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Evaluation of the Legal Cannabis Industry in the United States

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Evaluation of the Legal Cannabis Industry in the United States

Thesis directed by Professor Scott J. Savage

This dissertation examines aspects of the legal cannabis industry in the United States. This includes welfare implications of legalized cannabis in Colorado as well as motivations for legalization across the United States. The goal of this dissertation is to provide insight into a newly deregulated industry for which there is relatively little prior research.

My first chapter investigates the welfare implications of taxation for the recreational cannabis industry in Colorado. Welfare implications of tax policy on cannabis can be significant. I estimate the sales tax rate which maximizes tax revenue using sales data on cannabis edibles from 2014-2016. Estimation is conducted using a random coefficient logit model. Varying sales tax rates are simulated to determine consumer surplus, producer surplus, and tax revenue. Results suggest revenue from sales taxes is maximized at a rate of 47.6%.

My second chapter measures the determinants of cannabis legalization throughout the United States. I account for heterogeneous characteristics of cannabis laws which have been implemented since the 1990's. I construct a panel of state-year correlates which may be strong determinants of legalization. This includes information on population demographics, education, health, crime, and political variables. An event history analysis is conducted using a logit model. I find political and religious ideology as well as private interests in alcohol and cigarettes to be strong determinants of cannabis policy.

My third chapter explores the impact of available legal supply of cannabis on fatal traffic accidents in Colorado counties. Cannabis impaired driving is a major concern surrounding legalization. I measure legal supply of cannabis at the county and month level using cannabis dispensary licensing data from the Colorado Department of Revenue. Fatal accidents follow a count process with non-negative integer values. I utilize a Poisson fixed effects model to explore this impact. I find available legal supply of cannabis has no significant impact on the frequency of fatal accidents in Colorado Counties.

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Chapter 1

Taxation and Welfare in the Cannabis Industry: Evidence from Colorado Edibles 2014-2016

Legal cannabis expanded considerably in the United States in recent decades. Thirty-three states and the District of Columbia legalized cannabis use for medicinal purposes. Ten states and the District of Columbia legalized recreational cannabis for individuals 21 and older.[1] A significant number of states also passed legislation permitting the use of cannabidiol (CBD) extracts for medicinal purposes since 2014. Nebraska and Idaho remain the only states who prohibit cannabis and its extracts in all forms. Legal cannabis sales in the United States are estimated at $5.4 billion in 2015 and $6.7 billion in 2016 (Huddleston Jr., 2016). Roughly a quarter of the US population lives in a state which permits recreational cannabis use (Hansen, Miller and Weber, 2018). Implementation of taxes on cannabis products has important implications for policymakers. This paper utilizes a random coefficient logit model to estimate the revenue maximizing sales tax rate on cannabis edibles.

Colorado contributes a large share to total US sales. Figure 1 displays total sales in Colorado for 2014-2016. Sales in medical and recreational cannabis totaled approximately $996 million in 2015 and $1.31 billion in 2016. Growth in sales are largely driven by the recreational industry with sales of $588 million and $875 million in 2015 and 2016 respectively. The rapid growth of this industry provides the opportunity to generate significant tax revenue. Statewide sales of recreational cannabis in Colorado faced a 10% special sales tax rate in addition to the 2.9% state sales tax between 2014 and 2016.[2] Local governments impose additional city and county specific sales tax rates. The average local sales tax rate in Colorado was 4.62% in 2016.[3] Local governments have the option to impose additional taxes on recreational cannabis. The city of

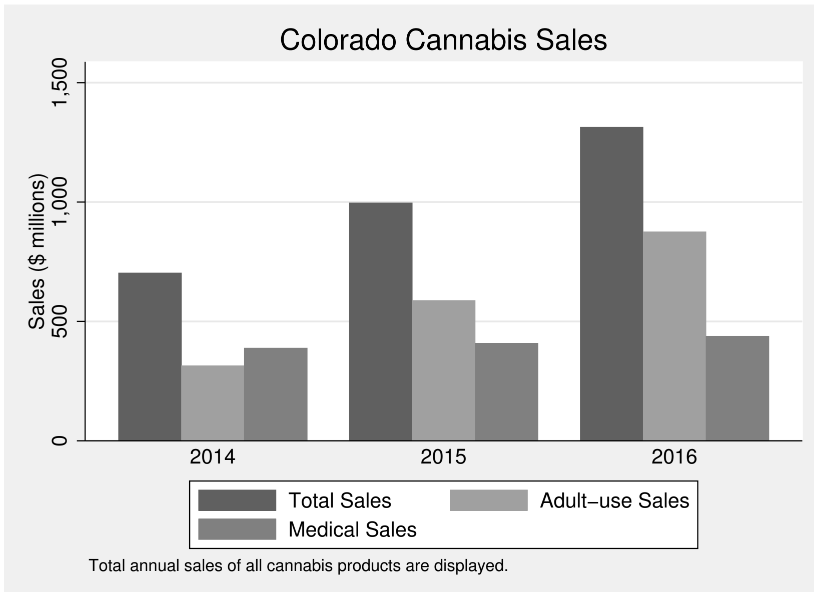
[1] These numbers are accurate through January 1st, 2019.

[2] The tax rate on recreational cannabis was changed effective July 2017. The special sales tax rate was raised from 10% to 15% while sales are made exempt from the state sales tax. The 15% rate for excise and sales taxes are the maximum rates allowed under Colorado law. Increasing the sales tax rate above 15% would require the approval of Colorado voters through a ballot initiative.

[3] https://taxfoundation.org/state-and-local-sales-tax-rates-2016/

Denver imposed a cannabis sales tax of 3.5% between 2014 and 2016 for example. Cultivators of cannabis additionally face a 15% excise tax on the value of unprocessed cannabis when their product is first transferred to a cannabis product manufacturer, retailer, or other cultivator.[4]

FIGURE 1.



Revenue is also generated through application and licensing fees. Employment in a cannabis facility requires an occupational license. A "support employee" who does not make operational decisions faces a $75 application fee, while a managerial "key employee" faces a $250 fee. Operating a cannabis facility requires a business license. The application fee for a recreational cannabis dispensary license is $4,500 as of August 2018.[5] The medical cannabis industry also generates tax revenue and licensing fees, though medical cannabis is exempt from the special sales and excise taxes levied on recreational sales. Figure 2 provides a breakdown of the monthly tax revenue provided by each source from cannabis between 2014 and 2016. The revenue generated by medical and recreational cannabis totalled $193,604,810 in 2016. A majority of this revenue is generated by the recreational cannabis industry.

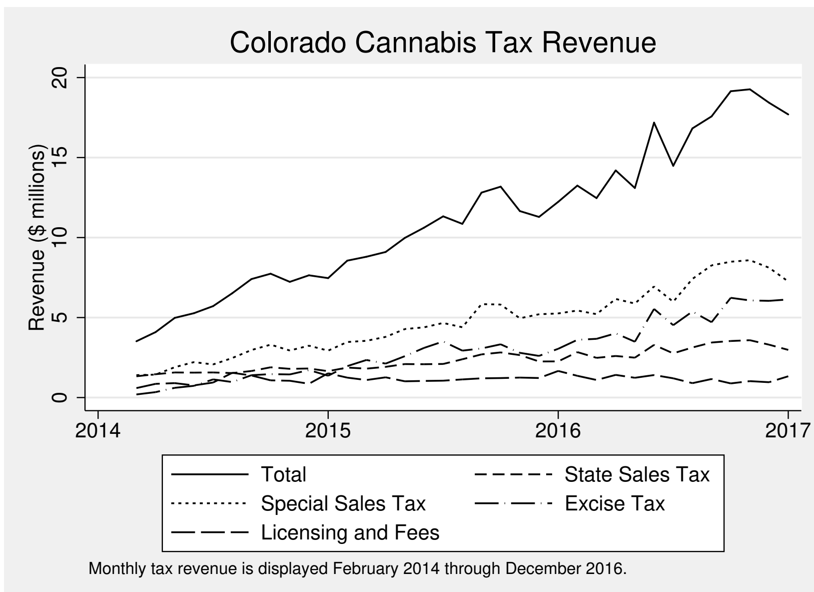
Tax revenue from cannabis is allocated to a variety of state programs and services. The first $40 million of

[4] Information regarding state cannabis tax policy can be found in C.R.S. § 39-26-106; § 39-28.8-202;§ 39-28.8-302

[5] A fee schedule is available at https://www.colorado.gov/pacific/enforcement/med-application-and-licensing.

annual revenue generated by the excise tax is allocated to the Public School Capital Construction Assistance Fund to pay for local K-12 school construction projects. Revenue from excise taxes in excess of $40 million are credited to the Public School Fund which provides income to K-12 schools. A total of $69.4 million has been allocated to these funds between fiscal years 2013-14 and 2015-16, including $2.4 million in excess revenue allocated to the Public School Fund. The special sales tax revenue is allocated between the state and local governments. Local governments receive 15% of this revenue while the remainder is allocated to the state's Marijuana Tax Cash Fund (MTCF).[6] The MTCF faces limitations on the timing, amount, and allocation of revenues. Funding is provided for services in agriculture, education, administration, health care, substance abuse treatment, and law enforcement.[7]

FIGURE 2.



Revenue generated from the state sales tax along with licensing and fees are also allocated to the MTCF. Revenue from these sources are subject to limitations under the Taxpayer's Bill of Rights (TABOR) of the Colorado state constitution. TABOR restricts growth in fiscal spending by the sum of inflation in the CPI

[6]This distribution has been modified effective July 2017. Local governments are now allocated 10% of the special sales tax revenue, with the remainder transferred to the MTCF

[7]A detailed table of the MTCF appropriations for fiscal years 2016-17 and 2017-18 can be found in pages 593-595 of the Colorado Joint Budget Committee's Appropriations Report Fiscal Year 2017-18

and population growth. Growth in fiscal spending includes both increases in expenditure and increases in reserves. Any revenues collected by the state which are not specifically exempt are subject to TABOR. Revenues in excess of this limit must be refunded in the next fiscal year unless voters approve revenue changes. Revenue from these sources totaled $49 million in fiscal year 2015-2016, with $31.6 million generated from state sales taxes and $17.4 million from licensing and fees.

I investigate the welfare implications of taxation in the cannabis industry. I use data on sales of cannabis edibles to estimate the revenue maximizing sales tax rate on these products. Data are provided by BDS Analytics, a cannabis market data and consumer insight service provider, which provide daily product-level average price and sales data for cannabis products sold in the state of Colorado from 2014-2016. The data provide significant advantage over previous studies which have had to rely on survey information or law enforcement data to infer cannabis purchases and use. The product-level sales data allows for estimation of the substitution patterns between many cannabis products, and permits analysis of tax impacts in the industry. I use the data to estimate a structural model of consumer demand. Estimation of structural parameters allows for simulation of a range of policy experiments which evaluate welfare in an equilibrium setting.

Edibles are a component of the entire industry. A significant portion of cannabis product sales are classified as flower or concentrates. These product categories serve as substitutes to edible products (Miller and Seo, 2018). Estimation of the revenue maximizing sales tax rate on edibles will be influenced by the degree of substitution consumers make between edibles and other product categories. Sales of edibles are chosen for estimation due to data constraints. Edibles are the only product category in the dataset which can be linked to their observable characteristics to permit estimation.

Consumption of cannabis is associated with adverse health and safety effects that may impose external costs on society. I conduct my estimation independent of this consideration and consider the case when external costs are zero. My results should be viewed as a component of the discussion surrounding cannabis and should be considered in conjunction with potential negative externalities. I assume consumers make optimal purchasing decisions taking into account the sales tax rate. Tax rates applied at the register have been shown not to be fully salient (Chetty, Looney and Kroft, 2009). Consumers reduce their demand for products when the sales tax is explicitly stated in the price of a good. The assumption that sales tax rates are salient can understate consumer demand. This may suggest the estimated revenue maximizing sales tax rate falls below its true value.

Cannabis products exhibit significant heterogeneity. I utilize a static discrete choice model in which consumers demand products based on their characteristics in order to estimate substitution patterns between the numerous products in the industry (McFadden, 1974; Berry, 1994). This implies a fixed market structure in which the number of firms producing in the industry remains unchanged given changes in tax policy. I follow closely the estimation strategy of Berry, Levinsohn and Pakes (1995) (BLP hereafter) and the notation in Nevo (2000). Consumer utility depends on both observable characteristics and unobservable (to the econometrician) characteristics or demand shocks. Consumers have heterogeneous preferences for product characteristics. It is likely that unobserved characteristics will be correlated with prices and induce a bias in the estimation of price coefficients. I utilize BLP instrumental variables consisting of own and competing product characteristics to address this endogeneity. I use the parameters of my estimation to conduct a counterfactual simulation of the impact on consumer surplus, producer surplus, and tax revenue for different tax rates.

United States public policy has historically placed little value on consumer and producer surplus in cannabis relative to its potential external costs. There are significant concerns evaluating industry welfare with consumer and producer surplus included. States have nevertheless implemented policies which suggest positive valuation of these sources of welfare. Colorado cites “individual freedom” as a reason for legalizing recreational cannabis in its constitution. Colorado additionally passed SB 16-040 in 2016 to expand investment opportunities in medical cannabis enterprises to out of state individuals. The law intends to allow businesses greater access to capital to remain competitive in the industry. Consumer and producer surplus measures are therefore considered to provide a complete depiction of the industry for states which may wish to consider these sources of welfare. Determining the revenue maximizing tax rate is an important consideration for the industry. States which permit recreational cannabis have implemented sales tax rates ranging from 10% in Maine to 37% in Washington. Identifying the revenue maximizing rate will have significant implications for state governments and industry participants. Simulation results in a tax revenue maximizing rate of 47.6% in total sales tax applied to cannabis edibles.

This research is related to previous work on excess burden and optimal taxation. This literature covers one of the oldest subjects in public finance, with roots in the nineteenth century (Dupuit, 1995; Auerbach, 1985). Optimal commodity taxes with respect to utility measures are derived in Ramsey (1927). The trade-off between tax rates and tax revenue was first coined as the "Laffer Curve" in Wanniski (1978). The idea that additional tax revenue could be raised by cutting tax rates proved influential in public policy through the tax cuts of the Reagan administration. Researchers have quantified this trade-off in a variety of contexts. Lindsey (1986) utilizes the Economic Recovery Tax Act of 1981 as a natural experiment to explore taxpayer response to tax cuts. The author concludes income tax revenue would be maximized at a rate of 40%.

The prospect of choosing a revenue maximizing tax rate is especially appealing in markets associated with negative externalities. Imposing a "sin tax" can account for external costs in commodities such as cigarettes, alcohol, or more recently, cannabis. Research on cannabis is severely limited by data constraints. Markets for cigarettes and alcohol may provide useful context for the cannabis industry as they are commodities used in recreation, are associated with negative externalities, and are prohibited in certain contexts. Grossman et al. (1993) utilizes cigarette demand functions from Becker, Grossman and Murphy (1994) to predict a revenue maximizing tax of $1.26 per pack in 1993. Jackson and Saba (1997) expand on this work by considering prices at which consumers are priced out of the market. They predict a revenue maximizing tax of $1.10 per pack. The average price of a package of cigarettes excluding the $0.24 federal excise tax was approximately $1.45 in 1993.[8] An excise tax of $1.10 suggests an effective sales tax rate of 75.9% for cigarettes.

Recent work has explored the revenue maximizing tax rate for cigarettes in Malaysia (Mohamed Nor et al., 2013). The authors find that revenue is maximized with an excise tax which is just over 49% of the retail price

[8] https://www.tobaccofreekids.org/assets/factsheets/0210.pdf

of a cigarette. This is lower than the tax applied by a majority of high-income countries, and is well below the 70% tax share in retail price suggested by the World Health Organization.[9] [10] This suggests a revenue maximizing sales tax rate of approximately 96%. Tax revenue depends significantly on consumer's ability to evade taxes. Goolsbee, Lovenheim and Slemrod (2010) explore this issue by estimating the relationship between internet usage and cigarette tax revenue. Purchasing cigarettes online allows consumers to evade applicable state taxes more easily. The authors find that tax-free internet sales of cigarettes lead to a 9% decrease in revenue between 2001-2005, though states remain well below revenue maximizing tax rates. Tax evasion through illicit smuggling is a significant concern in the cannabis industry, which currently exhibits an extensive black market in the United States. States may additionally permit home cultivation of cannabis. This provides another avenue in which cannabis consumers may evade high tax rates. Finally, consumers may find it possible to obtain a physician's recommendation to access medical cannabis at lower tax rates. These concerns could suggest a lower value of the revenue maximizing tax rate than is estimated in this paper.

The revenue maximizing tax rate on alcohol spirits is explored in Miravete, Seim and Thurk (2018). A simple theoretical model deriving the Laffer curve in industries with market power is provided. The authors utilize the random coefficient logit model of BLP to calculate the revenue maximizing sales tax rate of 39.31% when regulators are endowed with perfect foresight of firm responses to taxation. The results of these papers are consistent with those in Dutkowsky and Sullivan (2014). The paper models excise taxes using a constant elasticity of demand function under monopolistic competition. The authors compute the revenue maximizing tax-price ratios for alcohol and cigarettes to be approximately 0.25 and 0.43 respectively. This equates to sales tax rates of 33.3% and 75.4% respectively. Previous results in labor, alcohol, and cigarette markets suggest the estimated revenue maximizing sales tax rate for cannabis edibles is feasible.

Recent work provides insight into the impact of tax policy within the recreational cannabis industry in Washington. Hansen, Miller and Weber (2017) investigates changes in Washington's tax on recreational

[9] http://www.worldbank.org/en/topic/health/publication/economics-of-tobacco-toolkit
[10] http://www.who.int/tobacco/economics/taxation/en/

cannabis to find the original policy of implementing a 25% tax on gross receipts at each step of the supply chain strongly encouraged vertical integration. Tax policy was reformed to place only a 37% excise tax on retail sales. The authors find Washington to be near the peak of the Laffer curve and state that further increases in tax rates may not increase revenue. My paper is closely related to Hollenbeck and Uetake (2018). The authors use administrative sales data in Washington to explore cannabis industry market power and tax policy in the state. Estimation of tax policy implications is explored using a random coefficient nested logit model. Results find that increasing Washington's tax rate will increase tax revenue with excise tax rates on retail sales as high as 50%. The paper has the benefit of estimating demand for all cannabis products sold in Washington with additional data on wholesale transactions. The results of the demand estimation provide similar results to those in this paper. The authors find the average own-price elasticity of all cannabis products to be -2.71 compared to my estimate of -2.73. The authors define cannabis product characteristics as product types and retailer-time fixed effects. This leaves significant unobserved heterogeneity. My estimation has the benefit of controlling for much of the observable heterogeneity in individual cannabis edibles. This includes important demand characteristics such as the strength of the edible measured by the milligrams of tetrahydrocannabinol (THC) in the product. My estimation is consistent with the results of these papers which explore recreational cannabis taxation in Washington. The similarity between results found in Washington and Colorado suggest the tax implications of these papers may additionally be relevant for other states which permit recreational cannabis.

Previous research has explored the substitution patterns between cannabis and other recreational substances. It is frequently argued that cannabis serves as a substitute for alcohol and cigarettes (Chaloupka and Laixuthai, 1997; DiNardo and Lemieux, 2001; Mark Anderson, Hansen and Rees, 2013; Baggio, Chong and Kwon, 2017; Choi, Dave and Sabia, 2018). This raises the concern that tax revenue raised from legalizing recreational cannabis may reduce consumption and tax revenue from alcohol and cigarettes. Miller and Seo (2018) finds that 22% of revenue raised from cannabis would have been raised from alcohol and cigarettes in Washington, while Irvine (2019) finds that net revenue from cannabis legalization is likely to be negative due to reduced revenue from alcohol and cigarettes in Canada. These results have important welfare implications for recreational cannabis legalization. Regulators seeking to maximize revenue for public works must account for the potential loss of alcohol and cigarette revenue. There may be net welfare benefits associated with substitution from alcohol and cigarettes to cannabis. Mark Anderson, Hansen and Rees (2013) argues medical cannabis legalization reduces fatal traffic accidents through individuals substituting alcohol for cannabis for example.

This paper is also part of a growing literature on cannabis use. Researchers have investigated its negative impacts through its potential function as a gateway drug that induces individuals to consume additional drugs (DeSimone, 1998; Van Ours, 2003; Bretteville-Jensen and Jacobi, 2011). These papers provide some evidence that cannabis use can increase the probability of further drug use such as the use of cocaine. Others have investigated the impact of cannabis legalization or decriminalization. These include Miron and Zwiebel (1995); Pacula et al. (2000); Clements and Zhao (2009); Pacula et al. (2010); Pudney (2010); Donohue III, Ewing and Pelopquin (2010); Williams, Van Ours and Grossman (2011); Jacobi and Sovinsky (2016). These papers estimate varying responsiveness of cannabis use to legalization or decriminalization. Despite the health and safety costs associated with increased cannabis use, it is argued that decriminalization or legalization are preferred to prohibition.

The paper proceeds as follows. Section I discusses the history of cannabis prohibition and legalization in the United States as well the production process for cannabis products in Colorado. Section II details the empirical model for the cannabis market and the simulation undertaken to determine the revenue maximizing tax rate. Section III describes the data. This details the characteristics used in estimation as well as the assumptions made to permit the estimation of the discrete choice model. Section IV discusses the results of the estimation. This includes a description of instrumental variables. The results of the demand estimation and simulation of tax rates are discussed. Section V concludes.

I. Background

A. Cannabis Policy

Federal prohibition of cannabis came into effect with the Marijuana Tax Act of 1937. The act imposed de facto prohibition of cannabis through steep penalties associated with impermissible sales and use. Prohibition strengthened with the passage of the Controlled Substances Act in 1970. This made it explicitly illegal to manufacture, distribute, or possess cannabis in the United States. A large number of states chose to legalize medical or recreational cannabis use in spite of strict federal prohibition. See Kirsch (2019) for a detailed description of the history of federal prohibition and state cannabis legalization policies.

Colorado and Washington became the first states to legalize recreational cannabis on November 6th, 2012. Legalization began in Colorado with the passage of Amendment 64 by approximately 55% of the vote. The amendment was added to the state constitution as Article XVIII Sec. 16 by executive order of Governor John W. Hickenlooper on December 10th, 2012. The article states that cannabis should be taxed and regulated in a manner similar to alcohol "in the interest of the efficient use of law enforcement resources, enhancing revenue for public purposes, and individual freedom." Individuals twenty-one and older are allowed to possess, use, and grow restricted quantities of cannabis. Licensed individuals are allowed to operate cultivation, manufacturing, testing, and retail cannabis facilities. The article mandates the adoption of certain regulations for the industry. This includes requirements and qualifications to receive a cannabis license, security requirements, product labeling requirements, health and safety standards, and advertising restrictions. The first licensed retail cannabis stores opened their doors on January 1st, 2014.[11]

Relatively little is known regarding optimal taxation in this industry. Early states to legalize recreational cannabis like Colorado, Washington, and Oregon opened up markets for popular cannabis products for which there was very little data on prices or use. Most previous studies have been able to observe some data on quantities and prices of cannabis flower. It has widely not been possible to observe data on the use of edi-

[11] https://www.denverpost.com/2013/12/31/a-colorado-marijuana-guide-64-answers-to-commonly-asked-questions/

bles and concentrates. A description of these products is included in the following section. Prior experience with illicitly produced cannabis edibles or concentrates are unlikely to provide necessary knowledge of these products to predict consumer demand and the implications for tax revenue in the recreational cannabis industry. Legalization of these products has allowed for large production facilities, innovation, differentiation of products, and consistency of products which was not available in the illicit market. State legislatures additionally have varying motivation for legalization. States may value reduction in law enforcement and incarceration costs, or may value personal freedom and the expansion of legal businesses in their state for instance. The result has been a wide range of tax policies across states with recreational cannabis. Welfare implications of cannabis policy may also vary according to state characteristics. Demographic characteristics for Colorado are listed in Table 1. Differences in consumption of cannabis across race, ethnicity, sex, age, education, and income can influence the revenue maximizing sales tax rate.

