginal effect for boys in math is 0.0082 (0.0246) right after legalization and -0.0229 (0.0309) in the later years. Column (6) shows that the proportion of 11^{th}-grade girls who are not proficient in ELA increased by 0.0152 (0.0227) in the short run and 0.0671 (0.0254) in the medium run. The latter is statistically greater than zero at the 1% level of significance. The same proportion for boys decreased by 0.0289 (0.353) right after legalization and increased by 0.0163 (0.0310) in the medium run (column (7)). Note that these test score models only include 2018 in the medium run because of data availability.

Overall, the medium-run effects of legalization appear larger than the short-run effects. These results show that, as the legal marijuana market expanded, access to marijuana and marijuana use increased, which subsequently drove educational outcomes down over time.

8.2 Two-Sample Instrumental Variables Estimation

A natural next step is to take the ratio of the reduced form effect of legalization on educational outcomes to the first stage effect on marijuana use to see how using marijuana affects educational outcomes. I do this formally by estimating the effect of marijuana use on educational outcomes using a two-sample instrumental variables strategy. Since the data on marijuana use and educational outcomes are at different levels, I aggregate both datasets up to the county level. Using this county-year panel, I then estimate the effect of marijuana use on chronic absenteeism, dropout rates, and non-proficiency rates with legalization as my instrument for marijuana use (the IV is specifically *Legal x Post*), and county and year fixed effects. Results are in Table 12. Panel A shows the effects of the probability of using marijuana on educational outcomes and Panel B shows the effects of the frequency of marijuana use on educational outcomes. For each educational outcome and marijuana use pair, I report marginal effects, standard errors clustered at the county level, standard 95% confidence intervals, and 95% confidence intervals adjusted for weak instruments.

In column (1) of Panel A, the proportion of chronically absent students increases by 0.8022 (0.2387) when the probability of using marijuana in the past month goes from 0 to 1. On the intensive margin, using marijuana one more time in the past month leads to a 0.1373 (0.0486) increase in the proportion of chronically absent students, as shown in column (1) of Panel B. Both effects on absenteeism are statistically significant at the 1% level after adjusting for weak instruments. Columns (2)-(7) of Panels A and B show that dropout rates and the proportions of students not proficient in math or ELA fall for girls and boys with both measures of marijuana use, but not in statistically significant ways.

I could have aggregated up to the county-level and used a TSIV strategy in my main analysis, but I chose not to because the measures of marijuana use are for 11th graders only, while the educational outcome measures are across different grades. While students are tested in math and ELA in 11th grade, chronic absenteeism and dropout rates are measured across all high school students. Because of these differences, the changes in educational outcomes resulting from changes in 11th-grade marijuana use only measure the true effect as long as 11th-grade use is indicative of marijuana use in other high school grades, which I cannot test in this setting.

8.3 School Heterogeneity

From a policy perspective, it is important to know which students are most affected by recreational marijuana legalization. While I have already considered heterogenous effects by student gender, it is possible that there are differences across student academic achievement levels and socioeconomic status. I do not have student-level data on these measures, so I look instead at differences in these characteristics across schools. In addition, I determine whether there is heterogeneity by school location, i.e., urban, suburban, and rural schools, given that there is an urban-rural divide between opt-out (rural) and non-opt-out (urban) counties. I will discuss the estimation results for differences across school economic disadvantage and location, but not academic performance because the results are ambiguous.[31]

8.3.1 Economic Disadvantage

The school-level data from the ODE includes the percentage of students who are eligible for free-or-reduced-price lunch. I use this to proxy for school economic disadvantage. Specifically,

[31] I grouped schools by terciles of the proportion of students who are not proficient in math and re-estimated equation (3) for all outcomes for each tercile. I did the same for the proportion not proficient in ELA. The results are ambiguous for both subjects.

I calculate terciles of the percentage of free-or-reduced-price lunch eligible students across all school years in my sample. Thus, schools are grouped into three categories, which I call "less poor", "poor," and "more poor," and these designations can change over time. I re-estimate equation (3) for each of the behavioral and performance outcomes for each tercile of economic disadvantage. The results are presented in Table 13. Panel A includes behavioral outcomes while Panel B includes academic performance outcomes. Each column shows the regression coefficients of *Legal x Post* for each outcome by tercile. Standard errors clustered by county are in parentheses and one-sided p-values are in square brackets.

