Federalism, Partial Prohibition, and Cross Border Sales: Evidence from Recreational Marijuana

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Abstract

Marijuana is partially prohibited: though banned federally, it is available to 1 in 4 U.S. adults under state statutes. We measure the size of the interstate trade generated by state-level differences in legal structure with a natural experiment: Oregon allowed stores to sell marijuana for recreational use on October 1, 2015, next to Washington where stores had been selling recreational marijuana since July 2014. Using administrative data covering the universe of Washington's sales and a differences-in-discontinuities approach, we find retailers along the Oregon border experienced a 36% decline in sales immediately after Oregon's market opened. Our results imply that Washington has earned between $64 million and $100 million in tax revenue from cross-border shoppers to date. These findings suggest that cross-border incentives may create a "race to legalize."

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1 Introduction

A long literature in public economics and finance has debated trade-offs created by federalized systems and the circumstances under which is it optimal for federal governments to set rules, regulations, and tax instruments, as opposed to leaving those decisions to local jurisdictions (Musgrave, 1959; Oates, 1972, 1999). Decentralization allows members to make welfare-maximizing choices, but these choices may have spillover effects that can be costly to neighbors. Indeed, while governments in different regions may wish to implement differentiated tax rates that correspond to local differences in preferences and endowments, the ability of consumers to engage in arbitrage across borders reduces the effectiveness of such differentiation (Mintz & Tulkens, 1986; Kanbur & Keen, 1993; Nielsen, 2001; Agrawal, 2015).

The challenges posed by arbitrage are particularly relevant in the context of sin goods. When borders are closed, local regulations or taxes on these goods can be light in regions with high consumption value net of externalities, and heavy in regions where the opposite is true.[1] Here too, arbitrage in the form of cross-border shopping threatens the potential efficiency of decentralized regulation (Lovenheim, 2008; Merriman, 2010; Harding et al., 2012; DeCicca et al., 2013). Moreover, the act of arbitrage can lead to further externalities: Lovenheim & Slemrod (2010) find that evading local minimum-age drinking laws increases traffic fatalities. Cross-border shopping incentives depend on differences in local prices or availability. In the case of sin goods, these are often caused by regional differences in regulation and taxation.

Marijuana policy provides a stark example of these issues. The production and consumption of marijuana has been prohibited by the U.S. federal government since 1938.[2] However,

[1] Geographic variation in policies can also be motivated by differences in externalities across regions.

[2] Marijuana is currently a Schedule I drug, a substance with "no currently accepted medical use and a high potential for abuse." Other Schedule I drugs include methamphetamine and heroin. See `https:`

since 1996, many states have opted to legalize marijuana for medical use, and since 2012 some have additionally chosen to legalize marijuana for recreational use. The federal government has semi-formally recognized this environment of partial prohibition by deprioritizing the enforcement of federal prohibition laws in states where marijuana is legal (Cole, 2013). This environment has generated state-level conflict, as states which neighbor legalizers have claimed that cross-border behavior has led to significant externalities (Graf, 2013; Ingold, 2014). Indeed, Hao & Cowan (2017) and Lu (2017) find that arrests for marijuana possession increase in states bordering newly legal recreational markets.[3]

We contribute to this debate by estimating the amount of cross-border marijuana purchases for the first time, which illuminates both the costs of partial prohibition – by quantifying the volume of potential spillovers–and the benefits – through measuring the revenues captured by a legalizer from other states' residents. We focus on Washington state, where retail sales of recreational marijuana began in July 2014. Washington neighbors Oregon – which permitted 'medical marijuana' sales at the time of Washington's legalization – and Idaho – where marijuana was and is illegal for all purposes. We measure cross-border sales using administrative data on the universe of Washington's recreational marijuana sales via two approaches. First, we model store-level demand as a function of local demographics and estimate parameters using data from the interior of Washington. We then apply the estimated coefficients to stores near the Idaho and Oregon borders and compare the predicted demand to the actual demand to calculate a measure of "excess" demand in each region. In the second approach, we focus on Oregon, where retail sales of recreational marijuana began

//www.dea.gov/drug-scheduling.

[3]This increase, however, occurs before legal retailers open – implying that their observations may be driven by increased law enforcement efforts as opposed to cross-border behavior alone. Indeed, Rubin (2018) finds that local police endogenously change enforcement of state drug laws after local marijuana legalization.

unexpectedly on October 1, 2015. We test whether Washington's sales fell along the Oregon border and interpret any fall as an estimate of cross-border shopping.

We find that in the months prior to Oregon's market opening, sales along the Oregon border were 25 percent higher than predicted by our local demand model. Sales along the Idaho border were 52 higher than predicted. Using regression discontinuity in time and differences-in-discontinuities approaches, we find that Oregon's market opening prompted a 36-38 percent decrease in sales along the border. Furthermore, we find these decreases in sales are largely driven by declines in "large" transactions. We conclude that between 9.4% and 13.7% of the marijuana sold in Washington in the months leading up to Oregon's market opening was sold to cross-border shoppers.

These findings suggest that legalization in one state increases access to marijuana for those who reside in nearby states where marijuana is illegal (or less legal). As measured by the grams of marijuana sold per state resident, we estimate that legalization in Washington effectively led to between 5% and 6% legalization in Oregon and between 29% and 50% legalization in Idaho. This result also has significant implications for research on the public health and other impacts of marijuana policy liberalization efforts: differences-in-differences approaches which rely on border states for controls are likely to have estimates biased toward zero (see, for example, Anderson et al., 2013, 2015; Dills et al., 2017; Marie & Zölitz, 2017; Aydelotte et al., 2017; Cerdá et al., 2017).

Our results also highlight the fiscal incentives offered to early adopters by cross-border shopping. Out of the $1.02 billion in excise tax revenue earned by Washington between its market opening and September 30, 2018, we estimate that between $68 and $100 million came from out-of-state consumers. Just as tax competition pressures states and local juris-

dictions to "race to the bottom" (Devereux et al., 2008; Jacobs et al., 2010), these incentives potentially create a "race to legalize." Indeed, several other states have chosen to legalize, in part due to expected tax revenues, and more are expected to follow suit.

We proceed in Section 2 by providing background on marijuana policy and Washington's marketplace. Section 3 describes our data and the methods we use to estimate the size of cross-border shopping in Washington. The results are detailed in Section 4. We conclude in Section 5 with a discussion of policy implications at local and federal levels.

2 Background

The U.S. federal prohibition on marijuana began in 1938 with the passage of the Marijuana Taxation Act, though many states had banned the substance earlier including Washington and Oregon in 1923, and Idaho in 1927 (Sanna, 2014, p. 88). The Controlled Substances Act of 1970 strengthened the prohibition against marijuana by increasing penalties for production, distribution, and possession.

Despite this consistent federal prohibition, public attitudes towards marijuana use have shifted, particularly about use for medical reasons ("medical marijuana"). Policies in many jurisdictions have changed as a result. Washington reduced penalties for marijuana possession in 1971, and in 1973, Oregon became the first state to decriminalize marijuana possession. The first successful medical marijuana legalization effort occurred in 1996 in California via ballot initiative. Oregon and Washington followed in 1998. Currently, 27 states and regions permit medical marijuana in some form, with varying restrictions. Notably, Idaho

has neither decriminalized possession nor permitted any use of marijuana in any form.[4]

In the November 2012 election, Washington voters approved Initiative 502, which legalized the production, sale, possession, and consumption of marijuana for recreational purposes for adults over 21. Colorado passed a similar ballot measure, making these two states the first to create legal recreational marijuana markets. Oregon followed suit in the November 2014 election, and several other states have chosen to legalize since, despite no change in federal statutes (Hawken et al., 2013).

Initially, federal prosecutors enforced the Controlled Substances Act in states with medical marijuana laws. These efforts culminated in *Gonzales v. Raich*, a 2005 U.S. Supreme Court case stemming from a 2002 enforcement action that destroyed marijuana plants owned by Californian licensees. Patients sued the government and made a federalism argument by claiming, in part, that since the marijuana had been produced and used entirely within California's borders, interstate commerce was unaffected and therefore Congress had no power to regulate their behavior. In it's 6-3 opinion, the Supreme Court sided with the government, in part due to the "difficulties that attend distinguishing between marijuana cultivated locally and marijuana grown elsewhere ... and concerns about diversion into illicit channels."

However, as the number of states with some form of legal marijuana markets grew, and public opinion shifted, federal enforcement policy adjusted even as federal laws went unchanged. In August 2013, during the implementation of Initiative 502, the Department of Justice responded to the Washington and Colorado efforts with a memo written by then-Deputy Attorney General James Cole. The "Cole Memo" emphasized the federal prohibition

[4]In 2015, the Idaho legislature passed a bill allowing the use of cannabidiol oil for treatment of severe epilepsy, mirroring the highly restrictive medical marijuana laws of several other states. The bill was vetoed by the governor and has not been reconsidered (Associated Press, 2015).

of marijuana but provided guidance to U.S. Attorneys as to specific enforcement priorities.[5] One priority was "preventing the diversion of marijuana from states where it is legal under state law in some form to other states." Other priorities included preventing consumption by minors, preventing marijuana sales revenue from going to "criminal enterprises, gangs, and cartels," and "preventing drugged driving and the exacerbation of other adverse public health consequences associated with marijuana use." Importantly, the Department established a clear expectation that "states and local governments... will implement strong and effective regulatory and enforcement mechanisms." States in compliance with the Memo were promised that the federal government would not seek to eliminate legal marijuana markets.

Bordering states also expressed concerns. In March 2013, Idaho's legislature passed a resolution in support of the federal prohibition policy after local law enforcement agencies claimed that the changes in Washington and Colorado had led to a rise in trafficking activity in the state (Graf, 2013). Nebraska and Oklahoma sued Colorado claiming that unilateral legalization increased their law enforcement costs, though the suit was eventually dismissed (Ingold, 2014). Indeed, according to FBI arrest statistics, the drug violation arrest rate increased 9.2% in Idaho and 8.2% in Oregon from 2012 to 2013 even as the national rate decreased 4.0%. These increases could have stemmed from an increase in cross-border activity—though an increase in enforcement effort would also explain the change. Rates in Nebraska and Oklahoma remained nearly flat (Puzzanchera & Kang, 2017).

The need for effective enforcement was not lost on Washington policymakers. The ballot measure created a three-tiered supply chain, with separate licenses for cultivators (legally

[5]The Cole Memo was a follow-up to a previous 2009 memo focusing on medical marijuana which specified that "federal resources in [legal] States" should not be focused "on individuals whose actions are in clear and unambiguous compliance with existing state [medical marijuana] laws." (Ogden, 2009, p.2).

'producers'), wholesalers (legally 'processors'), and retailers.[6] To comply with the priorities laid out in the Cole Memo, Washington implemented a "traceability" system to track the cultivation, testing, processing, and retail sales of marijuana. At every step, the system tracks each gram of marijuana produced and each dollar transferred. The data is verified through random site audits—on average eight per licensed location per year—backed by penalties ranging from fines to inventory destruction and loss of license. In this way, Washington's system is designed to ensure that marijuana is not diverted from within the supply chain to black markets. We provide more details on the administrative data gathered from this system in Section 3.

Washington's market opened on July 8, 2014, though the opening was not without some friction. As part of the original Initiative, regulators capped licenses throughout the state based on each local jurisdiction's share of the population. Potential retail entrants could apply for a single license covering up to three sales locations. In places where more potential entrants applied than could be satisfied by the cap, a lottery was held (Thomas, 2018). In other words, although entrepreneurs may have wished to concentrate entry in areas where they expected the highest demand, the regulatory license quota made it difficult to endogenize entry in this way. Though at least some licenses were granted across every jurisdiction before the market opened, the Initiative gave local authorities the power to impose additional zoning restrictions or enact moratoria on retail entry; many did so. As a consequence, only 26 stores opened in July 2014, though 140 locations operated by 139 firms were operating by the time Oregon's market opened. Figure 1 illustrates the locations of each of the retail

[6]Initiative 502 set up vertical integration and ownership constraints for firms; these constraints do not bear upon this analysis. Additionally, the Initiative specified a tax structure that was later reformed extensively before Oregon's market opened. Hansen et al. (2017) examine these details of Washington's policy.

firms throughout the state at the time Oregon's market opened.

Though the Oregon measure legalized the recreational use of marijuana on July 1, 2015, retail stores were not expected to open until late 2016. However, in July 2015, Oregon's governor signed a bill allowing the roughly 400 existing medical dispensary locations to sell recreational marijuana starting on October 1, 2015. The governor cited the need to curb black market usage and hasten the transition to a revenue-producing legal market (Sebens, 2015). This opening of retail sales acts as a demand shock to Washington's market insofar that some of Washington's sales along the border came from Oregon residents. As the market opened many months earlier than expected, we treat the precise date as exogenous variation in demand for Washington's marijuana retailers.[7]

While we proceed to use this demand shock to identify the amount of cross-border shopping in terms of the weight of dry marijuana flower ('usable marijuana') sold, interpreting the results requires an understanding of marijuana dosage and consumption rates. However, relative to other substances such as nicotine or alcohol, establishing a standardized measure of consumption is difficult, both due to the variety of consumption paths, and variation in potency measured by the concentration of tetrahydracannabinol (THC) and cannabidiol (CBD) (Gray et al., 2009). Indeed, in our data the average potency of marijuana sold in Washington's marketplace has increased substantially since its market opened, from roughly 13% THC and CBD content by weight to more than 20%. The most relevant estimate of use by Washington's consumers comes from Cuttler & Spradlin (2017), who surveyed over 2,000 marijuana users at a major university in Washington and found that users consumed

[7]While Oregon developed a tracking system comparable to Washington's system, it was not available when recreational sales began. Because of this, we cannot observe the details of Oregon's retail market at the time of its opening, as we can with Washington. In any case, any demand change in Washington's market is the key sufficient statistic for identifying the movement of marijuana from Washington to Oregon.

marijuana on an average of 7.82 days per month and, conditional on use, the average weight consumed per day was 0.99 grams. Other measures of consumption come implicitly from the market: stores generally sell usable marijuana in packages of 1g, 2g, 3.5g, 7g, 14g, and 28g (one ounce).[8] Pre-rolled joints are included in the category of 'usable marijuana', often contain smaller amounts of dried flower (e.g. .33g or .5g), and are also commonly sold in packs (e.g. three packs, six packs, or ten packs). We therefore define a "large transaction" as any transaction where the weight of usable marijuana sold was greater than 6g.

