Geographical Access to Recreational Marijuana

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Abstract: We investigate whether adult marijuana use in Washington responds to increased local access as measured by drive time to the nearest legal marijuana retailer as well as measures of retail density. Using survey data from the Behavioral Risk Factor Surveillance System, we find that as retailers open closer to where they live, more individuals use marijuana and more frequently. From these results, we obtain overall elasticities of any use and frequency of use with respect to travel time of -0.12 and -0.15, respectively. However, effects are substantially larger among young people (ages 18-26), particularly young women. Retail density does not impart an independent effect on past-month use.

JEL classifications: I12, I18, I10

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1. INTRODUCTION

Initiative 502 in Washington State and Amendment 64 in Colorado were passed in November 2012, marking the beginning of new drug control policies in the United States. Prior to the passage of these first recreational marijuana laws (RMLs), legal access in the United States was available only through medical marijuana laws (MMLs).[1] Initiative 502 (I-502) legalized the possession and consumption of marijuana products for individuals over 21 years of age and licensed the production, processing, and retail of marijuana products to qualifying businesses. Legalized possession began in December 2012 and legal sales began in July 2014.

Though a large literature examines the effects of medical legalization (and, more recently, recreational legalization) on marijuana consumption, less is known about how factors *within* a legalized environment affect such use.[2] Our primary hypothesis is that any secular effect of legalization on marijuana use masks heterogeneity by local access to marijuana retailers. The elasticities of use at different margins with respect to geographical distance to a retailer and to the density of retailers in one's area are important measures for local jurisdictions to know as they grapple with how to regulate marijuana retail in a legalized state. For example, the state of Washington is currently considering proposals that would expand the number of retail licenses (which is currently fixed) as well as allow for home delivery of some marijuana products.[3]

Our analysis uses data from the 2014, 2015, and 2016 Behavioral Risk Factor Surveillance System (BRFSS) for Washington. We utilize geographic information systems

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[1] Marijuana remains illegal at the federal level as a Schedule I controlled substance.
[2] See Chu (2014), Chu (2015), Hasin et al. (2017), Martins et al. (2016), Pacula, Powell, Heaton, and Sevigny (2015), and Wen, Hockenberry, and Cummings (2015) for studies on the effects of MMLs on adult marijuana use.
[3] https://www.nwpb.org/2019/08/27/5-years-in-washington-regulators-considering-changes-to-legal-marijuana-rules/ (accessed 8/28/2019).

(GIS) to compute ZIP code-level measures of distance to each retailer to investigate if drive time to the nearest retailer affects an individual's propensity to use marijuana in the past month. We also examine the impact of local retail density in order to determine if having many options—and its implicit effect on price, variety, and quality—affects use.

We find that on average, a 33% reduction in drive time (e.g., from 30 to 20 minutes) is associated with a 0.10-day increase in past-month use. In addition, a 33% decrease in drive time increases the probability of having used marijuana in the past month by 0.62%, while the probability of heavy past-month use (using 20 or more days) increases by 0.26%. The elasticities of any use, heavy use, and the number of days used with respect to travel time are -0.12, -0.12, and -0.15, respectively. Retail density (the number of proximate sellers) does not affect a consumer's use at the extensive or intensive margins.

In addition to our main sample estimates, we stratify the data by sex and age. We find that the probability of use and heavy use as well as frequency of use increases especially for women and young adults (age 18-26) as retailers get closer. For example, a 33% reduction in travel time increases the probability of young adults having used by 2.2% (an elasticity equal to -0.22), using heavily by 2.0% (an elasticity equal to -0.55), and the number of days used in the past month by 0.56 days (an elasticity equal to -0.43). For women as a whole, the same reduction in travel time raises the probability of any use by 0.76% (an elasticity equal to -0.18) and days used by 0.12 days (an elasticity equal to -0.22) in the past month. For men as a whole, proximity to a retailer is not significantly associated with any of the three measures of marijuana use in the past month.

In a recently published study, Everson, Dilley, Maher, and Mack (2019) also examine local retail availability of marijuana on adult use in Washington. Our paper is different from theirs in several ways. First, we control for a local price measure of retail marijuana, which may be a confounding factor with distance in explaining marijuana use. Second, we use travel time rather than straight-line distance as our measure of proximity to marijuana retail; though these are of course highly correlated, we believe travel time is more relevant for measuring local retail access. Third, we decompose our analysis into subgroups to see if the effects of access differ by sex and age, finding substantial differences across these dimensions. Perhaps most importantly, we rely solely on within-ZIP code variation in distance over time to identify our effects. Everson et al. (2019) exploit cross-sectional variation in addition to variation over time, which is more likely to result in omitted variable bias, since locations with shorter average distances are likely to have higher marijuana use than those with longer distances for reasons other than distance itself (we provide evidence to this effect in our empirical methodology section below). Throughout this paper, we compare our methodology, as well as our results, to Everson et al. (2019).

Our identification strategy, which relies on within-ZIP code variation over time in the presence of marijuana retailers, would be threatened by the possibility that marijuana retailers locate in areas that are likely to experience higher growth in marijuana consumption over time. In falsification tests, we check whether various demographic characteristics of our sample differ based on proximity to marijuana retailers. We find little association between proximity to retailers and race, education, income, and several other characteristics. These results lend confidence to the idea that our parameter estimates represent a causal effect of local distance to a marijuana retailer on marijuana use.

2. BACKGROUND

In Washington State, the location of marijuana retailers is highly regulated and varies by jurisdiction (Dilley et al., 2017). The Revised Code of Washington (RCW) 69.50.331(8) compels all retailers to locate at least 1,000 feet from elementary and secondary schools, playgrounds, recreation centers and facilities, child care centers, public parks, public transit centers, libraries, and game arcades (in which minors are admitted).[4] Retail licenses are prohibited on property used as a residence (WAC 314-55-015(5)). Towns, cities, and counties may choose to regulate marijuana production and retail differently through zoning restrictions or additional buffers. The Liquor and Cannabis Board (LCB) then has the final say in whether a retailer is granted a state license (MRSC, 2019). In order to operate, a proposed retailer must first apply and fulfill requirements, such as not having certain criminal convictions, having received no objections from local governments, and meeting rules on zoning (Washington State Liquor and Cannabis Board, 2016).

I-502 requires the state to establish "the maximum number of retail outlets that may be licensed in each county, taking into consideration: (a) Population distribution; (b) security and safety issues; and (c) the provision of adequate access to licensed sources of useable marijuana and marijuana-infused products to discourage purchases from the illegal market" (Initiative 502, p. 19). This provision was formerly implemented with a total of 334 retail licenses across counties and cities; in December 2015, the cap grew to 556 in order to consolidate retail and medical marijuana markets (Dilley et al., 2017). Local governments may establish more restrictive limits on the number of permitted retailers or prohibit them outright with bans or moratoria. Also, local authorities may require a special local license, specific to marijuana, or

[4] This distance is measured as the shortest straight line from the boundary of the retailer to that of the places listed (Washington Administrative Code (WAC) 314-55-050). RCW 69.50.331(8) also permits local governments to pass ordinances that reduce this buffer to 100 feet around all places, excluding schools and public playgrounds (MRSC, 2019).

require an additional general business license. State law prohibits personal cultivation of marijuana (known as "homegrows") as well as home delivery services (Dilley et al., 2017). Therefore, adults may only access legal marijuana via licensed retail outlets.[5]

Prior to legalization, individuals either had to obtain marijuana through the black market, grow illegally, or obtain a medical marijuana recommendation from a physician to be able to legally purchase or grow. After legalization, retail stores opened across the state with a median price of about $25 per gram of marijuana, falling to about $10 per gram by the end of 2015 (Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017). Since July 2014, the physical and financial accessibility of marijuana has increased dramatically: over 300 more shops have opened across the state and products' average prices have fallen by greater than 50%.

Previous research indicates that marijuana use may increase as it becomes more accessible, apart from any effect of a change in its legal status. Everson et al. (2019) find increases in adult use in Washington as recreational marijuana becomes more accessible. In the Netherlands, Palali and van Ours (2015) find that individuals who grow up within 20km of a legal marijuana seller, known there as coffeeshops, begin using marijuana at a younger age. In a survey around the time of the first legal sales in Washington, Subbaraman and Kerr (2016) found that in a sample of about 2,000 adult residents of Washington State, nearly 10% of past-year nonusers said they would be more likely to use marijuana if they were able to purchase it from a legal retail shop. Other papers (e.g., Pacula, 2010; Hall & Lynskey, 2016) have predicted that recreational legalization will increase use at the extensive and intensive margins (based on its

[5] Individuals that have a medical marijuana authorization may register to grow up to 15 plants (or four without registering), subject to restrictions outlined in RCW 69.51A.250 and RCW 69.51A.260 (see https://www.doh.wa.gov/YouandYourFamily/Marijuana/MedicalMarijuana/AuthorizationDatabase/FrequentlyAskedQuestions). These rules went into effect on July 1, 2016. Prior to that date, the medical market was highly unregulated, with many collective gardens and dispensaries producing and selling marijuana.

expected effects on price and local availability) but estimates of adult use after actual sales began are lacking.

Some studies on I-502 focus on the tax structure for legal marijuana and its implications for prices and tax incidence. Initially, Washington taxed each level of the supply chain (producers, processors, and retailers) at 25%. Beginning July 1, 2015, the old policy was abandoned in favor of a 37% excise tax levied on the consumer at the point of sale. Hansen, Miller, and Weber (2017) find that the price elasticity of demand for usable marijuana (flower) was -0.43 immediately after the July 2015 tax change, while it becomes more price-elastic in the long run. Similarly, Miller and Seo (2019) find the combined price elasticity of marijuana, alcohol, and tobacco is -0.40, while the price elasticity of marijuana is -1.94. The authors also report that the own-price elasticities for flower, extracts, and edibles are -1.53, -1.26, and -0.93, respectively.

Analyses of geographical accessibility to alcohol and tobacco provide us with examples of how the use of these substances can be affected by local availability. As alcohol outlets become closer to residences, alcohol consumption increases (Picone, MacDougald, Sloan, Platt, & Kertesz, 2010; Kavanagh et al., 2011; Halonen et al., 2013). The likelihood of tobacco cessation decreases as accessibility to tobacco outlets increases (Reitzel et al., 2011; Halonen et al., 2014). Berg, Henriksen, Cavazos-Rehg, Haardoerfer, and Freisthler (2018) highlight studies finding that both higher density of medical marijuana dispensaries across California (Freisthler & Gruenewald, 2014) and the presence of medical marijuana dispensaries in neighborhoods (Mair, Freisthler, Ponicki, & Gaidus, 2015) led to increased adult use and marijuana-related hospitalizations, respectively. We contribute to the above literature by examining the effect of local recreational accessibility, which makes marijuana available to anyone 21 and older at legal retailers, on adult marijuana use.