The marginal effects of legalization on chronic absenteeism in less poor and poor schools are 0.0140 and 0.0115, as shown in columns (1) and (2) of Panel A, respectively. Neither effect is statistically significant. The effect on chronic absenteeism in poorer schools, however, is 0.0381, which is statistically positive at the 10% level (column (3)). A similar pattern emerges for dropout rates for both girls and boys. Columns (1) and (2) show that there is no change in dropout rates in less poor and poor schools after legalization. Column (3) shows that dropout rates increase by 0.0329 for girls and 0.0234 for boys in poorer schools. I can reject the null hypothesis that these effects are less than or equal to zero at the 1% level of significance.

The effects on the proportion of girls and boys not proficient in math are ambiguous. None of the coefficients in columns (1)-(3) of Panel B are statistically significant at the standard levels. The effects of legalization on the proportion of girls not proficient in ELA, however, seem to be driven by poorer schools. In column (1), the coefficient is -0.0480 and in column (2) it is 0.0182. Neither are significant. Column (3) shows that the proportion of girls not proficient in ELA increases by 0.0488, which is statistically positive at the 5% level. Unlike girls, the proportion of boys not proficient in ELA does not change across schools of different economic disadvantage.

Overall, schools with more poor students are those most impacted by legalization. The effects on chronic absenteeism for all students, dropout rates for girls and boys, and ELA performance for girls are larger in magnitude and statistically significant for poorer schools compared to schools that are less poor or poor.

8.3.2 School Location

To estimate the effects of legalization for schools in different locations, I use information from the Common Core of Data (CCD). The CCD classifies schools as being in one of the following locations based on U.S. Census Bureau definitions of urban and rural: small, midsize, or large cities; small, midsize, or large suburbs; remote, distant, or fringe towns; and remote, distant, or fringe rural areas. I create three categories of location based on these classifications: city schools, suburban and town schools, and rural schools. I group suburban and town schools together for sample size reasons. Then, I re-estimate equation (3) for each behavioral and performance outcome for these three locations separately. The results are presented in Table 14, and like Table 13, Panel A shows results for behavioral outcomes while Panel B shows results for academic performance outcomes. The columns include the coefficients of *Legal x Post*, standard errors clustered by county in parentheses, and one-sided p-values in square brackets for each outcome by location.

The marginal effect of legalization on chronic absenteeism in city schools is 0.0596, as shown in Panel A, column (1). The coefficient is statistically positive at the 1% level of significance. Columns (2) and (3) show smaller, but positive and statistically significant effects of legalization on chronic absenteeism in suburban and town schools and rural schools. The effect for suburban and town schools is 0.0371 while the effect for rural schools is 0.0200. Interestingly, the effects on dropout rates appear to be driven by schools in suburbs and towns. Column (2) shows

that the dropout rate increases by 0.0113 for girls and by 0.0084 for boys after legalization. I can reject the null hypothesis that these are less than or equal to zero at the 10% level. Panel B shows that the effects on math and ELA performance across school location are more ambiguous, though it does appear that boys do better in ELA in city schools after legalization (-0.0524 in column (1)).

Overall, chronic absenteeism increases in all schools, but the most in city schools; dropout rates for girls and boys increase in suburban and town schools; and academic performance does not change across school location.

8.4 Drive-Time Model

So far in this paper, 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 2, Lane County voted for Measure 91. Map (a) in Figure 6 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.

8.4.1 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.[32]

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 6 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.

[32] I have requested this data from the OLCC and the OMMP.

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. As I described in section 7, 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. While the drive-time to a Washington dispensary may not be a good predictor of the drive-time to 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 7 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.

8.4.2 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 15 and 16 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 15. 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.[33]

Table 16 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 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

[33] 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.

set of dispensaries open over time), my hope is that these results will be more precise and indicative of the full picture of legalization in Oregon.

9 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.

9.1 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.[34] 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.[35] 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

[34] Byrnes, J., Miller, D., and Schafer, W. (1999) and Harris, C., Jenkins, M., and Glaser, D. (2006).
[35] The SWS asks about smoking specifically, while the HTS asks about *using* marijuana. I treat these as the same questions for this analysis.

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 17. 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 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.

9.2 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. As I discussed earlier in the paper, 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. 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 18. 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.

9.3 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 8 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. The general fund is spent on instruction, support services, enterprise and community services, facilities acquisition and construction, and other uses. Most of the general fund is spent on instruction and support services. Instructional services include regular elementary, middle, and high school programs; special education programs to support English language learners, talented and gifted students, students with disabilities, and many others; continuing education programs; and summer school programs. Support services include student support programs like counseling, speech pathology, attendance services, and school nurses; support services for instructional staff and administrators; business services like financial accounting, student transportation, maintenance, and security services; and other services to support central activities like recruitment and technology. Enterprise and community services include food service, community recreation and public library services, and support for the custody and care of children. Facilities acquisition and construction is self-explanatory, and other uses include short- and long-term debt service.