Marijuana is also available in other forms, including edibles – processed foods which contain THC or CBD extract – and concentrates – highly purified extracts that are consumed with a vaporizer. The nature of these forms precludes using the weight or number of units sold directly as a measure of quantity, as these measures are not comparable across products. We therefore use revenue instead of weight when analyzing these products.

2.1 Population centers, border crossings, and retail locations

To understand the degree to which we could expect cross-border behavior at different locations, it is useful to consider the geography of Washington's borders. For example, approximately 75% of Washington's border with Oregon is formed by the Columbia River and there are only ten road crossings over the roughly 300 mile length of the river border (Holmes, 1998). In contrast, Washington's borders with Idaho and Canada are defined by longitude and latitude lines, respectively. There are thirteen land crossings between Canada and Washington, with four serving the Seattle-Vancouver region. The Washington-Idaho

[8]Washington limits purchases to one ounce per transaction, though there is no tracking of purchase behavior across stores.

border is considerably more porous.

We proceed by splitting Washington into four zones by county: the Oregon border, the Idaho border, the Canadian border, and the interior. Figure 1 maps these zones and the location of Washington retailers at the time that Oregon's market opened. Most retailers are located in the interior region within the greater Seattle-Tacoma area, though there are several located in the middle of the state near Wenatchee. The greatest concentration of retailers along the Canadian border are in Bellingham, less than 60 miles from Vancouver, British Columbia, though there is a single retailer less than one mile from the border.

Retailers in the Oregon border region are spread more evenly, with many located along the Columbia River Gorge near river crossings. The greatest number are in the Vancouver, Washington, area, near Portland and along the Interstate 5 corridor.[9] Appendix Table A.1 groups Oregon's counties by the Washington county with the closest retailer and reports county populations and the distance to the closest Washington retailer. Appendix Figure A.1 illustrates this data with a map of Oregon's counties.

Idaho border region retailers are almost all located near Spokane, though one is located in Pullman. Several of Idaho's population centers are within 30 miles of the Washington border, including Coeur d'Alene, which is close to Spokane, and Moscow, which is close to Pullman. The proximity of Moscow and Pullman is particularly relevant, as both host land-grant universities (University of Idaho and Washington State University, respectively).

The porous nature of the Washington-Idaho border makes characterizing specific routes for individual travellers difficult, but the most direct route from Boise, Idaho's most populous city, to Washington, passes through Oregon along Interstate 84. However, no recreational or

[9]The I-5 corridor traverses the Willamette valley, home to approximately 70% of Oregon's population

medical dispensaries were open in Oregon along the I-84 corridor until 2016.[10] The closest Washington dispensaries to Boise at the time of Oregon's market opening included locations in Prosser (305 miles) and Pullman (295 miles). Several of Montana's population centers are closer in driving distance to Washington than Colorado, including Missoula, Great Falls, Helena, and Bozeman. For these reasons, after estimating the impact of Oregon's market opening on Washington, we also examine Washington sales along the Idaho border both to test whether Oregon's market opening also affected firms along the Idaho border.

3 Data and Methods

We estimate the extent of cross-border shopping with records from Washington's traceability system. We observe, for each retail transaction, the types (i.e. usable marijuana, edibles, or concentrates) and quantities of products sold, the prices paid by consumers, and the wholesale prices paid by retailers. Though the data are generally reported in real time, we aggregate our data to the weekly level to avoid cyclical day-to-day variation in sales.

We apply some cleaning steps to our data. In particular, systematic changes in the state's reporting system and third-party tools used by many firms must be accounted for. Hansen et al. (2018) detail the steps needed to transform the raw traceability database into a usable form for research, and we follow their procedure. Most of the details in that paper are focused on the technical features of this administrative data set and are not directly relevant to this analysis. For the purposes of examining sales in the period immediately surrounding

[10]Opposition to Oregon's recreational legalization ballot measure was much stronger along the I-84 corridor in the eastern part of the state than along the I-5 corridor in the western part of the state. The largest town along the corridor, Ontario, banned the sale of marijuana. Retailers eventually opened in rural areas.

Oregon's market opening, we drop firms in their first 14 days of operation and firms which have inconsistent reporting behavior (e.g. firms which report sales one day per week) within a month of Oregon's market opening. After applying these restrictions, we drop 11% of the data as measured by the total weight sold in the raw data versus the cleaned data.[11]

Table 1 reports aggregates of our data at the region level over three periods. The first column aggregates data over the two months before Oregon's law took effect (May and June 2015). The second column reports aggregates for the two months before Oregon's market opened (August and September 2015), and the third column details our data for the two months after Oregon's market opened (October and November 2015). The first three rows within each region report the total weight, average tax-inclusive price, and share of the total weight sold in the state for the relevant time period. The remaining rows report the region's population share, share of men from age 20 to 24 (relative to the total in the state), and share of college enrollees taken from the 2015 American Community Survey.

The top panel reports statistics for the interior region. Though the interior has 75.4% of Washington's population, its market share was only 66.5% before Oregon's market opened. Its market share increased to 70.4% afterwards. In contrast, the Idaho border region has only 8.1% of Washington's population, but captures roughly 19% of its market share. Though there were small changes in the distribution of the market share across the Idaho and Canadian border regions, the largest change over the period we study came from the Oregon border region, where the market share fell from 9.9% in the two months before Oregon's market opened to 6.7% in the two months afterward. Similar patterns exist when comparing

[11]The largest single contribution to this percentage comes from firms which initially reported irregularly and then switched a more regular reporting scheme. We choose to eliminate these firms to ensure that our results are not driven by changes in the composition of firm reporting behavior which are not likely to be caused by Oregon's market opening.

the market shares to shares of men from age 20 to 24 and their share of college students.

Figure 2 illustrates the time-series nature of our data by plotting the total revenue from usable marijuana, concentrates, and edibles, as well as the total weight of usable marijuana sold in each of the four regions by week during the period we study. The outcomes are indexed to the week before Oregon's market opened. In the Oregon border region, all four outcomes drop in the weeks after legalization, though the drop in sales of concentrates and edibles is smaller than the drop in usable marijuana sales.

Transactions are heterogeneous in the weight of usable marijuana sold. Table 2 details the distribution of transaction sizes across regions for the two-month period before Oregon's market opened. The plurality of transactions—33.8% statewide—are of a single gram of marijuana. Transactions between one and two grams make up the next largest category, at 25.6%. The largest category, transactions of greater than six grams, comprise 6.4% of sales in the state. Roughly 5% of transactions in the interior and Canadian border regions are "large." However, 9.3% of sales in the Oregon border region and 11.8% of sales in the Idaho border region are "large." By weight, large transactions comprised roughly 31% of the weight sold statewide, 37% of the weight along the Oregon border, and nearly 44% of the weight sold along the Idaho border.

3.1 Excess Local Demand

The summary statistics presented in Tables 1 and 2 identify significant discrepancies in the market shares and transaction size distributions between the Oregon and Idaho border regions and the rest of the state. These stylized facts are consistent with the hypothesis that

some portion of demand in border counties is coming from cross-border shoppers. However, it is possible that local demand conditions for the firms in border counties varies in a consistent way that is unrelated to their proximity to the border.

To explore this in more detail, we estimate a model designed to capture any "excess demand" or "excess large transactions" in the border regions after accounting for observable local conditions. We collect data from the 2015 American Community Survey at the census-tract level and construct variables representing the demographics of the individuals residing within census tracts that have centroids within ten kilometers of each firm. We capture the total population, the fraction who are male, the fraction who are between the ages of 20 and 34, the fraction with a college degree, the fraction employed full time, the fraction who are currently enrolled in college, and the mean individual earnings. We also calculate average prices at the firm level and the "experience" of the firm defined by the number of days it has been open, and collect county-level voting results for the original legalization initiative.

We model y_f, the log-weight of usable marijuana sold by firm f in the two months before Oregon's market opened, as a function of local demographic and firm characteristics X_f as

$$y_f = \beta_r X_f + u_f. \tag{1}$$

To calculate the excess demand along the border, we estimate the parameters β_r using only observations of firms in Washington's interior, and predict the log-weight sold by border firms using those parameters. Positive differences between the predicted and actual sales indicate that firms experienced some demand beyond that explained by local demographics.

3.2 Regression Discontinuity Design

Our demand estimation procedure is designed to capture any "excess" demand which may have existed in the border regions prior to Oregon's market opening. To estimate the causal impact of Oregon's market opening on Washington's sales, we use a regression discontinuity (RD) design with time as the running variable and treatment determined by the date Oregon legalized – a regression discontinuity in time (RDIT). We model some outcome variable y_t as a function of time with

$$y_t = \beta_0 + \beta_1 * ORLegal_t + f(t) + u_t. \tag{2}$$

In this equation, $f(t)$ is a function of the running variable – we use a first-degree polynomial and allow the slope to vary across the discontinuity. $ORLegal_t$ is an indicator which is one if the date is October 1st 2015 or greater. β_1 is the parameter of interest.

This approach relies on the key identifying assumption that there are no changes in the outcome variable other than those caused by Oregon's market opening. RDIT is a somewhat unique application of the RD approach. As discussed by Hausman & Rapson (2017), tests of covariate balance or sorting are not possible when time is the running variable. Concerns about identification generally stem from seasonality, as cyclical or non-linear variation in the response variable over time can lead to bias in the estimate of β_1. We choose bandwidths following Calonico et al. (2014)[12] and address these concerns by exploring the sensitivity of our estimates to a variety of bandwidths—thus changing the level of non-linear variation in

[12]We used the statistical packages 'rdrobust' and 'rdplot', described in Calonico et al. (2017) to estimate our regression discontinuity models.

the response variable—and polynomial orders (Gelman & Imbens, 2017)—thus affecting our ability to capture non-linear variation.

Motivated by pronounced day-of-week effects which reflect the stylized fact that many consumers buy marijuana once per week, we aggregate to the region-week level, consistent with the data shown in Figure 2. Calonico et al. (2018) show that including additional covariates in a RD design can also affect consistency and precision. We avoid this concern because after aggregating to the region level, the only covariate remaining is the week relative to Oregon's legalization, our running variable.

3.3 Differences-in-Discontinuities

The RD design cannot account for all potential threats to identification. If an external shock occurs coincident in time with the treatment, RD models will be biased as they will attribute all of the observed change to the treatment, when in reality multiple factors changed at the threshold. This is particularly concerning in our application, as regulatory changes in Washington generally occur at the state level; if some change occurred around the time of Oregon's market opening that affected the weight sold, our RD estimates will not successfully capture the impact of Oregon's policy change.

This concern can be addressed if there is another group which does not experience a coincident change in treatment, but which does experience any external shock. In such a case, one can estimate the reduced-form effect of the external shock for this control group, which provides an estimate of the bias present in the RD estimate of the treatment effect. Grembi et al. (2016) first implemented this "differences-in-discontinuities" approach in studying the

impacts of regional fiscal rules. We use the interior of Washington as such a control group. The treatment effect of Oregon's market opening is recovered by subtracting the RD estimate of the effect for the control group from the RD estimate for the treatment group.

We perform difference-in-discontinuities analysis with a single regression. For a region r, we model the region-time level outcome variable y_{rt} with

$$y_{rt} = \beta_0 + \beta_1 * ORLegal_t + \beta_2 * ORBorder_r + \beta_3 * ORBorder_r * ORLegal_t + f(t) * (ORBorder_r) + g(t) * (1 - ORBorder_r) + u_{rt}. \quad (3)$$

In this equation, $ORLegal_t$ is an indicator variable which is one if the date is October 1st 2015 or greater, while $ORBorder_r$ is an indicator variable which is one if r is the Oregon border region. β_3 is the parameter of interest. The function $f(t)$ is a first-order polynomial in the running variable which is interacted with the Oregon border indicator, while $g(t)$ is a separate first-order polynomial for the Washington interior region. We allow $f(t)$ and $g(t)$ to vary across the $ORLegal_t$ discontinuity.

This approach accounts for any coincident changes in policy or seasonal changes in the response variable that are common across the interior and border regions. Our standard errors are calculated allowing clustering at the level of the running variable (Lee & Lemieux, 2010).[13] We choose a bandwidth following Calonico et al. (2014) and explore the sensitivity of our estimates to the bandwidth selection criteria suggested by Ludwig & Miller (2007) and Imbens & Kalyanaraman (2012).

[13]When we aggregate to the region by week level for the initial regression discontinuity models, this is mathematically equivalent to standard heteroskedastic robust standard errors, as there are no repeated observations and hence only one observation per time unit.

4 Results

4.1 Excess Local Demand

Summary statistics for the variables we use to estimate demand are presented in Table 3. The first column reports statistics for all 140 firms included in our analysis. On average, firms sold 38 kilograms of usable marijuana in the two months before Oregon's market opened, at an average price of $12.87 per gram. Firms are located in relatively populated areas – the average population in tracts within 10 kilometers is 133,269. The remaining columns categorize firms by county into interior firms and those along the Oregon and Idaho borders. The average weight sold is similar in the interior and Oregon border, but is significantly higher, at nearly 60 kilograms, along the Idaho border. Prices along the Oregon border are slightly higher than the interior, despite lower wholesale prices. Idaho features lower prices than the interior. As the Idaho border firms are mostly located near Spokane, the average population nearby, 124,369, is close to the interior average of 157,763. Firms along the Oregon border have an average local population of 60,901. Individuals near interior firms are more educated than those near border firms.

To calculate the residual demand along the borders, we regress sales on our collected variables for those firms in the interior. We instrument price with the average wholesale cost. Appendix Table A.2 reports the estimates. Column (1) reports estimates for total weight, and Column (2) reports estimates for the share of large transactions. The estimates are noisy, likely due to the small number of firms observed in the interior (94). However, the signs of many variables align with sensible priors: higher prices and greater educational attainment are associated with lower sales. Population, experience, employment, the college

enrollment rate, and local support for legalization are associated with higher sales.

Using these estimates, we predict the log weight sold by each firm and subtract the prediction from the actual data to form the residual, or excess, demand experienced by those firms. Table 4 reports the distribution of these residuals in the Oregon and Idaho border regions. On average, firms in the Oregon border region experienced 25.1% greater demand during the period than would have been expected given the characteristics of the local environment. Firms in the Idaho border region experienced 52.9% greater demand on average than predicted. Figure 3 illustrates the results at the firm level.[14] Along the Oregon border, the firms closest to Portland and The Dalles have positive residuals, while firms closer to the interior of Washington have residuals closer to zero. In the Idaho border region, the firms in and around Spokane generally have positive residuals. The largest residual state-wide comes from the firm in Pullman.