Table 1—Colorado Demographics 2016

Variable	Value
Population	5,530,105
African-American	4.5%
Asian/Pacific Islander	3.5%
Native-American/Alaskan	1.6%
White	87.5%
Other	3%
Hispanic	21.3%
Female	49.8%
Median Age	36.4
Aged 20-24	7.1%
Aged 25-34	14.9%
Aged 35-44	13.5%
Aged 45-54	13.4%
Aged 55-64	12.6%
Aged 65+	12.6%
Bachelor's Degree or Higher	38.7%
Average Household Income	$84,384

Maine has implemented the lowest tax rate with a 10% sales tax being the only tax applied to cannabis sales. Washington has implemented the highest tax rate with a 37% excise tax applied to retail sales. This is in addition to relevant state and local taxes. The state sales tax rate for Washington is 6.5%. Washington's Department of Revenue estimates a weighted average local sales tax rate of 2.82% for 2018.[12] This implies recreational cannabis sales are taxed at a total rate of 46.32%. Remaining states which permit recreational cannabis sales have implemented tax rates typically significantly lower than that of Washington. California has implemented a 15% excise tax on the average market price of cannabis on retailers. Cultivators are additionally charged a specific tax of $9.25 per ounce of cannabis flower. Massachusetts has implemented an excise tax of 10.75% on retailers. Nevada charges a 10% excise tax on retail sales in addition to a 15% tax on wholesale sales paid by cultivators. Oregon charges a tax rate of 17% on retail sales, with an option for localities to increase this rate to 20%. Finally, Alaska charges an excise tax of $50 per ounce of cannabis flower charged to cultivators. Vermont recently passed legislation permitting recreational cannabis. A dispensary and tax system have yet to be established. The District of Columbia additionally does not have a formal dispensary system established.[13]

B. Production

Licensing is required for producers of cannabis. Colorado created the Marijuana Enforcement Division (MED) for the purpose of regulating the industry. The MED issues retail, cultivation, product manufacturing, testing, transportation, occupational, and business operator licences.[14] Retail licenses permit the operation of a store to sell cannabis to individuals twenty-one and older. Cultivation licenses permit the operation of a facility which grows cannabis for sale to other licensed organizations. Product manufacturing licenses permit the operation of a facility which manufactures products with extracts of cannabis including edibles and concentrates. Testing licenses permit the operation of a facility which tests products to determine their potency and quality. Transportation licenses permit the transportation of cannabis products between licensed organizations. Occupational and business operator licenses permit ownership and employment within li-

[12] "Marijuana sales tax table" accessed at https://dor.wa.gov/about/statistics-reports/recreational-and-medical-marijuana-taxes
[13] All information is current as of September, 2018
[14] C.R.S. 12-43.4-401.

censed cannabis facilities. Producers are required to track every cannabis product from its cultivation to its retail sale.

Production of cannabis products begins with the cultivation of the cannabis plant. Cultivators operate both indoor and outdoor facilities for growing cannabis. Plants are generated either from seeds or from cloning a mature plant. Cloning involves cutting a section from the stem of a plant. The resulting cut can be treated with rooting hormones and placed in soil or other growing medium where it will form into a mature plant. Plants are treated with different cycles of nutrients, light, and water over the course of a few months. The plants are then harvested and hung to dry before being trimmed of leaves and stems to produce the dried flower of the cannabis plant.[15] Cultivators pay an excise tax equal to 15% of the average wholesale price of their cannabis before transporting their product to a licensed retail, manufacturing, or additional cultivating facility.

Product manufacturers extract cannabinoids from cannabis flower to produce concentrates and edibles. Extraction may be water, food, or solvent based.[16] Extracts are used to produce a variety of products. Extraction using solvents such as butane and CO_2 leave behind a high potency substance that may be vaporized and inhaled for consumption. These extracts are sold in retail stores as concentrates. Examples of concentrates include oil, wax, and shatter. Extracts are also infused into food and beverages to produce edibles. Additional ingestible goods such as capsules and tinctures are also sold as edibles.

Products require testing prior to being transferred from a cultivator or manufacturer. Products are tested to determine the presence of contaminants and the potency of cannabinoids in the product. Testing is conducted to determine the presence of microbials such as Salmonella, E. Coli., yeast, and mold as well as residual solvents such as butane.[17] Manufacturers of edibles are required to test the potency of their product. Concerns over misuse of edible products encouraged restrictions on the strength of cannabinoids. Edibles must be

[15] Knowledge of cultivation comes from a tour of an anonymous cultivation center in Denver, CO.

[16] Water-based methods use water, ice, or dry ice. Food-based methods use propylene glycol, glycerin, butter, olive oil or other cooking fats. And solvent-based methods use butane, propane, CO_2, ethanol, isopropanol, acetone, or heptane to extract cannabinoids. See 1 CCR 212-2-R 103; 1 CCR 212-2-R 605(A)(2).

[17] 1 CCR 212-2-R 1501

clearly divided into single servings consisting of no more than 10 milligrams of THC, with a total of 100 milligrams included in an entire package. Products which are not easily separable such as soft drinks and tinctures must include an appropriate pouring measurement to achieve a single serving.

Products which satisfy testing requirements may be transported to retail stores for final sale to consumers. Customers must provide valid identification verifying that they are twenty-one or older. Licensed recreational dispensary employees facilitate the sale of cannabis products to consumers. This may include providing consumers information on the numerous products to suit their desired use of cannabis. Customers choose between flower, concentrates, and edible products. Purchases often involve a single class, though purchases of multiple types of products is not uncommon. Consumers may choose to purchase multiple packages of edibles. The discrete choice model of consumer demand for edibles should be viewed as an approximation of the true purchasing behavior for cannabis. This is similar to the assumption utilized in the market for cereal in Nevo (2001). Consumers demand edibles based on their product characteristics. Quantity of cannabinoids and price are particularly influential in determining consumer choice. Edibles list the quantity of tetrahydrocannabinol (THC) or cannabidiol (CBD) in a package. While some edibles list the inclusion of additional cannabinoids such as cannabinol (CBN), these products are relatively uncommon. Edibles which display the same characteristics may differ in quality and consistency. A less desirable product may concentrate cannabinoids disproportionately among units in the package for example. Consumers may have strong preferences for certain brands of edibles as a result.[18]

[18]Knowledge of consumer preferences comes from a personal interview with a cannabis dispensary manager.

II. Empirical Framework

A. Market Demand

Consumers demand cannabis edibles based on their product characteristics. They are assumed to demand one serving of edibles which provides maximum utility in a market. Consumers will have heterogeneous preferences for the characteristics of edibles based on individual tastes. Edibles are differentiated across a variety of factors. This includes the composition of THC or CBD in the edible. This will be a primary source of demand for a product. A package will be divided into a varying number of units of edibles. Some consumers may prefer units of edibles with a high concentration of cannabinoids per unit while others prefer a package of edibles to be divided into a greater number of units to provide smaller and more easily controlled doses of cannabinoids. There are different broad classes of edibles such as beverages or candy. These are available in a variety of flavors like chocolate or fruit. Finally, edibles will be differentiated according to the brand which produced them. The brand of edible may be of particular importance to consumers in this industry as a signal of product quality and consistency.

I describe the model following the exposition of Nevo (2000). Consumer utility is modeled as a function of product characteristics (x, ξ, p) and individual characteristics ν. Here x denotes observable product characteristics including fixed effects, ξ denotes unobserved product characteristics, and p denotes price. Parameters to be estimated are represented by θ. There are t = 1,...,T markets observed with i = 1,...,M_t consumers who decide between purchasing one unit of j = 1,...,J products. Markets are defined to be monthly observations for the state of Colorado. Consumers are assumed to observe the prices and characteristics of all products in a market. The outside option of not purchasing any products in the market is denoted by j=0. The indirect utility of consumers is given by:

$$U_{ijt}(x_{jt}, \xi_{jt}, p_{jt}, \nu_i; \theta) = \alpha_i(1+\tau) \cdot p_{jt} + x_j'\beta + \rho_{f(j)} + \lambda_{b(j)} + \eta_{c(j)} + \gamma_t + \xi_{jt} + \epsilon_{ijt} \tag{1}$$

Characteristics x_j denote a K×1 vector of observed product characteristics k for product j, p_{jt} is the average pre-tax price of product j in market t, $\rho_{f(j)}$ is a time-invariant fixed effect measuring average consumer preferences for flavor $f(j)$ of product j, $\lambda_{b(j)}$ is a time-invariant brand fixed effect which measures average consumer preferences for brand $b(j)$ that produces product j, $\eta_{c(j)}$ is a time-invariant product class fixed effect which measures average consumer preferences for product class $c(j)$ of product j, γ_t is a product-invariant fixed effect that controls for changes in consumer's preferences for cannabis products over time, and ξ_{jt} is unobserved (by the econometrician) product characteristics or demand shocks for product j in market t. The parameter τ denotes the sales tax rate. This is equivalent to the sum of the cannabis sales tax, the state sales tax, and the average local sales tax for Colorado in the demand estimation. Parameter β denotes a K×1 vector of marginal utilities for the K product characteristics, α_i is the marginal utility of price for individual i, and ϵ_{ijt} is an independently and identically distributed type I extreme value error term with mean zero. Denote this distribution by $P_\epsilon(\epsilon)$ Consumers have heterogeneous preferences for prices. The marginal utility of price for consumer i in market t is given by the following:

$$\alpha_i = \alpha + \sigma\nu_i, \quad \nu_i \sim N(0,1) \tag{2}$$

Characteristic ν_i is an unobserved consumer attribute and σ is a parameter to be estimated. The parameter σ corresponds to the standard deviation of the marginal utility of price. Individual characteristics ν are assumed to be independently and identically distributed with distribution function $P_\nu(\nu_i)$.

Consumer utility can be decomposed into the mean utility of purchasing product j in market t, δ_{jt}, and an idiosyncratic deviation from that mean according to individual characteristics, μ_{ijt}. Let θ=(θ_1, θ_2), where θ_1 denotes parameters associated with mean utility and θ_2 denotes parameters associated with individual utility. Mean utility of choosing the outside option $j = 0$ is normalized to zero.

(3) $$U_{ijt} = \delta_{jt}(x_{jt}, \xi_{jt}, p_{jt}; \theta_1) + \mu_{ijt}(x_{jt}, p_{jt}, \nu_i; \theta_2) + \epsilon_{ijt}$$

(4) $$\delta_{jt} = \alpha(1+\tau) \cdot p_{jt} + x_j'\beta + \rho_{f(j)} + \lambda_{b(j)} + \eta_{c(j)} + \gamma_t + \xi_{jt}$$

(5) $$\mu_{ijt} = (1+\tau) \cdot p_{jt} \cdot \sigma\nu_i$$

Consumers choose the product j which maximizes utility given individual characteristics. The set of individual characteristics A_{jt} which lead to the purchase of product j in market t is given by:

(6) $$A_{jt}(x_{.t}, \xi_{.t}, p_{.t}; \theta) = \{\ (\nu_i, \epsilon_{i0t}, ..., \epsilon_{iJt}) \mid U_{ijt} \geq U_{ilt}\ \ \forall\ l = 0, ..., J\ \}$$

Given ϵ_{ijt} is distributed type I extreme value, the probability that a consumer i purchases product j in market t is given by:

(7) $$s_{ijt}(x_{.t}, \xi_{.t}, p_{.t}, \nu_i; \theta) = \frac{exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J} exp(\delta_{kt} + \mu_{ikt})}$$

Market shares are found by integrating the probability of purchasing product j over the distribution of characteristics which lead to the purchase of product j:

(8) $$s_{jt} = \int_{(v,\epsilon)\in A_{jt}} s_{ijt}\ dP_v(v)dP_\epsilon(\epsilon)$$

Market demand is computed as the product of market share and the number of consumers in the market, $M_t s_{jt}$. The integral above is evaluated using simulation techniques involving random draws of consumers in a market. Random draws are generated using Halton sequences (Train, 2009). Mean utility δ_{jt} is calculated by matching simulated market shares to observed market shares using the contraction mapping suggested by (Berry, 1994). Parameter estimates are found using non-linear generalized method of moments (GMM).

Instrumental variables are necessary to address the endogeneity between prices and unobserved product characteristics. Let instrumental variables $z_{jt} = [z_{1jt},\ z_{2jt}, ...,\ z_{Rjt}]$ be a vector of instruments which are correlated with price but uncorrelated with ϵ_{ijt}. R corresponds to instruments generated from functions of product characteristics k. Instrumental variables z_{jt} satisfy:

(9) $$E[\xi_{jt}|z_{jt}] = 0 \qquad \forall\ j, t$$

B. Market Supply

Supply is determined by Bertrand competition in which firms choose the price of their products to maximize profits. There is a fixed number of firms f = 1,...,F. Each firm produces a subset $J_f \in J$ of products. Product characteristics are determined exogenously prior to the pricing game. Firms observe all product characteristics as well as the prices of competing products in a market. This includes unobservable (to the econometrician) characteristics ξ. Firm knowledge of ξ induces a bias in the price coefficient and necessitates instrumental variable estimation. Firms choose prices to maximize profits given the characteristics of their products and the prices and characteristics of competing products. A Nash equilibrium to this pricing game is assumed to exist. Profits for firm f are given by:

(10) $$\Pi_{ft} = \sum_{j \in J_f} (\ p_{jt} - mc_{jt}\ ) M_t s_{jt}(x, \xi, p; \theta)$$

Where mc_{jt} is marginal cost of product j in market t. Marginal costs are assumed to be constant. A firm f sets an average price p_{jt} for each $j \in J_f$ that satisfies the first order conditions:

(11) $$s_{jt}(x, \xi, p; \theta) + \sum_{r \in J_f} (\ p_{rt} - mc_{rt}\ ) \frac{\partial s_{rt}(x, \xi, p; \theta)}{\partial p_{jt}} = 0$$

This condition provides the optimal markup for each product in a market. Define a matrix Ω by the following:

(12) $$\Omega(x, \xi, p; \theta) = \begin{cases} \frac{\partial s_{rt}(x,\xi,p;\theta)}{\partial p_{jt}}, & r, j \in J_f; \\ 0, & otherwise. \end{cases}$$

The J first order conditions may therefore be expressed by a vector of marginal costs:

(13) $$mc = p + \Omega^{-1}(x, \xi, p; \theta) s(x, \xi, p; \theta)$$

Marginal costs can then be calculated as a function of observed prices. Market shares, prices, and marginal costs determine producer surplus in the industry according to the profit equation.

C. Simulation

New sales tax rates τ are simulated holding constant coefficients θ and marginal costs mc_{jt}. It is assumed that there are no changes to the outside option for different tax rates. It is additionally assumed that there is no entry or exit of firms. This implies new market shares s_{jt} and equilibrium prices p_{jt} which determine welfare for the industry. Consumer surplus for individual i in market t is measured as the following:

$$CS_{it} = \frac{1}{|\alpha|} \cdot ln[1 + \sum_{j=1}^{J} exp(\delta_{jt} + \mu_{ijt})] \tag{14}$$

Dividing by $|\alpha|$ translates consumer utility into dollars. Producer surplus is given by the profit equation. Tax revenue is calculated as the percentage of total sales revenue.

III. Data

Data for this estimation comes from BDS Analytics. The data include sales from approximately 19% of dispensaries operating in Colorado. Sales data are weighted to be representative of total industry sales based on the algorithms of BDS Analytics. The data provide daily product level average pre-tax price and sales for cannabis products sold in Colorado between 2014 and 2016. Colorado is chosen as it is the first state to have opened its doors to retail recreational cannabis sales on January 1st, 2014. The dataset is compiled and combined with product characteristics at the end of 2016.[19]

I focus my estimation on sales of recreational cannabis edibles. Edibles comprise approximately 17% of cannabis sales between 2014 and 2016. Focusing on this segment of the cannabis industry is similar to the strategy employed in Miravete, Seim and Thurk (2016), in which the authors focus on sales of spirits and exclude beer and wine from their analysis. Edibles are the ideal product class for measuring consumer

[19]The data is restricted to sales occurring prior to 2017. A major provider of software which tracks sales of cannabis from dispensaries faced hacks and outages in January of 2017. This resulted in dispensaries which were forced to shut down or record sales by hand momentarily. Sales after 2016 are eliminated to avoid biases in the estimates due to this event.

preferences for characteristics in the data. All cannabis products are required to list their composition of cannabinoids measured through potency tests.[20] This means consumers will face different characteristics for a product across dispensary locations and across time. I am unable to provide potency information on flower and concentrates as a result. However, a majority of edibles will have a stated composition of cannabinoids displayed on their packaging which is constant through time. The stated composition of a package of edibles is often reported on dispensary menus, and is more readily viewed by consumers choosing between cannabis products compared to potency test results. I assume consumers choose edibles based on their stated composition of cannabinoids rather than their potency test results. Additionally, flower and concentrate products created from a particular strain of cannabis may be produced by multiple firms. I am unable to observe the producing firm of these products in the data. A particular edible will be produced by a unique firm. The ability to observe the brand of edible permits estimation of the profit maximizing behavior of firms. I choose the market for recreational cannabis as it is the recreational industry which faces high tax rates and generates the majority of revenue for the entire industry.

I use BDS Analytics consumer survey data to consider differences in the population of individuals who consume edibles compared to the entire population of individuals who purchase cannabis at dispensaries.[21] The largest share of cannabis Consumers is between the ages of 25 and 34. Consumers are significantly more likely to have obtained a bachelor’s degree or higher. Consumers are less likely to be married, and less likely to have children in their household compared to the Colorado population. Consumers who prefer edible cannabis products differ in characteristics compared to Dispensary Shoppers. Consumers of edibles are older on average by 2.3 years. Preference for edibles is significantly less likely for individuals aged 21-24, while preference for edibles is significantly more likely for individuals aged 55-64. Women are more likely than men to prefer edibles. Individuals who prefer edibles are more likely to hold a bachelor’s degree or higher, earning close to $10,000 more per year in household income compared to Dispensary Shoppers. Consumers of edibles consume cannabis less frequently. They are significantly less likely to consume daily, and more

[20] 1 CCR 212-2-R 1004.5
[21] BDS Analytics: “Cannabis in the USA; Public Attitudes and Actions Toward Legal Cannabis in CO” Q1 (2017).

likely to consume on a less than weekly basis. Differences between individuals who consume edibles rather than flower or concentrates are likely to influence the revenue maximizing tax rate on cannabis. Higher income may imply individuals who consume edibles are less price sensitive, leading to a tax rate which overstates the revenue maximizing rate for the entire industry. In this case the tax rate may be viewed as an upper bound on the revenue maximizing rate for all cannabis products.

Individuals choose whether or not to purchase a product in every market. Markets are defined to be monthly observations. Observable characteristics of edibles include a product class, brand, flavor, chemical composition, and number of units in a package. Product classes refer to the type of the food or drink item. Examples of product classes include beverages, candy, or baked goods. Categories of flavor are generated to control for consumer taste. Examples of flavor categories include chocolate, fruit, and caramel. Chemical composition refers to the milligram quantity of THC or CBD included in the edible. I additionally include an indicator for an edible containing 100 mg THC in a package to account for products whose chemical composition meets the maximum allowed by law. Price is calculated as the average pre-tax retail price of a good in that market. Prices are scaled to 2016 dollars using the biannual CPI for the Denver-Boulder-Greeley metropolitan area. The average state sales tax rate is calculated as the sum of the special recreational cannabis sales tax, the state sales tax, and the average local sales tax in Colorado as calculated by the Tax Foundation.[22]

Product characteristics must be collected for each individual edible. I link products to their composition of THC and CBD, units per package, and flavor using firm websites, cannabis product websites, product images, and other online sources. There is partial information regarding these characteristics for some products in the data. However, this must be completed through individual search for a majority of the products. Table 2 displays summary statistics for the products used in estimation. There are over two-thousand unique product entries in the data. This includes a significant number of unpopular items which sell infrequently, as well as items from firms who briefly produced in the industry before exiting or merging with other cannabis

[22] https://taxfoundation.org/state-and-local-sales-tax-rates-2014/; https://taxfoundation.org/state-and-local-sales-tax-rates-2015/; https://taxfoundation.org/state-and-local-sales-tax-rates-2016/

firms. It is a concern with the large number of products that coefficient estimates may be largely driven by the value of the error term in order to explain consumer choices. Additionally, collection of product characteristics is significantly time consuming. I reduce the sample to the top quintile of cannabis edibles in terms of total sales over this time period to feasibly permit the collection of product characteristics. I exclude products with prices in the top and bottom percentile of this sub sample to eliminate transactions which are not representative of the typical retail cannabis transaction. Retailers sold products with prices near zero as a promotional activity for example.

TABLE 2—SUMMARY STATISTICS

Variable	Mean	Std. Dev.
Quantity	1666	2473
Price	18.89	6.96
THC	83.8	27.4
CBD	2.9	15.2
Units/pkg.	8.3	5.2
Market Size	848925	11181
obs.	7,469	

* Quantity is the number of sales for an individual edible in a month. Price, THC, CBD, and Units are measured per individual package. Market Size is the number of potential cannabis consumers in a market.

A number of products in the data are not uniquely identifiable by their product name. This is because a product name may be associated with multiple characteristics. For example, an edible may come in the form of 10mg or 100mg total THC per package. These products are excluded from the data. Identifiable products in the top quintile comprise approximately 76% of all sales in the data. This results in a selected data set of products which sold relatively well in a market. This will potentially bias my coefficient estimates. This issue is detailed in Gandhi, Lu and Shi (2017). A selected sample may bias the price coefficient and demand elasticity towards zero. This could lead to an estimated revenue maximizing tax rate which overstates the true rate by predicting less price sensitive consumers. I nevertheless estimate demand elasticities which predict product markups which closely resemble what is observed in the industry. My estimates potentially provide credible measures of consumer demand for cannabis as a result.

I use BDS Analytics consumer survey data to determine population demographics for recreational cannabis in Colorado.[23] Consumers of cannabis are defined to be adult Colorado residents who have consumed cannabis in the previous six months. Consumers comprise 25% of the adult population of Colorado. 84% of Consumers do not have a medical card and are supplied cannabis through the recreational market. I utilize this population in my preferred specification. I consider alternative market size measures using survey data from Light et al. (2014). This survey determines nearly 13% of the total Colorado population reports yearly use of cannabis, 9% report monthly use, and 3% report daily use. Approximately 7.3% of sales in the recreational market are made to out of state consumers who visit Colorado. I use the population of monthly cannabis users who receive cannabis through the recreational market to test the robustness of my results with respect to the choice for market size.

Consumers are assumed to purchase one unit of cannabis products in a market. I define one unit of cannabis products to be the average consumption of cannabis users in a month. This is similar to the strategies employed by Nevo (2001) and Miravete, Seim and Thurk (2016). Nevo (2001) calculates market shares by defining a unit of cereal to be equivalent to the serving size suggested by the manufacturer, and Miravete, Seim and Thurk (2016) define a unit of alcohol spirits to be equivalent to a 750 ml bottle.

Survey data suggests consumers of cannabis use between 0.3-1.6 grams of cannabis flower on a day of use (Light et al., 2014). I use the percentage of consumers by frequency of use to calculate average monthly usage. This provides a measure of between 13.2 - 16.6 grams per month. I utilize the pharmacokinetic equivalency of cannabis flower to convert this number into quantity of edibles (Orens et al., 2015). This measure assumes that consumers demand equivalent psychoactive impacts of cannabis when purchasing products. This measure translates 13.2 grams of flower into 39.6 10mg edibles. Edibles are often sold in packages of ten units containing 10mg each. This suggests consumers purchase approximately four packages of edibles each month. Discussions with industry professionals suggest that this number may be large for

[23]BDS Analytics: "Cannabis in the USA; Public Attitudes and Actions Toward Legal Cannabis in CO" Q1 (2017).

the average consumer. I reduce this number by half and assume that consumers purchase two packages of cannabis edibles in a month, or choose the outside option of no purchase. I consider units defined to be four packages of edibles to test the robustness of my results with respect to the choice for serving size.