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 19.

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, Hedges, and Laine (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 and 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, Johnson, and Persico (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.

10 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 11^{th}-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 11^{th}-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 11^{th} 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 11^{th}-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 (2022). 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. I am currently working to identify the demand for capital investment in Colorado using a windfall of marijuana tax revenue from 2016 and changes in the state matching contributions on capital expenditures.

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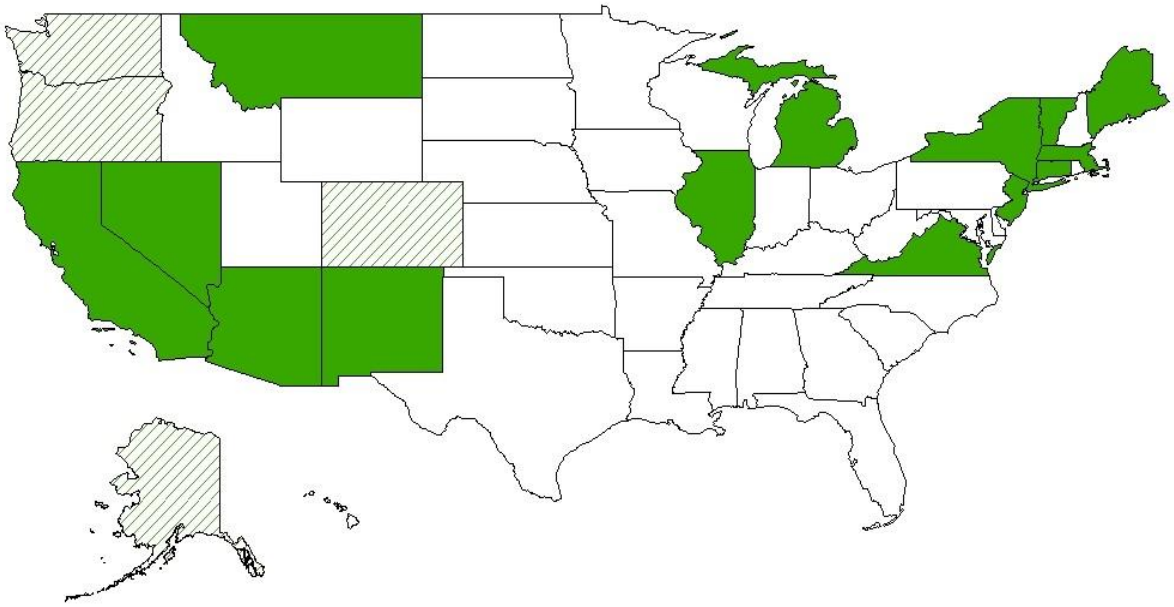
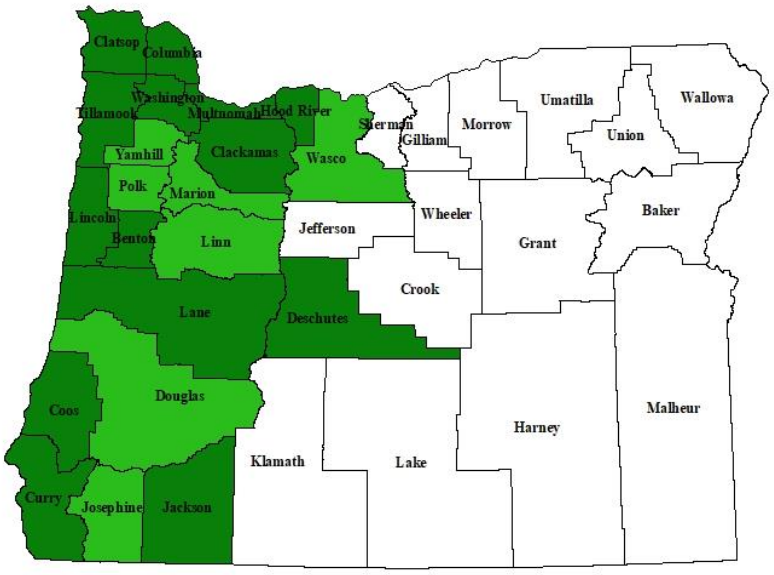
Figures