We conclude that some external factor which isn't present in the interior is increasing demand along the borders. We proceed to our time-series analysis focusing on the change in demand in Washington created by the opening of Oregon's market to test our hypothesis that this external factor is cross-border shopping.

4.2 Oregon's Market Opening

The previous analyses provide suggestive evidence that a sizable proportion of the marijuana sold in the border regions was sold to cross-border shoppers. However, these analyses ultimately rely on cross-sectional variation. In this section, we focus on the exogenous panel variation provided by Oregon's market opening on October 1, 2015.

[14] Appendix Figures A.3 and A.4 zoom in on the Oregon and Idaho border regions.

Table 5 reports estimates of the effect of Oregon's legalization on marijuana sales in Washington. Each coefficient in the table is the treatment effect of Oregon's legalization estimated via separate regressions. Columns (1) through (4) investigate the effect of legalization on different outcomes: the weight of usable marijuana, total transaction counts, revenue from marijuana concentrates, and revenue from edibles. Since the outcome in each regression has been transformed by the natural logarithm, the coefficients in the table can be interpreted as semi-elasticities—in other words they reflect the percentage change in the dependent variable due to Oregon's legalization. Figure 4 illustrates the predicted model fits relative to the raw data for each of our outcome variables for both the Oregon border and Washington interior regions.[15] Shifts in marijuana sales in Oregon are evident, while the sales appear essentially unchanged in the Washington interior.

The rows of Panel A of Table 5 report our regression discontinuity estimates (with week as the running variable) for each region of the state. Across the four regions, only the Oregon border shows a consistently significant drop in sales following the opening of recreational stores in Oregon. The optimal bandwidth is 8 weeks, providing a total of 17 observations including the week of legalization where the running variable is zero. The point estimates suggest that the weight of usable marijuana sold in the Oregon border region fell by 38 percent after Oregon's market opened, while the count of sales fell by 32 percent. Revenues from concentrates and edibles fell by 18 percent and 12 percent respectively. Notably, edibles and concentrates were not available in Oregon in October 2015 (though they are today), which could in part explain why sales of those products fell by a smaller margin than usable

[15]We follow the approach recommended by Calonico et al. (2015) and fit a 4th order polynomial on each side of the discontinuity. While this does not perfectly mirror the results in the tables, they suggest this provides a more global view of the potential shift relative to the entire data series. Appendix Figure A.2 illustrates outcomes in the Idaho and Canadian border regions.

marijuana. In other regions of the state, the estimated decreases are small and largely imprecise. Only one of the estimates approaches significance, which we would expect when testing 12 coefficients even when the null is true.

Panel B reports estimates based upon our differences-in-discontinuities approach. These estimates are formed by including observations from the Washington interior region in the same regression with the different border regions—one could construct the point estimates by subtracting the estimates from the Washington interior from the estimates from the other regions of the state. The point estimates from this approach suggest that the weight of usable marijuana sold fell by 36 percent in the Oregon border region, and the count of sales declined by 28 percent, and revenues from concentrates and edibles fell by 16 percent and 10 percent, respectively. In the other border regions of the state, the estimated declines are small, and mostly indistinguishable from zero. We do find a marginally significant 8 percent decline in revenues from edibles along the Canadian border, but again this is in line with the number of hypotheses we test.

To summarize, Oregon's market opening provides quasi-experimental evidence of the prevalence of cross-border sales. Our estimates suggest that weight of usable marijuana sold in stores near the border fell by 36-38 percent. The estimates produced using the regression discontinuity in time and the differences-in-discontinuities approaches are nearly identical. The estimates also suggest that the decline in usable marijuana sales was larger than the decline in sales of other marijuana products, concentrates and edibles, which were not available when retailers first began recreational sales.

4.3 Robustness, heterogeneity, and other outcomes

Our estimates may be subject to a variety of concerns, including the possibility of treatment phase-in, our choices of polynomial order and bandwidth, and treatment effect heterogeneity. We explore the robustness of our estimates to these concerns by modifying our specifications.

If treatment effects phase in over time—if the effects are smaller the precise week Oregon's market opens and larger in subsequent weeks—then RD estimates are biased. We investigate if this substantially affects both our RD and differences in discontinuities approaches by implementing 'donut' regressions (Barreca et al., 2011), in which the first week of treatment is removed. The results are reported in Table 6, which reproduces the structure of Table 5. In general, the estimated effects are slightly larger. The point estimates from the RD approach (Panel A) suggest that along the Oregon border, the weight of usable marijuana sold fell by 45 percent, the count of sales declined by 36 percent, and revenues from concentrates (edibles) fell by 25 percent (15 percent). The point estimates from the differences-in-discontinuities design are also slightly larger. Those estimates suggest that the weight of usable marijuana sold fell by 41 percent, the count of sales declined by 31 percent, and revenues from concentrates (edibles) fell by 25 percent (15 percent). Once again, the point estimates for either approach suggest in other regions of the state were largely unaffected by Oregon's legalization. While these results suggest that there was a small phase-in period, the estimates of Table 5 and Table 6 are not significantly different from each other.

In Figure 5 we explore the robustness of our estimates to local polynomial choice and the bandwidth selection criterion. We focus on estimates of the change in the log weight of usable marijuana sold in the Oregon border region. Panel A reports RD estimates, while

Panel B presents results from differences-in-discontinuities models. Increasing the order of the polynomial results in slightly smaller point estimates, although they remain statistically different from zero and overlap with each other. Using the bandwidth selection criterion of Ludwig & Miller (2007) and Imbens & Kalyanaraman (2012) results in slightly larger bandwidths – 20 and 25 weeks, respectively – and larger point estimates. Again, the estimates using all three approaches are not significantly different from each other. In short, our results are both qualitatively and quantitatively similar over polynomial choices and bandwidths. Moreover, our preferred estimates from the previous section tend to be in the middle of the range of values generated by these alternative specifications.

We explore the heterogeneity of the effect across transaction sizes in Figure 6. We focus on the Washington interior and Oregon border regions. In addition to testing the robustness of our results, this can help to identify potential mechanisms. If our results were driven by marijuana tourism – i.e. individuals coming to Washington, consuming marijuana there, and then returning home – we would expect to see the largest declines in the number of small transactions, such as those involving 1 gram or less of marijuana. On the other hand, if individuals are purchasing marijuana in Washington and bringing it back to other places where it is illegal for longer-term consumption or distribution, then would expect to see large effects for large transactions. Along the Oregon border, we find the estimated decreases in marijuana sales are close to zero for smaller transactions, and grow in the transaction size. The estimate is 46 percent for sales ranging from 3.5 grams to 6 grams and 58 percent for sales larger than 6 grams. This is consistent with individuals stockpiling for later consumption.

We explore heterogeneity by retailer by estimating retailer-specific models using a RD

design.[16] Figure 7 reports the results on our map of Washington. Darker colors indicate a more negative point estimate (i.e. a larger estimated decline in sales). The largest declines are in the Oregon border region, while the magnitude of coefficients follows a white noise pattern in the other parts of the state. Figure 8 colors locations according to the t-statistic of the point estimate – darker colors indicate a larger t-statistic and therefore greater significance. As with the point estimates, significance is only consistently found near the border.[17]

Appendix Table A.3 contains estimates for a variety of other outcomes include measures of marijuana potency, prices, and inventory levels. The point estimates are generally small across all regions in Washington, suggesting the Oregon border did not experience sizable changes in its market other than amount of marijuana sold. Given the reductions in the quantity of marijuana sold is plausibly a demand shock (since the number of retailers did not change), then the small (and sometimes insignificant) changes in price would suggest that supply is elastic. The point estimates derived from the differences-in-discontinuity estimates would suggest the elasticity of supply is 10. However, there may be asymmetric responses for supply if there was a sudden demand increase.

4.4 Measuring cross-border shopping

Given the size of our estimated effects, a natural question is the degree to which cross-border shopping contributed to the overall size of the state's market. Our different estimation approaches naturally lend themselves to different ways of measuring this total effect. Table 7 reports estimates of the weight sold, the market value, and the tax revenue generated by cross

[16] We fix the bandwidth to facilitate the comparison across stores.
[17] Appendix Figures A.5 and A.6 focus on the Oregon border region.

border shopping along both the Oregon and Idaho border across two different strategies for the two months leading up to Oregon's market opening. The first strategy uses the estimates of excess demand and assumes that the source of the excess demand is cross-border sales. Under such a scenario, we estimate that Oregon shoppers were responsible for $1,784,757 in sales and $660,360 in tax revenue for Washington, while Idaho's shoppers spent $6,432,471 and generated $2,380,014 in tax revenue.

The second strategy uses the differences-in-discontinuities estimate for the Oregon border region as the fraction of weight sold to cross-border shoppers along both the Oregon and Idaho borders. For the Oregon border, this approach results in a higher level of estimated cross-border sales ($2,559,811) and tax revenue ($947,130). Along the Idaho border, the estimates are smaller than the estimates from the first strategy: $4,377,485 in sales and $1,619,670 in tax revenue.

Combining the strategies, we estimate that out of the $25,116,410 in tax revenue earned by Washington in the two months prior to Oregon's market opening, between $2,279,730 (9.1%) and $3,327,145 (13.2%) came from out-of-state shoppers. Out of the $1.02 billion in excise tax revenue earned by Washington between its market opening and the end of September, 2018, between $2.72 and $3.90 million came from Oregon shoppers, and between $65.6 million and $96.4 million came from Idaho shoppers.[18]

These quantities have a much bigger impact when considered in light of the relative populations of Oregon and Idaho – Washington has roughly 1.8 times the population of Oregon and 4.3 times the population of Idaho. Under Strategy 1, we estimate that 680,500 grams of marijuana were purchased by cross-border shoppers. Under these assumptions,

[18]Or shoppers from other regions nearby in Montana.

sales to Washington residents were 0.314 grams per person per month. Taken over the entire population of each state, Washington provided 0.017 grams per person-month to Oregon residents and 0.157 grams per person-month to Idaho residents.[19] Combining the strategies, assuming 0.314 grams of marijuana per person represents full legalization, Washington's market contributed to an increase in legalization between 5.1% and 6.4% in Oregon, and between 29.7% and 50.1% in Idaho.[20]

5 Conclusion

The ability of a federal government to efficiently delegate responsibility depends partly upon the degree to which citizens are able to engage in arbitrage across local borders and the degree to which the government can enforce decisions within those borders. The *de facto* partial prohibition of marijuana in the U.S., despite *de jure* total prohibition, is a prime example of these tensions. Though public opinion has consistently shifted in favor of legalizing marijuana and states began legalizing marijuana for medical use in 1996, marijuana arrests exceeded those for all violent crimes as recently as 2015 (Williams, 2016). Furthermore, the burden of marijuana prohibition has fallen largely on people of color, who are arrested for marijuana-related crimes at much higher rates than whites despite similar consumption rates (Matthews, 2013). Though the federal government has recently taken a more passive approach and effectively allowed individual states to choose policies independently, claims of spillovers have led to state-level conflict (Ingold, 2014).

[19]These calculations implicitly assume that cross-border shoppers came from Oregon and Idaho alone, and not from, say, Montana, Utah, or other states.

[20]If instead we assume that cross-border shoppers come from the Montana cities of Missoula, Great Falls, Helena, and Bozeman in proportion to their population, we conclude that Washington's market led to an increase in legalization of between 26.5% and 44.6%.

We show this state-by-state roll-out does indeed come with spillovers in the form of cross-border shopping. The sequential opening of markets in neighboring states provides a natural experiment for measuring the extent of this behavior. We find that sales in Washington along its border with Oregon dropped by nearly 40% when Oregon's market opened. Our results indicate that Washington's unilateral decision to legalize may have effectively given Idaho residents roughly half of the access to marijuana that they would receive were they to choose to legalize themselves; Oregon residents may have received roughly 6% access.

Spillovers may provide strong pro-legalization incentives to states; we find that as much as 10% of Washington's marijuana tax revenue to-date has come from cross-border shoppers. In contrast to the oft-cited 'race to the bottom' in tax policy, there may be a 'race to legalize' driven by the ability to collect revenues from one's neighbors (or recover revenues being lost to a neighboring state which has already legalized). Whether all states ultimately act to legalize marijuana on their own depends partly on the market power in the industry (Agrawal & Trandel, 2017) as well as the costs of cross-border shopping. If and when the federal government decides to de-schedule marijuana and collect its own excise tax, that tax will create vertical externalities on the revenue streams of states. For example, Fredriksson & Mamun (2008) find that cigarette taxes in states come down by roughly 48 cents in response to a $1 increase in the federal excise tax rate. Canada, which has legalized marijuana at the federal level, has addressed this concern in part by allocating a portion of federal tax revenue to provinces. More broadly, to the extent that a state is able to profit through arbitrage by being different than its neighbors, we should expect competition by differentiation.

Our findings, particularly with respect to the differences between the Oregon and Idaho border, suggest that the western United States may experience minimal cross-border shop-

ping relative to the rest of the country. Although the opening of California's market may have dramatically increased the supply of marijuana grown in the U.S., California is surrounded by states where marijuana is legal – for recreational use on 81 percent of its borders (Oregon and Nevada), and for medical use on the remaining 19 percent (Arizona). On the other hand, significant cross-border shopping might be more likely in Massachusetts, New Jersey, and Michigan, states whose neighbors have not legalized marijuana for recreational use, and whose medical marijuana regimes are relatively restrictive.

These results also speak to the need to consider arbitrage opportunities when federal authorities create a regime of partial prohibition. For example, many political commentators believe that the federal government may allow states to ban abortion in the near future. From the perspective of a state government wishing to enact a ban, its ability to do so effectively depends upon the ease with which state residents can travel to jurisdictions with access. Fischer et al. (2018) and Lindo et al. (2017) study recent changes in Texas law that closed abortion clinics and find significant decreases in abortions in locations where the distance to the nearest clinic increased substantially. Other sin goods may move into a partially prohibited regime as well; while MDMA has been a Schedule I drug since 1988, the Food and Drug Administration has recently allowed limited medical trials (Philipps, 2016).