3. DATA

Our analysis uses repeated cross-sectional data from the BRFSS, an annual telephone survey for adults 18 and over conducted by the Centers for Disease Control (CDC). The survey asks a broad range of questions on topics including health issues, demographics, and substance use. Cellular phones were incorporated into the survey beginning in 2011, with weights assigned to landline and cell-based respondents. The 35,714 individuals interviewed after the first marijuana stores began selling were sampled across Washington State with 5,339 respondents in 2014, 16,116 in 2015, and 14,259 in 2016. We analyze data from July 2014 (the first month of legal sales in Washington) through December 2016.

Our three outcome variables of interest are how many days in the past month the individual reported using marijuana and indicator variables representing whether the respondent used any marijuana as well as if they used heavily (20 or more days) in the past month.[6] The average past-month use was 1.8 days, but only 12.6% of our sample used in the past 30 days; 5.1% of our sample used on 20 or more days in the past month and 3.5% used daily. Overall, heavy users compose 40.3% of marijuana users, while daily users make up 27.6% of those reporting use.

In conjunction with the BRFSS, we utilize data from the LCB on monthly sales volumes and addresses of all 363 stores that operated at some point during our sample window (Washington State Liquor and Cannabis Board, 2017). The sales data allow us to model the

[6] The BRFSS is conducted with computer-assisted telephone interviewing (CATI), so marijuana use is likely to be underreported (see Tourangeau and Yan (2007) for an extensive discussion of sensitive survey questions and Corkrey and Parkinson (2002) for a study comparing different methods of conducting surveys on reported substance use). Such underreporting is likely to diminish the impact of geographical accessibility on marijuana use.

introduction of recreational marijuana retailers in a survey respondent's jurisdiction.[7] We combine this with sales data aggregated from Washington's BioTrackTHC seed-to-sale database (Dilley, 2018). From this data, we compute average price measures at each location for each of the three most popular types of marijuana products: usable marijuana, extracts for inhalation, and edibles. Dividing reported total sales by total weight sold, we compute average price per gram for flower and extracts. We compute average price per unit of edibles similarly, substituting total units sold for total weight sold. Bulk discounts (e.g., the lower per-gram price of an ounce of flower in comparison to a gram of the same product) are not separately accounted for.[8] We discuss the use of this price data in our analysis later in the paper.

From the addresses reported to the LCB,[9] we incorporate GIS data with the ZIP code of each BRFSS respondent (which is the smallest unit of geography available in the data). Using the stores that had positive sales during the month of the respondent's interview, we create a list of potential retailers that could be visited statewide. From ArcGIS Network Analyst calculations, we find the distance in miles and the driving time in minutes from the respondent's ZIP code to the closest of these retail stores to obtain a measure of geographical accessibility to legal marijuana.[10]

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[7] The LCB retail sales data is reported for the whole month, so there may be periods during the month when retailers are not operating, such as not yet being open if new or closing down.

[8] Smart et al. (2017) find that small quantities of flower (<5g) composed almost 75% of flower purchases in 2016. Therefore, an ideal average price measure would separately account for small amounts of flower, such as an eighth of an ounce (3.5g).

[9] We use latitude and longitude data provided to us by Julia Dilley, which are based off of the addresses of each marijuana retailer. We checked their locations against the addresses reported through the LCB data that ends in October 2017 and all but five retailers' locations corresponded closely to their address. We correct the affected stores using GIS estimates based on their addresses reported to the LCB.

[10] ArcGIS bases its ZIP code calculations on post office locations; therefore, the estimates are not entirely representative of an individual's residence. The BRFSS, a public use survey, does not provide more specific location data on respondents than ZIP code.

We use travel time in our regressions instead of distance for two reasons. First, it is common for an individual to think in terms of how much time it takes to get somewhere, as opposed to the distance travelled. Second, a 10-mile trip could be very different in terms of travel time for two different places, due to differences in speed limits and traffic. It is relevant to note that in July 2014, the mean drive time was 33.3 (S.D. = 29.6) minutes and the closest store was on average 18.9 (S.D. = 16.1) miles away. In December 2016, those averages were 8.1 (S.D. = 10.0) minutes and 4.2 (S.D. = 5.1) miles, respectively.[11]

Our GIS measures are similar to Everson et al. (2019), but with a few key differences. They use straight-line distance to the nearest operating retailer,[12] while our measures of distance follow the road network that cars travel. We model distance as a continuous variable, while they use categorical distance measures. We compare our retail density measures to those of Everson et al. (2019) in the robustness checks section.

Although we model accessibility to retailers only within Washington, it is possible that some adults chose to travel to Oregon after it began to allow medical marijuana dispensaries to sell marijuana to adults over 21 (October 1, 2015) while it established a regulatory framework for its RML—Measure 91 (Crombie, 2016b). We believe that this is not likely because Washington's market was already relatively well-established at that point. Oregon's RML has been implemented with many jurisdictions banning retail sales, causing most retailers to locate in Western Oregon (particularly in the Portland area).[13] Also, edibles and extracts were not for sale

[11] The correlation between travel time and distance to the nearest retailer is 0.90.
[12] Specifically, they model proximity by first dividing Washington into a grid composed of many 0.9-square mile cells. They obtain the straight-line distance from the center of each cell to every operating store in each month. They then choose the minimum distance for each cell in each month. They estimate the proportion of the population that each grid cell contributes to a ZIP code and then aggregate the proximity value from each cell using these proportions to the ZIP code level. This means that their measure of distance accounts for differences in the population distribution within each ZIP code.
[13] For example, see this map (https://www.arcgis.com/apps/webappviewer/index.html?id=5b1c97ec0b34471bbba6dda8830f7628), choose "Layer

to recreational consumers (who did not have a medical marijuana card) at medical marijuana dispensaries in Oregon until June 2, 2016, a stopgap lasting for the months preceding the establishment of the first recreational shops in October 2016 (Crombie, 2016a). Therefore, it is unlikely that consumers in Washington would have the incentive to drive across state lines, breaking the law to bring marijuana back to a state that had greater accessibility and more types of products to begin with.[14]

Table 1 presents summary statistics for the key variables incorporated in our analysis and consists of the individuals that make up our preferred sample.[15] The respondents who compose our preferred model have no missing values for travel time, sex, age, race, education, marital status, and their county's unemployment rate (Employment Security Department of Washington State, 2017).[16]

Figures 1 and 2 depict mean likelihood of having used marijuana and mean number of days used in the past month, respectively. We see that by both measures, use appears to be trending upward throughout our sample window, though there is significant month-to-month variation around the trend. The next figure shows how many respondents are heavy marijuana users (Figure 3); we observe less of an upward trend here. In Figure 4, we present the average drive time in minutes and distance in miles to the nearest marijuana retailer. Both of these

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List" in the upper-right corner, and check the "Jurisdictions with Marijuana Ban" box. Also, see (https://www.oregon.gov/olcc/marijuana/Documents/Cities_Counties_RMJOptOut.pdf) for a list of counties and cities that have banned recreational marijuana businesses.

[14] Hansen, Miller, and Weber (2018) find that retailers in Washington near the Oregon border experienced a large decrease in sales after Oregon's recreational market opened. This is because adults from Oregon had fewer incentives to go to Washington to buy marijuana after it became available to purchase in their state. The findings of HMW (2018) suggest that some individuals are willing to travel long distances to obtain marijuana legally.

[15] In Table A1, we include summary statistics on additional individual characteristics that appear in falsification tests as well as more saturated models. We also compare our preferred regression's sample to that of those who were not included in the sample because they were missing one or more variables (excluding household income). We see that both the mean probability of using marijuana and intensity of use in the past month, as well as the average travel times experienced, are similar between the two samples. The rest of the variables have similar averages across the two samples (with the exception of a few ethnicity groups).

[16] About three percent of respondents who reported a ZIP code in our data were not matched with the GIS data.

measures of proximity are decreasing substantially over the first year and more gradually after that.

Figure 5 shows the average tax-inclusive prices of flower, concentrates, and edibles for all operating retailers. The effect of the tax change occurs as we move from June to July 2015. Hansen et al. (2017) determine that consumers bore 44% of the tax burden and that the tax-inclusive price they faced for the same flower products went up by 2.3% after the change. In our figure, it appears that the prices of concentrates and edibles became cheaper, while the price of flower went up slightly with the new tax regime. This could be related to the increasing market share of non-flower products, which were scarce in the market at its inception (Top Shelf Data, 2018). Caulkins et al. (2018) find that at the beginning of legal sales in Washington, the markets for extracts and edibles were highly concentrated for processors but unconcentrated for retailers, while the market for usable marijuana was unconcentrated for both processors and retailers.

After the earliest months of sales, we see that the average price per gram of usable marijuana declines in a stable manner, while the average prices of extracts and edibles are more volatile. Caulkins et al. (2018) note that it is ambiguous why the average prices of extracts initially increased and decreased dramatically in the seed-to-sale dataset.[17] In Figure 6, we show the evolution of the retail market. As the number of retailers across the State grew from 18 in the first month of sales to 346 by January 2017, retail density and accessibility substantially increased.

Our final figure (Figure 7) depicts four histograms, consisting of the travel time that each ZIP code experienced in July 2014, March 2015, November 2015, and July 2016.[18] Each bin's

[17] They note, "It is not clear whether that is simply because there were so few observations, whether the extracts market had not matured, or whether perhaps some stores were not yet recording data on extracts correctly" (p. 90).
[18] Note that some ZIP codes appear often throughout the sample window, while others are scarcer. Most of the sample (67%) is from urban areas, which experience lower travel times (on average) to marijuana retailers.

width is five minutes of driving time, so it is clear that at the beginning, there was substantial variation in geographical accessibility across the sample (with some ZIP codes several hours away from an operating retailer); as we move across time, we observe that the right tail of the distribution is pulled in closer to the middle and that the density of those living very close to a retailer continues to grow.