IV. Results

A. Instrumental Variables

Identification of the marginal utility parameters comes from variation in consumer choices across product choice sets provided by firms in different markets. Endogeneity between prices and unobserved characteristics will bias parameter estimates. Consumers will choose to purchase goods with high unobserved quality at higher prices. The estimation of the price coefficient will be biased towards zero. This necessitates the use of instrumental variables in estimation. I use BLP type instruments consisting of own and rival product characteristics as instruments for price. I am unable to link cost characteristics to the individual products for use as instrumental variables due to data constraints.

Instrumental variables include the sum of the characteristics of every other product, the sum of the characteristics of every other product produced by the same firm, and the sum of characteristics of all products not produced by the same firm in a market. The number of competing products in a market is also considered as an instrument. I additionally compute these variables within product classes and within product flavors. Identification of the parameters comes from variation in the choice set of products in a market which determine the optimal pricing strategy for a firm. From equation (10), the pricing decision of a firm depends on market share s_{jt}, which is a function of all product characteristics x. From equation (1), the utility a consumer derives from a product depends only on that product's characteristics. BLP type instruments therefore satisfy the relevance and exclusion requirements of instrumental variables. I test for weak instrumental variables using the Cragg-Donald F-statistic. I test the exclusion requirement using the Hansen J statistic of Hansen (1982).

B. Demand Estimation

The results of equation (1) are displayed in Table 3. Columns (1) and (2) display the results of the fixed coefficient logit model.[24] This specification assumes the marginal utility of product characteristics does not vary between consumers. Column (1) reports OLS logit results. Column (2) reports instrumental variables estimation. The coefficient on price increases in magnitude and significance when instrumental variables are used. This is consistent with instruments which control for the correlation between price and unobserved characteristics. The fixed coefficient logit model leads to unrealistic substitution patterns between products. Cross-price elasticities are proportional to a product's market share. Products with the same market shares will have equivalent elasticities given a change in the price of another product. This is unrealistic as one might expect consumers to substitute towards goods with similar characteristics given a change in the price of a particular product. Estimation of the BLP model addresses this concern by allowing the marginal utility of characteristics to vary by consumer.

Column (3) displays the results of the random coefficient logit model of BLP with a random coefficient on price.[25] Edibles frequently exhibit similar concentrations of THC. Price is a strong determinant of consumer demand for an edible as a result. The standard deviation of the coefficient on price is smaller in magnitude than its mean coefficient. This implies negative marginal utility with respect to price for every individual simulated in the market.

The marginal utility associated with other product characteristics are of the expected sign. THC and CBD provide positive utility to consumers. The sign on their squared terms are negative, suggesting consumers have declining marginal utility with respect to these characteristics. I have no strong priors on the sign of the coefficient for units per package. Consumers may prefer strong edibles which come in a smaller number of units, or consumers may prefer a larger number of separable units in their edibles package to allow for smaller

[24] Estimation of coefficients is undertaken using the Stata random coefficient logit command, accessible at: https://econpapers.repec.org/software/bocbocode/s458216.htm

[25] Estimation with additional random coefficients is attempted, however limitations with instrumental variables make it difficult to identify a set of instruments which satisfy the relevance requirement and exclusion restriction.

TABLE 3—DEMAND ESTIMATION

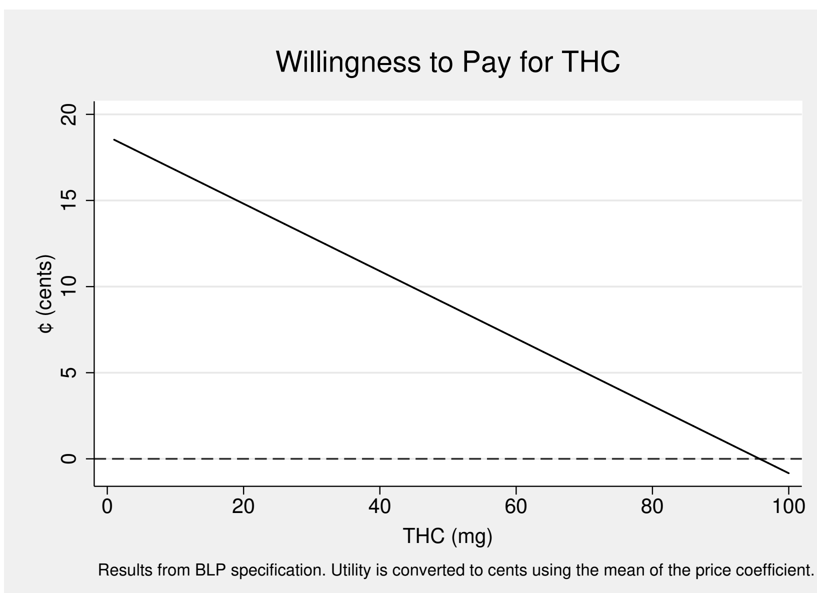
	Fixed Coefficient Logit		Random Coefficient Logit
	(1)	(2)	(3)
Variables	OLS	IV	BLP
$Constant$	-9.669***	-9.416***	-9.398***
	(0.340)	(0.440)	(0.414)
THC	-0.00193	0.0467**	0.0516***
	(0.00444)	(0.0184)	(0.0156)
THC^2	1.73e-05	-0.000231**	-0.000269***
	(4.13e-05)	(0.000103)	(9.02e-05)
CBD	0.0267***	0.0816***	0.0780***
	(0.00401)	(0.0203)	(0.0172)
CBD^2	-0.000317***	-0.000118	-0.000516***
	(4.04e-05)	(8.74e-05)	(8.62e-05)
$Units$	-0.115***	-0.0566*	-0.0497
	(0.0227)	(0.0333)	(0.0310)
$Units^2$	0.00409***	0.00170	0.00160
	(0.000929)	(0.00135)	(0.00127)
$Price$			
Mean	-0.00460	-0.188***	-0.275***
	(0.00434)	(0.0660)	(0.0547)
S.D.	.	.	0.111**
			(0.0543)
Relevance	.	19.200	11.839
Exclusion	.	0.8908	0.3697
Observations	7,411	7,411	7,411

* The following table displays the results from estimating equation (1). The first column corresponds to the OLS fixed-coefficient logit model. The second column corresponds to the fixed-coefficient logit model with IV's. The third column corresponds to the random-coefficient logit (BLP) model. Units refers to units per package of edible. Flavor, brand, class, and time fixed effects are not reported. F-stat is the Cragg-Donald Wald F statistic. Exclusion is the p-value of the Hansen J statistic. Robust standard errors in parentheses.
** p<0.01, ** p<0.05, * p<0.1

and more easily controlled doses of cannabinoids. The coefficient on Units is negative and insignificant in the BLP specification. The coefficient on the indicator variable for products whose THC composition meets the maximum allowed by law is not reported and is insignificant in all specifications. Columns (2) and (3) both satisfy tests for relevance and exclusion given by the Cragg-Donald Wald F-statistic and Hansen-J statistic. First stage results are reported in the appendix Table A1.

The coefficients on THC and its square are used to construct consumers' willingness to pay for THC depicted in Figure 3. Marginal utility is positive for THC concentrations up to 95 milligrams per edible. Total utility from an edible is maximized near the legal limit of 100 milligrams chosen by many edibles producers. The THC component of a 100 milligram edible is valued at $8.95. Additional valuation of an edible is explained through preferences for flavors, brands, classes of edibles, and product invariant consumer preferences for edibles through time. This arguably provides a realistic measure of consumer utility for THC.

FIGURE 3.



C. Simulation

Consumer characteristics ν are simulated using Halton sequences.[26] The demand elasticities implied by the BLP estimation are reported in Tables 4 - 6. I report the own and cross-price elasticities for the top 10,

[26]See Train (2009). Estimation of predicted market shares is undertaken using 200 draws to approximate the integral in equation (8). This is the number of draws in which there is little change in the set of random coefficients. Simulation results are similar when the number of draws is increased to 1,000.

middle 10, and bottom 10 products in terms of sales for the month. The sales weighted average own-price elasticity of the products is -2.73.

TABLE 4—DEMAND ELASTICITY: TOP 10 PRODUCTS

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10
Item1	-2.91095	.02177	.03115	.03387	.01902	.03475	.04338	.03162	.02384	.05205
Item2	.02253	-3.04429	.03364	.03691	.02055	.03814	.046	.03446	.02618	.05391
Item3	.02258	.02356	-3.0279	.03667	.02044	.03786	.04585	.03424	.02598	.05388
Item4	.02253	.02372	.03365	-3.03137	.02056	.03815	.04601	.03448	.02619	.05392
Item5	.02258	.02358	.03348	.0367	-3.0418	.03789	.04587	.03427	.02601	.05389
Item6	.02247	.02383	.03377	.03709	.02064	-3.03351	.0461	.03463	.02632	.05391
Item7	.02263	.02319	.03299	.03608	.02015	.03719	-2.99522	.03369	.02552	.05366
Item8	.02253	.02372	.03365	.03693	.02056	.03816	.04601	-3.03397	.02619	.05392
Item9	.02246	.02383	.03378	.0371	.02064	.03836	.04611	.03465	-3.04577	.0539
Item10	.02257	.02258	.03222	.03514	.01968	.03614	.0446	.03281	.0248	-2.94612

* The following table displays the elasticities of demand with respect to price for the top 10 products in terms of sales for June 2015.

TABLE 5—DEMAND ELASTICITY: MIDDLE 10 PRODUCTS

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10
Item1	-3.03717	.0035	.00386	.00364	.00341	.00375	.00214	.00306	.00359	.00369
Item2	.00345	-2.95861	.00364	.00357	.0034	.00359	.00235	.00314	.00341	.00349
Item3	.00363	.00347	-3.07074	.00363	.00334	.00386	.00186	.00289	.00373	.00387
Item4	.00349	.00347	.0037	-2.98164	.0034	.00363	.0023	.00312	.00346	.00354
Item5	.00337	.0034	.0035	.00351	-2.89637	.00348	.00245	.00316	.0033	.00336
Item6	.00361	.0035	.00395	.00365	.00339	-3.05875	.00203	.003	.00366	.00378
Item7	.00215	.00239	.00199	.00241	.0025	.00212	-1.73176	.0027	.00194	.00192
Item8	.00307	.00319	.00308	.00327	.00321	.00313	.00269	-2.66563	.00293	.00297
Item9	.00363	.00349	.004	.00364	.00337	.00384	.00194	.00295	-3.06788	.00382
Item10	.00363	.00348	.00404	.00363	.00334	.00385	.00188	.00291	.00373	-3.07071

* The following table displays the elasticities of demand with respect to price for the middle 10 products in terms of sales for June 2015.

TABLE 6—DEMAND ELASTICITY: BOTTOM 10 PRODUCTS

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10
Item1	-2.28901	.00013	.00001	.0004	.0002	.00004	.00023	.00013	.00004	.00027
Item2	.00003	-3.05897	.00001	.0003	.0002	.00008	.00019	.00018	.00004	.00036
Item3	.00003	.00023	-3.07244	.00032	.0002	.00007	.0002	.00018	.00004	.00036
Item4	.00004	.00013	.00001	-2.35383	.00021	.00004	.00023	.00013	.00004	.00028
Item5	.00004	.00017	.00001	.0004	-2.73411	.00006	.00024	.00015	.00004	.00032
Item6	.00003	.00023	.00001	.00031	.0002	-3.06883	.0002	.00018	.00004	.00036
Item7	.00004	.00015	.00001	.0004	.00021	.00005	-2.50602	.00014	.00004	.0003
Item8	.00004	.00022	.00001	.00035	.00021	.00007	.00022	-3.0542	.00004	.00036
Item9	.00004	.00018	.00001	.00039	.00022	.00006	.00023	.00016	-2.8627	.00034
Item10	.00004	.00021	.00001	.00036	.00022	.00007	.00022	.00018	.00004	-3.02374

* The following table displays the elasticities of demand with respect to price for the bottom 10 products in terms of sales for June 2015.

Constant marginal costs implied by equation (13) are calculated from the predicted market shares. The average marginal cost to produce a package of edibles is estimated to be $12.55 with a standard deviation of $4.24. Predicted costs range from $0.61 to $24.67. The lowest cost item corresponds to a single 10 milligram serving edible which sells at low prices. The highest cost item corresponds to an edible containing high concentrations of both THC and CBD. Recreational cannabis products which include both cannabinoids typically sell at significantly higher prices. Marginal costs imply an average markup of 40.8%. Most top brands in the industry target a retail markup of 50% according to industry professionals. Conversations with accountants in the industry are used to investigate the spending patterns of cannabis businesses. The average retail business creates value-added which is approximately 30% of revenue for the business. This suggests my estimates provide a realistic measure of marginal cost for products in the industry.

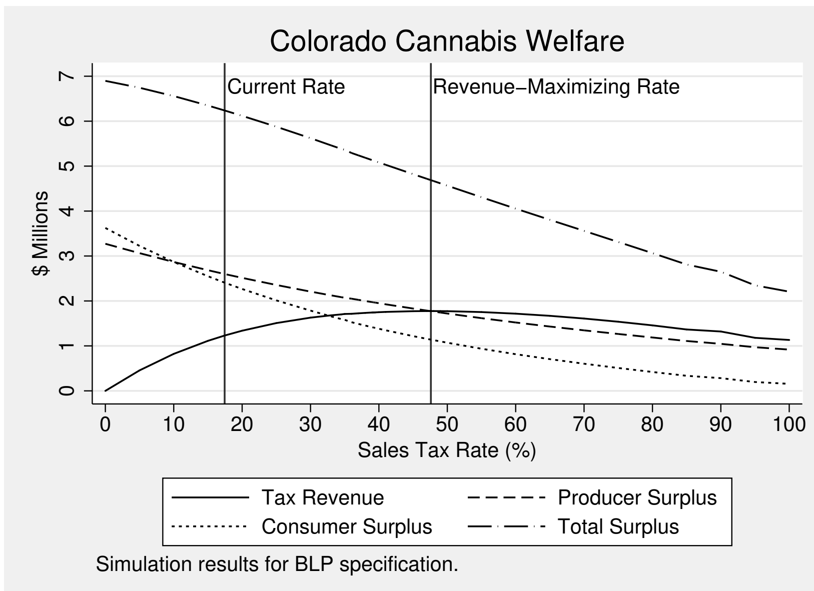
Different sales tax rates τ are simulated.[27] Marginal costs and demand parameters are held constant. Varying sales tax rates imply a new profit maximizing pricing decision for firms and purchasing decision for consumers. New equilibrium prices and market shares are calculated given the sales tax rate. This allows for the estimation of consumer surplus, producer surplus, and tax revenue for any rate τ. I simulate welfare for sales tax rates between 0-100% in intervals of 5. I then conduct simulation necessary to determine the revenue maximizing rate within 0.1%.

The result of the sales tax simulation is reported in Figure 4. Simulation is conducted for the month of June, 2015. This month signifies the midpoint of the data set. The revenue maximizing tax rate occurs at 47.6%. The tax pass-through rate measuring the change in equilibrium price relative to the change in tax revenue is 1.55 on average at this sales tax rate.[28] Equilibrium prices before taxes are found to increase with higher sales tax rates. This result can be found as a consequence of the curvature of the product demand curves in which firms respond to tax rates by increasing prices to sell to a price inelastic population of consumers (Anderson, De Palma and Kreider, 2001; Hollenbeck and Uetake, 2018). Over two-thirds of the maximum revenue is achieved at the current tax rate of 17.44%. This corresponds to a maximum revenue of $1.78 million relative to current revenue of $1.23 million in the data. Consumer and producer surplus decline by 52.7% and 31.8%

[27] Simulation is programmed in Matlab.
[28] The tax pass-through rate is found to be 1.9 for cannabis products in Washington (Hollenbeck and Uetake, 2018).

respectively from their current rates when the tax rate is raised to 47.6%. Revenue changes near tax rates of 47.6% are relatively small. 96.4% of maximum revenue is achieved at a tax rate of 35% for instance. States which value cannabis consumer or producer surplus may therefore wish to consider charging a tax rate less than the revenue maximizing rate. States which do not value cannabis consumer and producer surplus can charge the revenue maximizing rate and expect significantly decreased production and consumption from the legal market.

FIGURE 4.



The simulation results do not account for additional revenue that may be raised through excise taxes on cultivators and through licensing and fees. These sources of revenue are significant. Revenue from excise taxes on recreational cannabis totalled 6.0% of the value of total sales between 2014-2016. It is unclear how these sources of revenue will change with the sales tax rate. Excise taxes are calculated as 15% of the Average Market Rate (AMR) for unprocessed cannabis sold between a cultivator and another licensed cannabis firm. AMRs are calculated biannually by the Department of Revenue. The quantity of unprocessed cannabis used in a package of edibles will vary across time and between firms. Unprocessed cannabis will possess different levels of cannabinoids. Firms will have varying levels of efficiency in converting this flower into their particular variety of edible. Sales tax rates may additionally influence the wholesale price of unprocessed cannabis and directly impact the calculation of the AMR. It is difficult to predict how license and fee revenue will change with higher sales tax rates. Higher rates could reduce firm entry and more drastically reduce license and fee revenue. I conduct a back-of-the-envelope calculation to consider the impact of excise taxes, licensing, and fees. I assume revenue from these sources remains a constant fraction of total sales, as calculated by the ratio of total excise, licensing, and fee revenue to total sales from 2014-2016. Revenue from all sources is maximized at a sales tax rate of 39.2% under this assumption.

I test the robustness of my results by considering an alternative definition for the size of the market and a unit of cannabis edibles. I define the market size to be the population of monthly cannabis users who are supplied through the recreational cannabis industry based on Light et al. (2014). This results in a measure of market size which is just under half of the preferred market size. Simulation results in a revenue maximizing sales tax rate of 59.5%. The revenue maximizing sales tax rate does not appear to be largely dependent on the definition for market size given the substantial difference in the two measures. The market size defined to be the population of adults who have consumed cannabis in the past six months is preferred to this definition as it is derived from more recent survey data using respondents who have had the opportunity to participate in the recreational cannabis industry. This additionally takes into account infrequent users who may not use cannabis every month, but may nonetheless be a significant consideration for the market. I additionally redefine a unit of cannabis to contain four packages of edibles and use my preferred measure for market size. This definition results in a revenue maximizing tax rate of 43.8%. My results do not appear to be strongly dependent on the definition for a serving of edibles. Demand estimation for alternative definitions of market size are reported in Table A2 of the appendix.

The revenue maximizing tax rate is estimated for alternative methods of taxation. Legislators could impose a tax on the quantity of edibles packages sold. The revenue maximizing tax on quantity occurs at a rate of $10.65 per package. The average price of an edible is approximately $18.89 before taxes. This excise tax rate is therefore equivalent to a 56.4% sales tax rate applied to a package of edibles sold at the average price.

Legislators could also impose a tax on the concentration of THC in an edible. This could more directly address concerns regarding the negative impact of THC. The revenue maximizing tax on THC concentration occurs at 12.7 cents per milligram of THC. The average concentration of THC in an edible is 83.8 milligrams per package. This tax rate on THC is therefore equivalent to a 56.3% sales tax rate applied to the average edible.

There may be concerns that the sample used in estimation includes a large number of products. Consumer choice may be largely explained by the value of the error term as a result. I consider reducing the sample to include the top ten and top five percent of products in terms of sales over the sample period. Estimation within these samples achieves qualitatively similar coefficient estimates for the fixed-coefficient logit model. However, estimates suffer from weak instrumental variables. Simulation is not conducted within the reduced samples as a result. My sample includes a comparable number of products to Miravete, Seim and Thurk (2016).

These results may be sensitive to the modeling assumptions. I assume a fixed number of producing firms with constant marginal costs. There has been variation in the number of firms in the industry. There were a large number of firms which began production at the start of the industry in 2014. This included inexperienced and inefficient firms which produced edibles at high cost or low quality. Firms have additionally faced large fixed costs in complying with industry regulations such as licensing and product testing. There has been consolidation of firms as a result.[29] Larger and more experienced firms are able to produce higher quality edibles at lower cost. This trend may persist as the industry continues to grow. Lower costs will increase total welfare in the industry and provide the opportunity to extract greater revenue from sales. This may suggest a higher revenue maximizing sales tax rate.

The results may be sensitive to the type of cannabis product used in estimation. Consumers of edibles differ from consumers of flower and concentrates. Edibles consumers are typically higher income, older, and less frequent users of cannabis. This may suggest less price sensitive consumers who have a revenue

[29] Knowledge of firm consolidation comes from a personal interview with a cannabis product manufacturer.

maximizing rate which is higher than the rate for the cannabis industry as a whole.

The potential to raise revenue through the cannabis industry is substantial. Colorado has collected $638 million in total revenue from the industry between 2014 and 2017. Implementation of the revenue maximizing sales tax rate may raise additional funds to provide for important government programs. The industry has permitted the contribution of over $150 million to public school works between fiscal years 2013-14 and 2016-17. Funds have provided for public programs in substance abuse, mental health services, affordable housing, and many others. Funds have additionally been allocated towards more effective law enforcement and correction services through training, diversion programs, and jail-based behavioral services.

There are trade-offs of imposing high tax rates. Producer surplus declines significantly at the revenue maximizing rate. Lower profits for legitimate business means less employment and growth in the industry. This may place additional pressure on smaller scale producers and reduce competition. Consumers have a variety of substitutes to the recreational cannabis industry. Consumers may be encouraged to undertake home cultivation to avoid high tax rates. The rate of home cultivation at high prices could be significant. Home cultivation accounted for 3.9% of illicit cannabis supply prior to legalization. The rate of home cultivation among medical cannabis patients in Washington is estimated to reach as high as 17% (Light et al., 2014). This figure may provide a reasonable estimate for the potential of recreational consumers to switch to home cultivation if tax rates are raised to their revenue maximizing rate. Consumers could additionally find it possible to obtain certification to access medical cannabis at lower tax rates. The medical cannabis market has persisted to an unexpected degree in Colorado despite recreational legalization. The difference in prices paid for recreational and medical cannabis appear to provide enough incentive for individuals to undertake the costs associated with registering to use medical cannabis. An estimated 16% of cannabis consumers access supply through the medical industry. Finally, consumers could increasingly find it worthwhile to procure cannabis on the black market. Recent estimates suggest the illicit market in Colorado has been entirely absorbed by the regulated industry (Orens et al., 2018). Higher taxes could nevertheless induce substitution to the illicit market. Increased illicit activity means higher law enforcement and incarceration costs for a state and profits from cannabis which fund criminal organizations. Black market production additionally means consumers access products for which there are no health or safety regulations.

V. Conclusion

Legalization of cannabis has become a topic of significant interest to legislators in recent years. Legal cannabis provides the opportunity to generate tax revenue for a state that may fund important programs in education, health, and law enforcement. This paper provides the first estimate of the revenue maximizing sales tax rate in the industry measured using a structural model of consumer and firm behavior in equilibrium. This rate will be an important consideration for policymakers. States have implemented sales tax rates for recreational cannabis ranging from 10% - 37%. States have varying motivations for legalizing recreational cannabis. Colorado has implemented policies which place value on cannabis consumers and seek to increase firm access to capital to improve competitiveness and facilitate innovation in cannabis products. Washington has implemented relatively steep tax rates which generate significant revenue at the expense of industry growth. States currently prohibiting recreational cannabis which may consider legalization in the future may consider potential tax revenue to be of primary concern. The results of this paper should provide context for the welfare implications of varying recreational cannabis policy.