As more states legalize marijuana, the balance of incentives may change. In states where marijuana is legal both locally and in neighboring jurisdictions, cross-border shopping may drive states to compete on tax rates or regulatory frameworks. To-date, the states which have opted to legalize have chosen a variety of tax regimes, ranging from flat fees assessed per unit of weight to percentages assessed on retail sales, as in Washington. The extent to which cross-border shopping continues to exert pressure on states depends on the extent to

which price and quality competition between firms near borders incentivizes consumers to travel. In other words, tax competition will be driven by the extent to which the grass is greener (or perhaps cheaper) on the other side.

References

Agrawal, D. R. (2015). The tax gradient: Spatial aspects of fiscal competition. *American Economic Journal: Economic Policy*, *7*(2), 1–29.

Agrawal, D. R. & Trandel, G. (2017). A spatial model with discrete policy choices that may not match: The case of regulatory competition. *Working Paper*.

Anderson, Mark, D., Hansen, B., & Rees, D. I. (2013). Medical marijuana laws, traffic fatalities, and alcohol consumption. *The Journal of Law and Economics*, *56*(2), 333–369.

Anderson, M. D., Hansen, B., & Rees, D. I. (2015). Medical marijuana laws and teen marijuana use. *American Law and Economics Review*, *17*(2), 495–528.

Associated Press (2015). Otter vetoes marijuana extract oil bill. *Idaho Statesman*.

Aydelotte, J. D., Brown, L. H., Luftman, K. M., Mardock, A. L., Teixeira, P. G., Coopwood, B., & Brown, C. V. (2017). Crash fatality rates after recreational marijuana legalization in washington and colorado. *American journal of public health*, *107*(8), 1329–1331.

Barreca, A. I., Guldi, M., Lindo, J. M., & Waddell, G. R. (2011). Saving babies? revisiting the effect of very low birth weight classification. *The Quarterly Journal of Economics*, *126*(4), 2117–2123.

Calonico, S., Cattaneo, M. D., Farrell, M. H., & Titiunik, R. (2017). rdrobust: Software for regression discontinuity designs. *Stata Journal*, *17*(2), 372–404.

Calonico, S., Cattaneo, M. D., Farrell, M. H., & Titiunik, R. (2018). Regression discontinuity designs using covariates. *Review of Economics and Statistics*, (0).

Calonico, S., Cattaneo, M. D., & Titiunik, R. (2014). Robust nonparametric confidence intervals for regression-discontinuity designs. *Econometrica*, *82*(6), 2295–2326.

Calonico, S., Cattaneo, M. D., & Titiunik, R. (2015). Optimal data-driven regression discontinuity plots. *Journal of the American Statistical Association*, *110*(512), 1753–1769.

Cerdá, M., Wall, M., Feng, T., Keyes, K. M., Sarvet, A., Schulenberg, J., Omalley, P. M., Pacula, R. L., Galea, S., & Hasin, D. S. (2017). Association of state recreational marijuana laws with adolescent marijuana use. *JAMA pediatrics*, *171*(2), 142–149.

Cole, J. M. (2013). Memorandum for all United States attorneys. `https://www.justice.gov/iso/opa/resources/3052013829132756857467.pdf`. Accessed: 2017-07-20.

Cuttler, C. & Spradlin, A. (2017). Measuring cannabis consumption: Psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (dfaq-cu). *PLOS ONE*, *12*(5), 1–14.

DeCicca, P., Kenkel, D., & Liu, F. (2013). Excise tax avoidance: the case of state cigarette taxes. *Journal of health economics*, *32*(6), 1130–1141.

Devereux, M., Lockwood, B., & Redoano, M. (2008). Do countries compete over corporate tax rates? *Journal of Public Economics*, *92*(5-6), 1210–1235.

Dills, A. K., Goffard, S., & Miron, J. (2017). The effects of marijuana liberalizations: Evidence from monitoring the future. Working Paper 23779, National Bureau of Economic Research.

Fischer, S., Royer, H., & White, C. (forthcoming 2018). The impacts of reduced access to abortion and family planning services on abortion, births, and contraceptive purchases. *Journal of Public Economics*.

Fredriksson, P. G. & Mamun, K. A. (2008). Vertical externalities in cigarette taxation: Do tax revenues go up in smoke? *Journal of Urban Economics*, *64*(1), 35–48.

Gelman, A. & Imbens, G. (2017). Why high-order polynomials should not be used in regression discontinuity designs. *Journal of Business & Economic Statistics*, (just-accepted).

Graf, S. (2013). Idaho lawmakers, cities want no part of relaxed marijuana laws. *Boise State Public Radio*.

Gray, K. M., Watson, N. L., & Christie, D. K. (2009). Challenges in quantifying marijuana use. *Am J Addict*, *18*(2), 178–179.

Grembi, V., Nannicini, T., & Troiano, U. (2016). Do fiscal rules matter? *American Economic Journal: Applied Economics*, *8*(3), 1–30.

Hansen, B., Houghton, K., Miller, K., & Weber, C. (2018). Washington traceability data: a researcher's guide. *Working Paper*.

Hansen, B., Miller, K., & Weber, C. (2017). The taxation of recreational marijuana: Evidence from Washington state. Technical report, National Bureau of Economic Research.

Hao, Z. & Cowan, B. (2017). The cross-border spillover effects of recreational marijuana legalization. Working Paper 23426, National Bureau of Economic Research.

Harding, M., Leibtag, E., & Lovenheim, M. F. (2012). The heterogeneous geographic and socioeconomic incidence of cigarette taxes: Evidence from nielsen homescan data. *American Economic Journal: Economic Policy*, *4*(4), 169–98.

Hausman, C. & Rapson, D. S. (2017). Regression discontinuity in time: Considerations for empirical applications. Technical report, National Bureau of Economic Research.

Hawken, A., Caulkins, J., Kilmer, B., & Kleiman, M. (2013). Quasi-legal cannabis in Colorado and Washington: local and national implications. *Addiction*, *108*(5), 837–838.

Holmes, T. J. (1998). The effect of state policies on the location of manufacturing: Evidence from state borders. *Journal of Political Economy*, *106*(4), 667–705.

Imbens, G. & Kalyanaraman, K. (2012). Optimal bandwidth choice for the regression discontinuity estimator. *The Review of economic studies*, *79*(3), 933–959.

Ingold, J. (2014). Nebraska and oklahoma sue colorado over marijuana legalization. *The Denver Post*.

Jacobs, J., Ligthart, J., & Vrijburg, H. (2010). Consumption tax competition among governments: Evidence from the united states. *International Tax and Public Finance*, *17*(3), 271–294.

Kanbur, R. & Keen, M. (1993). Jeux sans frontires: Tax competition and tax coordination when countries differ in size. *The American Economic Review*, *83*(4), 877–892.

Lee, D. S. & Lemieux, T. (2010). Regression Discontinuity Designs in Economics. *Journal of Economic Literature*, *48*(2), 281–355.

Lindo, J. M., Myers, C., Schlosser, A., & Cunningham, S. (2017). How far is too far? new evidence on abortion clinic closures, access, and abortions. Working Paper 23366, National Bureau of Economic Research.

Lovenheim, M. F. (2008). How Far to the Border?: The Extent and Impact of Cross-Border Casual Cigarette Smuggling. *National Tax Journal*, *61*(1), 7–33.

Lovenheim, M. F. & Slemrod, J. (2010). The fatal toll of driving to drink: the effect of minimum legal drinking age evasion on traffic fatalities. *Journal of health economics*, *29*(1), 62–77.

Lu, R. (2017). When weed is legalized next door: How does colorado's recreational marijuana affect neighboring states' illegal marijuana possession? Technical report, University of California, San Diego.

Ludwig, J. & Miller, D. L. (2007). Does head start improve children's life chances? evidence from a regression discontinuity design. *The Quarterly journal of economics*, *122*(1), 159–208.

Marie, O. & Zölitz, U. (2017). high achievers? cannabis access and academic performance. *The Review of Economic Studies*, rdx020.

Matthews, D. (2013). The black/white marijuana arrest gap, in nine charts. *Washington Post*.

Merriman, D. (2010). The micro-geography of tax avoidance: Evidence from littered cigarette packs in chicago. *American Economic Journal: Economic Policy*, *2*(2), 61–84.

Mintz, J. & Tulkens, H. (1986). Commodity tax competition between member states of a federation: equilibrium and efficiency. *Journal of Public Economics*, *29*(2), 133 – 172.

Musgrave, R. (1959). *The theory of public finance*. McGraw-Hill.

Nielsen, S. B. (2001). A simple model of commodity taxation and cross-border shopping. *The Scandinavian Journal of Economics*, *103*(4), 599–623.

Oates, W. (1972). *Fiscal Federalism*. The Harbrace series in business and economics. Harcourt Brace Jovanovich.

Oates, W. E. (1999). An essay on fiscal federalism. *Journal of Economic Literature*, *37*(3), 1120–1149.

Ogden, D. W. (2009). Memorandum for selected United States attorneys. `https://www.justice.gov/archives/opa/blog/memorandum-selected-united-state-attorneys-investigations-and-prosecutions-states`. Accessed: 2017-07-20.

Philipps, D. (2016). F.d.a. agrees to new trials for ecstasy as relief for ptsd patients. *The New York Times*.

Puzzanchera, C. & Kang, W. (2017). Easy Access to FBI Arrest Statistics 1994-2014.

Rubin, E. (2018). Are our hopes too high? testing cannabis legalizations potential to reduce criminalization. Technical report, University of Oregon.

Sanna, E. (2014). *Marijuana: Mind-Altering Weed*. Simon and Schuster.

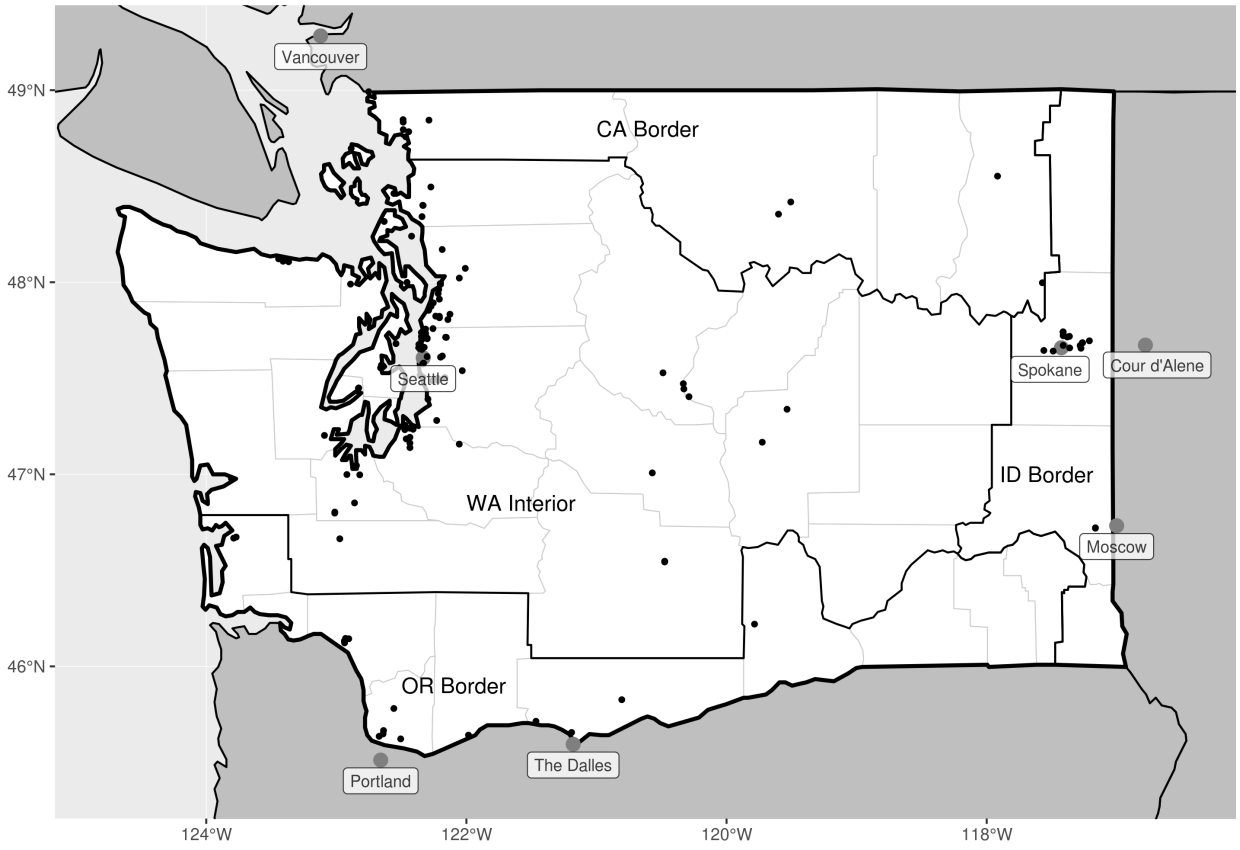
Sebens, S. (2015). Oregon governor OKs early sales of recreational-use marijuana. *Reuters*.

Thomas, D. K. (2018). License quotas and the inefficient regulation of sin goods: Evidence from the Washington recreational marijuana market. *Working Paper*.

Williams, T. (2016). Marijuana arrests outnumber those for violent crimes, study finds. *The New York Times*.

6 Figures and Tables

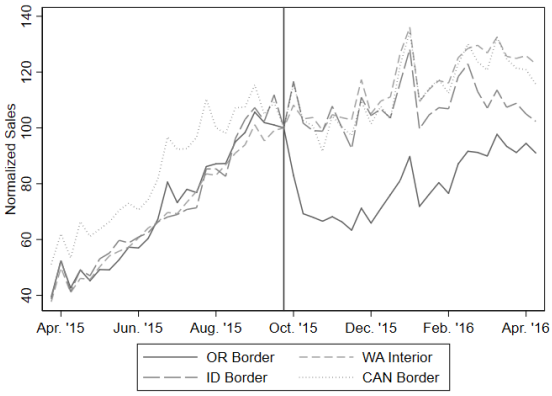
Figure 1: Marijuana retail locations in Washington at the time of Oregon's market opening



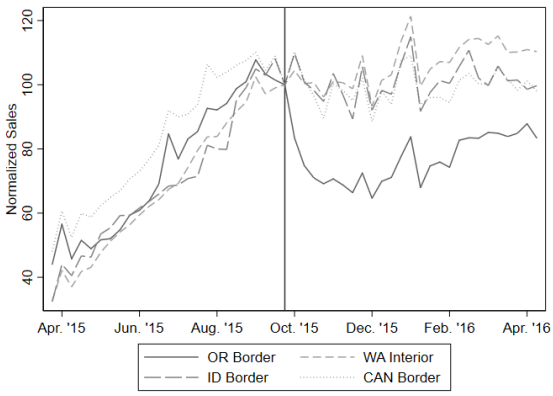
Notes: This map shows the locations of all marijuana retailers included in our analysis. Black lines denote region boundaries.