4. METHODS

First, we estimate the following model to capture the effect of travel time on marijuana use:

$$Y_{izt} = \beta_0 + \beta_1 \ln(Travel_{zt}) + \beta_2 \ln(Price_{zt}) + \beta_3 X_{izt} + \beta_4 Z_{ct} + v_z + \omega_t + \varepsilon_{izt} \quad (1)$$

where Y_{izt} measures past-month marijuana use of individual i in ZIP code z at month t; $Travel_{zt}$ denotes estimated drive time to the nearest operating I-502 marijuana retailer; $Price_{zt}$ is the average tax-inclusive price per gram of flower at the nearest retailer; X_{izt} is a vector of individual-level controls, including sex, age, imputed race/ethnicity, marital status, and indicators for educational attainment; Z_{ct} is the county-level unemployment rate; v_z represents time-invariant ZIP code effects; ω_t represents unique month-year effects (such as July 2014); and ε_{izt} is the error term. Since the natural logarithm produces negative numbers when computed for values less than one (e.g., with travel times under one minute), we assign the log of these values to zero.[19] Our chosen functional form allows us to interpret the coefficient on travel time in terms of relative changes. By using the natural log of travel time, we are able to account for the fact that a 10-minute reduction in drive time (say, from 60 to 50 minutes versus 30 to 20 minutes) will be different, depending on the initial distance. All specifications use standard errors clustered at the ZIP code-level.[20]

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[19] 3.6% of the travel time values are below one minute. The estimated coefficient on ln(travel time) is robust when we allow for negative log values across specifications.

[20] Due to the relatively large number of fixed effects and clusters, in all regressions we use the multi-way fixed effects estimator developed by Correia (2017). In Stata, the package used is "reghdfe."

We utilize time dummies to account for unobservables such as changing attitudes toward legalization, as well as seasonality of marijuana use (Langworthy & McKelvie, 2005). ZIP code dummies account for local differences that persist throughout the period of the study. Due to the fact that individual counties and cities are allotted different numbers of retail licenses and that some jurisdictions have chosen to prohibit retail sales, it follows that local access to marijuana retailers is correlated with the effects of the areas themselves.

Everson et al. (2019) use multilevel models (also known as mixed effects models), in which they include a random intercept for each community, which assumes that the effect of each community is independent of local retail access. If this assumption is violated, estimated effects of retail access on marijuana use will be biased. Since we use a fixed effects design, we allow v_z to be correlated with our chosen covariates.[21] Therefore, we consider our estimates of retail access on marijuana use to be more conservative than those of Everson et al. (2019). In Table A2, we perform two right-hand side joint balancing tests (Pei, Pischke, & Schwandt, 2019), first while including ZIP code fixed effects and then upon excluding ZIP fixed effects. We find that we do not reject the null hypothesis of the demographic controls being equal to zero in the former case, while we reject the null in the latter. Therefore, this provides evidence that unobservable variation across ZIP codes could confound our results if we did not include our location fixed effects.

We test our primary hypothesis using a linear probability model (LPM), in which Y_{izt} takes the value of one if an individual used marijuana in the past 30 days.[22] We also use OLS to

[21] For comparisons of fixed effects models and mixed effects models, see McNeish and Kelley (2019) and Bell, Fairbrother, and Jones (2019).

[22] Using logit models, we check our primary findings for if a respondent used marijuana in the past month, as well as heavy past-month use. Estimated marginal effects are similar, however, in some cases the magnitude of the effect is higher under logit. This is probably because for heavy use, a larger portion of the sample is omitted (since there is less variation in the dependent variable).

test our second hypothesis: whether proximity to legal marijuana retailers increased the intensity of past-month marijuana use.

Although we created average price measures for the three most popular types of marijuana products, we only include the flower price as a control in our regressions. This is because edibles and extracts sales are rarer and data on them is not always available in every store. Usable marijuana (flower) accounts for most product sales (Top Shelf Data, 2018), with a market share of 85.8% in October 2014 and 66.6% in September 2016 (Smart et al., 2017).

For our coefficient of interest (β_1) to be unbiased, the common trends assumption of our two-way fixed effects model must be met. If place-specific time-varying unobservables are correlated with both the opening of new retailers and marijuana use, then there would be cause for concern (for example, stores may locate in areas that are likely to experience rising marijuana demand). We first attempt to address this issue with the use of county-specific linear time trends in an additional specification:

$$Y_{izt} = \beta_0 + \beta_1 \ln(Travel_{zt}) + \beta_2 \ln(Price_{zt}) + \beta_3 X_{izt} + \beta_4 Z_{ct} + \nu_z + \omega_t + \theta_c{*}t + \varepsilon_{izt} \quad (2)$$

where $\theta_c{*}t$ represents county-specific linear trends. Also, in robustness checks, we examine whether the demographic characteristics of individuals in our sample are correlated with distance to nearest retailer in regressions similar to (1) and (2). Null results from this exercise would assuage concerns that our results on the effect of retail distance on marijuana use are driven by endogenous location decisions on the part of stores or individuals.

5. RESULTS

We begin our analysis of the effect of travel time on the use of marijuana in the past month. The results, reported in Table 2 for various specifications, indicate a negative coefficient significant at a p-value of 0.01 between travel time and the likelihood of using marijuana in the past 30 days. None of the estimates for travel time reported in Table 2 are statistically different from each other at a p-value less than 0.05. Our preferred specification is in column (2) because it incorporates pertinent pre-determined demographic characteristics and retains most of the respondents; the column indicates that a 33% decrease in travel time (e.g., from 30 to 20 minutes) is associated with a 0.62%[23] increase in the probability of having used in the past month. This effect is a 4.9 percent increase relative to the mean.

Across all specifications in Table 2, a 33% decrease in travel time is associated with a change in use ranging from 0.62% to 0.72% (column (1)). Upon including county-specific linear time trends to the model, we see that the magnitude and significance of the coefficients remain stable across specifications. Our estimate of the elasticity of the probability of use with respect to travel time is -0.12, implying that use does not respond as much to changes in proximity as it does to changes in price as found in other studies (Hansen et al., 2017; Miller & Seo, 2019).

To examine the effect of travel time on use at the intensive margin, as reported in Tables 3 and 4, we apply the same analysis with an indicator for heavy use and the number of days marijuana was consumed in the past month as the dependent variables, respectively. In Table 3, we notice that the coefficient on travel time in our preferred regression (column (2)) is not significant at conventional levels and is lower in magnitude than in column (2) of Table 2. Two of the five coefficients reported in Table 3 are significant at the 10% level. The estimate in column (2) implies that a 33% reduction in travel time is associated with a 0.26% increase in the probability of heavy use in the past month (a 5.0% increase relative to the mean). The elasticity of the probability of heavy use with respect to travel time is -0.12.

[23] These results are from computing $\Delta y = \beta_1 * ln([100+p\%]/100)$, where p% is the percent change in travel time. So for $\beta_1 = -0.0150$, we have $\Delta y = -0.0150 * ln(0.667) = 0.00610$.

All but one of the reported coefficients in Table 4—where days used in the past month is the dependent variable—are significant at the 5% level. Again, the inclusion of county-specific trends slightly increases the magnitude of the coefficients, while significance remains unchanged (excluding the move from column (2) to (4), which becomes significant at the 5% level). From column (2), a 33% decrease in travel time is associated with a 0.10-day increase in past-month use, or a 5.9% increase relative to the mean. The elasticity of the number of days used with respect to travel time is -0.15, again implying a relatively modest effect of retailer proximity on marijuana consumption overall.

Our estimates of accessibility indicate that because of the change in average distance to the nearest retailer from the beginning of our sample (July 2014) to the end (December 2016), adults are 2.2% more likely to have used marijuana (a 17.3% increase relative to the mean), 0.9% more likely to use it heavily (a 17.6% increase relative to the mean), and use it for an additional 0.37 days (a 20.6% increase relative to the mean) in the past month.[24] The preceding estimates are similar to the findings of Wen et al. (2015) on the effect of MMLs on marijuana use by adults aged 21 and older. The authors find that MMLs lead to a 1.3 percentage point increase (14% increase relative to the mean) in the probability of past-month adult marijuana use.[25]

Although we model retail access differently, our results agree qualitatively with the proximity results from Everson et al. (2019). They find that the closer retailers are to adults, the odds of marijuana use in the past month increase significantly. Specifically, they find that current use (if an individual used in the past month) increases significantly for the closest three

[24] These calculations are performed with coefficient estimates obtained from our preferred specifications (column (2) of Tables 2, 3, and 4). We apply our point estimates to the mean travel times for July 2014 and December 2016, and then compute the changes in probability of use and heavy use and the intensity of use, respectively. The caveat here is that we are applying estimates of marginal changes to overall changes.

[25] Similarly, Kerr, Ye, Subbaraman, Williams, and Greenfield (2018) observe a 1.2% increase in past-year use for Washington adults aged 18 and older after recreational legalization, though the change is not statistically significant. However, that paper does not examine the heterogeneous effects of legalization by distance to marijuana retailers.

categories of proximity (up to 18.4 miles away), while frequent use (use on 20 or more days) only increases for those with a retailer operating within 0.8 miles of their ZIP code (the closest category). Therefore, both our study and Everson et al. (2019) do not find as strong of a relationship between proximity and heavy use as with proximity and use on the extensive margin. This discrepancy may occur because heavy users were less sensitive to marijuana's former social and legal stigma.

While we include the average tax-inclusive price per gram of flower at the nearest retailer in our regressions, we omit the resulting coefficient estimates and standard errors from our tables. The coefficient on this price measure is typically not significant at conventional levels and often changes sign across specifications. This could be a result of location and time fixed effects explaining more of the variation in prices than distance to nearest retailer; in other words, multicollinearity may interfere with our ability to identify true price effects given our study design. Thus, we are cautious about the interpretation of these effects.[26]

To continue our analysis, we stratify the data by sex and age in Tables 5, 6, and 7 to see if certain subgroups are affected more by travel time than others. The effect of travel time is negative and significant at the 5% level for women in column (1) of Table 5 (and at the 10% level in Table 7), but the coefficient is much smaller and insignificant for men in column (2) of all three tables. The estimates in column (1) indicate that a 33% reduction in travel time increases the likelihood of women using marijuana by 0.76% (a 7.3% increase relative to the mean) and that women use it 0.12 more days in the past month (8.7%). Only one of the estimates for different age groups of women in Table 5 is significant at conventional levels (and we note that the magnitude of the effect on young women ages 18-26 is particularly large). This

[26] Excluding this price measure has a negligible effect on our distance results.

may simply be a result of lower power from the smaller sample sizes of these subgroups of women.