Figure 1: Legality of Recreational Marijuana Across the United States



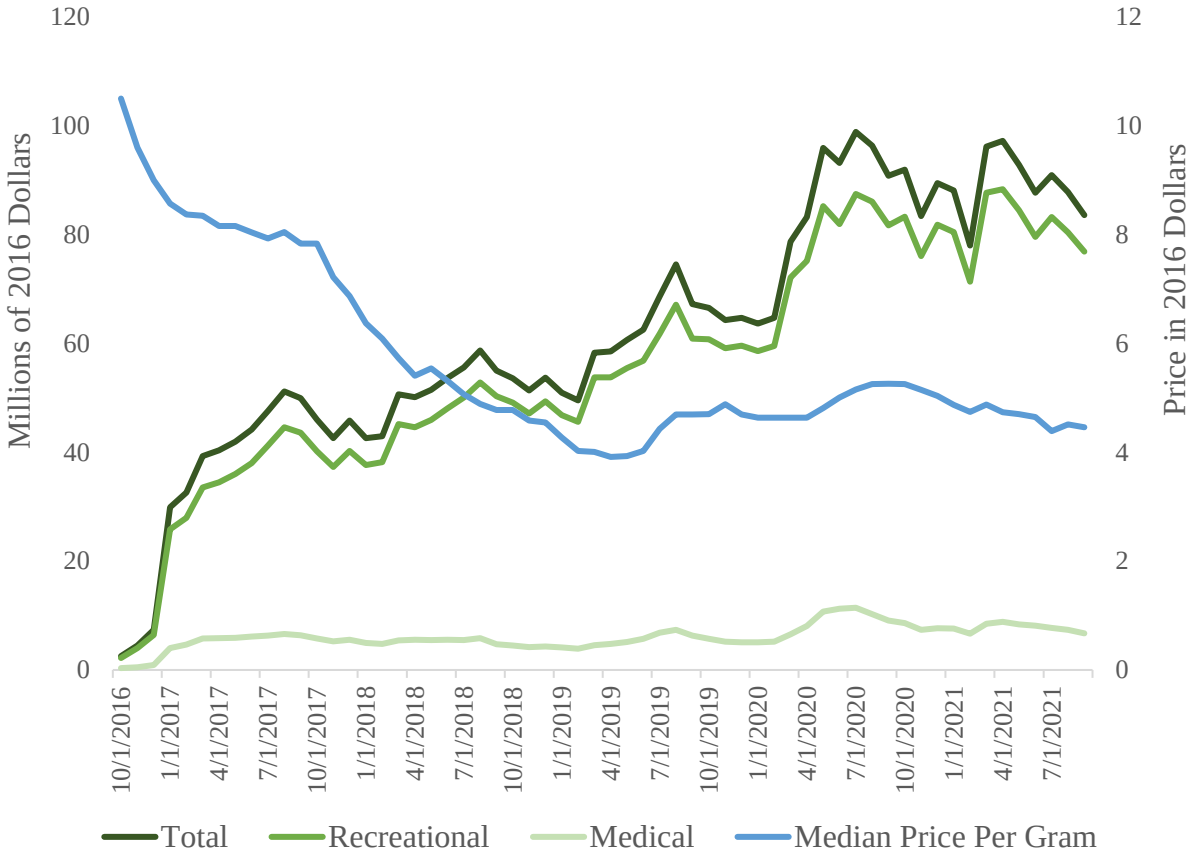
Notes: This figure shows which states legalized recreational marijuana by September 2021. The states with stripes legalized recreational marijuana by 2014, including Oregon. The solid green states are those that have legalized marijuana since 2014.

Figure 2: Legality of Recreational Marijuana by County in Oregon



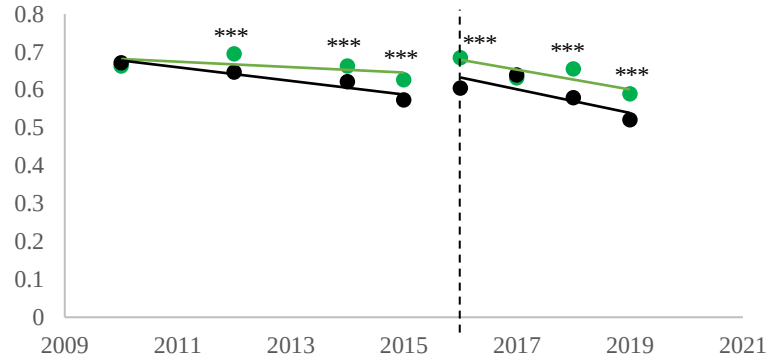
Notes: This figure shows which counties in Oregon were able to opt-out after legalization. The counties in white had a 55% majority against Measure 91 and were allowed to (and did) opt out. Those in light green had a 50% majority against legalization but were not allowed to opt out. Counties in dark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