Figure 2: Marijuana Sales by Washington Region near Oregon's Market Opening

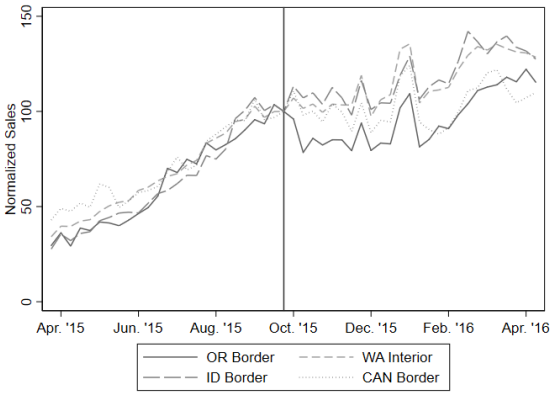
(a) Usable Marijuana (Weight)



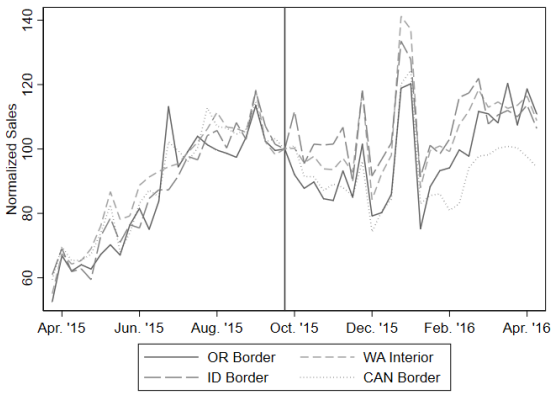
(b) Usable Marijuana (Number of transactions)



(c) Concentrates (Revenue)

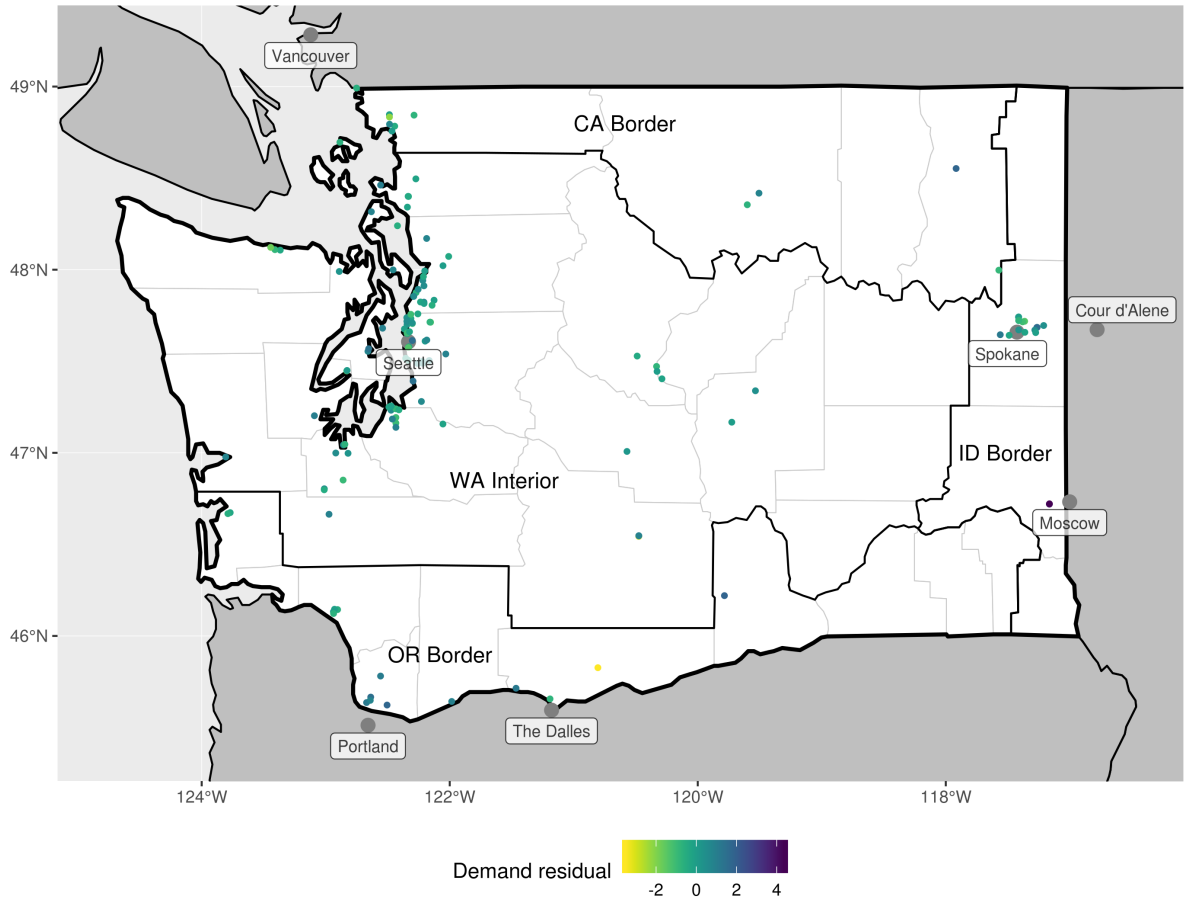


(d) Edibles (Revenue)



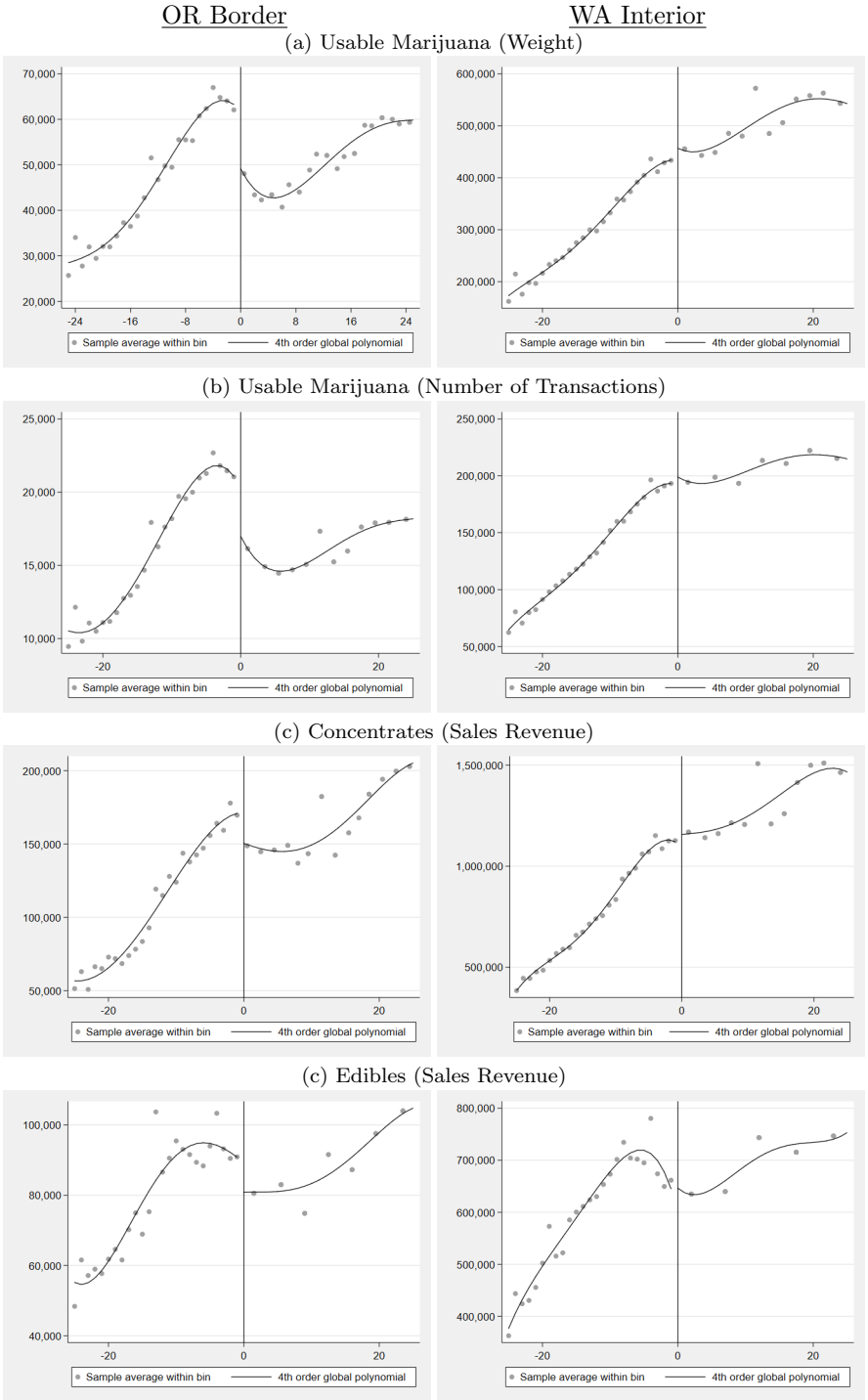
Notes: These figures illustrate trends in the marijuana market in four regions of the state: the interior, the Oregon border, the Idaho border, and the Canadian border. The sales in each region are normalized to the week before legalization – sales in that week equal 100 by construction.

Figure 3: Excess local demand results by retail location



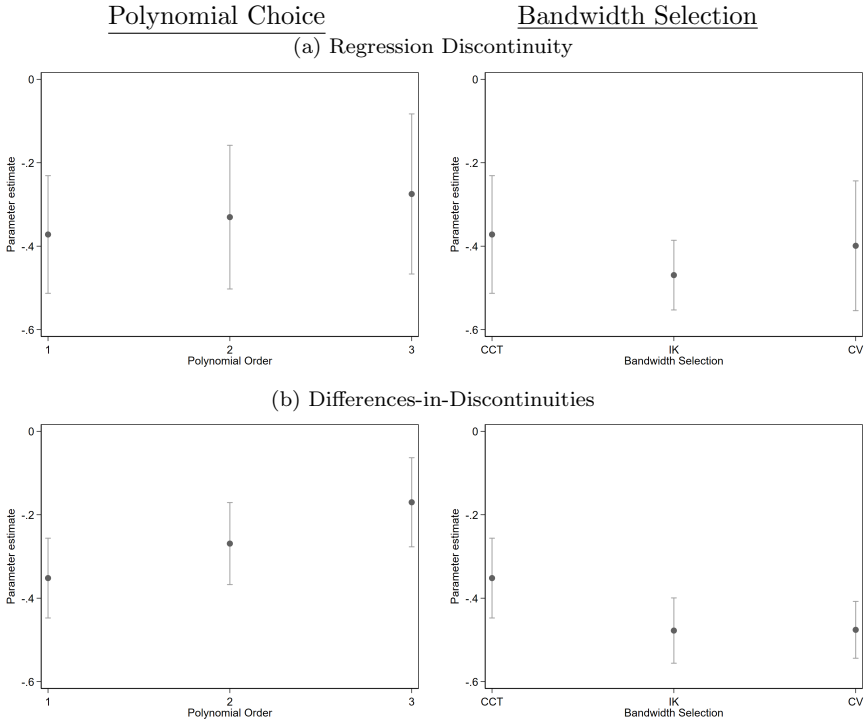
Notes: This figure illustrates the results of our excess demand exercise by firm. To construct the demand residual illustrated here, we estimate Equation 1 using the firms in the interior, and then take the difference between the predicted and actual sales for firms across all regions. Darker dots indicate a more positive demand residual, or in other words that the demand experienced by the firm was greater than predicted by the model.

Figure 4: Washington Market Outcomes around Oregon's Market Opening



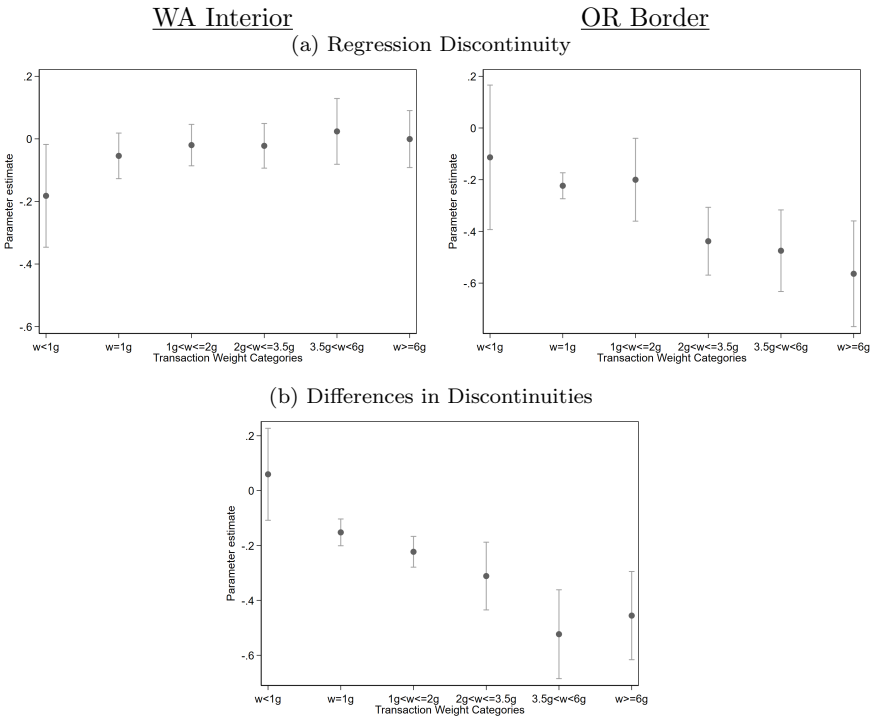
Notes: These figures illustrate trends in the sales of marijuana. The horizontal axis is the week relative to Oregon's market opening. The left-hand graphs illustrate outcomes in the Oregon border region, and the right-hand graphs illustrate outcomes in the interior region. Dots illustrate the raw data at the region-week level. The line is a global 4th-order polynomial fit based on the approach of Calonico et al. (2015).