Men typically use marijuana more often than women (Center for Behavioral Health Statistics and Quality, 2016) and use larger amounts than women (Cuttler, Mischley, & Sexton, 2016). Cuttler et al. (2016) find from a survey of recent marijuana users that methods of marijuana use, effects of the drug (i.e., the subjective description of impairment), and withdrawal effects differ significantly between men and women.

Mauro et al. (2019) examine the effect of MMLs on different age groups by gender with the National Survey on Drug Use and Health (NSDUH) from 2004-2013. They find that among people 26 and over, past-month marijuana use in men went from 7.0% before to 8.7% after passing an MML (a 24.3% increase) and past-month marijuana use in women went from 3.1% before to 4.3% after (a 38.7% increase). Additionally, for individuals reporting marijuana use, daily marijuana use in men over 26 went from 16.3% before passing an MML to 19.1% after (a 17.2% increase), while daily marijuana use for women over 26 went from 9.2% before to 12.7% after (a 38.0% increase). Therefore, in the context of MMLs for people over 26, past-month use and daily use increase relatively more for women than for men. These relative changes agree with the pattern in our subgroup results for past-month marijuana use at both the extensive and intensive margins, however the absolute changes in use for men and women differ with our results.

Fairman (2016) examines trends in registered medical marijuana participation (excluding Washington, which had no registry prior to July 2016) and finds that two-thirds of participants are male, however sex differences in utilization may be diminishing. Therefore, men in Washington were likely more involved with medical marijuana than women prior to the emergence of I-502 retailers. This could mean that women saw a sharper increase in access to marijuana after the first retail stores opened relative to men.

Elder and Greene (2019) analyze gender differences in opinions on marijuana legalization in a 2013 Pew survey. They find that women are significantly less likely to support marijuana and the legalization of it, are less comfortable being around it, and are less likely to have used it. In our preferred regression sample, 57.8% of men and 47.9% of women reported using marijuana at least once in their life, while 14.9% of men and 10.4% of women reported using it in the past month. Results from a 2018 Pew Research Center survey indicate that women are more supportive of marijuana legalization now than in 2013 (Hartig & Geiger, 2018). Therefore, the difference we find between men and women in our results could be from the relative differences in use habits (with women starting at a lower baseline level of marijuana use) and changing attitudes toward marijuana.

It may also be the case that women are more sensitive to the legality of marijuana in their consumption: indeed, in Marie and Zölitz (2017), the authors find that women experience a greater increase in academic performance than men under a marijuana ban in the Netherlands and posit that it is because women are more likely to comply with the law.

In addition to the effects of travel time by sex, we find that younger people are more likely to initiate use and use more heavily when travel time decreases. From column (3) in Tables 5, 6, and 7 (corresponding with 18-26 year-olds), a 33% decrease in travel time yields a 2.2% increase in the likelihood of using (9.1% increase relative to the mean), a 2.0% increase in the likelihood of heavy use (22.3% increase relative to the mean), and a 0.56-day increase in the number of days used (17.4% increase relative to the mean), respectively. These estimates are similar in size to the findings of Miller, Rosenman, and Cowan (2017) with respect to

Washington State University students' past-month likelihood of using marijuana as a result of recreational legalization. The authors find an increase in probability of use between 2.0-3.5%.

No other age groups' travel time coefficients are significantly associated with use at the extensive margin. At the intensive margin, those aged 65 and over are significantly associated (at the 5% level in Table 6 and at the 10% level in Table 7) with using more as accessibility improves, although much less than younger people. Young people have elasticities of the probability of use and heavy use with respect to travel time of -0.22 and -0.55, respectively, which are higher than those of the full sample (-0.12). Their corresponding elasticity for the number of days used is -0.43 (compared to -0.15 for the full sample).

These larger effects of travel time on the marijuana use of young adults could be indicative of several factors: greater latent demand for marijuana that is manifest once it becomes accessible, poorer access to transportation (making it more difficult to travel long distances to obtain marijuana), or less control over impulses (which are more likely to be indulged when a marijuana retailer is close). 24.2 percent of the young adults in our sample used marijuana in the past month; 8.8% of those aged 18-26 used heavily; and on average they used 3.2 days—these figures are nearly double those of the 27-64 age group. Similar findings have been documented in other datasets (e.g., Ghosh et al., 2017; Davenport, 2018).

Our results for young adults may be concerning because brain development occurs until age 25 (Arain et al., 2013). Prior studies on the effects of marijuana use on adolescents and young adults yield mixed findings: some indicate that early use leads to impaired brain development, which may persist through adulthood (Levine, Clemenza, Rynn, & Lieberman, 2017; Volkow, Baler, Compton, & Weiss, 2014); others indicate that cognitive impairment from marijuana use may subside with abstinence (Gorey, Kuhns, Smaragdi, Kroon, & Cousijn, 2019;

Scott et al., 2018). Early onset of marijuana use is associated with using the drug more often and larger amounts of it relative to those with a later age of first use (Gruber et al., 2012), greater likelihood of becoming dependent (Volkow et al., 2014), and greater odds of other drug use and alcohol dependence (Lynskey et al., 2003). In addition to developmental concerns, there is evidence that early marijuana use leads to decreases in educational attainment (Beverly, Castro, & Opara, 2019; Maggs et al., 2015; van Ours & Williams, 2009) and increasing frequency of use from a young age negatively affects other life outcomes (Fergusson & Boden, 2008).

In columns (6) through (11) of Tables 5, 6, and 7, we break down the data by both sex and age groups simultaneously. Not surprisingly, we see that the greatest effects are concentrated among 18-26-year-old women, though we lose precision owing to the reduced sample sizes (all of the travel time coefficients for this group are significant at the 10% level). For 18-26-year-old women, the elasticities of the probability of use and heavy use, as well as the corresponding elasticity for the frequency of use with respect to travel time are -0.35, -0.82 and -0.60; these values reflect a greater sensitivity to distance than all young adults.

5.1 Robustness Checks

We now examine the sensitivity of our estimates to the inclusion of retail density measures.[27] Retail density is important to consider for a few reasons: first, because it is correlated with travel time, it could be that part of our previously estimated effects are due to retail density rather than travel time *per se*. The more concentrated an area becomes with retailers, competition for

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[27] In additional robustness checks, we verify whether the results of Tables 2-7 hold using quarterly measures of travel time and price (keeping everything else the same). Tables 2-4 are largely similar to the monthly versions, with coefficient magnitudes being somewhat higher in the quarterly Table 2 and slightly lower in Tables 3 and 4. In the subgroup analyses, the coefficient on travel time for 18-26 year-olds remained significant at the 5% level for Tables 5-7 (with the same pattern in magnitudes as the quarterly Tables 2-4). For women (column (1)), the coefficient in Table 5 remains significant at the 5% level with a very similar magnitude, however in Tables 6 and 7 there are some differences. The coefficient for young women becomes insignificant and smaller in all three tables, while for women it becomes insignificant and smaller in Table 7. Also, in Table 5, the coefficient on travel time in columns (4) and (8) becomes larger in magnitude and significant at the 10% level.

customers increases in various ways, such as advertising, product pricing, and offering a larger selection of products. Since stores are not randomly allocated**,** the number of retailers nearby captures some of the heterogeneity in local policies with respect to banning retail sales or being allotted fewer licenses. Second, if demand in an area is high, we would expect there to be many retailers concentrated in that place (such that if we do not control for it again our coefficients on travel time may be biased upward in absolute value).

Our measures of retail density differ from those of Everson et al. (2019); we simply count the number of operating retailers within various travel times of a ZIP code (which varies over time as the market developed). Everson et al. (2019) have two time-varying measures of retail density, the first being based on the nearest five operating stores and the second accounting for community size.[28]

Tables 8, 9, and 10 report models incorporating retail density. None of the coefficients on any of the retail density measures are significant at conventional values while the magnitudes and significance on the coefficients on travel time remain relatively stable. Since retail density is not explaining any of the variation in use, it would appear that consumers' use of marijuana is insensitive to the number of options available once distance to the nearest option is controlled for (of course, we do not observe BRFSS consumers' quantities of or expenditures on marijuana products, which may be more sensitive to retailer density).[29] Our retail density results contrast

[28] The first measure, geospatial density, is the sum of the inverse of the distances from a grid cell to each of its five nearest retailers (which, like proximity, is aggregated to the ZIP code level). Therefore, geospatial density accounts for how close the nearest five stores are to a ZIP code, weighted based on estimates of that ZIP code's population distribution. The second measure, per capita density, is the number of operating retailers in an adjacent city or unincorporated county (corresponding to the ZIP code and county of a respondent) divided by the estimated 2014 population.

[29] In Table A3, we also examine the impact of quintiles of travel time to the nearest retailer on past-month marijuana use. We find some evidence that, relative to the closest quintile of travel time, use on the extensive margin declines when individuals are located farther away from an operating retailer—an outcome similar to the proximity findings of Everson et al. (2019). This lends support to the idea that convenience matters to consumers. However, none of

with those of Everson et al. (2019), who find that for geospatial density, current use increases significantly for the three highest density categories, but frequent use only increases for communities at the top 5% of retail density. They also find an increase in current use for all of their per capita density categories.

We also perform falsification tests in Tables 11 and 12 to see if proximity is correlated with any of our demographic controls. Retailers may choose to locate in a specific place for a variety of reasons, like anticipating greater demand for marijuana, greater visibility to the public, cheaper property, or lower chances of being required to move by local laws and regulations. Additionally, individuals may choose to move toward or away from retailers, due to an appreciation/aversion of marijuana, concerns of effects on family members, or perceived effects on property values (Burkhardt & Flyr, 2018; Conklin, Diop, & Li, 2017). We examine the effect of travel time on various demographic characteristics to see if stores tend to locate near certain groups of people or if these groups tend to move in response to new stores. If people or stores move in response to each other, then that would cast doubt on the exogeneity of our treatment variable.

We find no significant correlation between reported income and proximity to retailers (Table 12, columns (1)-(3)).[30] Other characteristics, such as sex, race, marital status, education, and number of children are also not significantly associated with being close to marijuana stores. The only specifications that yield a significant coefficient on travel time are in columns (2) (at the 10% level) and (7) (at the 5% level) of Table 11. The coefficient on age in column (2)

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the coefficients were individually significant for heavy use in column (2); in column (3), only the people farthest from a retailer experienced a significant reduction in the number of days used.