Figure 3: Monthly Marijuana Sales and Prices in Oregon

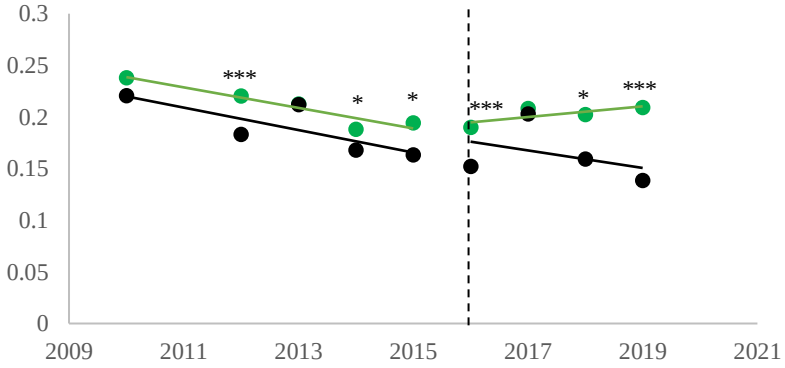


Notes: This figure shows trends in total, recreational, and medical marijuana sales, as well as the median price per gram of recreational, smokable marijuana, in Oregon from October 2016 through September 2021. Sales and prices are in 2016 dollars. The data was extracted from the Oregon Liquor and Cannabis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

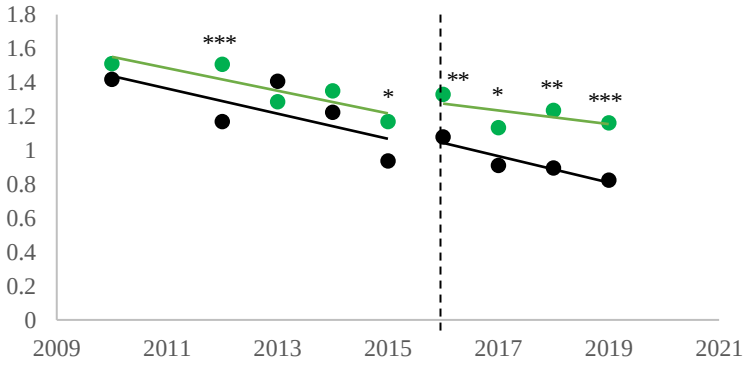
Figure 4: Trends in Average Marijuana Access and Use in Oregon for Opt-Out (Black) and Non-Opt-Out (Green) Counties



(a) Marijuana Access



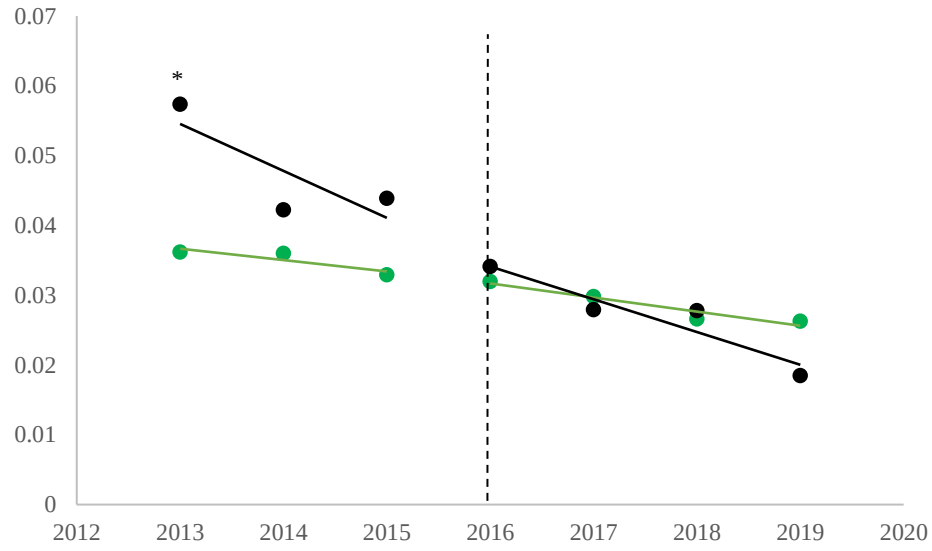
(b) Marijuana Use (Extensive)