Figure 5: Robustness to Local Polynomial and Bandwidth



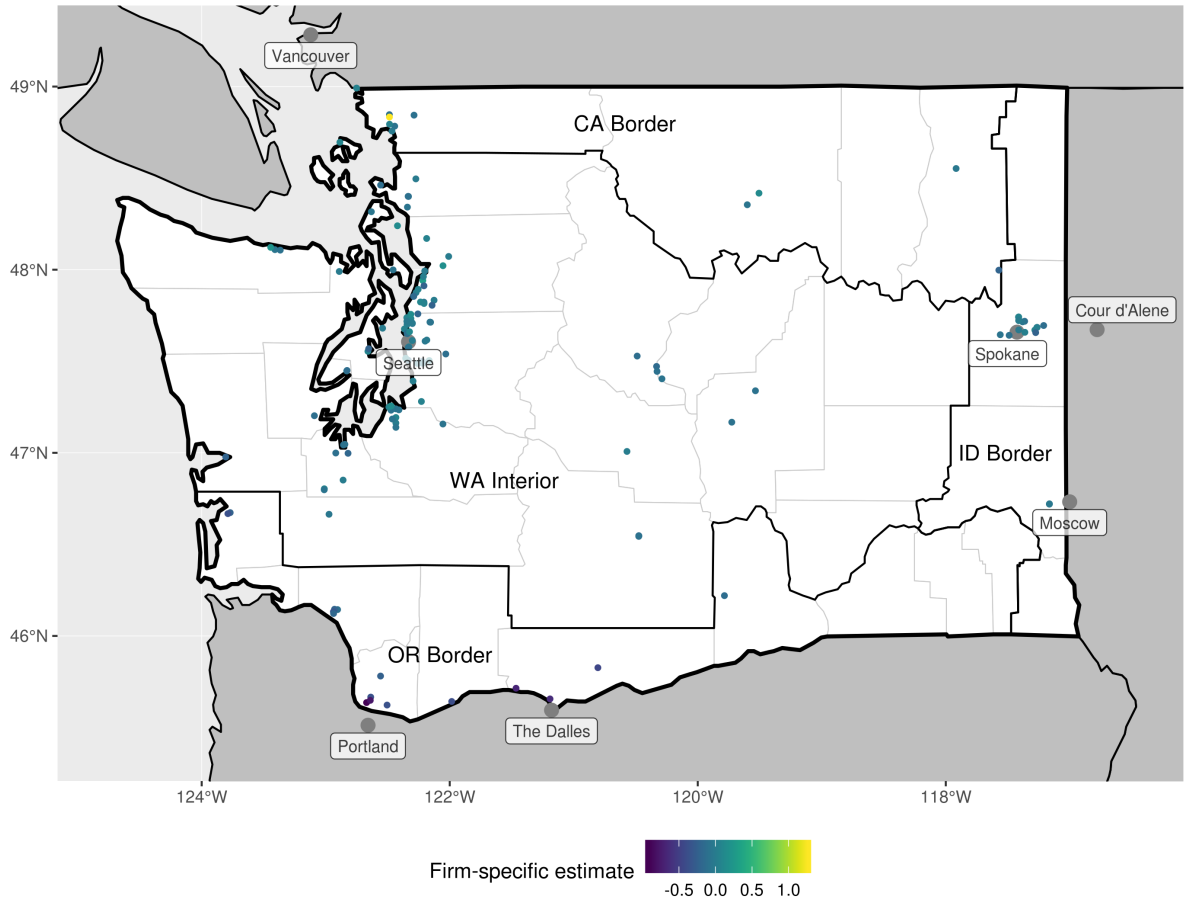
Notes: These figures illustrate the robustness of our regression discontinuity and differences-in-discontinuities estimates of the change in the log weight of usable marijuana sold. The figures report the point estimates and 95% confidence intervals across a variety of polynomial orders and bandwidth selection procedures. CCT refers to Calonico et al. (2014), IK refers to Imbens & Kalyanaraman (2012), and CV refers to the cross validation procedure suggested by Ludwig & Miller (2007).

Figure 6: Heterogeneity by Transaction Size



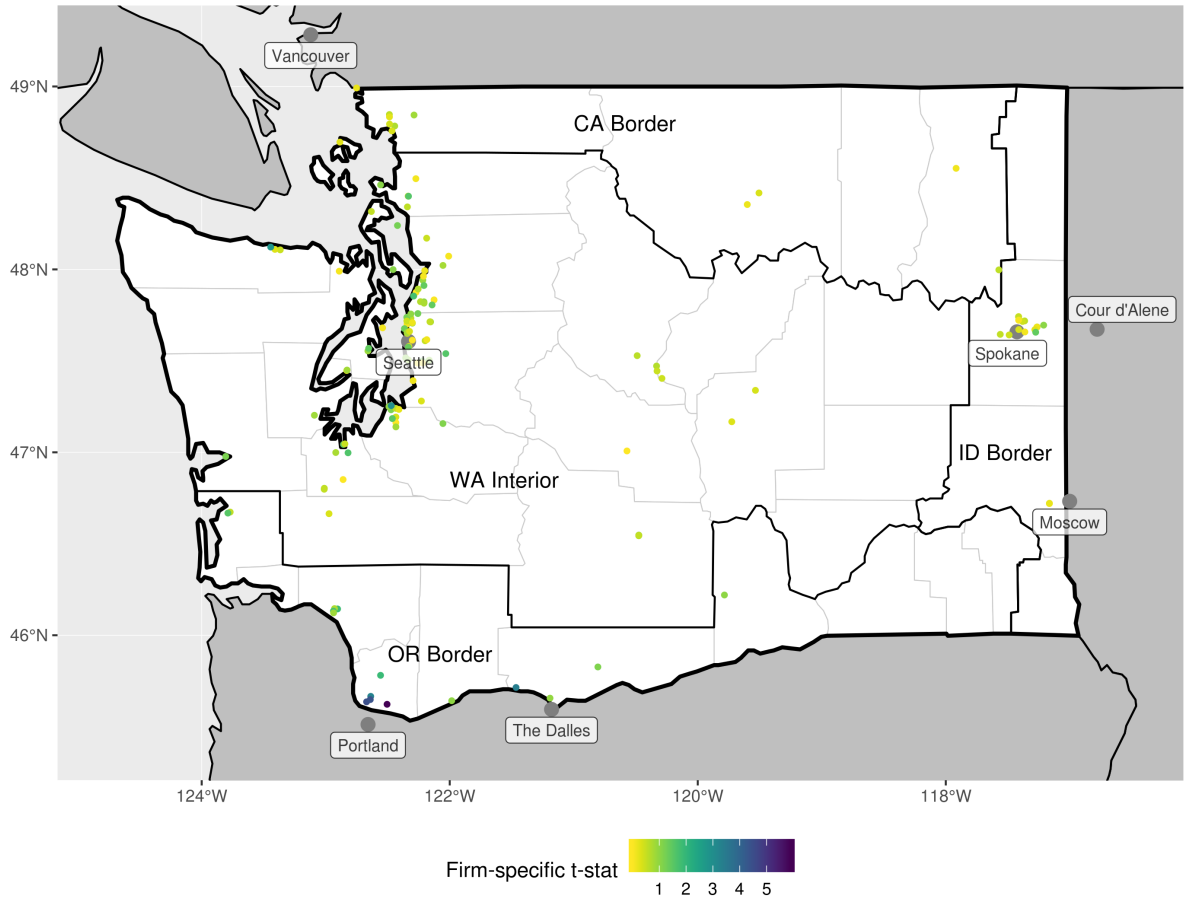
Notes: These figures report the point estimates and 95% confidence intervals for regression discontinuity and differences-in-discontinuities models that estimate the change in the weight of usable marijuana sold across six transaction categories: less than 1 gram, 1 gram, 1 to 2 grams, 2 to 3.5 grams, 3.5 to 6 grams, and 6 grams or more. The model estimates seen here follow the bandwidth selection approach of Calonico et al. (2014).

Figure 7: Regression Discontinuity Estimates for Retailers by Location



Notes: This figure reports firm-specific point estimates of the change in the log weight of usable marijuana sold formed from regression discontinuity models. Bandwidths are selected following Calonico et al. (2014). Darker dots indicate places where the weight sold fell a greater amount.

Figure 8: Regression Discontinuity T-Statistics for Retailers by Location



Notes: This figure reports firm-specific test statistics (in absolute value) from estimates of the change in the log weight of usable marijuana sold formed from regression discontinuity models. Bandwidths are selected following Calonico et al. (2014). Darker dots indicate places with a more significant estimated change.

Table 1: Weight Sold and Population across Washington Regions

	Pre-OR Legal	**Pre-OR Mkt. Open**	**Post-OR Mkt. Open**
		Interior	
Total Weight (in grams over two months)	2,128,930	3,543,950	4,054,352
Average Tax-Inclusive Price	$13.67	$12.91	$12.55
Market Share	0.670	0.665	0.704
Total Population	5,268,793	5,268,793	5,268,793
Population Share	0.754	0.754	0.754
Men 20-24 Share	0.736	0.736	0.736
College Share	0.718	0.718	0.718
		Oregon Border	
Total Weight (in grams over two months)	302,977	529,850	384,862
Average Tax-Inclusive Price	$14.07	$13.42	$12.45
Market Share	0.095	0.099	0.067
Total Population	854,462	854,462	854,462
Population Share	0.122	0.122	0.122
Men 20-24 Share	0.110	0.110	0.110
College Share	0.102	0.102	0.102
		Idaho Border	
Total Weight (in grams over two months)	597,980	1,020,964	1,090,151
Average Tax-Inclusive Price	$11.87	$11.91	$11.47
Market Share	0.187	0.192	0.189
Total Population	562,577	562,577	562,577
Population Share	0.081	0.081	0.081
Men 20-24 Share	0.103	0.103	0.103
College Share	0.126	0.126	0.126
		Canadian Border	
Total Weight (in grams over two months)	148,747	235,740	228,208
Average Tax-Inclusive Price	$13.02	$12.13	$11.47
Market Share	0.047	0.044	0.040
Total Population	299,632	299,632	299,632
Population Share	0.043	0.043	0.043
Men 20-24 Share	0.055	0.055	0.055
College Share	0.057	0.057	0.057

Border regions consist of those counties along the relevant border; the interior consists of the remaining counties. See Figure 1 for a map. Corner counties (Asotin and Pend Oreille) are assigned to the Idaho border region; no retailers are in those counties. Pre-OR Legal calculates each row over the two months before Oregon legalized marijuana (May and June 2015). Pre-OR Mkt. Open calculates each row over the two months before Oregon opened its recreational marijuana market (August and September 2015). Post-OR Mkt. Open calculates each row over the two months after Oregon opened its recreational marijuana market (October and November 2015). Total weight is the total weight (in grams) of marijuana sold over the relevant two month window for the counties specified. Population share divides the total population in those counties by the total population in the state of Washington. Men 20-24 share and college share divides the total applicable population in those counties by the total relevant population in Washington. Market share divides the total weight in those counties by the total weight in Washington. All population measures are derived from the 2015 American Community Survey. The average tax-inclusive price is the average retail location price across the two-month interval.

Table 2: Pre-legalization transaction size distribution

	Avg. weight in bin (g)	Entire state	Borders			
			Interior	OR	ID	CAN
Weight < 1g	.630	5.85	6.73	3.06	4.11	2.70
Weight = 1g	1.00	33.84	35.28	23.74	28.43	44.86
1g < Weight <= 2g	1.65	25.64	26.32	30.97	18.32	27.82
2g < Weight <= 3.5g	3.12	19.46	18.09	19.44	28.64	13.29
3.5g < Weight <= 6g	4.11	8.80	8.46	13.51	8.69	6.33
6g < Weight	12.25	6.41	5.12	9.28	11.81	4.99
Obs.	2,290,854	2,290,854	1,657,581	191,574	326,896	117,398

Notes: This table reports the distribution of transaction sizes (measured by the weight sold) for the entire state and the regions defined per Table 1. The data illustrated here consists of all transactions in the two months before Oregon's market opened. Transaction size shares are percentages.

Table 3: Summary Statistics for Excess Demand Prediction

	Region			
Variable	Entire state	Interior	Oregon border	Idaho border
Total weight (g)	38,193	36,961	33,997	59,882
Frac. large transactions	.073	.059	.114	.116
Average price ($/g)	12.87	12.98	13.36	11.95
Average wholesale price ($/g)	3.76	3.84	3.57	3.70
Experience (days)	194	181	226	200
Census tracts within 10 km				
Population	133,269	157,763	60,901	124,369
Frac. male	.498	.498	.492	.502
Frac. 20-34	.228	.230	.180	.272
Frac. w/ college deg., 25+	.409	.436	.289	.395
Frac. employed full time	.311	.329	.255	.279
Frac. in college	.075	.070	.044	.135
Mean individual earnings	58,393	62,616	50,793	46,556
Within the county				
Num. competitors	13.0	15.3	3.5	13.5
Frac. voted for legalization	.552	.569	.492	.516
Obs.	140	96	16	17

Notes: This table reports firm-level summary statistics for the variables used in the excess demand prediction model described in Section 3.1. Regions defined per Table 1. Total weight and average prices are taken over the two months before Oregon's market opened. Experience is defined as the number of days since the retail location opened. Census tract figures were calculated by aggregating demographic data from the 2015 American Community Survey for each tract whose centroid was within ten kilometers driving distance of the firm. Fractions range from zero to one.

Table 4: Excess Demand Results

	Oregon Border	Idaho Border
	Log weight	
Mean	.251	.529
25th %-ile	-.566	-1.08
Median	.413	.024
75th %-ile	1.19	1.01
	Frac. large transactions	
Mean	.046	.022
25th %-ile	.001	-.001
Median	.036	.013
75th %-ile	.098	.038
Obs	16	17

Notes: This table reports the results of the excess demand prediction approach described in Section 3.1. Regions defined per Table 1. These residuals are calculated by estimating Equation 1 on the firms from the interior region, and then predicting firm-level demand in the Oregon border and Idaho border regions. Positive residuals mean that the observed outcome variable was higher than predicted by the model.