[30] Berg et al. (2018) discuss research concerning the demographics of neighborhoods where marijuana, alcohol, and tobacco outlets tend to locate. Medical marijuana dispensaries are more likely to be found in places with higher proportions of racial and ethnic minorities (Thomas & Freisthler, 2016; Thomas & Freisthler, 2017; Shi, Meseck, Jankowska, & Kuendig, 2016) and impoverished neighborhoods (Morrison, Gruenewald, Freisthler, Ponicki, & Remer, 2014).

implies that older adults are closer to marijuana retailers than younger adults. "Employed" takes a value of one if the respondent reported being employed for wages or self-employed. Therefore, the coefficient implies that as travel time to the nearest retailer decreases, the likelihood of being employed declines with it. However, considering the fact that the rest of the coefficients on travel time in Tables 11 and 12 are not significant at conventional levels, it could just be a result of type I error: given an alpha value of 0.05 and 13 specifications, we would expect approximately one false positive.

We also note that the magnitude and significance of the coefficients on travel time are stable in column (3) of Tables 2, 3, and 4 upon incorporating employment status (as well as additional potentially endogenous individual characteristics) compared to our preferred specification in column (2). Since none of the other demographic characteristics in our falsification tests appear to be correlated with travel time, we believe it is unlikely that unobservable determinants of store locations are driving our results.

6. CONCLUSIONS

We find that adult marijuana use has increased as the accessibility to legal sales in Washington State has improved under Initiative 502. Our results indicate that a 33% reduction in travel time is associated with a 0.62% increase in the probability of using marijuana, a 0.26% increase in the probability of using it heavily, and a 0.10-day increase in the number of days used in the past month. Upon stratifying the data, we find that women are induced to use marijuana and use it more frequently, while men are not. Younger adults are affected more than older adults: for a 33% decrease in drive time, those aged 18-26 are 2.2% more likely to use any amount and are 2.0% more likely to use heavily in the past month.

Retail density does not seem to play a role in a respondent's likelihood/intensity of use, as the number of stores within various drive times did not impart any effects of their own once we control for travel time. It appears that the time it takes to get to the nearest retailer matters more than the number of retailers nearby.

Although the effects of reducing travel time on marijuana consumption are modest overall, the stronger effects on young adults (ages 18-26) raise concerns about the public health consequences of raising or eliminating the cap on retailers. Thomas (2018) explores the effects of eliminating the quota on marijuana retailers and estimates that there is substantially more room for entry into that market. She finds substantial welfare gains of allowing free entry under the present tax regime (21.5%). These gains, however, do not account for potential negative externalities and "internalities" (if young users later regret their decision to consume marijuana or use it more heavily) that our results imply may be important, since the largest gains in (heavy) use are among young people, particularly young women.[31] Current proposals to increase the number of retail licenses in Washington or even allow for home delivery must weigh these costs against the benefits of increased access, greater competition, and higher tax revenues.

Conflict of Interest

The authors report no conflict of interest.

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[31] Although the welfare gains under free entry at the present tax rate in Thomas (2018) do not account for these types of negative externalities, the author accounts for negative externalities in subsequent analyses. In simulations, she finds that under free entry with a tax rate sufficiently high (76.5%) to keep marijuana consumption at the baseline, welfare still improves by 6.9%; similarly, keeping THC consumption the same under free entry with a tax rate of 66% leads to welfare gains of nearly 12%.

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Human Participant Protection

This study was reviewed by the Washington State Institutional Review Board (IRB): Project E-060216-H: "Marijuana Legalization: Assessing the Impact of Local Regulatory Policies".