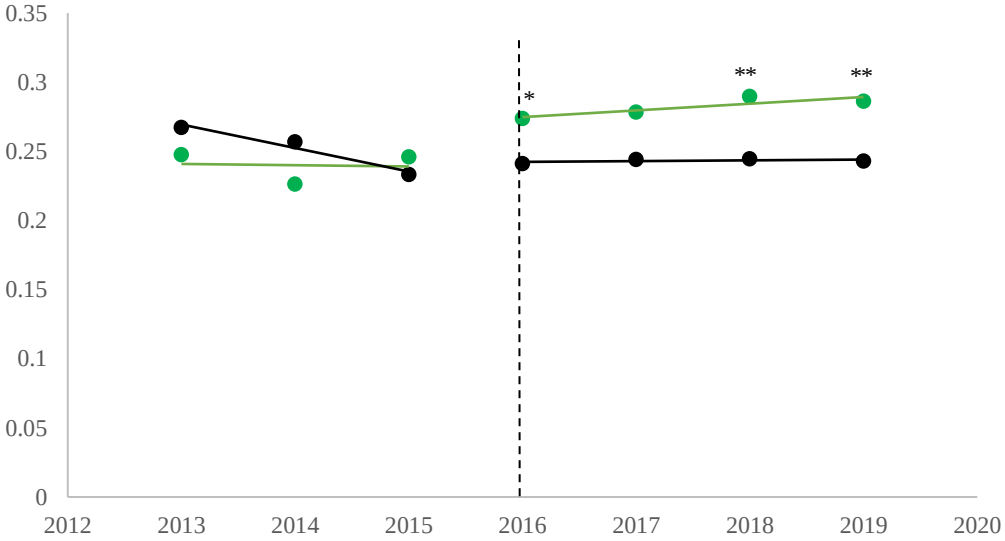
(c) Marijuana Use (Intensive)

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



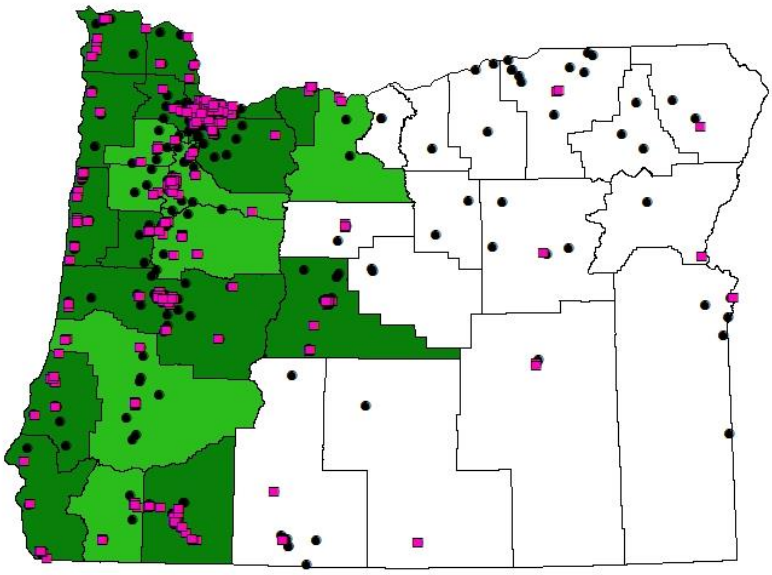
(a) Dropout Rate



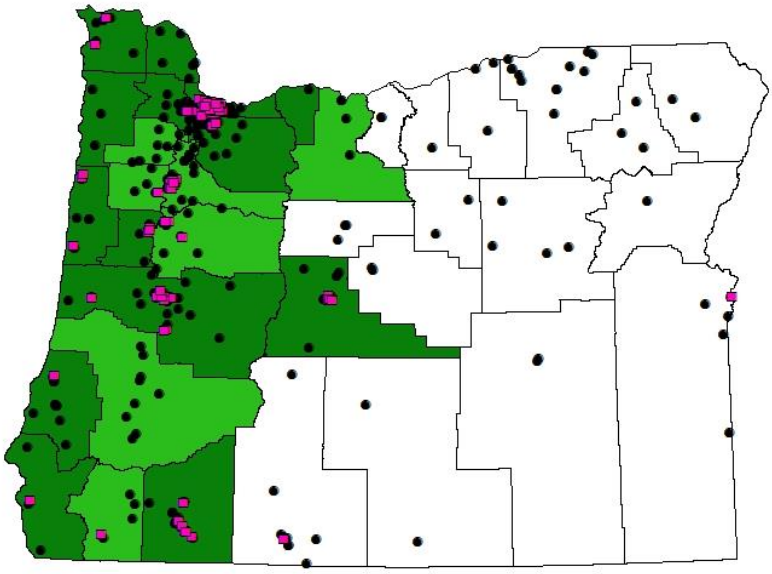
(b) Chronic Absenteeism

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 6: Distribution of Schools and Marijuana Dispensaries Across Oregon