Table 5: Regression Discontinuity Estimates of Oregon's Legalization on Washington's Sales

	(1) ln(Weight)	(2) ln(# Trans.)	(3) ln(Concentrates)	(4) ln(Edibles)
Panel A: Regression Discontinuity Estimates				
Washington Interior				
Treat	-0.020	-0.037	-0.020	-0.019
	(0.034)	(0.032)	(0.035)	(0.046)
Oregon Border				
Treat	-0.38***	-0.32***	-0.18*	-0.12*
	(0.068)	(0.050)	(0.071)	(0.045)
Idaho Border				
Treat	-0.083	-0.11	-0.043	-0.016
	(0.082)	(0.070)	(0.066)	(0.064)
Canadian Border				
Treat	-0.032	-0.024	-0.030	-0.097*
	(0.071)	(0.054)	(0.050)	(0.045)
N	17	17	17	17
Panel B: Differences-in-Discontinuities Estimates				
Oregon Border				
Treat*ORBorder	-0.36***	-0.28***	-0.16**	-0.10***
	(0.043)	(0.029)	(0.056)	(0.017)
Idaho Border				
Treat*ID	-0.064	-0.069	-0.023	0.0021
	(0.061)	(0.049)	(0.044)	(0.043)
Canadian Border				
Treat*CAN	-0.012	0.014	-0.0093	-0.078*
	(0.044)	(0.034)	(0.028)	(0.028)
N	34	34	34	34

Notes: This table reports point estimates from regression discontinuity and difference-in-discontinuity models. Columns indicate different outcome variables; "Concentrates" and "edibles" refer to the total revenue from those products. Rows indicate estimates for the regions defined by Table 1. Bandwidths are selected following Calonico et al. (2014). *, **, ***, respectively indicate significance at the 5%, 1%, and 0.1% levels.

Table 6: Donut Regression Discontinuity Estimates of Oregon's Legalization on Washington's Sales

	(1) ln(Weight)	(2) ln(# Trans.)	(3) ln(Concentrates)	(4) ln(Edibles)
Panel A: Regression Discontinuity Estimates				
Washington Interior				
Treat	-0.049	-0.054	-0.042	-0.036
	(0.034)	(0.036)	(0.041)	(0.061)
Oregon Border				
Treat	-0.45***	-0.36***	-0.25***	-0.15*
	(0.039)	(0.040)	(0.055)	(0.056)
Idaho Border				
Treat	-0.14	-0.14	-0.060	-0.063
	(0.069)	(0.068)	(0.069)	(0.062)
Canadian Border				
Treat	-0.094	-0.065	-0.069	-0.013*
	(0.062)	(0.054)	(0.047)	(0.050)
N	16	16	16	16
Panel B: Differences-in-Discontinuities Estimates				
Oregon Border				
Treat*ORBorder	-0.41***	-0.31***	-0.21***	-0.11***
	(0.023)	(0.024)	(0.046)	(0.019)
Idaho Border				
Treat*ID	-0.096	-0.087	-0.018	-0.028
	(0.052)	(0.049)	(0.053)	(0.033)
Canadian Border				
Treat*CAN	-0.045	-0.010	-0.027	-0.094
	(0.052)	(0.048)	(0.028)	(0.051)
N	32	32	32	32

Notes: This table reports point estimates from regression discontinuity and difference-in-discontinuity models where the week of treatment has been removed. Columns indicate different outcome variables; "Concentrates" and "edibles" refer to the total revenue from those products. Rows indicate estimates for the regions defined by Table 1. Bandwidths are selected following Calonico et al. (2014). *, **, ***, respectively indicate significance at the 5%, 1%, and 0.1% levels.

Table 7: Estimated weight, market value, and tax revenue from cross-border sales

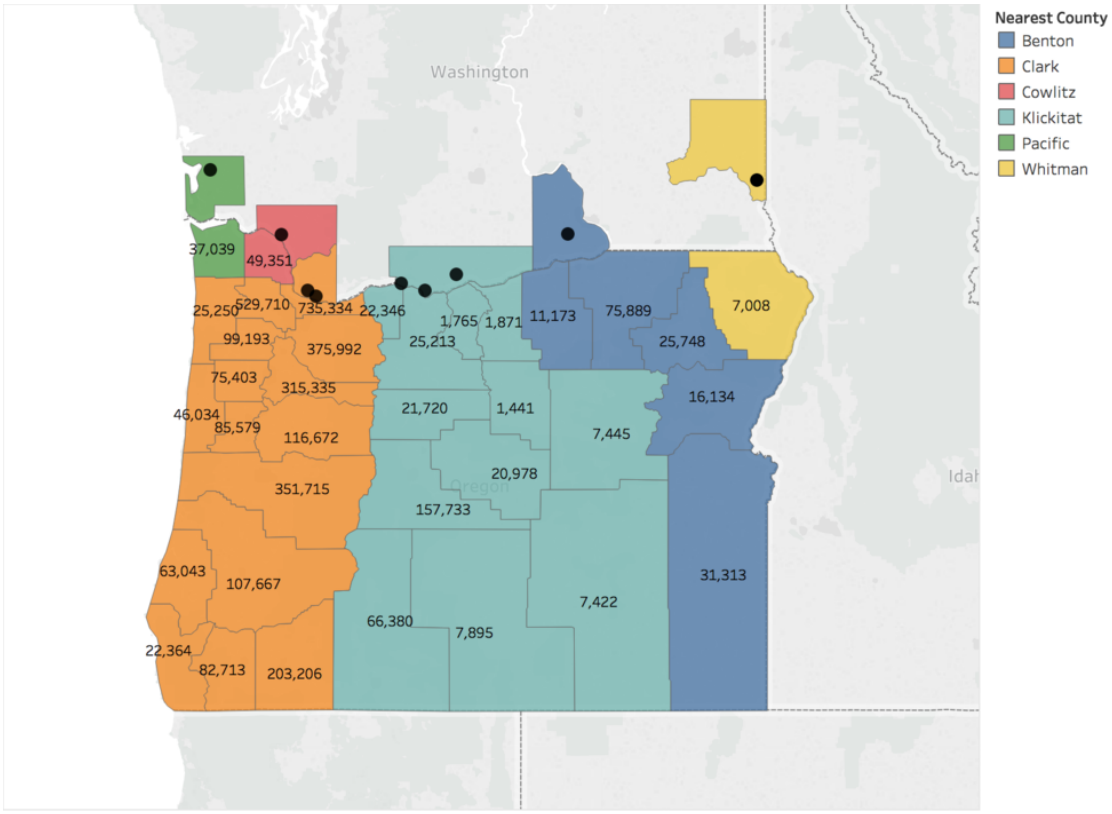
	Weight sold (g)	Market value ($)	Tax revenue ($)
Entire state	5,330,504	67,882,189	25,116,410
Oregon			
Strategy 1	132,992	1,784,757	660,360
Strategy 2	190,746	2,559,811	947,130
Idaho			
Strategy 1	540,090	6,432,471	2,380,014
Strategy 2	367,547	4,377,485	1,619,670

Notes: This table reports estimates of the weight, market value, and tax revenue from cross-border sales in the two months leading up to Oregon's market opening under two different strategies. The first strategy uses the excess demand estimates, and assumes that the source of the excess demand is cross-border sales. The second strategy uses the differences-in-discontinuities estimate for the Oregon border as the fraction of weight sold to cross-border shoppers and applies the same estimate to both the Oregon and Idaho borders.

Appendices

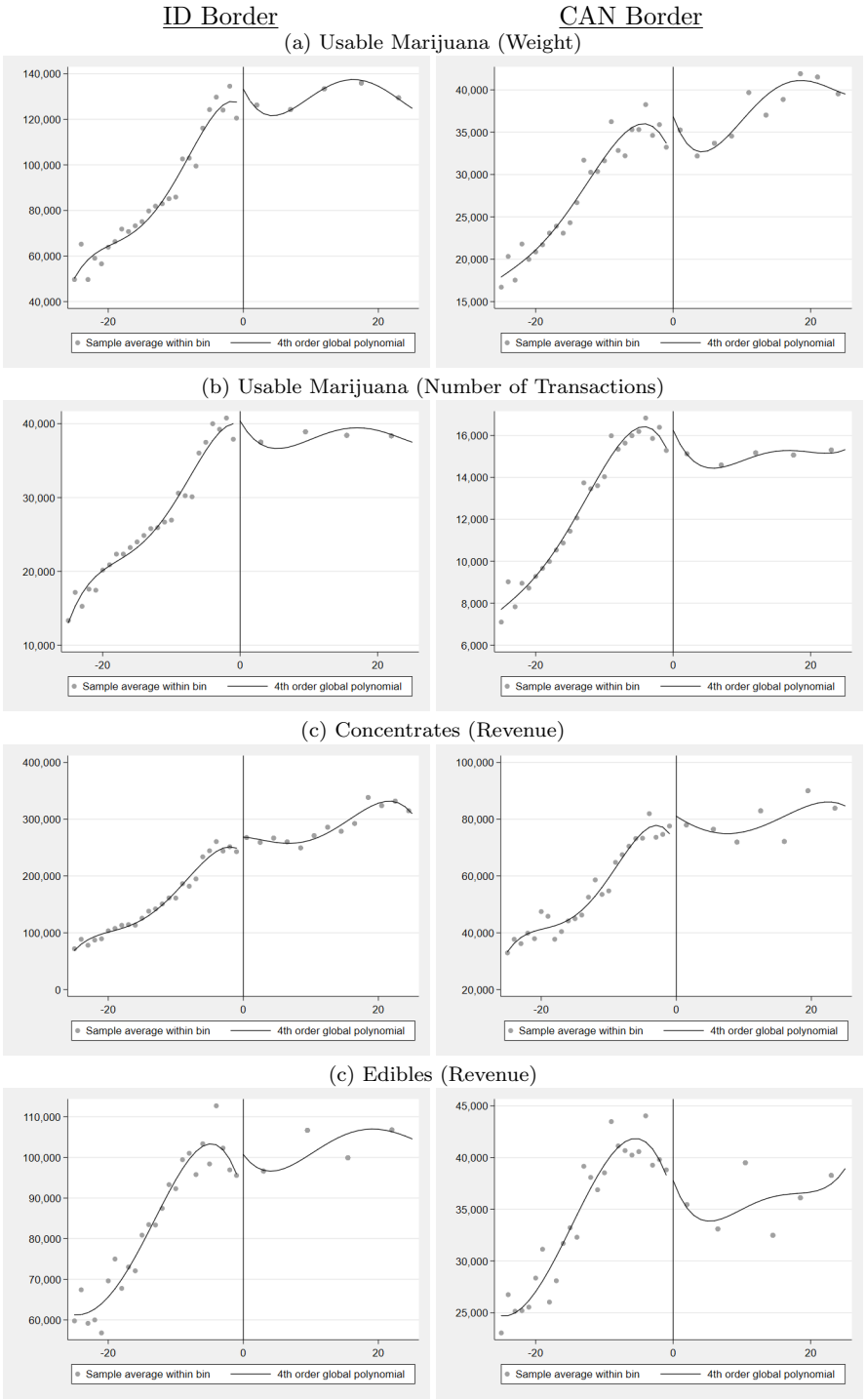
A Additional tables and figures

Figure A.1: Washington Border Retailers with Closest Oregon County



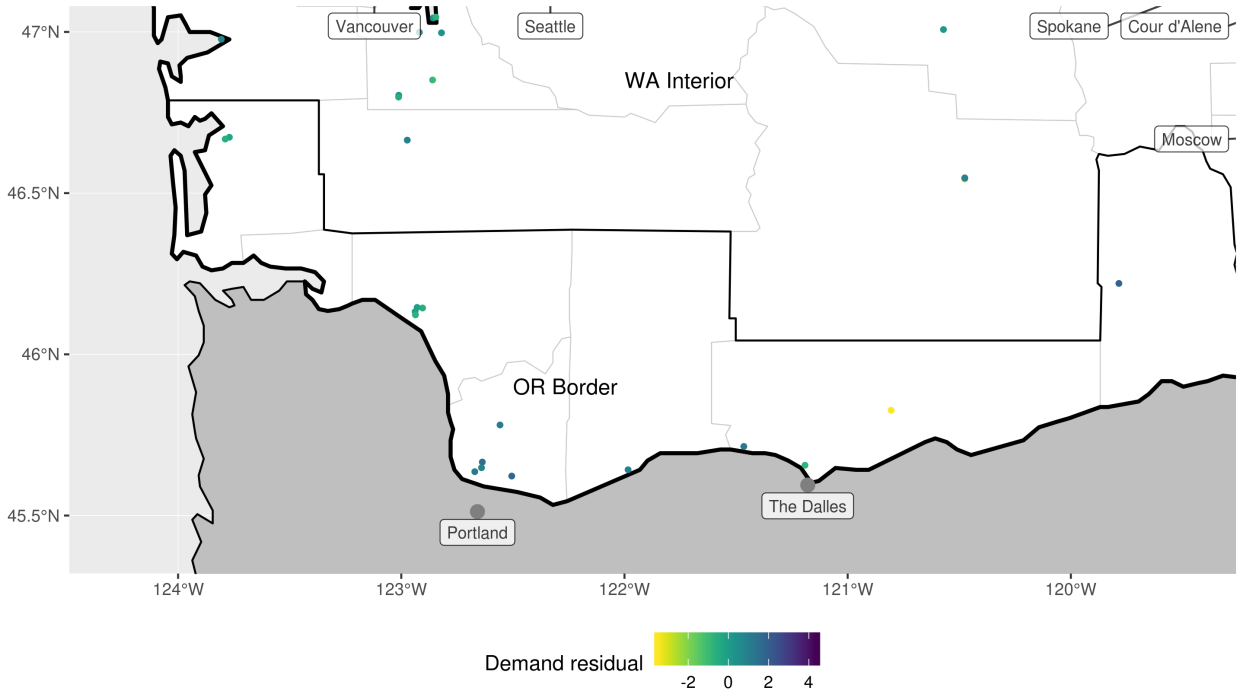
Notes: This map shows the location of the closest Washington retailers for each Oregon county. The numbers inside the Oregon county borders are that county's 2015 population, as estimated by the Census Bureau. Oregon counties are colored to represent the Washington county with the closest retailer based on driving distance.