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Appendix

Figure 1: Mean probability of having used marijuana in the past month

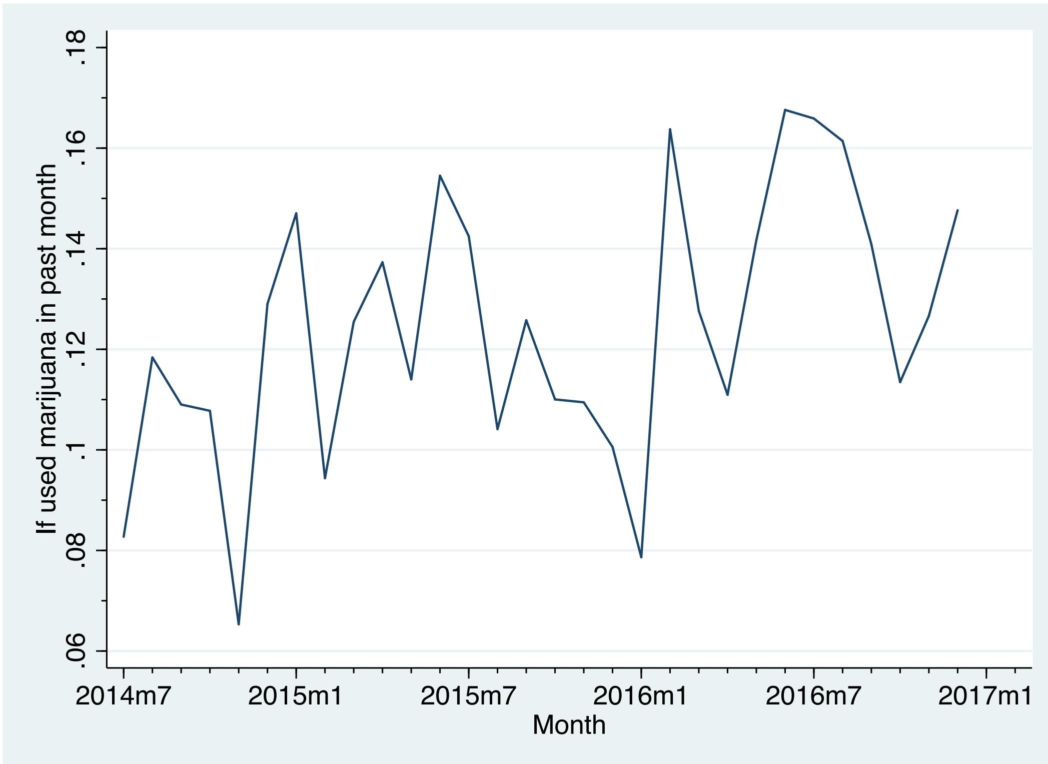

Figure 2: Mean number of days used marijuana in the past month

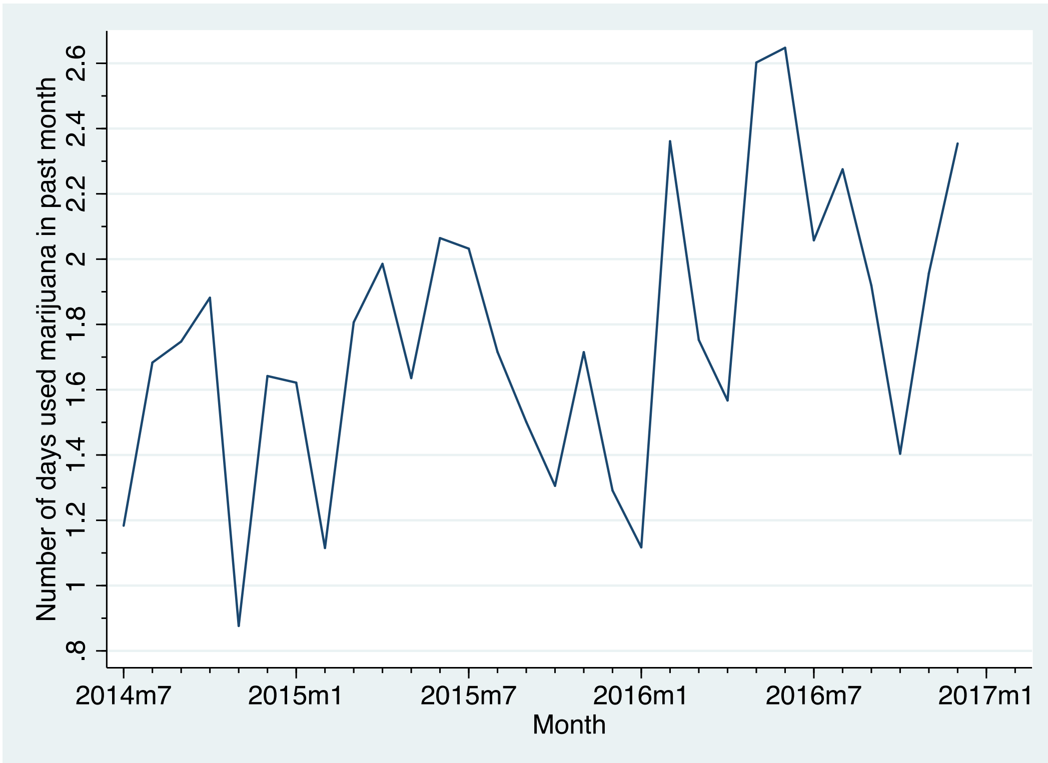

Figure 3: Mean probability of heavy marijuana use in the past month

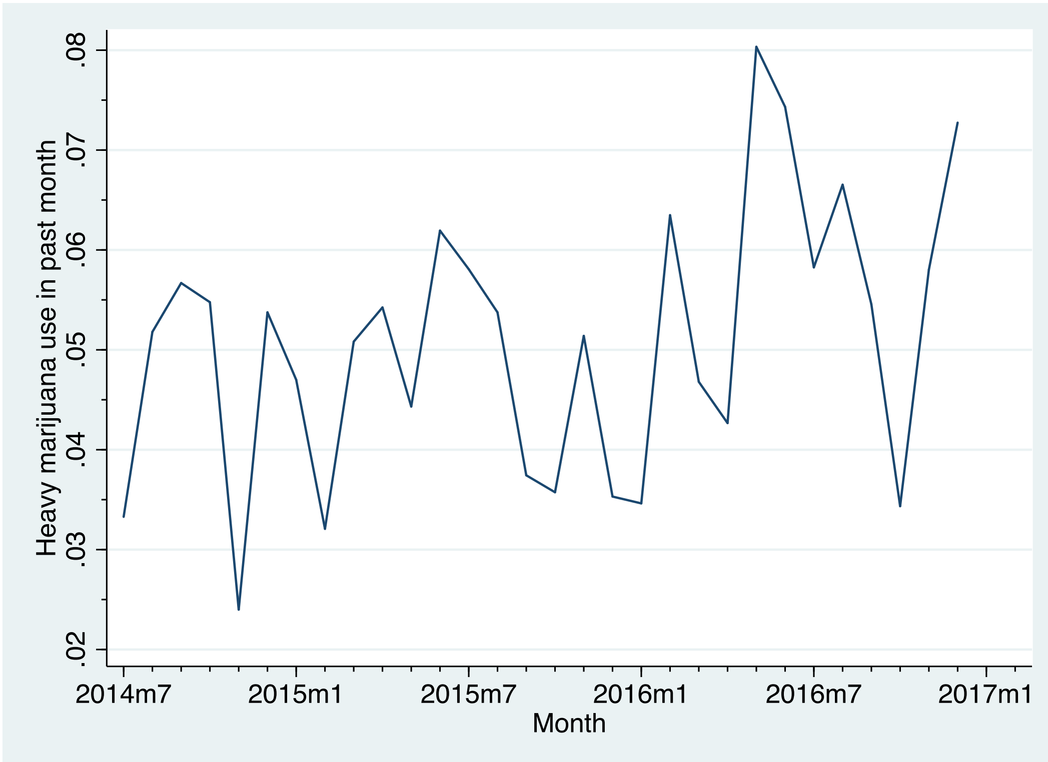

Figure 4: Mean drive time and distance to nearest operating retailer

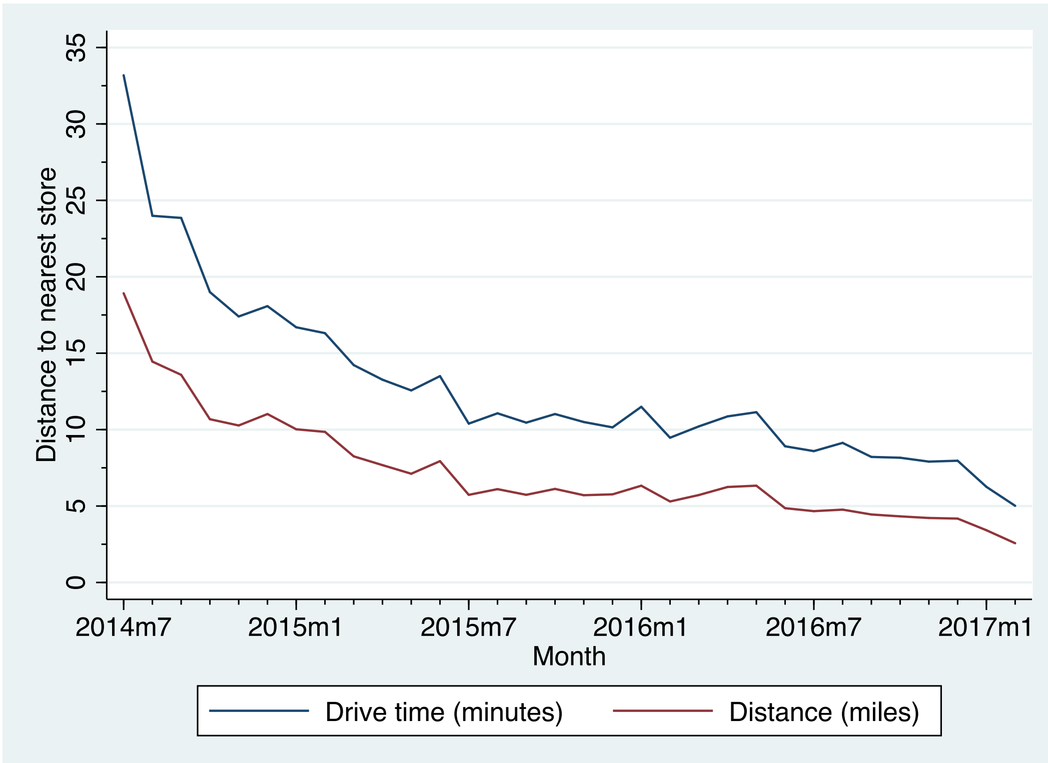

Figure 5: Average tax-inclusive prices of popular types of marijuana products

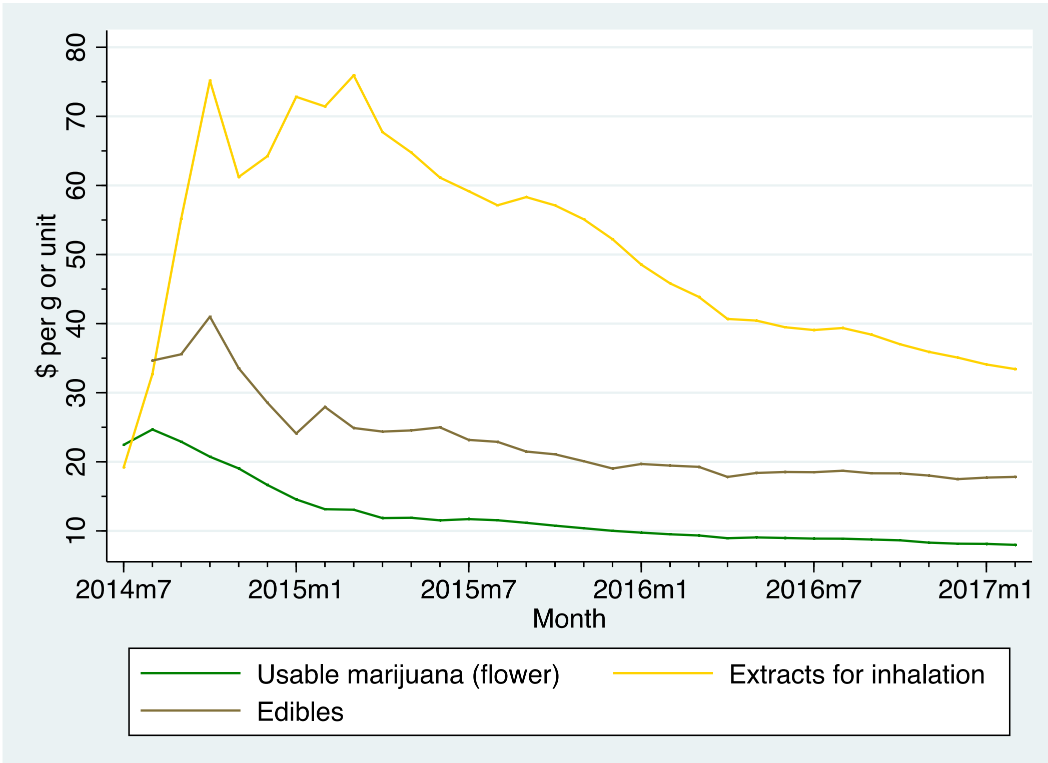

Figure 6: Number of operating retailers across Washington State

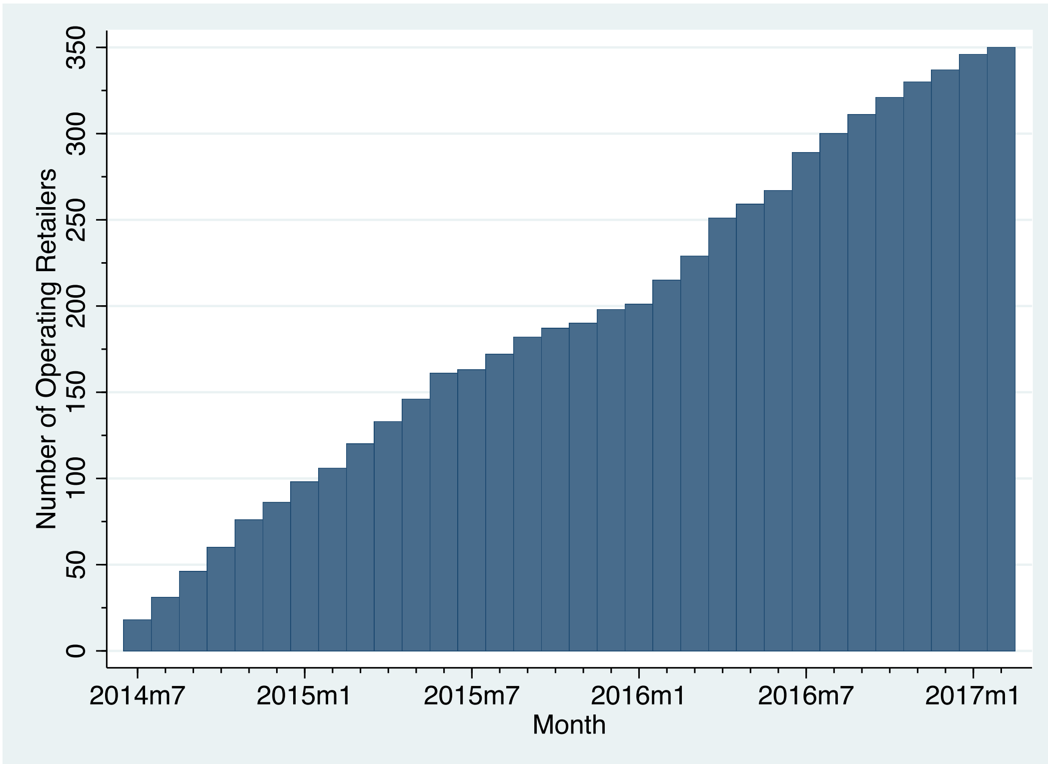

Figure 7: Distributions of travel time to the nearest retailer

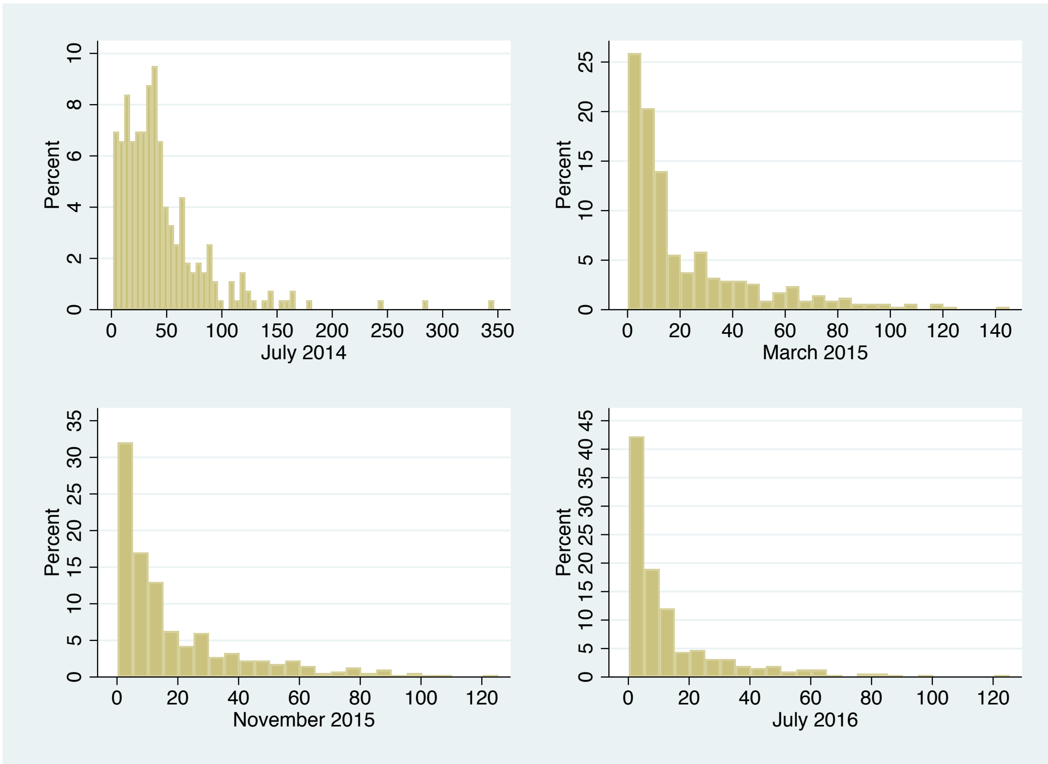

Table 1: Summary Statistics

Preferred Regression Sample (Table 2, Column 2)

Variable	N	Mean	S.D.
Used Marijuana in Past 30 Days	29,332	0.13	0.33
Heavy Marijuana Use (20+ Days) in Past 30 Days	29,332	0.05	0.22
Number of Days Used Marijuana During Past 30 Days	29,332	1.78	6.32
Independent Variables			
Travel Time to Nearest Store (minutes)	29,332	13.11	18.15
Mean Tax-Inclusive Flower Price at Nearest Store	29,332	13.26	5.62
Distance to Nearest Store (miles)	29,332	7.41	10.48
Number of Stores Within 120 Minutes	29,332	68.29	58.88
Number of Stores Within 90 Minutes	29,332	52.17	48.56
Number of Stores Within 60 Minutes	29,332	35.72	36.27
Number of Stores Within 45 Minutes	29,332	26.35	28.45
Number of Stores Within 30 Minutes	29,332	16.01	19.96
Number of Stores Within 15 Minutes	29,332	5.57	7.97
Number of Stores Within 10 Minutes	29,332	3.01	4.74
Number of Stores Within Five Minutes	29,332	0.96	1.73
Male	29,332	0.49	0.50
Age in Years	29,332	48.45	18.08
Imputed Race/Ethnicity			
White	29,332	0.76	0.43
Black	29,332	0.03	0.17
Asian	29,332	0.07	0.26
American Indian/Alaska Native	29,332	0.02	0.13
Hispanic	29,332	0.09	0.29
Other	29,332	0.03	0.18
Educational Attainment			
Under Grade 12	29,332	0.10	0.30
High School Graduate or GED	29,332	0.24	0.43
Some College	29,332	0.36	0.48
College Graduate	29,332	0.29	0.46
Marital Status			
Married	29,332	0.54	0.50
Divorced	29,332	0.12	0.33
Widowed	29,332	0.06	0.24
Separated	29,332	0.02	0.15
Never Married	29,332	0.20	0.40
Member of Unmarried Couple	29,332	0.05	0.22
Unemployment Rate	29,332	0.06	0.01

Notes: Weighted to be representative of the population of Washington State.

Table 2: The effect of travel time to nearest retailer on if used marijuana in past month

	(1)	(2)	(3)	(4)	(5)
Ln(Travel time to nearest store)	-0.0178***	-0.0153***	-0.0176***	-0.0152***	-0.0175***
	(0.00593)	(0.00576)	(0.00571)	(0.00573)	(0.00568)
Observations	29,835	29,332	29,053	29,332	29,053
R-squared	0.050	0.111	0.127	0.113	0.129
ZIP FEs?	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	No	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	No	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	Yes	No	Yes
County-specific time trends?	No	No	No	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 3: The effect of travel time to nearest retailer on heavy marijuana use in past month

	(1)	(2)	(3)	(4)	(5)
Ln(Travel time to nearest store)	-0.00787	-0.00630	-0.00769*	-0.00634	-0.00776*
	(0.00491)	(0.00473)	(0.00456)	(0.00473)	(0.00455)
Observations	29,835	29,332	29,053	29,332	29,053
R-squared	0.040	0.071	0.081	0.073	0.083
ZIP FEs?	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	No	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	No	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	Yes	No	Yes
County-specific time trends?	No	No	No	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 4: The effect of travel time to nearest retailer on number of days used marijuana in past month

	(1)	(2)	(3)	(4)	(5)
Ln(Travel time to nearest store)	-0.303**	-0.258*	-0.293**	-0.259**	-0.295**
	(0.137)	(0.131)	(0.128)	(0.131)	(0.128)
Observations	29,835	29,332	29,053	29,332	29,053
R-squared	0.041	0.083	0.096	0.085	0.098
ZIP FEs?	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	No	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	No	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	Yes	No	Yes
County-specific time trends?	No	No	No	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 5: Subgroup estimates of the effect of travel time to nearest retailer on if used marijuana in past month

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