The emerging legal cannabis industry provides ample opportunity for further research. Future work on this topic could incorporate all types of cannabis products including flower and concentrates and their observable characteristics to account for important differences across categories. Estimation would benefit from the use of cost instruments which could allow the use of optimal instruments to eliminate potential bias in the price coefficient. Further research could model this industry in a dynamic setting and account for firm entry or exit decisions. Merging of firms is significant in this industry. Modeling these changes may provide important insight into cost changes and the impact of firm mergers. Finally, there are significant concerns regarding the health and safety costs associated with cannabis products. Estimation of the externalities associated with cannabis is an important consideration for this topic.

Chapter 2

Determinants of Cannabis Legalization in the United States

Prohibition of cannabis has been in effect in the United States since the 1930's. A majority of states nevertheless passed laws which permit cannabis use in some form despite strict federal regulation. There are currently thirty-three states along with the District of Columbia which permit medical cannabis use for patients with varying qualifications. Ten states and the District of Columbia permit recreational cannabis use for individuals twenty-one and older.[30] Nineteen states have recently passed legislation to permit extracts of cannabidiol (CBD). This allows individuals to obtain the non-psychoactive extract of the cannabis plant for potential medical uses while still maintaining prohibition of tetrahydrocannabinol (THC) in cannabis products. Idaho and Nebraska remain the only states which have never enacted policies permitting cannabis use in some form.

State cannabis laws provide a unique environment to explore policy choices. The decision for states to legalize cannabis in spite of federal prohibition suggests strong motivations for enacting these policies. Deregulation of cannabis may be supported by economic considerations including the efficiency of the free market. Cannabis legalization varies from previous instances of industry deregulation in that voters and regulators may have strong ideological views in support or opposition of the cannabis industry. There is significant variation in regulatory decisions. This includes geographic variation which is not present in federal regulations. States considered legalization during different years. These laws exhibit heterogeneity in their provisions including the formation of patient registries, permissible use of cannabis, and available forms of legal supply. Policy choices are typically made through a legislature. Cannabis laws are unique in passing through both state legislatures and through ballot initiatives. The determinants of legalization as well as the provisions of the laws vary as a result. Cannabis legalization provides an environment to explore

[30]These numbers are accurate through January 1st, 2019.

various motivations for these policy decisions and how this relates to economic theories of regulation and the removal of regulation from an industry.

A number of theories exist to explain regulatory change. Early work in economics focuses on the public-interest theory of regulation which considers the role of the regulator as a social planner who maximizes welfare by mitigating market failures related to competition and externalities (Joskow and Noll, 1981). This view of regulation is insufficient at explaining regulatory decisions as it ignores the private incentives of regulators. The private-interest theory or economic theory of regulation views regulators as individuals who seek to maintain political power by exchanging policy decisions for votes (Stigler, 1971; Peltzman, Levine and Noll, 1989; Downs, 1957). A prediction of this theory is that well-organized producer interest groups which can facilitate votes and financial resources will often dominate dispersed consumer interest groups due to lower information and organizational costs. Interest groups will utilize the coercive power of regulators to extract rents at the expense of others. Regulatory decisions face imperfect information for both voters and regulators. The implications of policies are highly uncertain and individuals utilize subjective models to inform their decisions. Political ideologies and beliefs can be influential in determining policy as a result (North, 1990).

Theories of regulation have evolved to explain deregulation or removal of regulation from an industry (Peltzman, Levine and Noll, 1989). Public-interest theory suggests removal of regulation from an industry may be a result of changing technologies which eliminate market failures and make regulation unnecessary to maximize social welfare. Private-interest theory explains removal of regulation due to the changing political influence of producer or consumer interest groups. Finally, changes in the ideologies or beliefs of voters and legislators can lead to removal of regulation.

I investigate the determinants of cannabis legalization in this paper. I utilize a logit model to conduct an event history analysis which estimates the impact of political, economic, and social factors which influence the probability a state will pass a cannabis law.[31] The model does not provide an exhaustive consideration of

[31] This may equivalently be referred to as a duration model or hazard model. The logit estimation is suggested as it provides the discrete time approximation of the Cox proportional hazards model (Cox, 1975).

all of the potential motivating factors which contribute to cannabis policy decisions. The results of this paper should be interpreted as providing insight into the correlation between these factors and motivations behind legalization of cannabis. I expand on previous research by classifying recreational and CBD extract laws in addition to medical cannabis laws. I estimate the determinants of heterogeneous characteristics of cannabis laws to explore various motivations for regulatory decisions. The results of this paper provide insight into theories of regulation and why regulators may seek to remove regulation in an industry.[32]

Political and religious ideologies are found to be strong predictors of cannabis legalization. Greater control of a state government by the Republican party and greater percentage of religious adherents significantly reduce the probability of legalization. This is consistent with the results of previous studies which find greater Republican support or conservative ideologies predict reduced support for legalization. This provides evidence in favor of the importance of ideology and subjective models for determining regulation argued by Downs (1957) and North (1990). Consumption of alcohol and cigarettes are additionally found to be strong predictors of legalization. This provides support for the private interest theory of regulation in which consumer or producer interest groups are influential in affecting the policy choices of regulators.

VI. Previous Literature

Public-interest theory predicts the removal of regulation due to advancements in the cannabis industry which mitigate the external costs of use including addiction and crime. This does not appear to be a likely. Regulators' concerns regarding external costs persist. Appropriations for tax revenue generated by the cannabis industry in Colorado include funding for law enforcement and health professional training as well as substance abuse prevention to address these costs.[33] Public-interest theory may still be useful in explaining cannabis legalization. Improvement in information regarding the social welfare implications of cannabis regulation through experience over the past decades could influence removal of regulation. Pro-

[32] This estimation strategy is used frequently to study the determinants of policy choices. See for example Berry and Berry (1990); Aidt and Jensen (2009); Calcagno, Walker and Jackson (2010).

[33] See the Colorado Joint Budget Committee's "Appropriations Report Fiscal Year 2018-19." https://leg.colorado.gov/publications/fy-2018-19-appropriations-report

hibition has unintended consequences which reduce the efficacy of regulation and increase violent crime through the illegal cannabis market (Miron, 1998). Cannabis legalization may be influenced by the desire to mitigate the external costs of prohibition.

Private-interest theory predicts the removal of regulation from the cannabis industry is explained through the changing political influence of interest groups concerned with cannabis. The shift in influence between interest groups could be explained by changing organizational and information costs which permit more diffuse groups supporting cannabis legalization to contend with producer interest groups in related industries (Peltzman, Levine and Noll, 1989). Prohibition does not reflect the same environment of anti-competitive policy used to explain regulation in other industries. Producers and consumers of cannabis are entirely eliminated from the legal market. Private-interest groups in related industries may still explain the maintenance of strict regulation of cannabis. Research has found cannabis to be a substitute good for alcohol and cigarettes (Baggio, Chong and Kwon, 2017; Miller and Seo, 2018; Choi, Dave and Sabia, 2018; Irvine, 2019). Interest groups in industries including alcohol, cigarettes, law enforcement, and pharmaceuticals have contributed to anti-legalization efforts (Cohen, 2014). Removal of cannabis regulation can therefore be explained by the increased influence of cannabis consumer or producer interests groups in facilitating votes or financial resources to politicians. Recent legalization efforts have found significant favorable consumer interest group support (Hamilton, 2016).

The will of regulators' constituents can influence cannabis policy. Median voter models explore politicians' positions on public policy as a means to appeal to the median voter to sustain political power (Downs, 1957). Voters affect public policy through periodic elections in which representatives are held accountable to their policy choices. There may be significant restrictions on the ability for constituents to influence policy, however, as elections prove to be a "very dull instrument"(North, 1990; Lee, Moretti and Butler, 2004). Constituents' views on cannabis legalization have evolved substantially over the past decades. Gallup reports public support for cannabis legalization in the United States has climbed from 12% in 1969 to 66% in 2018 (McCarthy, 2018). Public support will influence cannabis policy to the extent which politicians represent their constituents' interests and the extent which support for cannabis legalization will influence election results. Voters will have relatively large influence on cannabis policy in instances where policy is decided through ballot provisions rather than through the state legislature.

Changes in ideologies and beliefs of regulators and their constituents can explain removal of cannabis regulations. Ideology played a significant role in the prohibition of cannabis. It is widely argued that anti-immigrant sentiments were a substantial factor in promoting prohibition in the early 1900's (Bonnie and Whitebread, 1970). The political ideologies associated with the Republican and Democratic parties could explain motivations for cannabis legalization. Deregulation in other industries is often argued on the grounds of efficiency of the free market and is associated with the Republican party. Removal of regulation in cannabis is associated with the Democratic party however. This may be a result of the social conservatism of the Republican party which is associated with opposition to activities like intoxication and gambling (Calcagno, Walker and Jackson, 2010). Religious ideology could additionally explain motivation for legalization. A greater religious population is found to be a strong predictor for opposition to legalization (Caulkins et al., 2012).

Political scientists additionally consider the diffusion of public policy to geographic neighbors as an important consideration for determinants of regulation (Berry and Berry, 1990). Observing the cannabis policy of close neighbors can eliminate significant uncertainty and information costs regarding the impact of cannabis legalization. Regulators could pursue legalization due to neighboring states' impact on constituents views and to compete with neighboring states' policies.

Past research has investigated the determinants of state medical cannabis laws. Hall and Schiefelbein (2011) provides the first estimates of the determinants of medical cannabis laws. It is found that medical cannabis laws are inversely related to church attendance, percentage of republican voters, and economic freedom as measured by the Fraser Institute. The authors do not account for heterogeneity in cannabis laws. Variation in cannabis policy can influence access and use of cannabis, and therefore the welfare impact of the policy. Determinants of cannabis laws are likely to vary with different legal provisions as a result. The provisions which have the greatest influence on public health and welfare are defined in Pacula, Boustead and Hunt (2014). Laws are classified according to their patient registry provisions, permissible medical uses of cannabis, and availability of cannabis supply. These classifications are utilized to explore determinants of legalization in Hunt and Saloga (2013). It is found that heterogeneity in cannabis laws do influence political determinants. Church attendance is found to be negatively related to cannabis laws which permit a dispensary or pharmaceutical supply system, but positively related to laws which permit cannabis use for research purposes.

Determinants of public support for cannabis legalization in the U.S., Uruguay, and El Salvador is explored in Cruz, Queirolo and Boidi (2016). The authors find higher levels of education are positively related to support for legalization. They also find that the percentage of individuals who consider religion important in their lives is negatively related to public support for cannabis legalization. Public support for legalization will potentially influence the adoption of cannabis laws. Additional determinants of cannabis laws are explored in Bradford and Bradford (2017). The authors estimate an event history analysis using a probit regression. The authors find medical cannabis laws in neighboring states are positively related to legalization. They do not find a significant relationship between legalization and the incidence of AIDS. Nevertheless, the prevalence of medical conditions may be likely to influence a state's medical cannabis laws. I expand on this research by considering heterogeneous characteristics of cannabis policy.

VII. Legal History

Federal prohibition of cannabis effectively began with the Marijuana Tax Act of 1937. The act did not explicitly prohibit the sale or use of cannabis. Registered physicians were allowed to prescribe and transfer cannabis to patients. The large fines and penalties imposed for violating the act created tremendous risk however (Meier, 1994). The act imposed de facto prohibition of cannabis until it was declared unconstitutional in 1969 with Leary v. United States. The act was quickly replaced by the Controlled Substances Act (CSA) of the Comprehensive Drug Abuse Prevention and Control Act of 1970. The CSA classified cannabis as a Schedule I controlled substance. This made it illegal for any individual to manufacture, distribute, or possess cannabis in the United States.[34]

The decisions to federally prohibit cannabis was controversial. The Congressionally appointed National Commission on Marihuana and Drug Abuse recommended criminality of cannabis possession imposed by the CSA was too strict of a punishment compared to the actual and potential harms of cannabis use (Nahas and Greenwood, 1974). A number of states responded by decriminalizing cannabis during the 1970's. California, Colorado, and Oregon are among the early states states which passed legislation removing incarceration and criminal records from the available punishments for possessing small amounts of cannabis (Scott, 2010). Alaska addressed prohibition more dramatically with the Alaska Supreme Court's decision in Ravin v. State 1975. The court decided that individuals have the right to possess and use small amounts of cannabis in their homes under their right to privacy provided by the Alaska State Constitution. Efforts were undertaken in the late 70's to establish medical cannabis research programs. Georgia, Maine, Minnesota, and New Mexico passed legislation permitting a medical cannabis program. These programs were mostly ineffective. New Mexico did establish an effective research program at this time. The Lynn Pierson Therapeutic Research Program was enacted in 1978. There were 180 participants in the program by 1983 (McNeill, 1983). The program ended in 1986 due to a lack of funding. Medical cannabis gained some traction in the state of Washington in 1979 with the decision in State v. Diana. The decision provided conditions under which an individual charged with cannabis possession may defend themselves from prosecution by asserting cannabis was medically necessary to minimize the effects of multiple sclerosis.

Efforts to remove regulations on cannabis stagnated in the 1980's before increasing drastically in the 1990's. These efforts coincide with public support for cannabis legalization. Generational turnover contributes to greater support for legalization due to greater cannabis use and experience among younger birth cohorts. There is additionally significant changes in support for legalization within birth cohorts over time. Changes in views on cannabis could be explained through experience with the negative consequences of

[34]21 U.S.C. § 812

prohibition and evolving arguments in favor of legalization including mitigating violent crime in the illicit market as well as providing cannabis for potential medical uses (Caulkins et al., 2012). Changes in public support may also be a consequence of changing religious ideology. The percentage of individuals in the United States which identify as Christian is declining while the percentage which does not affiliate with a religion is increasing (Cooperman, 2015). This should increase public support for cannabis as religious ideology is found to be a strong predictor for opposition to cannabis policy (Hall and Schiefelbein, 2011; Hunt and Saloga, 2013).

The establishment of effective state-wide medical cannabis programs started with California's Compassionate Use Act of 1996. The act permitted physicians to recommend cannabis to patients with any illness for which cannabis provides relief. Individuals with a physician recommendation are permitted to grow cannabis to treat their illness. Alaska, Maine, Oregon, and Washington soon followed California by establishing their own medical cannabis programs in the late 1990's. Washington D.C. additionally passed a ballot initiative legalizing medical cannabis with Initiative 59 in 1998. Government employees were initially prohibited from counting the ballot vote, however, and the issue of legalizing medical cannabis in Washington D.C. was postponed for over a decade.

States do not have the ability to authorize cannabis use in violation of federal law. Producers and consumers operating in accordance with state law have nevertheless faced prosecution from federal law enforcement including the Drug Enforcement Agency (Hymon, 2007). Federal enforcement of cannabis prohibition evolved in 2009. The Obama administration announced it would cease law enforcement raids on medical cannabis dispensaries (Johnston and Lewis, 2009). The Department of Justice released the "Ogden Memo" advising federal prosecutors not to utilize resources on the prosecution of medical cannabis use which is undertaken in compliance with state laws (Ogden, 2009). These decisions reduced the risk of undertaking medical cannabis use and strengthened confidence in state policies. A majority of states which permit medical cannabis passed legalization in the years following the change in federal enforcement.

Legalization of cannabis expanded beyond medical use in 2012 with the passage of recreational cannabis laws in Colorado and Washington. This permitted individuals twenty-one and older to purchase cannabis products at licensed dispensaries. Individuals in Colorado are additionally permitted to cultivate small amounts of cannabis in their home. The expansion of recreational cannabis laws to states such as California, Nevada, and Massachusetts since 2012 means that roughly a quarter of the US population lives in a state which permits recreational cannabis use (Hansen, Miller and Weber, 2018).

Recent legislation has focused on the legality of CBD extracts. Nineteen states passed legislation legalizing CBD extracts in some form at the state level since 2014. Legality of CBD extracts in all states became an issue of some contention with the Agricultural Act of 2014. The act permits states to cultivate industrial hemp for research purposes through institutions of higher education or through the state's department of agriculture. The act defined hemp as any part of the cannabis plant with a THC concentration of no more than 0.3%. The definition lead to significant confusion as CBD extracts may be produced with THC concentrations below this threshold. A number of retailers throughout the United States began selling CBD products under the belief that they are legally permitted to sell these products as hemp. Nevertheless, retailers of CBD extracts were in violation of federal law. First, CBD extracts were not being produced through an institution of higher education or through the department of agriculture. Second, the extracts are a derivative of cannabis which fell under the definition of marijuana as a schedule I controlled substance. Some retailers experienced raids and arrests as a result. Federal law concerning CBD extracts and hemp evolved with the Agricultural Improvement Act of 2018. The act expanded hemp production to licensed cultivators approved by the state or federal government. Extracts of CBD are now included in the definition of hemp. Extracts produced by a licensed cultivator in accordance with the Farm Bill as well as federal and state regulations are now exempt from Schedule I controlled substances status (Hudak, 2018).

VIII. Data

A. Cannabis Laws

Cannabis legislation exhibits significant heterogeneity between states which can impact the scale or effectiveness of the law. I account for this heterogeneity by classifying cannabis laws according to the criteria provided in Pacula, Boustead and Hunt (2014). All cannabis laws which materially alter the classifications for a state are included through January 1st, 2019. Classifications are expanded to recreational cannabis and CBD extract laws where relevant. This information is listed in Tables 7 - 10. There are a number of differences in my classification tables. These differences are detailed in the appendix.

Cannabis laws are classified according to their registry provisions, qualifying conditions for patients, and supply provisions. A patient registry system is relevant for medical cannabis and CBD extract programs. Registry provisions are classified according to the legal protections provided to patients. Some laws require patients to register in order to receive any legal protection for medical cannabis use. These laws are listed as “No Protection” to refer to laws which provide no legal protection if not registered. Other laws allow unregistered qualifying patients an affirmative defense to a prosecution related to cannabis if they have satisfied certain conditions. These laws are classified as “Some Protection.” Finally, some laws do not include registry provisions.

Qualifying conditions for patients are also relevant for both medical cannabis and CBD extract programs. A majority of cannabis laws require that a patient has a diagnosable medical condition. These typically specify a list of qualifying conditions such as cancer, AIDS, and multiple sclerosis. These laws will be classified as “Diagnosed.” Alternatively, laws may permit medical cannabis use for patients to treat chronic pain of unknown causes. These laws will be classified as “Chronic Pain.” In both instances, a state may decide to give physicians more discretion in recommending cannabis. This means a patient may receive a recommendation for cannabis for any diagnosable medical condition or for undiagnosed chronic pain when deemed appropriate by a physician. These laws will be classified under “Physician.”

Table 7—Medical Cannabis Law Registry Provisions and Qualifying Conditions

			Registry		Qualifying Conditions		
State	Law	Enacted	Some Protection	No Protection	Diagnosed	Chronic Pain	Physician
Alaska	Measure 8	1998	✓		✓		
	SB-94	1999		✓	✓		
Arizona	Prop. 200	1996					✓
	Prop. 203	2010	✓		✓		
Arkansas	Issue 6	2016		✓	✓		
California	Prop. 215	1996				✓	✓
	SB-420	2003	✓			✓	✓
Colorado	Amend 20	2000	✓		✓		
	HB-1284	2010	✓		✓		
	SB-109	2010	✓		✓		
	HB-1043	2011	✓		✓		
Connecticut	HB-5389	2012		✓	✓		
Delaware	SB-17	2011	✓		✓		
Washington DC	Initiative 59	1998			✓		✓
	B 18-622	2010		✓	✓		
	B 20-766	2014		✓	✓		✓
Florida	Amend 2	2016		✓	✓		✓
Hawaii	SB-862	2000		✓	✓		
	HB-321	2015		✓	✓		
Illinois	HB-1	2013		✓	✓		
Louisiana	SB-143	2015		✓	✓		
	SB-271	2017		✓	✓		
	HB-579	2018		✓		✓	
Maine	Question 2	1999			✓		
	LD-611	2002			✓		
	Question 5	2009	✓		✓		
	LD-1811	2010	✓		✓		
	LD-1296	2011	✓		✓		
Maryland	HB-702	2003					
	SB-308	2011			✓		✓
	HB-1101	2013			✓		✓
	HB-881	2014			✓		✓
Massachusetts	Question 3	2012	✓		✓		✓
Michigan	Proposal 1	2008	✓		✓		
	HB-4209	2015	✓		✓		
Minnesota	SF-2470	2014		✓	✓		
		2015		✓		✓	
Missouri	Amendment 2	2018	✓		✓		✓
Montana	I-148	2004	✓		✓		
	SB-423	2011		✓		✓	
	I-182	2016		✓		✓	
Nevada	Question 9	2000			✓		
	AB-453	2001	✓		✓		
	SB-374	2013	✓		✓		
New Hampshire	HB-573	2013		✓	✓		
	HB-157	2017		✓		✓	
New Jersey	S-119	2010	✓		✓		
New Mexico	SB-523	2007		✓	✓		
New York	SB-7923	2014	✓		✓		
North Dakota	Measure 5	2016		✓	✓		
	SB-2344	2017		✓	✓		
Ohio	HB-523	2016	✓			✓	
Oklahoma	Question 788	2018		✓			✓
Oregon	Measure 67	1998	✓		✓		
	HB-3460	2013	✓		✓		
Pennsylvania	SB-3	2016		✓		✓	
Rhode Island	SB-710	2006	✓		✓		
	SB-185	2009	✓		✓		
Utah	Prop. 2	2018	✓			✓	
	HB-3001	2018	✓			✓	
Vermont	S-76	2004		✓	✓		
	SB-17	2011		✓	✓		
Washington	Initiative 692	1998				✓	
	SB-5073	2011				✓	
West Virginia	SB-386	2017		✓		✓	

* This table displays the registry provisions and qualifying conditions of medical cannabis patients for state medical cannabis laws. "Some Protection" denotes some legal protection if not registered to use medical cannabis and "No Protection" denotes mandatory registry requirements to receive legal protection. "Diagnosed" denotes qualifying conditions to use medical cannabis must be a diagnosed condition while "Chronic Pain" allows pain of unknown cause to qualify a patient to use medical cannabis. "Physician" denotes laws in which physicians have discretion in determining if cannabis is appropriate to treat a diagnosed condition or chronic pain.

Table 8—Medical Cannabis Law Supply Provisions

State	Law	Enacted	Home Cultivation	Dispensary	Pharmacy	State Legislature	Ballot
Alaska	Measure 8	1998	✓				✓
	SB-94	1999	✓			✓	
Arizona	Prop. 200	1996			✓		✓
	Prop. 203	2010	✓	✓			✓
Arkansas	Issue 6	2016		✓			✓
California	Prop. 215	1996	✓				✓
	SB-420	2003	✓	✓		✓	
Colorado	Amend 20	2000	✓				✓
	HB-1284	2010	✓	✓		✓	
	SB-109	2010	✓	✓		✓	
	HB-1043	2011	✓	✓		✓	
Connecticut	HB-5389	2012		✓	✓	✓	
Delaware	SB-17	2011		✓		✓	
Washington DC	Initiative 59	1998	✓	✓			✓
	B 18-622	2010		✓		✓	
	B 20-766	2014		✓		✓	
Florida	Amend 2	2016		✓			✓
Hawaii	SB-862	2000	✓			✓	
	HB-321	2015	✓	✓		✓	
Illinois	HB-1	2013		✓		✓	
Louisiana	SB-143	2015			✓	✓	
	SB-271	2017			✓	✓	
	HB-579	2018			✓	✓	
Maine	Question 2	1999	✓				✓
	LD-611	2002	✓			✓	
	Question 5	2009	✓	✓			✓
	LD-1811	2010	✓	✓		✓	
	LD-1296	2011	✓	✓		✓	
Maryland	HB-702	2003				✓	
	SB-308	2011				✓	
	HB-1101	2013			✓	✓	
	HB-881	2014		✓	✓	✓	
Massachusetts	Question 3	2012	✓	✓			✓
Michigan	Proposal 1	2008	✓				✓
	HB-4209	2015	✓	✓		✓	
Minnesota	SF-2470	2014		✓		✓	
		2015		✓			
Missouri	Amendment 2	2018	✓	✓			✓
Montana	I-148	2004	✓				✓
	SB-423	2011	✓			✓	
	I-182	2016	✓	✓			✓
Nevada	Question 9	2000					✓
	AB-453	2001	✓			✓	
	SB-374	2013	✓	✓		✓	
New Hampshire	HB-573	2013		✓		✓	
	HB-157	2017		✓		✓	
New Jersey	S-119	2010		✓		✓	
New Mexico	SB-523	2007		✓		✓	
New York	SB-7923	2014		✓		✓	
North Dakota	Measure 5	2016	✓	✓			✓
	SB-2344	2017		✓		✓	
Ohio	HB-523	2016		✓		✓	
Oklahoma	Question 788	2018	✓	✓			✓
Oregon	Measure 67	1998	✓				✓
	HB-3460	2013	✓	✓		✓	
Pennsylvania	SB-3	2016		✓		✓	
Rhode Island	SB-710	2006	✓			✓	
	SB-185	2009	✓	✓		✓	
Utah	Prop. 2	2018	✓	✓			✓
	HB-3001	2018			✓	✓	
Vermont	S-76	2004	✓			✓	
	SB-17	2011	✓	✓		✓	
Washington	Initiative 692	1998					✓
	SB-5073	2011	✓			✓	
West Virginia	SB-386	2017		✓		✓	

* This table displays the supply provisions of medical cannabis laws as well as their means of passage through a state legislature or ballot. "Home Cultivation" denotes laws which allow medical patients to cultivate cannabis for personal use. "Dispensary" denotes laws which establish a formal system of retail dispensaries. "Pharmacy" denotes laws which supply medical cannabis through a licensed pharmacist.