Figure A.2: Washington Market Outcomes around Oregon's Market Opening, Idaho and Canadian Borders



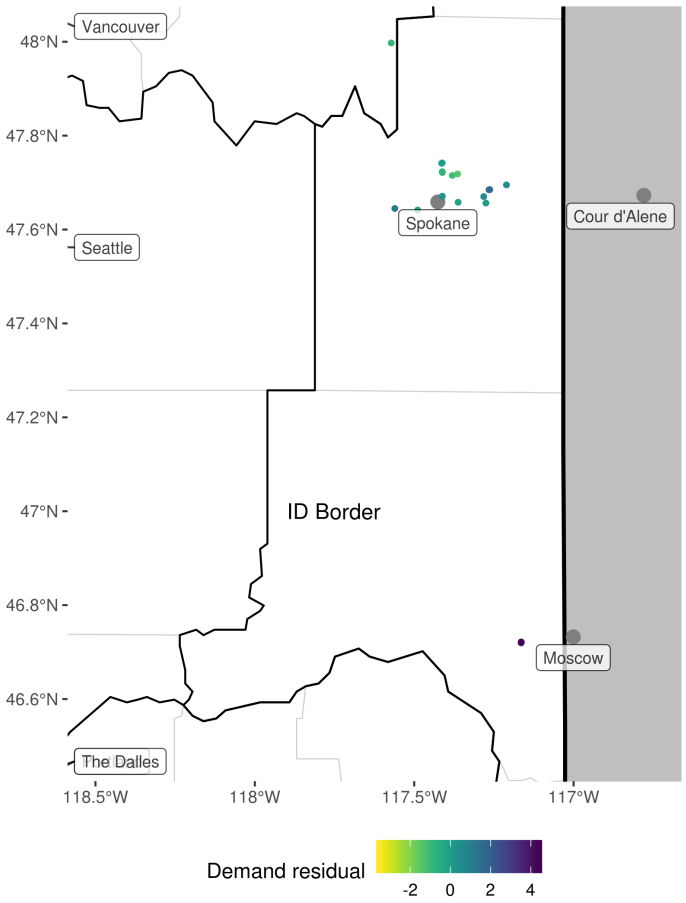
Notes: These figures illustrate trends in the sales of marijuana. The horizontal axis is the week relative to Oregon's market opening. The left-hand graphs illustrate outcomes in the Idaho border region, and the right-hand graphs illustrate outcomes in the Canadian border region. Dots illustrate the raw data at the region-week level. The line is a global 4th-order polynomial fit based on the approach of Calonico et al. (2015).

Figure A.3: Local demand prediction results by retail location, Oregon border region



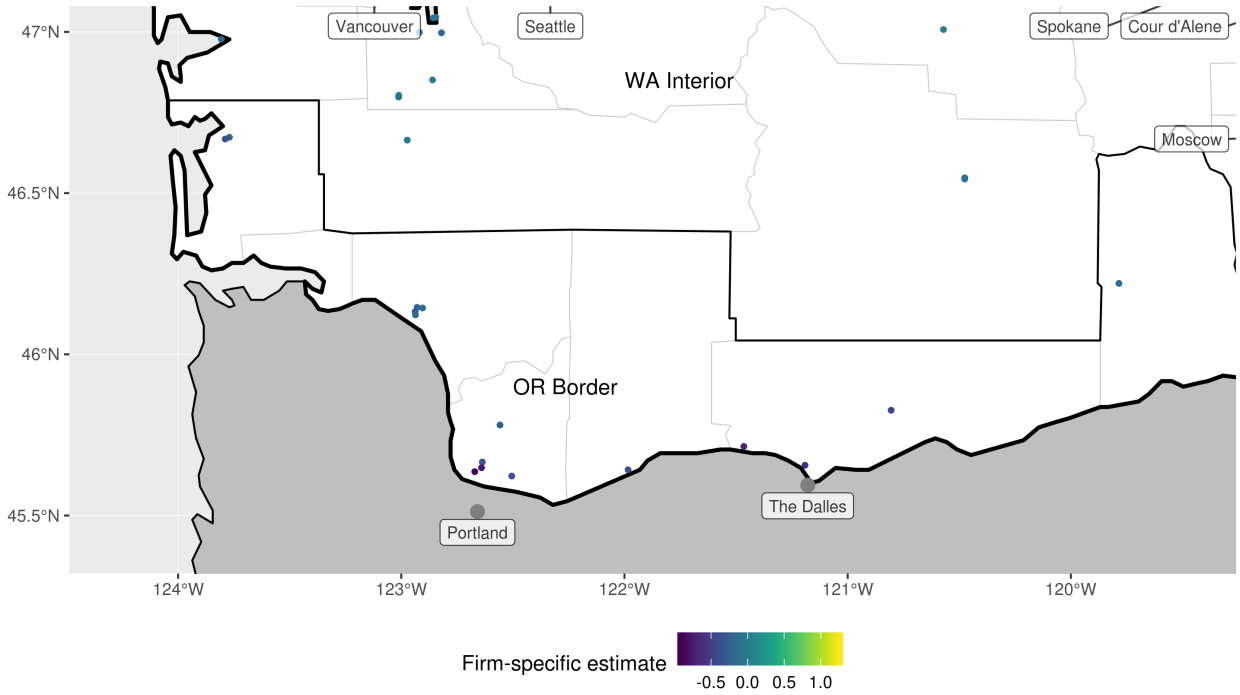
Notes: This figure illustrates the results of our excess demand exercise by firm for the Oregon border region. To construct the demand residual illustrated here, we estimate Equation 1 using the firms in the interior, and then take the difference between the predicted and actual sales for firms across all regions. Darker dots indicate a more positive demand residual, or in other words that the demand experienced by the firm was greater than predicted by the model.

Figure A.4: Local demand prediction results by retail location, Idaho border region



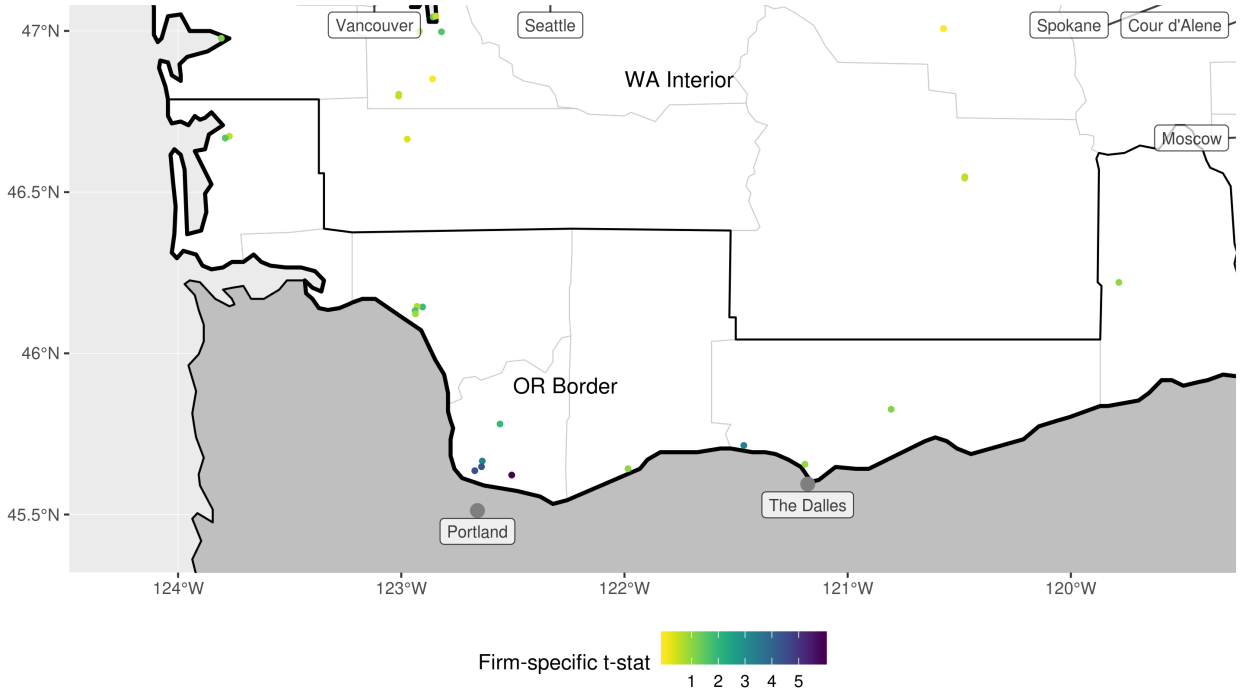
Notes: This figure illustrates the results of our excess demand exercise by firm for the Idaho border region. To construct the demand residual illustrated here, we estimate Equation 1 using the firms in the interior, and then take the difference between the predicted and actual sales for firms across all regions. Darker dots indicate a more positive demand residual, or in other words that the demand experienced by the firm was greater than predicted by the model.

Figure A.5: Regression Discontinuity Estimates by Retailer, Oregon border region



Notes: This figure reports firm-specific point estimates of the change in the log weight of usable marijuana sold formed from regression discontinuity models. Bandwidths are selected following Calonico et al. (2014). Darker dots indicate places where the weight sold fell a greater amount.

Figure A.6: Regression Discontinuity t-Statistics by Retailer, Oregon border region



Notes: This figure reports firm-specific test statistics (in absolute value) from estimates of the change in the log weight of usable marijuana sold formed from regression discontinuity models. Bandwidths are selected following Calonico et al. (2014). Darker dots indicate places with a more significant estimated change.

Table A.1: Washington Border Counties and Distance from Closest Retailer to Oregon Counties

WA County	Pop. (2010)	Retail locations	Oregon County	Pop. (2010)	Distance (Miles)
Benton	175,177	2			
			Baker	16,134	189
			Malheur	31,313	267
			Morrow	11,173	82
			Umatilla	75,889	78
			Union	25,748	149
			Total	**160,257**	**147**
Clark	425,363	6			
			Benton	85,579	90
			Clackamas	375,992	23
			Coos	63,043	242
			Curry	22,364	343
			Douglas	107,667	187
			Jackson	203,206	281
			Josephine	82,713	259
			Lane	351,715	122
			Lincoln	46,034	119
			Linn	116,672	88
			Marion	315,335	55
			Multnomah	735,334	12
			Polk	75,403	64
			Tillamook	25,250	82
			Washington	529,710	20
			Yamhill	99,193	43
			Total	**3,235,210**	**72**
Cowlitz	102,410	5			
			Columbia	49,351	29
Klickitat	20,318	3			
			Crook	20,978	120
			Deschutes	157,733	131
			Gilliam	1,871	68
			Grant	7,445	182
			Harney	7,422	267
			Hood River	22,346	10
			Jefferson	21,720	95
			Klamath	66,380	275
			Lake	7,895	280
			Sherman	1,765	29
			Wasco	25,213	13
			Wheeler	1,441	98
			Total	**342,209**	**153**
Pacific	20,920	2			
			Clatsop	37,039	55
Skamania	11,066	1			
			None		
Whitman	44,776	2			
			Wallowa	7,008	121

Notes: Pop. is population from the 2010 Census. Distance for Oregon counties is from the county's center of population, as determined by the Census Bureau for 2010, to the nearest Washington dispensary calculated using the Open Source Routing Machine with Open Street Map data. Oregon counties are listed under the "nearest" Washington county; Skamania County in Washington is along the Columbia River portion of the Washington-Oregon border but its retail location is not the closest location to any of Oregon's counties' centers-of-population. Distance for "Total" is from the author-calculated weighted center-of-population for counties in the panel to the nearest Washington dispensary.

Table A.2: Excess demand regression parameter estimates

VARIABLES	(1) ln(Total weight)	(2) Lg. trans. share
ln(Average price)	-5.184	-0.198
	(3.605)	(0.150)
ln(Experience)	1.022	-0.0872*
	(1.007)	(0.0418)
ln(Experience)^2	-0.0540	0.0117*
	(0.110)	(0.00457)
ln(Population)	0.297*	-0.0112*
	(0.152)	(0.00633)
% male	-5.362	0.533
	(10.14)	(0.421)
% 20-34	-1.780	-0.446**
	(4.931)	(0.205)
% w/ college deg., 25+	-3.169	0.240**
	(1.988)	(0.0825)
% employed full time	0.962	0.210
	(4.548)	(0.189)
% in college	1.096	0.110
	(5.771)	(0.240)
Mean indiv. earnings (000s)	0.0222	-0.00189***
	(0.0171)	(0.000712)
Num. competitors	0.00812	0.00145
	(0.0274)	(0.00114)
% voted for legalization	2.874	-0.280
	(3.901)	(0.162)
Constant	17.34	0.740
	(13.56)	(0.563)
Observations	96	96
R-squared		0.335

Notes: This table reports results of estimating Equation 1 with the data summarized in Table 3. Estimates are obtained via 2SLS with the average wholesale price used as an instrument for the average price. *, **, ***, respectively indicate significance at the 5%, 1%, and 0.1% levels.

Table A.3: Regression Discontinuity Estimates of Oregon's Legalization on Other Outcomes

	(1) ln(Price)	(2) ln(Inventory)	(3) ln(THC)	(4) ln(CBD)
Panel A: Regression Discontinuity Estimates				
Washington Interior				
Treat	0.013	0.033	0.0017	0.018
	(0.0067)	(0.029)	(0.0028)	(0.035)
Oregon Border				
Treat	-0.018	0.041	0.016	-0.10
	(0.0098)	(0.033)	(0.011)	(0.15)
Idaho Border				
Treat	0.013	-0.14*	0.0074	0.076
	(0.014)	(0.058)	(0.0068)	(0.060)
Canadian Border				
Treat	-0.0033	-0.018	0.029*	0.28
	(0.015)	(0.033)	(0.0098)	(0.15)
N	17	17	17	17
Panel B: Differences-in-Discontinuities Estimates				
Oregon Border				
Treat*ORBorder	-0.035**	0.0089	0.0050	-0.15
	(0.011)	(0.044)	(0.017)	(0.16)
Idaho Border				
Treat*ID	-0.0032	-0.19*	0.0044	0.027
	(0.013)	(0.085)	(0.0083)	(0.059)
Canadian Border				
Treat*CAN	-0.0087	-0.044	0.030**	0.20
	(0.015)	(0.035)	(0.0096)	(0.20)
N	34	34	34	34

Notes: This table reports point estimates from regression discontinuity and difference-in-discontinuity models. Columns indicate different outcome variables; "Price" is the average price per gram for usable marijuana, "Inventory" is the average inventory held by firms measured in grams of usable marijuana, "THC" and "CBD" refer to the average potency of the usable marijuana sold measured by the dry-weight percent content of the relevant chemical. Rows indicate estimates for the regions defined by Table 1. Bandwidths are selected following Calonico et al. (2014). *, **, ***, respectively indicate significance at the 5%, 1%, and 0.1% levels.