			Ages	Ages	Ages	Women	Men	Women	Men	Women	Men
	Women	Men	18-26	27-64	65+	18-26	18-26	27-64	27-64	65+	65+
Ln(Travel time to nearest store)	-0.0187**	-0.0104	-0.0540**	-0.0105	-0.00551	-0.0749*	-0.00491	-0.0140	-0.00780	-0.00667	-0.0104
	(0.00789)	(0.00960)	(0.0267)	(0.00744)	(0.00492)	(0.0429)	(0.0419)	(0.00943)	(0.0130)	(0.00549)	(0.00679)
Observations	16,614	12,641	1,723	16,242	11,222	757	857	9,072	7,077	6,608	4,514
R-squared	0.129	0.136	0.237	0.110	0.094	0.394	0.334	0.122	0.152	0.112	0.163
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 6: Subgroup estimates of the effect of travel time to nearest retailer on heavy marijuana use in past month

	(1) Women	(2) Men	(3) Ages 18-26	(4) Ages 27-64	(5) Ages 65+	(6) Women 18-26	(7) Men 18-26	(8) Women 27-64	(9) Men 27-64	(10) Women 65+	(11) Men 65+
Ln(Travel time to nearest store)	-0.00822	-0.00164	-0.0484**	0.00136	-0.00667**	-0.0595*	-0.0249	0.00151	0.00218	-0.00880**	-0.00667*
	(0.00575)	(0.00759)	(0.0208)	(0.00559)	(0.00328)	(0.0341)	(0.0298)	(0.00629)	(0.00997)	(0.00406)	(0.00352)
Observations	16,614	12,641	1,723	16,242	11,222	757	857	9,072	7,077	6,608	4,514
R-squared	0.083	0.106	0.223	0.086	0.088	0.375	0.302	0.094	0.134	0.124	0.158
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 7: Subgroup estimates of the effect of travel time to nearest retailer on number of days used marijuana in past month

	(1) Women	(2) Men	(3) Ages 18-26	(4) Ages 27-64	(5) Ages 65+	(6) Women 18-26	(7) Men 18-26	(8) Women 27-64	(9) Men 27-64	(10) Women 65+	(11) Men 65+
Ln(Travel time to nearest store)	-0.293*	-0.158	-1.391**	-0.0755	-0.190*	-1.625*	-0.820	-0.0624	-0.0611	-0.266**	-0.202**
	(0.167)	(0.206)	(0.602)	(0.153)	(0.0988)	(0.938)	(0.910)	(0.184)	(0.268)	(0.124)	(0.102)
Observations	16,614	12,641	1,723	16,242	11,222	757	857	9,072	7,077	6,608	4,514
R-squared	0.093	0.116	0.229	0.094	0.089	0.380	0.317	0.102	0.141	0.124	0.160
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 8: The effects of travel time and retail density on if used marijuana in past month

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln(Travel time to nearest store)	-0.0154***	-0.0153***	-0.0154***	-0.0154***	-0.0152***	-0.0148**	-0.0141**	-0.0145**	-0.0151**
	(0.00578)	(0.00577)	(0.00578)	(0.00579)	(0.00578)	(0.00585)	(0.00595)	(0.00653)	(0.00664)
Number of stores within 120 minutes	-4.18e-05								-0.000465
	(0.000126)								(0.000377)
Number of stores within 90 minutes		-1.44e-05							0.000876
		(0.000145)							(0.000657)
Number of stores within 60 minutes			-5.85e-05						-0.000493
			(0.000185)						(0.000984)
Number of stores within 45 minutes				-5.92e-05					-0.000398
				(0.000237)					(0.00140)
Number of stores within 30 minutes					6.11e-05				0.000590
					(0.000355)				(0.00120)
Number of stores within 15 minutes						0.000456			-0.00236
						(0.000936)			(0.00226)
Number of stores within 10 minutes							0.00137		0.00589
							(0.00167)		(0.00395)
Number of stores within five minutes								0.00139	-0.00366
								(0.00515)	(0.00662)
Observations	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332
R-squared	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 9: The effects of travel time and retail density on heavy marijuana use in past month

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln(Travel time to nearest store)	-0.00630	-0.00630	-0.00632	-0.00633	-0.00616	-0.00589	-0.00583	-0.00645	-0.00748
	(0.00473)	(0.00473)	(0.00474)	(0.00475)	(0.00475)	(0.00477)	(0.00480)	(0.00511)	(0.00523)
Number of stores within 120 minutes	-5.32e-06								-8.27e-06
	(9.11e-05)								(0.000324)
Number of stores within 90 minutes		-8.27e-06							9.82e-05
		(0.000105)							(0.000528)
Number of stores within 60 minutes			-2.50e-05						5.61e-05
			(0.000128)						(0.000629)
Number of stores within 45 minutes				-2.07e-05					-0.000631
				(0.000161)					(0.000795)
Number of stores within 30 minutes					7.58e-05				0.000489
					(0.000214)				(0.000743)
Number of stores within 15 minutes						0.000370			0.000975
						(0.000477)			(0.00170)
Number of stores within 10 minutes							0.000510		-6.79e-05
							(0.000855)		(0.00273)
Number of stores within five minutes								-0.000252	-0.00361
								(0.00246)	(0.00388)
Observations	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332
R-squared	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 10: The effects of travel time and retail density on number of days used marijuana in past month