Table 9—Recreational Cannabis Law

State	Law	Enacted	Home Cultivation	Dispensary	Ballot
Alaska	Measure 2	2014	✓	✓	✓
California	Prop 64	2016	✓	✓	✓
Colorado	Amend 64	2012	✓	✓	✓
Washington DC	Initiative 71	2014	✓		✓
Maine	Question 1	2016	✓	✓	✓
Massachusetts	Question 4	2016	✓	✓	✓
Michigan	Proposal 1	2018	✓	✓	✓
Nevada	Question 2	2016	✓	✓	✓
Oregon	Measure 91	2014	✓	✓	✓
Vermont	H-511	2018	✓		
Washington	Initiative 502	2012		✓	✓

* This table displays supply provisions for recreational cannabis laws. "Home Cultivation" denotes laws which allow individuals to cultivate cannabis for personal use. "Dispensary"" denotes laws which establish a formal system of retail dispensaries.

Table 10—CBD Extract Law

State	Law	Enacted	Some Protection	No Protection	Diagnosed	Chronic Pain	Physician	Dispensary	Pharmacy
Alabama	SB-174	2014			✓				✓
	HB-61	2016			✓				✓
Florida	SB-1030	2014		✓	✓			✓	
Georgia	HB-1	2015		✓	✓				✓
	HB-65	2018		✓		✓			✓
Indiana	HEA-1148	2017		✓	✓				
Iowa	SF-2360	2014		✓	✓				
	HF-524	2017		✓		✓		✓	
Kansas	SB-282	2018							
Kentucky	SB-124	2014					✓		✓
Mississippi	HB-1231	2014					✓		✓
Missouri	HB-2238	2014		✓	✓			✓	
North Carolina	HB-1220	2014		✓	✓				✓
Oklahoma	HB-2154	2015			✓				✓
South Carolina	SB-1035	2014			✓				✓
South Dakota	SB-95	2017			✓				✓
Tennessee	SB-2531	2014			✓				✓
Texas	SB-339	2015		✓	✓			✓	
Utah	HB-105	2014		✓	✓				
	HB-197	2018		✓	✓			✓	
Virginia	HB-1445	2015			✓				
	SB-1027	2017	✓		✓				✓
	HB-1251	2018	✓		✓		✓		✓
Wisconsin	AB-726	2014			✓				✓
	SB-10	2017					✓		✓
Wyoming	HB-32	2015		✓	✓				

* This table displays registry provisions, qualifying conditions, and supply provisions for CBD extract laws. "Some Protection" denotes some legal protection if not registered to use CBD extracts and "No Protection" denotes mandatory registry requirements to receive legal protection. "Diagnosed" denotes qualifying conditions to use CBD extracts must be a diagnosed condition while "Chronic Pain" allows pain of unknown cause to qualify a patient to use CBD extracts. "Physician" denotes laws in which physicians have discretion in determining if CBD extracts is appropriate to treat a diagnosed condition or chronic pain. "Dispensary" denotes laws which establish a formal system of dispensaries while "Pharmacy" denotes laws which supply CBD extracts through a licensed pharmacist. All CBD extract laws are enacted through the state legislature.

Supply provisions are relevant for all cannabis legislation. Cannabis may be supplied through home cultivation or through licensed dispensaries. Laws which allow home cultivation permit individuals to grow a small number of plants. Individuals in Colorado are permitted to grow up to 6 plants with no more than 3 mature plants which produce usable cannabis for example. Some states place strong restrictions on home cultivation. Arizona and North Dakota permit home cultivation only for patients who live a sufficient distance away from the nearest licensed dispensary. Laws establishing dispensary systems allow for the licensing of retail centers to provide cannabis to patients. A number of states require these dispensaries operate as non-profit organizations. Some states severely restrict the number of licensed cannabis producers and retailers. Other states do not establish a licensing system for dispensaries, and instead allow for cannabis to be supplied at a pharmacy or research institution. It is also not uncommon for cannabis laws to include no provisions to supply or obtain cannabis in the state.

Cannabis laws have been passed through both state legislatures and ballot initiatives. This should influence the probability a cannabis law is passed. Voter's preferences are likely to have less of an impact on the policy decision of legislators. This is due to the "rational ignorance" of voters (Downs, 1957; Peltzman, Levine and Noll, 1989). A voter will have imperfect information regarding the policy decisions which their regulator will face and the welfare implications of these decisions. There are substantial costs to obtaining information on these implications compared to the relative benefit of an individual's vote in deciding an election. This significantly reduces the incentive for a voter to inform themselves of the consequences of election outcomes. Additionally, voters ability to affect policy choices in the instance they are informed of an election's consequences is a "dull instrument" (North, 1990). The influence of voters should be higher with ballot initiatives. The cost of obtaining information on the welfare implications of a single policy is substantially lower and should lead to more informed voters. Cannabis laws passed through ballot initiatives should more directly reflect the preferences of constituents. I explore differences in the determinants of ballot approved and state legislature approved cannabis laws.

B. Determinants

State characteristics which can impact the probability of passing a cannabis law are collected. A number of important characteristics face constraints on data availability. Determinants of legalization are estimated from 1996-2016 as a result. Many characteristics are unavailable for the District of Columbia. The District of Columbia is excluded from estimation. The sample used in estimation includes legalization for twenty-nine of the thirty-three states which have passed medical cannabis laws. Table 11 reports summary statistics for state characteristics used in estimation.

Table 11—State Summary Statistics 1996-2016

Variable	Mean	Standard Deviation	Minimuim	Maximum
Household Income (2016 $'s)	56,320	8,828	35,850	82,954
Unemployment Rate (%)	5.5	1.9	2.3	13.7
Bachelor's Degree (%)	26.7	5.1	14.2	42.7
Population	5,944,632	6,554,952	488,167	39,250,016
Population Density (/sq. mile)	188.47	252.31	1.00	1205.89
Elderly (% 65+)	13.25	2.02	4.96	19.87
Non-White (%)	17.32	12.03	1.68	70.42
Female (%)	50.72	0.77	47.66	52.02
Hispanic (%)	9.42	9.58	0.51	48.53
Republican Control	0.53	0.38	0	1
Single Party Control	0.54	0.50	0	1
Religious (%)	52.75	10.98	29.28	77.62
State Budget$_{t-1}$	0.07	0.16	-0.76	1.25
Murder Rate (/100,000)	4.8	2.5	0.6	17.5
Alcohol Consumption	2.36	0.50	1.23	4.77
Cigarette Consumption	69.2	30.1	14.0	186.8
Prison Population (/100,000)	3.87	1.51	0.93	8.78
Police Officers (/100,000)	210	43	136	400
AIDS Diagnoses (/100,000)	9.2	8.2	0.5	72.3
Cancer Diagnoses (/100,000)	507.8	66.2	292.3	658.8
Drug Overdoses (/100,000)	12.8	6.0	2.0	49.8
Border Medical Law (%)	20.99	28.37	0	100

* This table displays the summary statistics for the independent variables used in estimation for all states between 1996-2016. Republican Control refers to the fraction of the state government under control by the Republican party while Single Party Control indicates full control of the state government by the Republican or Democratic party. State Budget is measured as the fraction of the state budget relative to total spending. Alcohol consumption is the average annual per capita consumption of ethanol in gallons. Cigarette consumption is the average annual per capita consumption of cigarette packs.

The influence of private-interest producer groups in alcohol, cigarettes, and law enforcement are considered.[35] The incentive for producers in these industries to lobby against cannabis legalization depends on the available welfare which can be extracted through anti-competitive regulation. I use the average consumption of alcohol and cigarettes in a state as proxies for the strength of these interest groups in combating legalization.[36] Alcohol consumption is measured as the annual gallons of ethanol consumed per capita in a state as measured by the National Institute on Alcohol Abuse and Alcoholism (Haughwout and Slater, 2018). Cigarette consumption is measured as the annual per capita number of cigarette packs consumed in a state as provided by the Center for Disease Control (CDC). Greater consumption of these products suggests greater incentive for opposing legalization and should reduce the probability of passing a cannabis law. Alternatively, consumption of these products could coincide with constituents preferences for recreational substances. Greater consumption of alcohol and cigarettes could suggest a greater preference for substitutable cannabis and increase the probability of legalization.

I measure the influence of law enforcement interest groups by considering the prison population and the number of police officers employed in a state. Higher prison populations and number of officers imply a greater incentive for organizations to lobby against cannabis legalization to maintain funding. Alternatively, greater prison populations and employment of officers could positively influence cannabis legalization through constituents' preferences to reduce imprisonment for cannabis related crimes and greater employment of police officers could increase concerns regarding law enforcement costs. I control for the prison population and number of full time equivalent police officers per 100,000 individuals in a state. Prison data is provided by the Bureau of Justice statistics and is retrieved from Rand State Statistics. Employment of police officers is retrieved from the Census Annual Survey of Government Employment and Payroll.

The prevalence of medical conditions which are potentially alleviated by cannabis and permit medical cannabis use should be important in determining the passage of cannabis laws. Potential cannabis patients

[35] Private-interest groups in cannabis are not included. Producer private-interest groups in cannabis are historically essentially nonexistent. There is minimal information regarding the potential for cannabis producers to lobby regulators on their behalf. These groups are not considered as a result. Consumer private-interests in cannabis are influential in determining cannabis policy. Previous use of cannabis is considered to measure this impact. Data on previous cannabis use at the state and year level is available from the National Survey on Drug Use and Health between 2002-2015. This sample eliminates a substantial number of states which approve medical cannabis and makes identification of the determinants difficult. Previous cannabis use is excluded from estimation as a result.

[36] Proxies for the lobbying efforts of private-interest groups are estimated. The actual monetary contribution of these interest groups to support or oppose cannabis policy would provide the ideal measure for the influence of private-interest groups.

may be viewed as consumer private-interest groups which lobby regulators to permit medical cannabis. I measure the prevalence of AIDS and invasive cancer conditions per 100,000 individuals in a state to consider this impact. Data on incidence of AIDS and cancer are provided through the CDC and are retrieved from Rand State Statistics. Greater prevalence of these conditions should be positively related to the passage of cannabis laws if these interest groups are effective in influencing regulators and voters.

Consumers of cannabis may substitute use away from other drugs. Chronic pain is frequently listed as a qualifying condition for medical use. Cannabis is permitted in some states specifically in cases where there are concerns regarding opiate use for pain management. Researchers find medical cannabis legalization is negatively associated with rates of opiate addiction and overdoses (Bachhuber et al., 2014; Powell, Pacula and Jacobson, 2018). I measure the rate of drug overdoses in a state per 100,000 individuals to explore whether this influences regulation. Data on overdoses are provided through the CDC.

Crime rates are considered as determinants of cannabis laws which seek to remove external costs of prohibition. Miron (1998) suggests prohibition increases violent crime through informal markets in which agreements are enforced through violence in the absence of a judicial system. The rates of violent crime and murder are considered. Crime rates are provided by the U.S. Department of Justice's Uniform Crime Reporting Statistics. Data are retrieved through the Correlates of State Policy Project (Jordan and Grossmann, 2016). Higher crime rates imply greater costs of prohibition and should increase the probability of passing a cannabis law to improve social welfare.

The political party of the governor and the majority political party in the state house and senate are used to control for the ideological views of a state's constituents and regulators. Data on the political party of the state government are provided by the Correlates of State Policy Project (Jordan and Grossmann, 2016). This information is transformed into the fraction of the state government composed of the governorship, senate, and house which is under republican control. Full control of the state government by a single political party is also indicated to explore changes in the likelihood of adopting cannabis laws under full control by a political party. These are the same controls are used to explore determinants of banking deregulation in Kroszner and

Strahan (1999).[37] Previous literature suggests Republican control of government reduces the probability of approving cannabis legalization.

I follow the literature on event history analysis by including a measure of the state's fiscal health. The state budget could influence regulators' and constituents' views through concerns regarding public debt. The state budget could additionally determine the resources available to regulators to address cannabis policy (Bradford and Bradford, 2017). I measure the impact of fiscal health as a state's budget given by total revenue less expenditure in a year. I divide the states' budget by the level of expenditure to make estimates comparable across states. I use the measure of fiscal health in the preceding year to investigate the impact of fiscal health on cannabis policy following Berry and Berry (1990). A budget deficit could increase the probability of legalization if regulators believe the cannabis industry will raise significant revenue.

Religion is additionally found to be a strong determinant of views regarding legal cannabis. The percentage of a state's population which adheres to a religious congregation as well as the population which attends church are considered to measure constituents' ideological views. The percentage of a state population which adheres to a religious congregation is calculated through data provided by the Association of Religion Data Archives. The longitudinal data file merges information on the count of religious congregations and their members every ten years (Quinn et al., 1982; Bradley, 1992; Jones, 2002; Grammich et al., 2010). The data suffer from issues of missing observations, varying survey reporting methods, and the merger or schism of religious congregations over time. These methodological issues are detailed in Bacon, Finke and Jones (2018). I account for missing data on congregations by linearly interpolating and extrapolating religious adherent counts where this is possible. This provides a measure of the number of religious adherents in a state for the years 1990, 2000, and 2010. I use these values to linearly interpolate and extrapolate the number of religious adherents in a state for all years from 1996-2016. This provides an approximation of the number of religious adherents in a state. There are significant concerns regarding the accuracy of these numbers

[37] A variety of additional political controls are considered. This includes individual indicators for Republican control of the state governorship, senate, and house as well as political ideology variables including the DW-Nominate measure of congressional ideology provided at Lewis et al. (2018) and the ideology of a state's citizens and state regulators defined in Berry et al. (1998). All political controls provide qualitatively similar results.

when measuring the number of religious adherents in a state and year. I additionally consider the percentage of a state's population which attends a Church, Synagogue, or Mosque at least once a week or almost once a week. This percentage is calculated through survey data provided by Gallup Analytics. The data cover church attendance from 2008-2016. I supplement this data using information provided in Newport (2006) which provides average church attendance by state between 2004 and 2006. Church attendance for 2007 is found through linear interpolation. This provides the church attendance measure used in Hunt and Saloga (2013). The religious population of a state controls for the ideological views of a state's constituents and is expected to reduce the probability of passing a cannabis law.

The views of constituents' as well as their preference for cannabis use may vary with a state's demographics. Controls for population, population density, age, race, sex, ethnicity, education, unemployment, and household income at the state and year level are included to account for these differences. Demographic data are provided by the U.S. Census Bureau's Population Estimates Program and American Community Surveys. Population density is expressed as the average number of individuals per square mile. I control for age by considering the percentage of the population which is over the age of 65. I control for race by considering the percentage of the population which is non-white. Census questions regarding race are not uniform over the sample period. Race responses available in the 1990 Census are White, Black, American Indian/Alaskan Native, Asian, and other. Race responses in subsequent Census surveys permit multiple race responses and add the Hawaiian/Pacific Islander category. I use the bridged Census race estimates provided by the CDC to utilize comparable estimates of race across years. The CDC bridges race responses by estimating the probability individuals responding to a later Census would identify race according to the responses available in the 1990 Census. Variables are re-scaled for reporting purposes. Estimation is conducted using household income expressed in thousands of dollars. Population is expressed using millions of people. And population density is expressed in units of one-hundred individuals per square mile. The impact of policy diffusion from neighboring states is considered by measuring the percentage of bordering states which have passed a similar cannabis policy.

C. Methodology

The event history analysis measures the hazard rate which refers to the conditional probability a state passes a cannabis law in a year given the state has not previously passed such a law (Berry and Berry, 1990). The dependent variable indicates whether or not a state has passed a cannabis law for all years up to and including the year of passage. A state drops out of the sample in subsequent years. The assumption is that policy changes are lasting events that cannot be repeated.[38] I follow Beck, Katz and Tucker (1998) by estimating the event history analysis using a logit model with year fixed effects. The authors recommend the logit model as the discrete time approximation of the Cox proportional hazards model (Cox, 1975).

$$P(y_{st} = 1 \mid x_{st}) = \Lambda(\alpha + x_{st}^{'}\beta + \delta_t) \tag{15}$$

Variable y_{st} indicates whether state s has implemented a cannabis law in year t, variables x_{st} denote state characteristics which influence the probability of implementing a cannabis law, and δ_t denotes year fixed-effects controlling for changes in the probability of cannabis legalization over time. Distribution Λ denotes the logistic CDF.[39]

IX. Results

The estimation results for the determinants of all medical cannabis laws are reported in Table 12. I include year fixed effects and demographic controls in every specification. The results for the full sample from 1996-2016 are listed in columns (1) - (3). Column (1) includes only controls for ideology given by the political party of the state government and the religious population of a state. Column (2) includes the public interest control given by the murder rate and private interest group controls given by alcohol consumption,

[38] The possibility that cannabis legalization can be repealed and repeated in later years is also considered. Estimation is conducted when states do not exit the sample following legalization. Results are qualitatively similar under this assumption.

[39] Estimation is additionally conducted using a probit model. Results are qualitatively similar with nearly identical marginal effects.

cigarette consumption, prison population, and incidence of AIDS. Column (3) includes the percentage of bordering states which have passed medical cannabis legalization to explore whether cannabis laws diffuse to neighboring states.

The probability a state passes a medical cannabis law decreases with a greater fraction of the state government controlled by the Republican party and with a greater percentage of religious adherents.[40] This suggests the ideologies and beliefs of a state are important determinants of cannabis policy. Cigarette consumption is negatively associated with medical cannabis laws. This is consistent with the hypothesis that producers of cigarettes want to maintain prohibition of cannabis to extract rents at the expense of cannabis producers and consumers. Alcohol consumption is positively associated with medical cannabis law. This is not consistent with the private interest theory of alcohol producers maintaining prohibition of cannabis. Instead, this may reflect the preferences of state voters for intoxicating substances. This is consistent with the hypothesis that voters consider the ability to obtain medical cannabis to be a substitute for alcohol and support cannabis legalization.

Columns (4) - (6) of Table 12 repeat the same estimation and include the incidence of cancer and drug overdoses in a state. The sample is reduced due to the data availability for these variables. The years 1999-2015 are used for this estimation. This eliminates ten of the twenty-nine states which approved medical cannabis prior to 1999 or in 2016. The total population, unemployment rate, and the percentage of the population which is over the age of 65 are found to decrease the probability of passing a medical cannabis law. The murder rate is positive and significant in the specification which excludes border medical cannabis laws. This is consistent for regulators seeking to maximize social welfare by mitigating the external impact of prohibition on violent crime. The coefficient on border medical cannabis laws is negative and significant. This could suggest legislators gain information from their neighbors regarding the negative impacts of medical cannabis legalization and reduces the probability of passing such a policy. Precaution must be taken inter-

[40] I use the percentage of religious adherents in a state calculated from the data provided by the Association of Religious Data Archives. This measure is preferred as it encompasses all years in the sample. Using the percentage of the population which attends church calculated by Gallup provides qualitatively similar results.

TABLE 12—DETERMINANTS OF MEDICAL CANNABIS LEGALIZATION

	Medical Cannabis Legalization					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	0.0008	-0.0016	-0.0019	-0.0011	-0.0054	-0.0051
	(0.0017)	(0.0021)	(0.0022)	(0.0019)	(0.0043)	(0.0043)
Unemployment Rate	0.0112**	0.0059	0.0064	0.0101	-0.0058	-0.0127**
	(0.0050)	(0.0073)	(0.0075)	(0.0085)	(0.0063)	(0.0063)
Bachelor's	0.0047*	0.0044	0.0048	0.0070**	0.0054	0.0059
	(0.0025)	(0.0031)	(0.0035)	(0.0033)	(0.0085)	(0.0084)
Population	-0.0004	0.0002	0.0005	-0.0043	-0.0052	-0.0072***
	(0.0019)	(0.0020)	(0.0021)	(0.0027)	(0.0033)	(0.0023)
Population Density	0.0021	0.0063	0.0068	0.0032	0.0105	0.0028
	(0.0031)	(0.0044)	(0.0048)	(0.0034)	(0.0102)	(0.0070)
Elderly	0.0026	-0.0038	-0.0029	-0.0053	-0.0392**	-0.0404***
	(0.0038)	(0.0054)	(0.0056)	(0.0082)	(0.0167)	(0.0097)
Non-White	-0.0005	-0.0007	-0.0005	0.0002	-0.0000	-0.0010
	(0.0006)	(0.0007)	(0.0008)	(0.0008)	(0.0014)	(0.0015)
Female	-0.0185	0.0034	-0.0002	-0.0159	-0.0079	0.0314
	(0.0201)	(0.0283)	(0.0311)	(0.0222)	(0.0507)	(0.0528)
Hispanic	0.0017**	-0.0006	-0.0007	0.0017**	0.0003	0.0016*
	(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0010)	(0.0009)
Republican Control	-0.0526**	-0.0472*	-0.0470*	-0.0754***	-0.0736***	-0.0745***
	(0.0228)	(0.0248)	(0.0242)	(0.0245)	(0.0213)	(0.0204)
Single Party Control	-0.0033	-0.0055	-0.0036	-0.0076	-0.0119	-0.0161
	(0.0164)	(0.0157)	(0.0157)	(0.0198)	(0.0179)	(0.0230)
Religious	-0.0034***	-0.0040***	-0.0038***	-0.0040**	-0.0076***	-0.0110***
	(0.0012)	(0.0013)	(0.0013)	(0.0016)	(0.0016)	(0.0035)
State Budget$_{t-1}$		0.0188	0.0307		-0.0534	-0.1055
		(0.0811)	(0.0834)		(0.0658)	(0.0687)
Murder Rate		0.0092	0.0094		0.0148***	0.0064
		(0.0058)	(0.0058)		(0.0051)	(0.0047)
Alcohol Consumption		0.0680***	0.0621***		0.0922***	0.1471***
		(0.0195)	(0.0216)		(0.0334)	(0.0354)
Cigarette Consumption		-0.0020***	-0.0019***		-0.0030***	-0.0044***
		(0.0006)	(0.0006)		(0.0005)	(0.0011)
Prison Population		-0.0031	-0.0039		-0.0053	0.0027
		(0.0083)	(0.0086)		(0.0086)	(0.0099)
Police Officers		-0.0004	-0.0004		-0.0001	0.0004
		(0.0002)	(0.0003)		(0.0004)	(0.0004)
AIDS Diagnoses		-0.0016	-0.0016		-0.0028	-0.0014
		(0.0019)	(0.0019)		(0.0021)	(0.0013)
Border Medical Law			0.0002			-0.0014***
			(0.0003)			(0.0003)
Cancer Diagnoses					0.0009***	0.0010***
					(0.0003)	(0.0004)
Drug Overdoses					0.0005	0.0037
					(0.0038)	(0.0041)
Observations	797	797	797	574	574	574

* This table displays average marginal effects of the logit regression for all medical cannabis laws. Years 1996-2016 are used for the first three columns. Years 1999-2015 are used for the final three columns due to the data availability for cancer and overdose rates. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

preting these variables. Restricting the sample to the years 1999-2015 eliminates important observations by excluding early states to legalize medical cannabis. These columns nevertheless show the incidence of cancer in a state increases the probability of legalizing medical cannabis. This is consistent with regulators who appeal to patients who may require medical cannabis to alleviate the symptoms of chemotherapy. Results which compare the influence of including cancer diagnoses and overdose rates on the samples 1999-2015 and 1996-2016 are displayed in Tables A3 - A4 with a discussion included in the appendix.