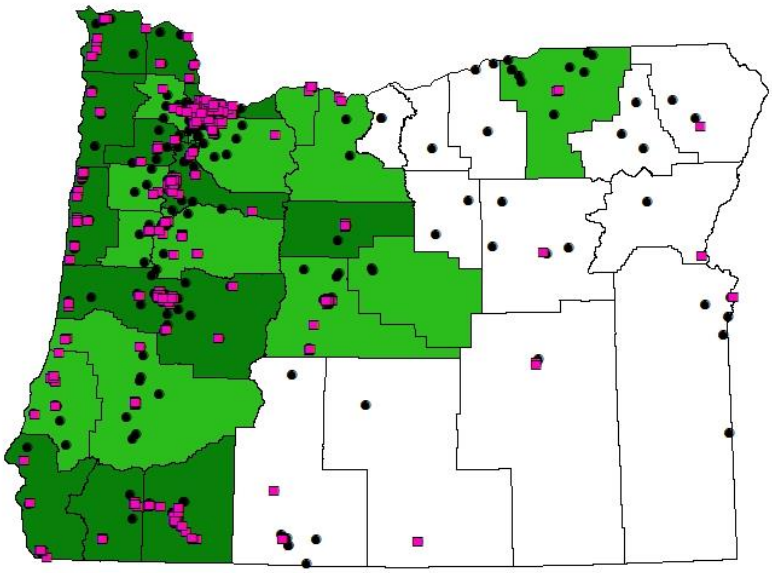
(a) Public High Schools and Recreational Marijuana Dispensaries



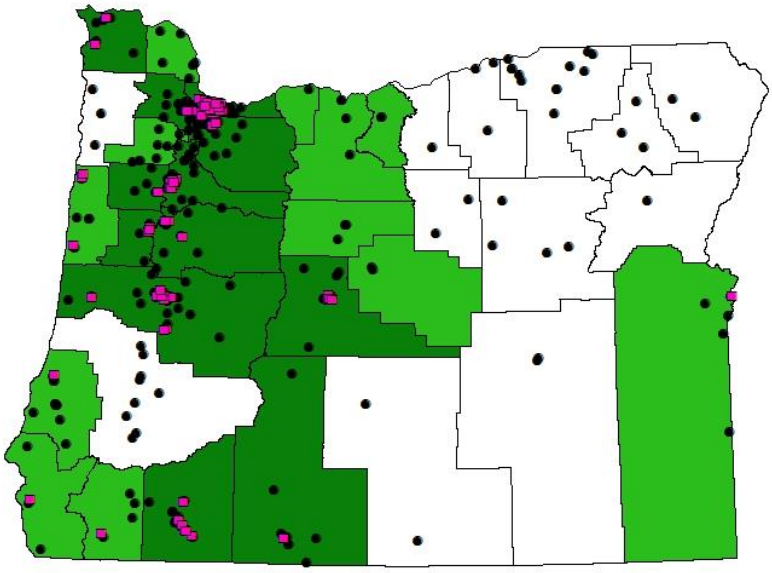
(b) Public High Schools and Pre-Existing Medical Marijuana Dispensaries