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln(Travel time to nearest store)	-0.258*	-0.258*	-0.260**	-0.261**	-0.256*	-0.247*	-0.244*	-0.260*	-0.291**
	(0.132)	(0.132)	(0.132)	(0.132)	(0.132)	(0.133)	(0.133)	(0.140)	(0.143)
Number of stores within 120 minutes	-0.000153								-0.00175
	(0.00255)								(0.00877)
Number of stores within 90 minutes		-0.000265							0.0102
		(0.00293)							(0.0146)
Number of stores within 60 minutes			-0.00162						-0.00999
			(0.00359)						(0.0185)
Number of stores within 45 minutes				-0.00159					-0.0114
				(0.00449)					(0.0230)
Number of stores within 30 minutes					0.000955				0.0104
					(0.00595)				(0.0203)
Number of stores within 15 minutes						0.0102			0.0280
						(0.0134)			(0.0459)
Number of stores within 10 minutes							0.0151		0.00360
							(0.0241)		(0.0779)
Number of stores within five minutes								-0.00285	-0.0955
								(0.0693)	(0.110)
Observations	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332	29,332
R-squared	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 11: Falsification tests

	(1) Male	(2) Age	(3) White	(4) Married	(5) Went to College	(6) College Graduate	(7) Employed
Ln(Travel time to nearest store)	-0.0123	-0.416*	-0.00116	0.00899	0.00524	0.00206	0.0210**
	(0.00918)	(0.245)	(0.00762)	(0.00880)	(0.00874)	(0.00740)	(0.00815)
Observations	29,332	29,332	29,332	29,332	29,332	29,332	29,206
R-squared	0.059	0.408	0.208	0.129	0.155	0.176	0.217
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table 12: Falsification tests

	(1) Income >=25-35K	(2) Income >=35-50K	(3) Income >=50-75K	(4) Number Children	(5) Veteran Status	(6) Healthcare Coverage
Ln(Travel time to nearest store)	-0.000389	-0.00419	0.00357	-0.0221	-0.00265	-0.00196
	(0.00833)	(0.00950)	(0.00891)	(0.0207)	(0.00450)	(0.00599)
Observations	25,558	25,558	25,558	29,277	29,308	29,247
R-squared	0.248	0.298	0.317	0.282	0.211	0.172
ZIP FEs?	Yes	Yes	Yes	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes	Yes	Yes	Yes
Additional demographic controls?	No	No	No	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.

Table A1: Additional summary statistics

	Preferred Sample			Missing 1+ Variable(s)		
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	N	Mean	S.D.	N	Mean	S.D.
Used Marijuana in Past 30 Days	29,332	0.13	0.33	2,608	0.11	0.31
Heavy Marijuana Use (20+ Days) in Past 30 Days	29,332	0.05	0.22	2,608	0.05	0.22
Number of Days Used Marijuana During Past 30 Days	29,332	1.78	6.32	2,608	1.71	6.19
Independent Variables						
Travel Time to Nearest Store (minutes)	29,332	13.11	18.15	4,240	12.46	17.55
Mean Tax-Inclusive Flower Price at Nearest Store	29,332	13.26	5.62	4,195	13.01	5.18
Distance to Nearest Store (miles)	29,332	7.41	10.48	4,240	7.22	11.33
Number of Stores Within 120 Minutes	29,332	68.29	58.88	4,240	69.16	57.69
Number of Stores Within 90 Minutes	29,332	52.17	48.56	4,240	53.42	48.04
Number of Stores Within 60 Minutes	29,332	35.72	36.27	4,240	36.85	35.86
Number of Stores Within 45 Minutes	29,332	26.35	28.45	4,240	27.15	28.31
Number of Stores Within 30 Minutes	29,332	16.01	19.96	4,240	16.82	20.19
Number of Stores Within 15 Minutes	29,332	5.57	7.97	4,240	5.83	8.02
Number of Stores Within 10 Minutes	29,332	3.01	4.74	4,240	3.19	4.86
Number of Stores Within Five Minutes	29,332	0.96	1.73	4,240	1.04	1.79
Male	29,332	0.49	0.50	6,611	0.53	0.50
Age in Years	29,332	48.45	18.08	6,075	42.54	17.73
Imputed Race/Ethnicity						
White	29,332	0.76	0.43	6,611	0.65	0.48
Black	29,332	0.03	0.17	6,611	0.04	0.19
Asian	29,332	0.07	0.26	6,611	0.12	0.33
American Indian/Alaska Native	29,332	0.02	0.13	6,611	0.01	0.12
Hispanic	29,332	0.09	0.29	6,611	0.13	0.33
Other	29,332	0.03	0.18	6,611	0.04	0.20
Educational Attainment						
Under Grade 12	29,332	0.10	0.30	6,435	0.13	0.33
High School Graduate or GED	29,332	0.24	0.43	6,435	0.24	0.43
Some College	29,332	0.36	0.48	6,435	0.34	0.47
College Graduate	29,332	0.29	0.46	6,435	0.29	0.46
Marital Status						
Married	29,332	0.54	0.50	6,291	0.53	0.50
Divorced	29,332	0.12	0.33	6,291	0.10	0.29
Widowed	29,332	0.06	0.24	6,291	0.05	0.21
Separated	29,332	0.02	0.15	6,291	0.02	0.15
Never Married	29,332	0.20	0.40	6,291	0.25	0.43
Member of Unmarried Couple	29,332	0.05	0.22	6,291	0.05	0.23
Number of Children Under 18 in Household	29,277	0.66	1.10	6,382	0.76	1.18
Employment Status						
Employed for Wages	29,206	0.49	0.50	6,314	0.55	0.50

Self-Employed	29,206	0.08	0.27	6,314	0.07	0.26
Unemployed 1+ Years	29,206	0.03	0.16	6,314	0.03	0.16
Unemployed < 1 Year	29,206	0.03	0.17	6,314	0.03	0.17
Homemaker	29,206	0.07	0.25	6,314	0.07	0.25
Student	29,206	0.05	0.22	6,314	0.07	0.25
Retired	29,206	0.20	0.40	6,314	0.14	0.34
Unable to Work	29,206	0.06	0.24	6,314	0.05	0.22
Is a Veteran	29,308	0.13	0.34	6,535	0.13	0.34
Has Any Kind of Health Care Coverage	29,247	0.91	0.28	6,462	0.87	0.33
Annual Household Income						
< $10K	25,568	0.04	0.19	4,682	0.05	0.23
$10-15K	25,568	0.04	0.19	4,682	0.04	0.20
$15-20K	25,568	0.05	0.23	4,682	0.07	0.25
$20-25K	25,568	0.08	0.27	4,682	0.09	0.28
$25-35K	25,568	0.10	0.30	4,682	0.10	0.30
$35-50K	25,568	0.14	0.34	4,682	0.15	0.36
$50-75K	25,568	0.17	0.38	4,682	0.14	0.35
$75K+	25,568	0.38	0.49	4,682	0.35	0.48
Unemployment Rate	29,332	0.06	0.01	6,611	0.06	0.01

Notes: Weighted to be representative of the population of Washington State.

Table A2: RHS Balancing Tests

	(1) Ln(TT)	(2) Ln(TT)
Ln(Average tax-inclusive price per gram of flower at nearest store)	0.00805	0.453***
	(0.0844)	(0.160)
Male	-0.00980	0.00806
	(0.00738)	(0.0137)
Age	-0.000402	0.000537
	(0.000252)	(0.000642)
White	0.0265	0.0533
	(0.0177)	(0.0372)
Black	0.0252	-0.123*
	(0.0290)	(0.0712)
Asian	0.0133	-0.0537
	(0.0223)	(0.0636)
American Indian/Alaska Native	0.0487	0.162**
	(0.0339)	(0.0707)
Hispanic	0.0509**	0.104
	(0.0207)	(0.0634)
High school graduate	0.00265	-0.0257
	(0.0197)	(0.0402)
Some college	0.00711	-0.0674*
	(0.0193)	(0.0399)
College graduate	0.00725	-0.132***
	(0.0205)	(0.0500)
Married	-0.00492	0.107**
	(0.0239)	(0.0462)
Divorced	-0.0243	-0.0345
	(0.0246)	(0.0452)
Widowed	0.0121	0.0129
	(0.0264)	(0.0514)
Separated	0.00536	-0.0426
	(0.0430)	(0.0738)
Never married	-0.0207	-0.0743
	(0.0262)	(0.0482)
County unemployment rate	2.174	19.23***
	(1.334)	(3.065)
Observations	29,332	29,332
R-squared	0.834	0.225
ZIP FEs?	Yes	No
Month-year FEs?	Yes	Yes
RHS balancing test: Joint	0.257	0.000

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. We test whether the coefficients on sex, age, race, education, and marital status are jointly different from zero.

Table A3: Effects of travel time quintiles on past-month marijuana use

	(1) If Used	(2) Heavy Use	(3) Number Days Used
2.74-5.01 minutes' drive time	-0.0329**	-0.00973	-0.284
	(0.0137)	(0.0109)	(0.308)
5.01-9.96 minutes' drive time	-0.0186	0.000587	-0.112
	(0.0153)	(0.0120)	(0.328)
9.99-22.57 minutes' drive time	-0.0342**	-0.00858	-0.304
	(0.0165)	(0.0120)	(0.347)
22.57-342.24 minutes' drive time	-0.0363*	-0.0187	-0.754*
	(0.0189)	(0.0153)	(0.419)
Observations	29,332	29,332	29,332
R-squared	0.111	0.071	0.083
ZIP FEs?	Yes	Yes	Yes
Month-year FEs?	Yes	Yes	Yes
Ln(Average flower price at nearest store)?	Yes	Yes	Yes
Basic demographic and economic controls?	Yes	Yes	Yes
Additional demographic controls?	No	No	No

*** p<0.01, ** p<0.05, * p<0.1.

Notes: All estimates are weighted and are obtained using OLS with standard errors clustered by ZIP code. Basic demographic and economic controls include sex, age, race/ethnicity, educational attainment, marital status, and the county-level unemployment rate. Additional controls include the number of children under 18, employment status, veteran status, and if the respondent has healthcare coverage.