The results of Table 12 show no evidence that cannabis policy diffuses to nearby neighbors as found in Bradford and Bradford (2017). It may be the case that states already obtain greater knowledge of the impact of medical cannabis policy from other U.S. states regardless of their proximity. There is also no evidence that the incidence of AIDS diagnoses in a state increases the probability of medical cannabis laws. Patients suffering from AIDS may be unable to sufficiently influence regulators. Rates of drug overdoses are similarly found to be insignificant in determining cannabis policy. However, there is evidence that cancer rates increase the probability of passing medical cannabis laws, providing some evidence that interest groups which hope to use medical cannabis to treat their qualifying conditions have a significant impact on regulators.

Table 13 compares the determinants of medical cannabis laws passed through ballot initiative with those passed through the state legislature. The percentage of religious adherents and consumption of cigarettes remain negative in both instances. The number of police officers in a state is a significant negative determinant of ballot approved cannabis law. This is consistent with private interests in police employment lobbying constituents against approving medical cannabis. The political party of the state government is only a significant determinant of state legislature approval. This suggests the political ideology of state representatives is influential for their policy decisions but not for the decision of their constituents. The coefficient on single party control of the state government is surprisingly negative and significant. This suggests greater probability of passing medical legalization through the state legislature under split control of the state government between Republicans and Democrats. The coefficient on the state budget is negative and significant for state legislature approval. This is consistent with legislators who are concerned with the state budget and seek to raise additional revenue through the cannabis industry. Finally, the coefficient on the murder rate is positive and significant for state legislature approval. This is again consistent with regulators who seek to eliminate the external impact of prohibition on violent crime in the state.

The heterogeneous provisions of medical cannabis laws are considered in Table 14. The probability of passing a medical cannabis law which permits either home cultivation of cannabis or establishes a formal dispensary system is considered. Religious ideology is found to be an important determinant of the probability of permitting home cultivation, while the political party of the state government is found to be an important determinant in opposing the formation of a formal dispensary system. The incidence of AIDS in a state is surprisingly found to be negatively associated with the formation of a formal dispensary system.

Estimation which accounts for the registry provisions and qualifying medical conditions of medical cannabis laws in addition to recreational cannabis and CBD extract laws is reported in the appendix. Registry provisions and qualifying conditions appear to be minor considerations in determining medical cannabis policy. Insufficient observations for states which have approved recreational cannabis make identification of the determinants of legalization difficult. And the motivations behind CBD extract laws appear to differ significantly from those of medical and recreational cannabis laws. A discussion is included along with the results in the appendix.

TABLE 13—DETERMINANTS OF BALLOT AND STATE LEGISLATURE APPROVED MEDICAL CANNABIS LEGALIZATION

	Ballot Approval			State Legislature Approval		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	-0.0003	-0.0007	-0.0008	0.0007	-0.0027	-0.0025
	(0.0013)	(0.0011)	(0.0011)	(0.0014)	(0.0017)	(0.0019)
Unemployment Rate	0.0034	0.0054	0.0056	0.0057	-0.0149	-0.0158
	(0.0032)	(0.0057)	(0.0060)	(0.0048)	(0.0172)	(0.0161)
Bachelor's	0.0018	0.0010	0.0011	0.0023	0.0004	-0.0000
	(0.0018)	(0.0014)	(0.0016)	(0.0033)	(0.0016)	(0.0025)
Population	0.0021	0.0020	0.0020	-0.0026**	-0.0016	-0.0015
	(0.0025)	(0.0013)	(0.0014)	(0.0013)	(0.0013)	(0.0012)
Population Density	0.0031	0.0041	0.0041	-0.0000	0.0142*	0.0140
	(0.0042)	(0.0033)	(0.0032)	(0.0024)	(0.0083)	(0.0087)
Elderly	0.0004	-0.0003	-0.0002	0.0038	-0.0115**	-0.0122*
	(0.0028)	(0.0020)	(0.0021)	(0.0042)	(0.0056)	(0.0068)
Non-White	-0.0009	-0.0011**	-0.0011*	0.0009	0.0005	0.0005
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0005)	(0.0006)
Female	-0.0227	-0.0180	-0.0180	0.0052	0.0441	0.0476
	(0.0231)	(0.0138)	(0.0139)	(0.0081)	(0.0344)	(0.0315)
Hispanic	-0.0003	-0.0004	-0.0005	0.0011**	-0.0012	-0.0012
	(0.0015)	(0.0009)	(0.0009)	(0.0005)	(0.0009)	(0.0010)
Republican Control	-0.0150	-0.0045	-0.0048	-0.0486***	-0.0743***	-0.0749***
	(0.0201)	(0.0207)	(0.0206)	(0.0124)	(0.0231)	(0.0216)
Single Party Control	0.0055	0.0147	0.0150	-0.0071	-0.0422**	-0.0436***
	(0.0070)	(0.0158)	(0.0166)	(0.0134)	(0.0165)	(0.0141)
Religious	-0.0020***	-0.0020**	-0.0020**	-0.0008	-0.0047**	-0.0047**
	(0.0008)	(0.0008)	(0.0008)	(0.0011)	(0.0023)	(0.0022)
State Budget$_{t-1}$		0.0297	0.0334		-0.0774**	-0.0776**
		(0.0367)	(0.0395)		(0.0357)	(0.0354)
Murder Rate		0.0043	0.0043		0.0192*	0.0190*
		(0.0037)	(0.0036)		(0.0112)	(0.0115)
Alcohol Consumption		0.0161	0.0156		0.0992***	0.1008***
		(0.0141)	(0.0126)		(0.0329)	(0.0299)
Cigarette Consumption		-0.0008**	-0.0008**		-0.0034*	-0.0035**
		(0.0004)	(0.0004)		(0.0019)	(0.0017)
Prison Population		-0.0136	-0.0137		0.0049	0.0055
		(0.0125)	(0.0128)		(0.0058)	(0.0056)
Police Officers		-0.0003*	-0.0003*		-0.0003	-0.0003
		(0.0001)	(0.0001)		(0.0002)	(0.0003)
AIDS Diagnoses		0.0000	0.0000		-0.0071	-0.0073
		(0.0008)	(0.0008)		(0.0058)	(0.0055)
Border Medical Law			0.0000			-0.0001
			(0.0002)			(0.0003)
Observations	797	797	797	797	797	797

* This table displays average marginal effects of the logit regression for medical cannabis laws passed either through a ballot initiative or through a state legislature. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TABLE 14—DETERMINANTS OF MEDICAL CANNABIS SUPPLY PROVISIONS

	Home Cultivation			Dispensary System		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	-0.0006	-0.0011	-0.0009	0.0005	-0.0007	-0.0010
	(0.0010)	(0.0012)	(0.0015)	(0.0012)	(0.0014)	(0.0016)
Unemployment Rate	0.0066	0.0061	0.0060	0.0027	-0.0014	-0.0015
	(0.0042)	(0.0045)	(0.0046)	(0.0044)	(0.0057)	(0.0056)
Bachelor's	0.0035**	0.0028	0.0025	0.0021	0.0008	0.0013
	(0.0017)	(0.0021)	(0.0023)	(0.0018)	(0.0033)	(0.0038)
Population	0.0007	0.0001	0.0000	-0.0013	0.0002	0.0002
	(0.0031)	(0.0032)	(0.0034)	(0.0018)	(0.0017)	(0.0014)
Population Density	0.0037	0.0051*	0.0049	0.0016	0.0089**	0.0096**
	(0.0032)	(0.0029)	(0.0030)	(0.0026)	(0.0036)	(0.0042)
Elderly	0.0038	0.0011	0.0009	0.0104***	0.0065	0.0072
	(0.0031)	(0.0053)	(0.0055)	(0.0039)	(0.0044)	(0.0046)
Non-White	-0.0003	0.0002	0.0000	-0.0006*	-0.0007	-0.0006
	(0.0004)	(0.0005)	(0.0006)	(0.0003)	(0.0005)	(0.0007)
Female	-0.0326*	-0.0209	-0.0196	-0.0030	0.0025	-0.0025
	(0.0185)	(0.0156)	(0.0188)	(0.0141)	(0.0213)	(0.0273)
Hispanic	-0.0006	0.0002	0.0003	0.0025***	0.0014*	0.0013
	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0008)	(0.0008)
Republican Control	0.0010	0.0220	0.0188	-0.0576***	-0.0670***	-0.0655***
	(0.0188)	(0.0193)	(0.0203)	(0.0204)	(0.0206)	(0.0196)
Single Party Control	-0.0057	-0.0044	-0.0034	0.0104	0.0185	0.0189
	(0.0084)	(0.0104)	(0.0108)	(0.0122)	(0.0152)	(0.0151)
Religious	-0.0016**	-0.0015**	-0.0016**	0.0001	-0.0008	-0.0007
	(0.0007)	(0.0006)	(0.0007)	(0.0007)	(0.0010)	(0.0011)
State Budget$_{t-1}$		0.0252	0.0190		-0.0102	-0.0097
		(0.0427)	(0.0469)		(0.0518)	(0.0519)
Murder Rate		0.0004	0.0005		0.0104**	0.0112**
		(0.0023)	(0.0023)		(0.0045)	(0.0049)
Alcohol Consumption		0.0154	0.0185**		0.0445***	0.0415***
		(0.0101)	(0.0092)		(0.0137)	(0.0147)
Cigarette Consumption		-0.0002	-0.0003		-0.0007	-0.0007
		(0.0003)	(0.0003)		(0.0007)	(0.0007)
Prison Population		-0.0087	-0.0087		0.0012	0.0004
		(0.0067)	(0.0075)		(0.0056)	(0.0058)
Police Officers		-0.0003**	-0.0003*		-0.0000	-0.0000
		(0.0002)	(0.0002)		(0.0002)	(0.0002)
AIDS Diagnoses		0.0002	0.0001		-0.0048*	-0.0047*
		(0.0009)	(0.0010)		(0.0025)	(0.0025)
Border Medical Law			-0.0002			0.0001
			(0.0003)			(0.0003)
Observations	873	873	873	958	958	958

* This table displays average marginal effects of the logit regression for medical cannabis laws which either permit home cultivation of cannabis or establish a formal dispensary system. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

X. Conclusion

The results of the event history analysis for medical cannabis laws in the United states suggest a variety of motivations for their passage based on the factors which correlate with legalization. The political party of the state government as well as the number of religious adherents in a state are found to be strong determinants of cannabis policy. Republican governments and more religious states strongly oppose legalization. There is some evidence that higher crime rates increase the probability of legalization. This is consistent with the hypothesis that regulators seek to mitigate the external costs of prohibition. Consumption of related goods in alcohol and cigarettes are found to be significant predictors of cannabis policy. Alcohol consumption is positively related to cannabis legalization. This does not fit the hypothesis that alcohol producers seek to maintain anti-competitive prohibition of cannabis. Instead, this may suggest preferences by constituents for intoxicating substances for which cannabis is a substitute for alcohol. Cigarette consumption is negatively related to cannabis legalization. This is consistent with the hypothesis that cigarette producers seek to maintain prohibition of cannabis. There is some evidence that the incidence of health conditions which may be alleviated through medical cannabis use influence cannabis legalization. Higher cancer rates are associated with increased probability of passing medical cannabis laws. Finally, I find no evidence that cannabis policy diffuses to neighboring states. Overall, the results indicate that private interests and the ideology of a state's constituents and regulators are important predictors of the probability a state passes cannabis legalization.

Further research on cannabis regulation could utilize the monetary contributions of private-interest groups who lobby in support or opposition of legalization to directly estimate the influence of these groups on regulators and voters. Estimation could focus on the voting patterns of legislators and constituents to explore differences in determinants for laws which passed with larger majorities. Finally, different models for event history analyses could be utilized to directly explore the timing of adoption in addition to the probability of adoption in a particular year as estimated in this paper.

Chapter 3

The Impact of Legal Cannabis on Traffic Fatalities: Evidence from Colorado Licensing Data

Legalization of medical or recreational cannabis is a frequent topic of debate among policy-makers in recent decades. Legalization has significant welfare implications. Cannabis can be effective at treating or mitigating the symptoms of medical conditions.[41] The potential for pain relief and substitutability with opiate drugs can reduce opiate addiction and overdose deaths (Bachhuber et al., 2014; Powell, Pacula and Jacobson, 2018). Legal markets provide income and tax revenue to a state. This reduces the size of the black market for cannabis and can mitigate the negative consequences of prohibition including violent crime (Miron and Zwiebel, 1995; Miron, 1998). Legalization raises concerns regarding external costs of use including negative health impacts and addiction. Cannabis could serve as a gateway drug which leads to subsequent use of other drugs including cocaine and opiates (DeSimone, 1998; Van Ours, 2003; Bretteville-Jensen and Jacobi, 2011). Legalization increases opportunities for individuals to access cannabis and increases consumption (Jacobi and Sovinsky, 2016). This can increase impaired driving. Legal cannabis may impose substantial welfare costs on society through increased fatal traffic accidents. This issue is explored in this paper.

It is feared that cannabis legalization has lead to increased fatal traffic accidents in Colorado (Migoya, 2017). These fears may be well founded. Cannabis is associated with impaired cognitive function involved in driving including impaired working memory, motor skills, and the ability to perform divided-attention tasks (Bondallaz et al., 2017). Driving simulation and road experiments primarily find cannabis intoxication increases variability of lane position and headway. Cannabis additionally impairs distance perception and reaction time. It is uncertain whether these impacts cause greater frequency of fatal traffic accidents. The effects of cannabis on driving may be mitigated to some degree by compensating behaviors of cannabis

[41] The U.S. Food and Drug Administration (FDA) has approved the prescription drug Epidiolex containing the cannabidiol (CBD) extract of the cannabis plant for treatment of severe epileptic conditions for example.

impaired drivers including reduced speed and increased following distance while driving (Kelly, Darke and Ross, 2004). Evidence of cannabis impairment's impact on frequency of collisions has been less conclusive than that of alcohol impairment, though the combination of both cannabis and alcohol impairment does have the potential to promote greater risk of accidents compared to impairment of either substance alone (Sewell, Poling and Sofuoglu, 2009). There are additional measurement concerns in determining the impact of cannabis on fatal accidents. Measurable THC from cannabis in an individual is found to be an imperfect measure of impairment (Compton et al., 2017). Drivers who have tested positive for THC following a fatal accident may not be impaired. Levels of THC may be detected in a consumer weeks following use (Berning and Smither, 2014).

This paper investigates the impact of available cannabis supply on monthly fatal traffic accidents within Colorado counties. The availability of legal cannabis is measured according to the number of licensed dispensaries and registered medical cannabis patients in a county. The data provide an advantage over previous research. Estimation is conducted within the state of Colorado. This alleviates concerns regarding heterogeneous state laws which influence fatal traffic accidents as well as variation in state alcohol and cannabis testing procedures following a fatal accident. The ability to consider this issue at the county and month level can provide greater identification of the impact of cannabis supply on fatal traffic accidents. Finally, the wealth of information regarding the available legal supply of cannabis in a county provides a measure of the degree to which a county is exposed to legal cannabis. This provides a more direct measure of the ability for drivers to consume cannabis compared to controlling for the incidence of cannabis laws. Fatal traffic accidents are a relatively infrequent occurrence for a county-month observation. I utilize a Poisson fixed effects model to account for the non-negative integer values of the outcome variables.

The results of this paper provide insight into the welfare implications of cannabis laws. This can inform regulators and voters in the debate surrounding legalization. Medical and recreational cannabis laws have expanded to a majority of states. Thirty-three states and the District of Columbia permit medical use while ten states and the District of Columbia permit recreational use.[42] These policies face significant uncertainty however. State legalization is incompatible with federal prohibition. Changes in federal enforcement could eliminate the efficacy of these policies. State regulators can choose to repeal cannabis laws in response to improved knowledge regarding to costs of legalization. Local governments may additionally choose to restrict the availability of legal cannabis through their authority to determine licensing constraints or taxes.

Previous research has investigated the impact of cannabis laws on traffic fatalities. Mark Anderson, Hansen and Rees (2013) provides the first estimates of the relationship between medical cannabis laws and traffic fatalities. The authors find legalization of medical cannabis is associated with a decrease in traffic fatalities of 8-11% in the first year. Results are larger and more significant for accidents involving alcohol and accidents occurring on nights and weekends. These results suggest traffic fatalities decline due to cannabis serving as a substitute to alcohol. This does not suggest driving under the influence of cannabis is safer than alcohol. Individuals are permitted to consume alcohol in public settings while cannabis use is restricted to private settings. This provides greater opportunity for alcohol consumers to drive while impaired. Santaella-Tenorio et al. (2017) provide evidence supporting this hypothesis that medical cannabis laws reduce traffic fatalities through reduced alcohol-impaired driving. The authors find evidence that states which enacted medical cannabis laws experienced immediate and persistent declines in traffic fatalities for individuals aged 25 to 44. The authors additionally consider the impact of states which have an active dispensary supply system on traffic fatalities and find qualitatively similar results compared to the impact of enacting any medical cannabis law.

Contrasting results have been found. Salomonsen-Sautel et al. (2014) explores the impact of the commercialization of medical cannabis in Colorado rather than the enactment of the law. Commercialization occurs in 2009 due to the state of Colorado rejecting limits on the number of medical patients to which caregivers could cultivate and provide cannabis. This spurred the formation of medical cannabis dispensaries. The authors find commercialization of cannabis in Colorado resulted in a significant increase in the proportion of

[42] These numbers are accurate through January 1st, 2019.

fatal traffic accidents which were cannabis related, while there is no significant change in the number of accidents which were alcohol related. Pollini et al. (2015) explore the impact of decriminalization of cannabis in California on traffic measures. The authors discover decriminalization is associated with increased cannabis related fatal accidents.

Recreational cannabis legalization may have more significant impacts compared to medical cannabis legalization due to the increased ability to access legal cannabis. Recreational cannabis laws provide access to individuals aged 21 and older and do not require qualifying medical conditions or registration. The impact of recreational cannabis legalization is explored in Aydelotte et al. (2017). The authors find no significant change in traffic fatalities following recreational legalization in Colorado and Washington. Hansen, Miller and Weber (2018) find similar results. The authors find no significant change in cannabis-related, alcohol-related, and overall fatal traffic accidents following recreational legalization.

Previous research investigates the impact of medical or recreational laws on fatal traffic accidents in a state compared to those which prohibit cannabis. This paper estimates the impact of increased local availability of cannabis within a state which has passed medical and recreational legalization. Results may differ from previous studies as a result. It is possible that the impact of legalization on fatal traffic accidents is imposed primarily through the passage of the law at the state level and changes in the number of licensed dispensaries or registered individuals have minimal impact on availability and consumption in a county.

XI. Background

Colorado permits cannabis for medical and recreational use. Voters approved Amendment 20 legalizing medical cannabis in Colorado on November 7th, 2000. This amended the Colorado Constitution to permit medical use of cannabis for individuals with debilitating medical conditions who have received a recommendation from a physician stating that the individual may benefit from the use of cannabis in connection with their debilitating condition. Examples of appropriate debilitating conditions include cancer, glaucoma, and HIV. Medical use of cannabis requires registration with the state identifying the qualifying patient. These patients are permitted to possess up to two ounces of usable cannabis and to grow up to six plants with up to three mature plants which produce usable cannabis flower. Concerns regarding the lack of regulatory environment surrounding cannabis lead to the passage of HB-1284 in 2010. This created a formal system of dispensaries which can provide cannabis to qualifying patients.

State cannabis laws exhibit significant heterogeneity (Pacula, Boustead and Hunt, 2014). Colorado permits physicians to recommend cannabis for diagnosed medical conditions which produce cachexia, severe pain, nausea, seizures, and muscle spasms. Some states permit medical use only for specified medical conditions such as cancer and HIV. Other states including California and Washington permit physicians to recommend cannabis to treat chronic pain of unknown cause. These laws additionally have varying supply provisions. States may permit cannabis to be supplied through home cultivation, dispensaries, or pharmacies. Some state medical laws simply do not allow for any intrastate supply, though they may allow for individuals to access cannabis legally in other states. Heterogeneous provisions will influence access and use of cannabis. The impact of legal cannabis markets on individual states will likely vary as a result.

Colorado voters approved recreational cannabis with the passage of Amendment 64 on November 6th, 2012. This permitted licensed cultivators, product manufacturers, and retailers to provide recreational cannabis to individuals twenty-one and older. Sales of recreational cannabis in Colorado began in January 2014. These ballot measures have permitted the formation of extensive dispensary supply systems. There are 473 medical centers and 549 recreational dispensaries licensed to operate in the state as of January 2nd, 2019.[43] Counties and cities may decide whether or not to permit licensing of medical and recreational facilities. This creates significant geographic variation in the presence of available legal cannabis supply. Counties which licensed a medical or recreational dispensary through 2017 are depicted in Figures 5 and 6 respectively.[44]

[43] https://www.colorado.gov/pacific/enforcement/med-resources-and-statistics

[44] Maps are created in STATA using the county data files provided at https://spot.colorado.edu/ jonathug/Jonathan_E._Hughes/Map_Files.html

Figure 5.