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



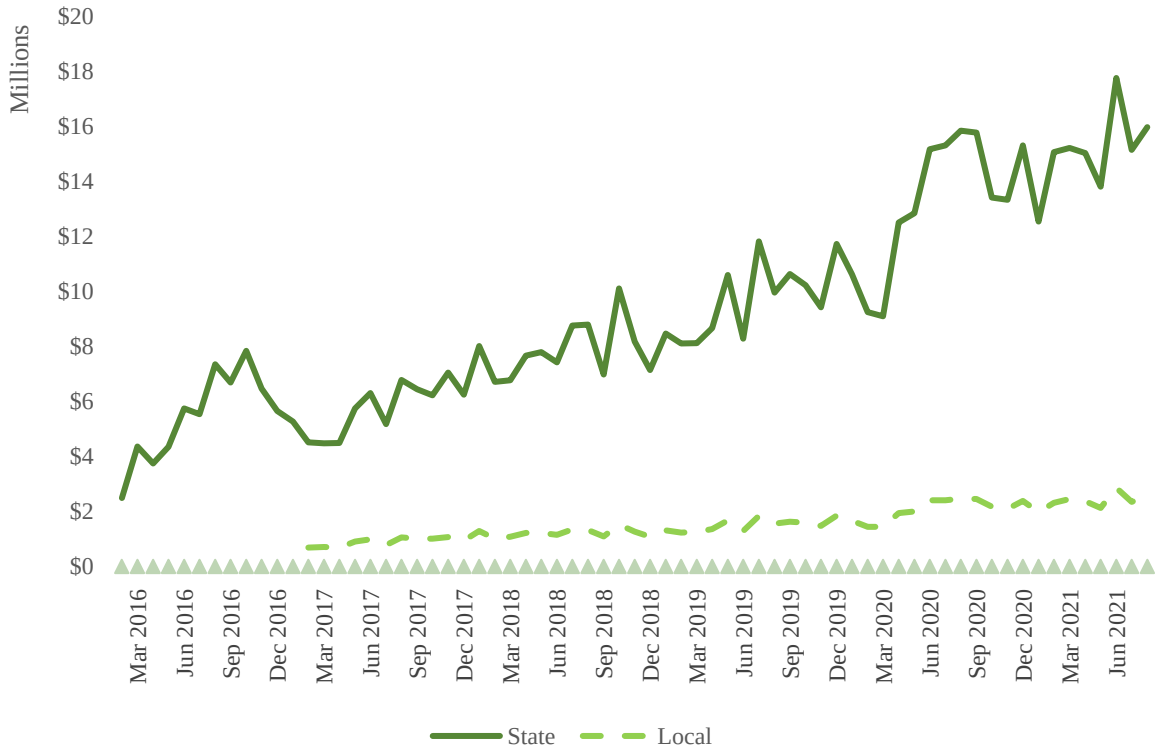
(a) Public High Schools and Recreational Marijuana Dispensaries



(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 8: 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 Treatment x Post	0.0007	-0.0027	-0.0448	0.0168	0.0009	0.0104	0.0089
	(0.0093)	(0.0074)	(0.0589)	(0.0149)	(0.0024)	(0.0139)	(0.0123)
	[0.468]	[0.357]	[0.224]	[0.133]	[0.356]	[0.229]	[0.236]
Observations	105,476	120,135	119,090	1,550	1,553	1,004	1,035
Panel B: Female							
Placebo Treatment x Post	-0.0031	0.0019	-0.0524		0.0010	0.0213	0.0176
	(0.0131)	(0.0102)	(0.0751)		(0.0023)	(0.0178)	(0.0168)
	[0.405]	[0.428]	[0.243]		[0.331]	[0.120]	[0.151]
Observations	53,277	60,541	60,140		1,553	766	777
Panel C: Male							
Placebo Treatment x Post	0.0049	-0.0075	-0.0345		0.0008	0.0146	-0.0162
	(0.0132)	(0.0107)	(0.0914)		(0.0029)	(0.0177)	(0.0163)
	[0.356]	[0.243]	[0.353]		[0.388]	[0.209]	[0.165]
Observations	52,199	59,594	58,950		1,553	777	814

Notes: This table reports marginal effects from the estimation of equations (2) and (3) where *Legal* is replaced with a binary variable *Placebo Treatment* 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%. 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 one-tailed p-values are shown in square brackets.

Table 5: 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 A2 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 6: 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 7: 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 8: 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 9: 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 10: 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 11: 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 12: 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 13: 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 14: 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. *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 15: 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 16: 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 17: 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 18: 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 19: 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

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: 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 A3: Robustness of the Effects on Marijuana Access and Use to Changes in Oregon's Minimum Wage

	Marijuana Access		Marijuana Use (Extensive)		Marijuana Use (Intensive)	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Legal x Post	0.0278	-0.0186	0.0339	0.0033	0.2575	0.0478
	(0.0231)	(0.0230)	(0.0185)	(0.0181)	(0.1276)	(0.1312)
	[0.114]	[0.209]	[0.033]	[0.429]	[0.022]	[0.358]
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 the minimum wage included as a control. See appendix table A2 for the minimum wage rates over time. 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.