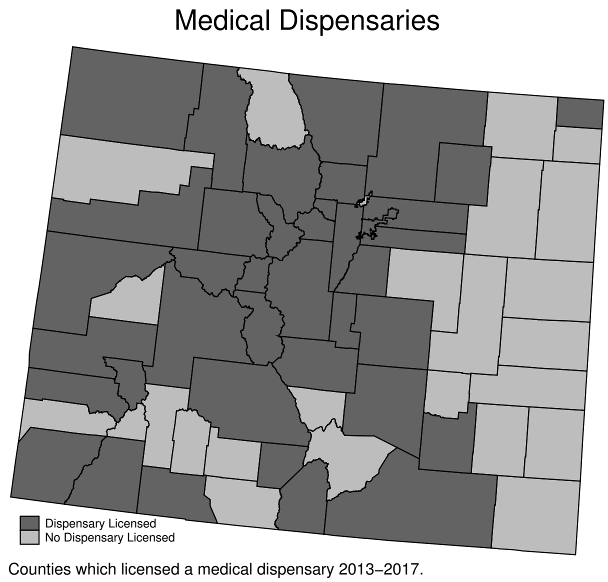
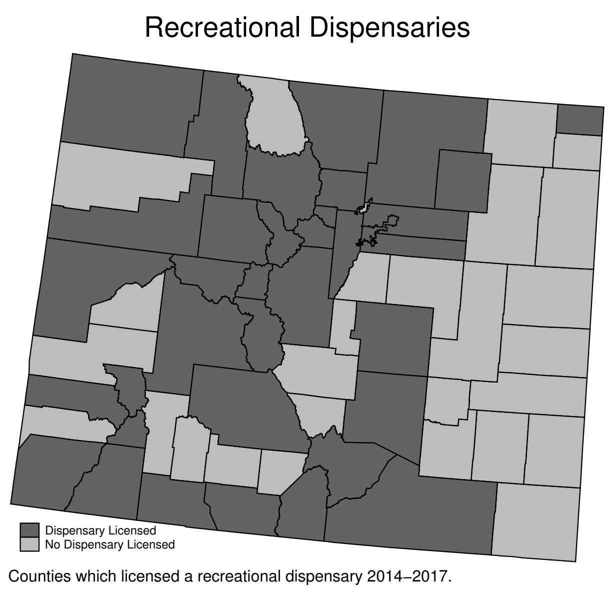


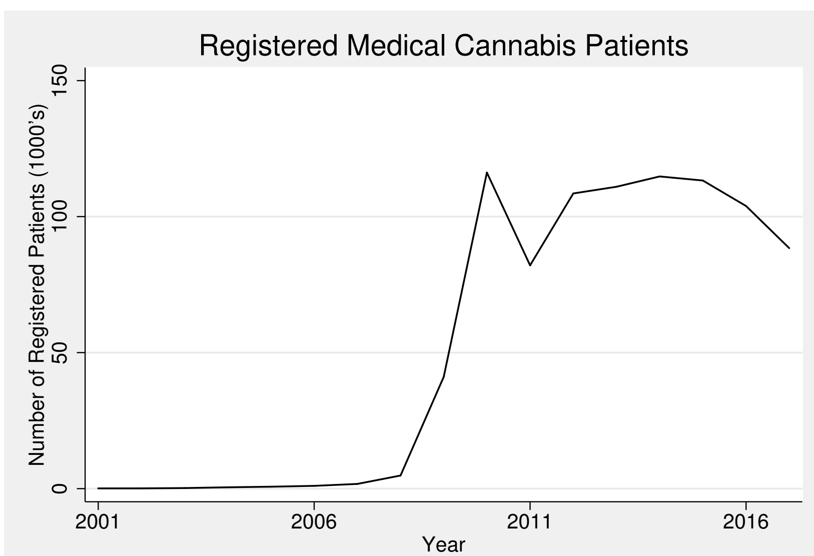
Figure 6.



XII. Data

Information on the available legal supply of cannabis is collected from the Colorado Department of Revenue (CDOR). Three alternative measures for the impact of legal cannabis supply are considered. This includes the number of licensed recreational and medical dispensaries as well as the number of registered medical cannabis patients in a Colorado county. Data are available for the number of registered medical cannabis patients at the county level since 2009. Information is unavailable at the county level for previous years. Data are available at the state level since 2001. The annual number of medical card holders in Colorado is depicted in Figure 7.[45] Data on the number of licensed medical cannabis dispensaries are available since 2013. This information is depicted in Figure 8. Medical cannabis dispensaries operated in Colorado prior to this date. Official licensing of medical dispensaries arose following the passage of HB-1284 in 2010, however operation of these facilities existed in an informal capacity prior to this date. And data on the number of licensed recreational cannabis dispensaries are available since the onset of the adult-use industry in January of 2014. This information is depicted in Figure 9. This issue is explored between years 2009 and 2017. The year 2009 is chosen as the initial year due to the availability of registered medical patient information. This provides a sufficient pre-period for the estimation of the impact of licensed recreational dispensaries. The year 2009 is additionally the beginning of commercialization of medical cannabis in Colorado (Santaella-Tenorio et al., 2017). Years 2013-2017 are considered for the impact of medical dispensaries due to data availability.

FIGURE 7.



Average annual number of registered medical cannabis patients in Colorado 2001–2017.

[45]CDOR reports an application backlog which results in a reduction in the number of registered patients in 2011.

FIGURE 8.

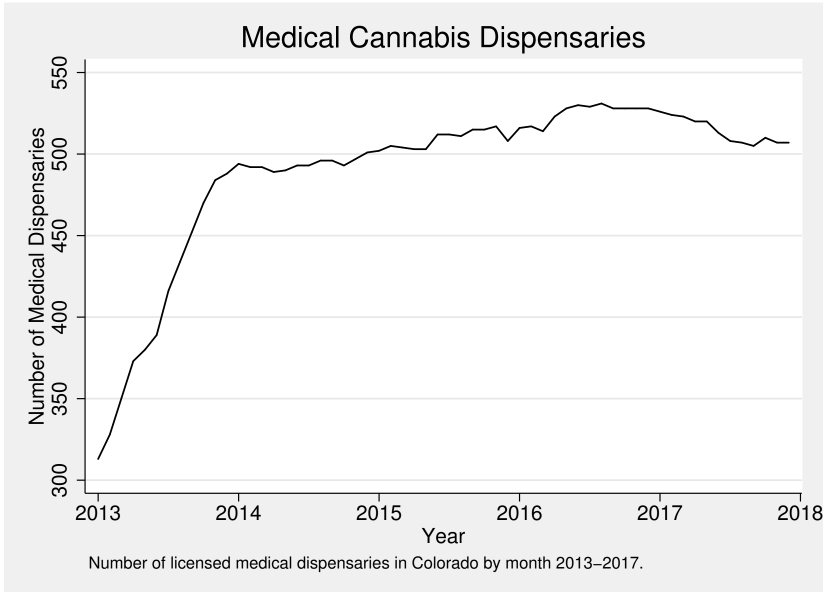
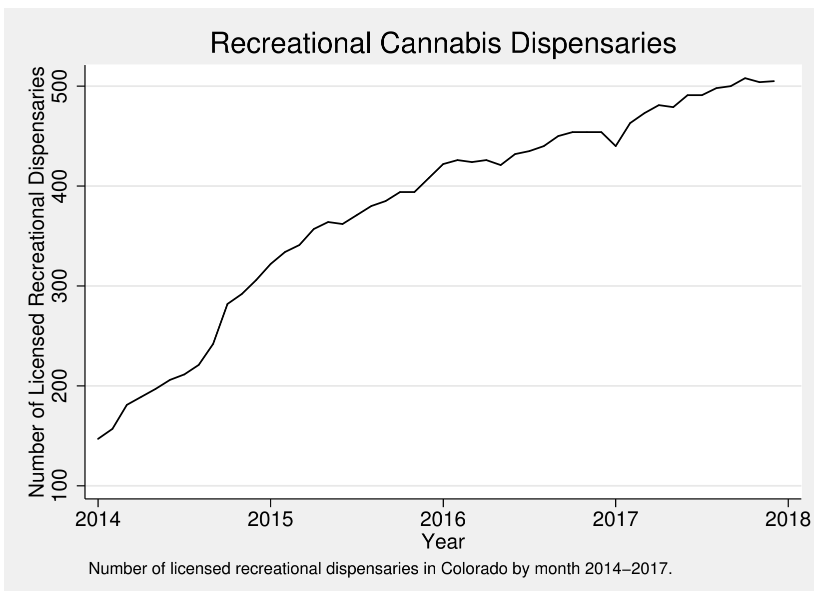


FIGURE 9.



Dispensary licensing information lists the name and address of each licensee in Colorado for each month. Licensees are linked to their respective county. A number of dispensaries are licensed in cities which are unique to a county. Unique city-county combinations are determined using information provided by the Colorado Department of Transportation (CDOT). A large number of dispensaries cannot be linked to a county according to the city of their address. This occurs frequently in the Denver metropolitan area. Street addresses are used to link these licensees to their respective county using the Census Geocoder.[46] Only exact matches between licensing data and Census Bureau addresses are used to determine a licensee county. The county of remaining licensees are determined through individual search using Google Maps. Measures of cannabis supply for an individual county as well as the sum of measures for a county and all of its bordering counties are considered to account for individuals who travel between counties to access legal cannabis.

The number of licensed medical or recreational cannabis dispensaries in a county is an imperfect measure of available legal supply. A dispensary may take some time to become operational following licensing. The number of licensed facilities should nevertheless be strongly correlated with the number of operational cannabis dispensaries in a county. The number of registered medical cannabis patients is considered as an additional measure of medical cannabis supply due to the missing information on medical dispensaries prior to 2013. The number of registered patients provides a valid measure of supply as this determines the number of individuals who are legally permitted to access cannabis at medical dispensaries. This additionally measures the number of individuals who are permitted to cultivate cannabis for personal use in their homes. Accounting for the number of registered patients has the benefit of controlling for available legal supply in counties which prohibit licensing of medical and recreational dispensaries. The number of licensed recreational cannabis dispensaries in a county is my preferred measure of available legal cannabis supply. Data on licensing of recreational dispensaries is provided for the entire length of the recreational market. These dispensaries are likely to have the greatest impact on use. Individuals must only satisfy the age requirement to access cannabis at recreational dispensaries.

CDOR additionally provides information on the collection of taxes as well as sales from the cannabis industry by month for Colorado counties. This provides a more direct measure of the exposure of a county to cannabis supply and consumption. The data are insufficient to estimate the impact of cannabis supply on fatal traffic accidents. Sales and tax revenues may only be reported in counties for which there are at

[46]https://www.census.gov/geo/maps-data/data/geocoder.html

least three taxpayers with no one taxpayer contributing over 80% of the total sales or revenue. This leads to substantial missing observations for counties which are likely to have a strong influence on the results. The licensing of dispensaries is preferred to this measure as a result.

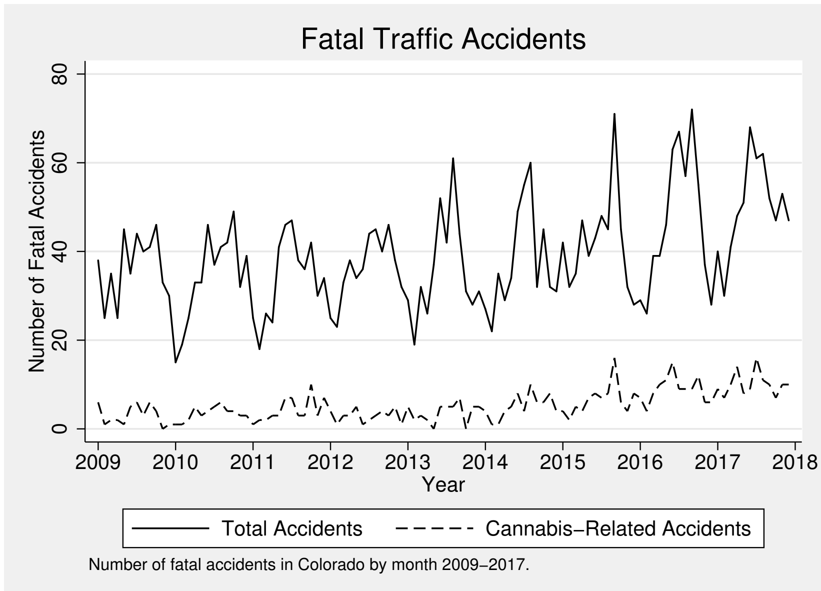
Information on the number of fatal traffic accidents in Colorado counties is provided by the Fatal Analysis Reporting System (FARS) of the United States Department of Transportation. FARS data provide detailed information on all traffic accidents occurring on public traffic-ways which resulted in a fatality within 30 days of the accident. Detailed information is provided for every accident. This includes demographics such as age, race, sex, and ethnicity of individuals involved in the accident. This additionally includes information on the location, timing, and circumstances surrounding the accident including involvement of alcohol and cannabis.

The characteristics of FARS data are utilized to consider a number of alternative dependent variables in addition to overall fatal traffic accidents. I conduct estimation for cannabis and alcohol-related fatal accidents. These are fatal accidents in which at least one driver tested positive for cannabis or alcohol. Figure 10 reports the total number of fatal accidents as well as cannabis-related accidents in Colorado from 2009-2017. Alcohol-related accidents are considered to explore if cannabis supply impacts alcohol intoxicated driving through the substitution of alcohol for cannabis as found in Mark Anderson, Hansen and Rees (2013). Fatal traffic accidents and intoxicated driving are correlated with time-of-day and day-of-week (Berning and Smither, 2014; Dee, 1999). I consider fatal accidents occurring during night and day as well as weekend and weekday.[47] Intoxicated driving is also correlated with age and sex of the driver. I estimate fatal traffic accidents for different age groups and sex of the driver. Cannabis markets can promote inter-county travel and tourism from other states to access legal cannabis. I consider fatal traffic accidents which involve a driver from outside of the county or outside of the state to account for these instances. The zip code of the driver's license is linked to a zip code tabulated area which is then linked to the primary county in which the zip code resides in order to determine out of county drivers. The state of the driver's license is used to

[47] I follow Dee (1999) and define night to be 12:00 - 4:59 AM and day to be 7:00 AM - 2:59 PM. I follow Haines et al. (2003) and define weekdays to be Monday-Thursday and weekends to be Friday-Sunday.

determine out of state drivers. Table 15 lists the summary statistics for select dependent variables reported in the results section.

FIGURE 10.



The number of fatal accidents will be strongly influenced by the degree of vehicle travel which occurs in a county. Information on the average daily vehicle miles traveled on Colorado highways by county and year is provided by CDOT.[48] This is an imperfect measure of vehicle travel. Monitoring of vehicle miles traveled is likely to vary between counties. There may be important differences in the timing in which data are collected. This measure does not account for travel occurring on county streets. Collection procedures for vehicle miles traveled in a county may additionally be correlated with the licensing of cannabis dispensaries as well as local policies which influence fatal traffic accidents. The retail price of gasoline is considered as an additional control for county demand for driving. However, this information is unavailable at the county level. County fixed effects account for the average difference in gasoline prices between counties, while month fixed effects account for the average change in fuel prices over time across counties. This arguably provides sufficient controls for driving demand for the estimation.

[48]http://dtdapps.coloradodot.info/staticdata/downloads/Reports/RoadwayReports/DVMT/

TABLE 15—FATAL TRAFFIC ACCIDENTS SUMMARY STATISTICS

Variable	Mean	Variance	Minimum	Maximum
Fatal Accidents:				
Total	0.61	1.55	0	10
Cannabis	0.08	0.10	0	4
BAC>0	0.18	0.27	0	5
BAC>0.1	0.14	0.19	0	5
Age 15-19	0.06	0.07	0	4
Age 20-29	0.20	0.31	0	6
Age 30-39	0.15	0.22	0	5
Age 40-49	0.13	0.17	0	4
Age 50-59	0.14	0.19	0	5
Age 60+	0.16	0.24	0	6
Out of County Driver Fatal Accidents:				
Total	0.33	0.57	0	8
Cannabis	0.04	0.05	0	3
BAC>0	0.08	0.11	0	4
BAC>0.1	0.06	0.07	0	3

* This table displays summary statistics for measures of monthly fatal traffic accidents in a county between 2009-2017. The variance is reported to provide insight into the dispersion of the outcome variables for the Poisson model. Cannabis refers to accidents in which at least one driver tested positive for cannabis use. BAC>0 and BAC>0.1 refer to accidents in which at least one driver recorded a positive blood alcohol level or a blood alcohol level over 0.1 respectively. Age groups refer to accidents in which at least one driver is in the specified age group. Out of county fatal accidents refer to accidents in which at least one driver has a license with a zip code associated with a county different from the county in which the accident occurred.

Population demographics may influence traffic fatalities due to varying levels of driving and consumption of cannabis. Annual data on population demographics are collected from the United States Census Bureau. Controls for population, sex, age, race, ethnicity, income, education, and unemployment are included. The percentage of the population which is over the age of fifteen is considered to control for the population which can obtain a license to drive. Fatal traffic accidents could be influenced by differences in decisions for driving age individuals to obtain a license to drive over time. Fatal traffic accidents could decline if a greater number of young people choose to forgo obtaining their license. There could be differences in the rate of driving between counties. It is likely the demand for driving varies among young people in rural and urban counties for example. County level data on driver's licenses by age is unavailable. County fixed effects control for the average preference for obtaining licenses by county, and month fixed effects control for average changes in the frequency of obtaining a license to drive over time. Table 16 lists the summary statistics for the control variables used in estimation.

TABLE 16—CONTROL VARIABLES SUMMARY STATISTICS

Variable	Mean	Standard Deviation	Minimum	Maximum
Recreational Dispensaries	6	19	0	177
Medical Dispensaries	8	28	0	212
Medical Registry Cards	1,475	3,373	0	20,186
Vehicle Miles Traveled	1,257,516	1,981,649	20,299	8,538,017
Population	80,088	159,882	489	678,467
Percent Female	48.30	3.77	27.82	57.46
Percent Age 15+	82.25	3.94	69.61	97.01
Percent Non-White	10.06	6.14	0.20	30.16
Percent Hispanic	19.16	14.03	0	65.61
Income (2017 $'s)	30,767	9,104	11,413	77,274
Bachelor's	29.3	13.0	7.0	61.2
Unemployment Rate	7.1	3.5	0.4	28.8

* This table displays county summary statistics for the control variables used in estimation. The summary statistics for medical and recreational dispensaries are calculated for 2013-2017 and 2014-2017 respectively. The remaining summary statistics are calculated between 2009-2017.

XIII. Methodology

I estimate the impact of legal cannabis supply on fatal traffic accidents using fixed-effects regression. Inclusion of county fixed-effects controls for unobserved time-invariant covariates which are potentially correlated with licensing of dispensaries and influence traffic fatalities. Localities which are concerned with regulating the number of licensed dispensaries may be inclined to impose more restrictive speed limits for example. I include time fixed-effects to control for unobserved county-invariant covariates which coincide with the timing of dispensary licensing. State traffic policies or seasonality may influence the incidence of fatal accidents for example.

The number of fatal traffic accidents follows a count process with non-negative integer values. I estimate a fixed-effects Poisson regression model. Fixed-effects count models have focused primarily on the estimation of Poisson and negative binomial regressions. These models are suggested as they do not suffer from the Incidental Parameters Problem in which the inclusion of individual fixed-effects lead to inconsistent coefficient estimates (Cameron and Trivedi, 2005). Poisson models impose the restrictive assumption that the conditional variance of the dependent variable is equivalent to its conditional mean. It is frequently determined that the conditional variance exceeds the conditional mean. This leads to the problem of "overdispersion" in the data in which predicted values understate the true dispersion of the data and predict too few number of zeros compared to what is observed. The negative binomial regression model is suggested as an alternative to Poisson to account for overdispersion (Hausman et al., 1984). However, It is found that the fixed-effects negative binomial model accounts for stable covariates only under a highly restrictive assumption (Allison and Waterman, 2002; Guimaraes, 2008). Estimation of the fixed-effects Poisson model controls for stable covariates and ensures consistent estimation of coefficients under less restrictive assumptions.

Let y_{it} denote the number of fatal traffic accidents, α_i denote county fixed-effects, and x_{it} denote covariates including month fixed effects for county i in month t. The joint density of fatal accidents in a county $y_i = (y_{i1}, ..., y_{iT})$ with $X_i = (x_{i1}, ..., x_{iT})$ is:

(16) $$f(y_i|X_i, \alpha_i, \beta) = \prod_{t=1}^{T} \frac{exp[-\alpha_i exp(x_{it}\prime\beta)][\alpha_i exp(x_{it}\prime\beta)]^{y_{it}}}{y_{it}!}$$

The coefficients β are estimated using maximum likelihood estimation. let $\lambda_{it} = exp(x_{it}\prime\beta)$ and $\bar{\lambda_i} = T^{-1}\sum_t exp(x_{it}\prime\beta)$. Maximization of the log likelihood function with respect to β yields first order conditions:

(17) $$\sum_{i=1}^{N}\sum_{t=1}^{T} x_{it}(y_{it} - \frac{\lambda_{it}}{\bar{\lambda_i}}\bar{y_i}) = 0$$

The restrictive variance assumption of the Poisson distribution will inflate the significance of the coefficients if overdispersion is present in the data. Coefficients β are estimated using quasi-maximum likelihood estimation to relax this assumption. This refers to maximum likelihood estimation under misspecification of the Poisson density. Consistency is maintained when the true data generating process is misspecified (Wooldridge, 1999). This only requires the conditional mean of the Poisson distribution is correctly specified. This requires $E(y_{it}|\alpha_i, x_{it}) = \alpha_i exp(x_{it}\prime\beta)$. Quasi-maximum likelihood estimation equates to estimating the coefficients of the model under the assumption that the data generating process is Poisson and recalculating the variance of the coefficients using a sandwich variance matrix (Cameron and Trivedi, 2005):

$$\hat{V}(\hat{\beta}) = \left[\sum_{i,t} \hat{\lambda_{it}} x_{it} x_{it}\prime\right]^{-1} \sum_{i,t,s} \hat{u_{it}} \hat{u_{is}} x_{it} x_{it}\prime \left[\sum_{i,t} \hat{\lambda_{it}} x_{it} x_{it}\prime\right]^{-1} \tag{18}$$

The terms $\hat{\lambda_{it}} = exp(x_{it}\prime\hat{\beta})$, $\hat{u_{it}} = y_{it} - \hat{\lambda_{it}}$, $\sum_{i,t}$ denotes $\sum_{i=1}^{N}\sum_{t=1}^{T}$, and $\sum_{i,t,s}$ denotes $\sum_{i=1}^{N}\sum_{t=1}^{T}\sum_{s=1}^{T}$.

XIV. Results

I report the results of the impact of available cannabis supply on the total number of fatal traffic accidents for each measure of available supply. County fixed effects are included in every regression. Standard errors are clustered at the county level using the bootstrap method suggested by Cameron and Trivedi (2010). Table 17 displays the results of the Poisson regression using the number of licensed recreational facilities in a single county. I vary the inclusion of month fixed effects and population demographics to explore the influence of these controls. I include vehicle miles traveled in every specification due to its importance in explaining incidence of fatal traffic accidents. I find no influence of the number of licensed recreational facilities on the total number of fatal traffic accidents. Controls for vehicle miles traveled and the percentage of the population over the age of fifteen are positive and significant as expected.

It is possible for consumers to travel to other counties to access a licensed recreational dispensary. Table

TABLE 17—SINGLE COUNTY RECREATIONAL DISPENSARIES AND TOTAL FATAL TRAFFIC ACCIDENTS

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Recreational Dispensaries	0.000325	0.000198	-0.000599	-0.000387
	(0.00388)	(0.00369)	(0.00389)	(0.00383)
Vehicle Miles Traveled	4.32e-07***	4.18e-07***	2.91e-07**	3.39e-07***
	(6.24e-08)	(6.94e-08)	(1.25e-07)	(1.22e-07)
Population			1.45e-06	1.08e-06
			(2.34e-06)	(2.54e-06)
Percent Female			3.016	3.300
			(3.029)	(3.013)
Percent Age 15+			4.695**	5.649**
			(2.353)	(2.750)
Percent Non-White			-1.332	-1.428
			(0.966)	(1.026)
Percent Hispanic			1.999	2.857
			(2.301)	(2.847)
Income			1.78e-05	1.46e-05
			(1.41e-05)	(1.76e-05)
Bachelor's			-1.15e-05	0.00544
			(0.0116)	(0.0133)
Unemployment Rate			-0.0295*	-0.0189
			(0.0163)	(0.0230)
Month fixed-effects		✓		✓
Observations	6,912	6,912	6,912	6,912

* This table displays coefficients of the Poisson regression with the measure of available cannabis given by the number of licensed recreational dispensaries present in a single county. County fixed effects are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

18 measures the number of licensed dispensaries in a county in addition to the number of licensed dispensaries in all bordering counties to consider this impact. Results are qualitatively the same as those for the number of licensed dispensaries in a single county. There is no evidence that an increase in the number of licensed dispensaries impacts the number of fatal traffic accidents. It is possible that the impact of recreational dispensaries on fatal traffic accidents is determined by the presence of any licensed dispensary in a county. Tables 19 and 20 consider whether fatal traffic accidents are influenced by the presence of any number of licensed recreational dispensaries in a single county or in any bordering counties. Indicators for the presence of a licensed recreational dispensary generate qualitatively similar results to the number of licensed dispensaries. There is no evidence the presence of recreational dispensaries in a county or in surrounding counties

impacts the overall level of fatal traffic accidents.

TABLE 18—BORDERING COUNTY RECREATIONAL DISPENSARIES AND TOTAL FATAL TRAFFIC ACCIDENTS

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Recreational Dispensaries	0.000571	0.000428	0.000235	0.000161
	(0.000511)	(0.000698)	(0.000622)	(0.000848)
Vehicle Miles Traveled	3.63e-07***	3.78e-07***	3.01e-07**	3.51e-07**
	(8.21e-08)	(9.85e-08)	(1.45e-07)	(1.40e-07)
Population			4.22e-07	3.84e-07
			(2.94e-06)	(3.08e-06)
Percent Female			2.818	3.197
			(3.050)	(3.033)
Percent Age 15+			4.687**	5.726**
			(2.325)	(2.771)
Percent Non-White			-1.130	-1.309
			(0.946)	(1.012)
Percent Hispanic			2.231	3.022
			(2.268)	(2.827)
Income			1.84e-05	1.38e-05
			(1.40e-05)	(1.77e-05)
Bachelor's			-0.00258	0.00425
			(0.0116)	(0.0134)
Unemployment Rate			-0.0247	-0.0155
			(0.0170)	(0.0238)
Month fixed-effects		✓		✓
Observations	6,912	6,912	6,912	6,912

* This table displays coefficients of the Poisson regression with the measure of available cannabis given by the number of licensed recreational dispensaries present in a county in addition to the number of licensed recreational dispensaries in all bordering counties. County fixed effects are included in every specification. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1.

The hypothesis of licensed dispensaries having zero impact on fatal traffic accidents is not rejected. Evidence that licensing of dispensaries has no impact on fatal traffic accidents can be strengthened if one can reject the hypothesis that fatal traffic accidents increased by some percentage. I test whether the presence of a licensed recreational or medical dispensary in a county or in a county and any bordering counties leads to a 10% increase in fatal traffic accidents. I am unable to reject this hypothesis for the presence of a recreational dispensary in a county and in a county or its bordering counties. I am also unable to reject this hypothesis for the presence of a medical dispensary in a county or its bordering counties. I do reject the hypothesis of a

TABLE 19—PRESENCE OF A RECREATIONAL DISPENSARY AND TOTAL TRAFFIC FATALITIES

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Recreational Dispensaries	0.0150	0.0520	0.00444	0.0499
	(0.0420)	(0.0708)	(0.0519)	(0.0702)
Vehicle Miles Traveled	4.27e-07***	4.05e-07***	3.15e-07***	3.48e-07***
	(6.83e-08)	(6.27e-08)	(1.21e-07)	(1.18e-07)
Population			5.81e-07	4.62e-07
			(2.59e-06)	(2.55e-06)
Percent Female			2.891	3.157
			(3.011)	(2.996)
Percent Age 15+			4.699*	5.708**
			(2.433)	(2.711)
Percent Non-White			-1.227	-1.416
			(0.939)	(0.997)
Percent Hispanic			2.228	3.132
			(2.260)	(2.824)
Income			1.81e-05	1.43e-05
			(1.48e-05)	(1.72e-05)
Bachelor's			-0.00148	0.00474
			(0.0113)	(0.0133)
Unemployment Rate			-0.0268	-0.0163
			(0.0167)	(0.0228)
Month fixed-effects		✓		✓
Observations	6,912	6,912	6,912	6,912

* This table displays coefficients of the Poisson regression with the measure of available cannabis given by an indicator for the presence of a licensed recreational dispensary in the county. County fixed effects are included in every specification. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1.

10% increase in fatal traffic accidents for the presence of a medical dispensary in a single county. It remains a possibility that legal cannabis supply does have an impact on fatal traffic accidents despite the fact that the hypothesis of zero impact is not rejected.

The results for the alternative measures of available supply on total fatal traffic accidents are reported in Table 21. Only the coefficient on the measure of available supply is reported. Coefficients on demographic variables remain qualitatively similar for all specifications. There is no evidence that the number of registered medical cannabis patients in a county or in bordering counties has any impact on the total number of fatal traffic accidents. The sample is reduced to the years 2013-2017 to consider the impact of licensed medical cannabis dispensaries. The results provide no evidence that available cannabis supply measured using the

Table 20—Presence of a Recreational Dispensary in Bordering Counties and Total Traffic Fatalities

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Recreational Dispensaries	0.00299	0.269	-0.0139	0.213
	(0.0419)	(0.192)	(0.0546)	(0.174)
Vehicle Miles Traveled	4.38e-07***	4.05e-07***	3.25e-07***	3.53e-07***
	(7.10e-08)	(6.63e-08)	(1.19e-07)	(1.16e-07)
Population			5.70e-07	3.78e-07
			(2.50e-06)	(2.52e-06)
Percent Female			2.934	3.120
			(3.032)	(2.994)
Percent Age 15+			4.922*	4.931*
			(2.535)	(2.581)
Percent Non-White			-1.253	-1.358
			(0.949)	(0.963)
Percent Hispanic			2.269	3.037
			(2.282)	(2.777)
Income			1.61e-05	1.68e-05
			(1.52e-05)	(1.72e-05)
Bachelor's			-0.000458	0.00410
			(0.0114)	(0.0130)
Unemployment Rate			-0.0274*	-0.0157
			(0.0165)	(0.0226)
Month fixed-effects		✓		✓
Observations	6,912	6,912	6,912	6,912

[*] This table displays coefficients of the Poisson regression with the measure of available cannabis given by an indicator for the presence of a recreational dispensary in the county or in any bordering counties. County fixed effects are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

number of registered medical cannabis patients or the number of licensed medical cannabis dispensaries has a significant impact on the total number of fatal accidents in a county.

I focus the remaining reported results on the measure of available supply given by the number of licensed recreational dispensaries in a county and its bordering counties. I report only the specification which includes county and month fixed effects as well as population demographic variables. Results are qualitatively similar when these controls are excluded. Table 22 measures the impact of recreational dispensaries on the number of fatal accidents which include at least one driver who tested positive for cannabis or alcohol. I report results for any positive alcohol test result as well as alcohol test results over a blood alcohol level of 0.1 to explore

TABLE 21—MEDICAL CANNABIS AND TOTAL FATAL TRAFFIC ACCIDENTS

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Number of Medical Card Holders:				
Single-County	-5.57e-06	-4.61e-06	-1.13e-07	-3.69e-06
	(5.73e-06)	(9.48e-06)	(7.66e-06)	(1.06e-05)
Bordering Counties	-6.03e-07	1.15e-06	9.53e-07	1.09e-06
	(1.59e-06)	(2.65e-06)	(1.82e-06)	(2.67e-06)
Population Demographics			✓	✓
Month fixed-effects		✓		✓
Observations	6,912	6,912	6,912	6,912
Number of Medical Cannabis Dispensaries:				
Single-County	-0.00316	-0.00445	-0.00203	-0.00409
	(0.00886)	(0.00978)	(0.00902)	(0.00888)
Bordering Counties	-0.000169	-0.00123	0.000156	-0.00124
	(0.00166)	(0.00229)	(0.00163)	(0.00249)
Population Demographics			✓	✓
Month fixed-effects		✓		✓
Observations	3,840	3,840	3,840	3,840

* This table displays the coefficient of the Poisson regression corresponding to the measure of available cannabis supply. County fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1.

fatal accidents involving significantly intoxicated drivers.[49] There is no evidence that the number of licensed recreational dispensaries impacts cannabis or alcohol related fatal accidents.

TABLE 22—CANNABIS AND ALCOHOL RELATED FATAL TRAFFIC ACCIDENTS

	Cannabis	BAC > 0	BAC > 0.1
Variables	(1)	(2)	(3)
Recreational Dispensaries	-0.000278	0.000256	1.75e-05
	(0.00182)	(0.00101)	(0.00187)
Observations	6,156	6,912	6,696

* This table displays the coefficient of the Poisson regression corresponding to the number of licensed recreational dispensaries in a county in addition to the number of licensed recreational dispensaries in all bordering counties. Dependent variables measure the number of fatal traffic accidents including at least one driver who tested positive for cannabis, who had a positive blood alcohol level, or who had a blood alcohol level over 0.1. County and month fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1.

[49] These are the measures for alcohol intoxication utilized in Mark Anderson, Hansen and Rees (2013).

Table 23 measures the impact of recreational dispensaries on the number of fatal traffic accidents which include at least one driver who's license zip code corresponds to a county which is different from the county in which the fatal accident occurred. There is no evidence that the number of licensed recreational dispensaries in a county and its bordering counties impacts traffic fatalities for individuals traveling between counties to access a dispensary.

TABLE 23—FATAL TRAFFIC ACCIDENTS FROM OUT OF COUNTY DRIVERS

Variable	Total (1)	Cannabis (2)	BAC>0 (3)	BAC>0.1 (4)
Recreational Dispensaries	0.00102	0.00351	0.000770	0.000392
	(0.000834)	(0.00285)	(0.00205)	(0.00246)
Observations	6,912	5,508	6,480	5,940

* This table displays the coefficient of the Poisson regression corresponding to the number of licensed recreational dispensaries in a county in addition to the number of licensed recreational dispensaries in all bordering counties. Dependent variables measure the number of fatal traffic accidents with at least one driver who's license zip code corresponds to a different county from the location of the fatal accident and who tested positive for cannabis, who had a positive blood alcohol level, or who had a blood alcohol level over 0.1. County and month fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Rates of cannabis and alcohol use as well as rates of intoxicated driving are likely to vary significantly with the age of a driver. Fatal traffic accidents involving at least one driver within different age categories are considered in Table 24. Results again find no evidence of an impact of recreational dispensaries on the number of fatal accidents occurring in a county.

TABLE 24—FATAL TRAFFIC ACCIDENTS BY AGE

Variable	15-19 (1)	20-29 (2)	30-39 (3)	40-49 (4)	50-59 (5)	60+ (6)
Recreational Dispensaries	0.000899	0.000512	-0.00100	0.000101	0.00124	0.000263
	(0.00237)	(0.00127)	(0.00187)	(0.00167)	(0.00136)	(0.00277)
Observations	5,724	6,696	6,156	6,480	6,588	6,696

* This table displays the coefficient of the Poisson regression corresponding to the number of licensed recreational dispensaries in a county in addition to the number of licensed recreational dispensaries in all bordering counties. Dependent variables measure the number of fatal traffic accidents involving at least one driver in the specified age group. County and month fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Endogeneity between fatal traffic accidents and licensing of dispensaries is a concern. The decision to permit licensing of dispensaries may be related to behaviors and policies concerning fatal traffic accidents. The issue of the potential endogeneity of medical cannabis laws and traffic fatalities is addressed in Mark Anderson, Hansen and Rees (2013). The authors utilize placebo medical cannabis laws as well as explore the relationship between medical cannabis laws and policies which influence traffic fatalities and find little evidence of endogeneity.

I address this issue by considering measures of available cannabis supply which are more plausibly exogenous from policy decisions. The number of medical cannabis card holders in a county is an exogenous measure of supply. Localities are unable to restrict individuals from registering with the state to permit home cultivation of cannabis for medical use. The results for the number of medical card holders in a county provide no evidence of an impact of available supply on fatal traffic accidents.

I consider the impact of licensed recreational dispensaries on a county for counties which never permit licensed dispensaries. These counties may be impacted by the available supply of cannabis provided by licensed dispensaries in bordering counties through which their residents may access cannabis. The decision for bordering counties to license dispensaries is exogenous to the policy decision for a particular county. I additionally consider the impact of licensed recreational dispensaries on a county for only those counties which ever choose to permit licensed dispensaries. This explores the possibility that, conditional on a county's decision to permit any licensing of recreational dispensaries, the number of licensed dispensaries is exogenously determined. The decision to permit the licensing of an additional dispensary may be independent of concerns regarding traffic fatalities and may instead be determined by considerations such as the number of applicants for a license or economic concerns. The results are reported in Table 25. There is no evidence licensing of recreational dispensaries impact fatal traffic accidents within these samples.

A majority of counties which choose to prohibit licensing throughout the sample are located on the eastern border of Colorado. Estimation is conducted with eastern counties excluded to consider the potential bias from including these counties which may be significantly different from the remaining Colorado counties.[50] Table 26 reports the results on total fatal traffic accidents for all measures of available supply in a county.

[50]Excluded counties in eastern Colorado include Baca, Bent, Cheyenne, Crowley, Elbert, Kiowa, Kit Carson, Lincoln, Logan, Otero, Phillips, Prowers, Sedgwick, Washington, and Yuma county.

Table 25—Dispensary Licensing Choice and Fatal Traffic Accidents

Variable	Total (1)	Cannabis (2)	BAC>0 (3)	BAC>0.1 (4)
Never Permitted Recreational Dispensary Licensing:				
Recreational Dispensaries	-4.08e-05	0.00215	0.0103	0.0135
	(0.00577)	(0.0157)	(0.00865)	(0.0117)
Observations	3,024	2,592	3,024	2,808
Permitted Recreational Dispensary Licensing:				
Recreational Dispensaries	-0.000114	-0.000498	0.000281	-0.000435
	(0.000572)	(0.000852)	(0.000466)	(0.000555)
Observations	3,888	3,564	3,888	3,888

* This table displays the coefficient of the Poisson regression corresponding to the number of licensed recreational dispensaries in a county in addition to the number of licensed recreational dispensaries in all bordering counties for counties which never permitted dispensary licensing and for only counties which ever permitted dispensary licensing. Dependent variables additionally measure fatal accidents in which there was at least one drive who tested positive for cannabis, who had a positive blood alcohol level, or who had a blood alcohol level over 0.1. County and month fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

There is no evidence that dispensary licensing or the presence of registered medical cannbis patients impacts traffic fatalities.

The results are not reported for a large number of specifications. The model is estimated for each measure of available cannabis supply. Additional considerations for dependent variables include measuring the number of fatal accidents in which at least one driver is from a bordering county, from out of state, is male or female, or in which both drivers are sober.[51] I additionally test for the number of fatal accidents occurring during inclement weather,[52] during the week, during the weekend, during weekend nights, during the day, at night, on a highway or street, or in a rural or urban area. There is little evidence in all instances that measures of available cannabis supply impact the number of fatal accidents. I consider alternative measures to the number of fatal accidents. I estimate these variables for the total number of fatalities associated with fatal accidents and the number of drivers involved in fatal accidents. The results are qualitatively similar to the results for the number of fatal accidents.

[51] sober drivers are defined for fatal accidents in which both drivers are tested for alcohol and the tests report a zero blood alcohol level.
[52] Inclement weather involves precipitation including rain, snow, sleet, and hail.

Table 26—Fatal Traffic Accidents Excluding Eastern Counties

	Total Fatal Accidents			
Variable	(1)	(2)	(3)	(4)
Recreational Dispensaries:				
Single County Number	0.000313	5.39e-05	-0.000838	-0.000746
	(0.00526)	(0.00471)	(0.00479)	(0.00656)
Bordering Counties Number	0.000619	0.000380	0.000120	3.20e-05
	(0.00108)	(0.000973)	(0.00112)	(0.00147)
Single County Indicator	0.0132	-0.0230	-0.0198	-0.0106
	(0.0525)	(0.0883)	(0.0551)	(0.0863)
Bordering Counties Indicator	0.0166	0.0697	-0.0183	0.109
	(0.0435)	(0.274)	(0.0496)	(0.265)
Observations	5,292	5,292	5,292	5,292
Medical Card Holders:				
Single County	-5.66e-06	-3.14e-06	2.95e-06	-1.86e-07
	(7.51e-06)	(1.11e-05)	(1.00e-05)	(1.35e-05)
Bordering Counties	-3.32e-07	2.56e-06	2.10e-06	2.86e-06
	(2.29e-06)	(3.14e-06)	(2.53e-06)	(3.36e-06)
Observations	5,292	5,292	5,292	5,292
Medical Dispensaries:				
Single County	-0.00317	-0.00420	-0.00236	-0.00422
	(0.00586)	(0.00561)	(0.00514)	(0.00543)
Bordering Counties	1.26e-05	-0.000745	0.000358	-0.000743
	(0.00222)	(0.00273)	(0.00217)	(0.00309)
Observations	2,940	2,940	2,940	2,940
Population Demographics			✓	✓
Month fixed-effects		✓		✓

* This table displays the coefficient of the Poisson regression for measures of cannabis supply for all counties excluding the counties on the eastern border of Colorado which mostly prohibit dispensary licensing. "Single County Number" refers to the number of recreational dispensaries in a county while "Bordering Counties Number" refers to the sum of the number of recreational dispensaries in a county and the number of recreational dispensaries in all bordering counties. "Single County Indicator" indicates the presence of a recreational dispensary in a county while "Bordering Counties Indicator" indicates the presence of a recreational dispensary in a county or in any bordering counties. "Single County" and "Bordering Counties" report the number of registered medical cannabis patients and medical dispensaries in a county and the number in a county in addition to the number in all bordering counties respectively. County and month fixed effects as well as demographic variables are included in every specification. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

XV. Conclusion

The results of this paper find no evidence that the available supply of legal cannabis has a significant impact on fatal traffic accidents in a county. Increased availability of cannabis is not found to reduce fatal accidents through substitution with alcohol as found in Mark Anderson, Hansen and Rees (2013). My results support the conclusions found in previous studies which observe no significant changes in fatal accidents following cannabis legalization (Aydelotte et al., 2017; Hansen, Miller and Weber, 2018). This does not suggest that individuals driving while impaired from cannabis do not increase the probability of causing a fatal accident. It is possible that changes in the number of licensed cannabis dispensaries in a county or nearby counties has little influence on use for consumers who are willing to drive while intoxicated. Cannabis may be readily available to these consumers through home cultivation, the black market, or other means through which the number of licensed dispensaries has little influence. The results of this paper offer insight into the negative externalities associated with cannabis legalization. A number of remaining concerns regarding cannabis use persist. Available legal supply of cannabis may impose significant costs in the form of workplace accidents, drug treatment admissions, or adverse health conditions.

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Appendix

A1. Chapter 1 Demand Estimation

Table A1 reports the first stage regression of price on instrumental variables for the fixed and random coefficient logit models reported in columns (2) and (3) of Table 3. The instrument $f(x_j)$ corresponds to the sum of THC or the sum of CBD in columns (1) and (2) respectively for all other products in the same class in a market. The instrument $g(x_j)$ corresponds to the number of competing products of the same flavor in a market. And instrument $h(x_j)$ in column (2) corresponds to the sum of CBD for all products of the same flavor in a market. Both of the first stage results satisfy the test for weak instruments given by the Cragg-Donald Wald F statistic.

Table A2 records the results of the demand estimation for alternative specifications. Column (1) reports the results when the squared terms for THC, CBD, and $Units$ are excluded. The marginal utility with respect to price remains negative while the marginal utilities with respect to THC and CBD remain positive. The marginal utility with respect to $Units$ remains negative but is significant at the 5% level in this specification. This suggests consumers prefer edibles which are packaged with a lower number of separable units. Revenue is maximized at a sales tax rate of 42.6% under this specification. Estimation with squared terms is preferred to this specification. This is because squared terms permit the estimation of declining marginal utility with respect to cannabinoids in a package. This is believed to be important for estimating cannabis demand based on survey information and discussions with industry professionals. Column (2) reports the results for the alternative definition for the market of cannabis consumers defined in Light et al. (2014). Column (3) reports the results when a serving of edibles is defined to be four packages in a month. Coefficients are qualitatively similar to those in the preferred specification.

TABLE A1—FIRST STAGE RESULTS

Variables	Fixed Coefficient Logit (1)	Random Coefficient Logit (2)
$Constant$	2.238	1.372
	(1.551)	(1.551)
$f(x_j)$	0.000432***	-0.00283***
	(7.48e-05)	(0.000530)
$g(x_j)$	-0.0115***	-0.0106***
	(0.00398)	(0.00403)
$h(x_j)$	.	0.000877**
		(0.000355)
THC	0.263***	0.268***
	(0.0164)	(0.0164)
THC^2	-0.00131***	-0.00139***
	(0.000155)	(0.000155)
CBD	0.304***	0.301***
	(0.0128)	(0.0128)
CBD^2	0.00106***	0.00105***
	(0.000134)	(0.000134)
$Units$	0.336***	0.313***
	(0.0720)	(0.0721)
$Units^2$	-0.0137***	-0.0128***
	(0.00301)	(0.00301)
F-Statistic	19.200	11.83
Observations	7,411	7,411

[*] This table displays the first stage regression of price on instrumental variables for the fixed and random coefficient logit models reported in columns (2) and (3) of Table 3. The instrument $f(x_j)$ corresponds to the sum of THC or the sum of CBD in columns (1) and (2) respectively for all other products in the same class in a market. The instrument $g(x_j)$ corresponds to the number of competing products of the same flavor in a market. And instrument $h(x_j)$ in column (2) corresponds to the sum of CBD for all products of the same flavor in a market. Flavor, brand, class, and time fixed effects are not reported. F-Statistic is the Cragg-Donald Wald F statistic. Robust standard errors in parentheses.
** $p<0.01$, ** $p<0.05$, * $p<0.1$

TABLE A2—ALTERNATIVE DEMAND ESTIMATION

	Random Coefficient Logit		
Variables	(1)	(2)	(3)
$Constant$	-8.650***	-8.989***	-9.789***
	(0.484)	(0.417)	(0.414)
THC	0.0173***	0.0507***	0.0534***
	(0.00658)	(0.0157)	(0.0156)
THC^2	.	-0.000259***	-0.000284***
		(9.04e-05)	(9.04e-05)
CBD	0.0423*	0.0810***	0.0760***
	(0.0228)	(0.0173)	(0.0172)
CBD^2	.	-0.000511***	-0.000516***
		(8.48e-05)	(8.90e-05)
$Units$	-0.0298**	-0.0505	-0.0470
	(0.0116)	(0.0312)	(0.0311)
$Units^2$	.	0.00163	0.00148
		(0.00127)	(0.00127)
$Price$			
Mean	-0.261***	-0.230***	-0.323***
	(0.0579)	(0.0549)	(0.0547)
S.D.	0.0926*	0.0992**	0.122**
	(0.0474)	(0.0480)	(0.0601)
Relevance	11.327	11.839	11.839
Exclusion	0.9283	0.3546	0.4056
Observations	7,411	7,411	7,411

* This table displays alternative results from estimation equation (1). Column (1) removes the squares of the variables THC, CBD, and $Units$. Column (2) reports the estimation results using the alternative market definition from Light et al. (2014). And Column (3) reports the estimation results when a serving of edibles is defined to be four packages in a month. Units refers to units per package of edible. Flavor, brand, class, and time fixed effects are not reported. F-stat is the Cragg-Donald Wald F statistic. Exclusion is the p-value of the Hansen J statistic. Robust standard errors in parentheses.
** $p<0.01$, ** $p<0.05$, * $p<0.1$

A2. Chapter 2 Classifications

The classifications of cannabis laws provided in this paper differ from those provided in Pacula, Boustead and Hunt (2014). The authors only classified effective medical cannabis laws. I am interested in classifying all relevant cannabis legislation which was successful in passing regardless of its effectiveness. Arizona passed Proposition 200 in 1996 which permitted medical cannabis use for patients who receive a prescription from their physician for example. This was entirely ineffective as physicians could be penalized for prescribing a Schedule I controlled substance. I wish to classify this law to explore what determinants lead to its passage. I additionally classify laws according to the year they were enacted and not the year in which they became effective.

Classifications also differ as a result of some disagreement on the appropriate classifications in some cases. Hawaii's SB-862 in 2000 is recorded as having no registry provisions. I find that Act 228 of the 2000 regular session enacted by SB-862 does include the provision that physicians must register themselves and their patients with the Department of Public Safety. I classify Hawaii as providing "No Protection" to patients who are not registered as a result. It is recorded that subsequent laws altered a state's classification from "Some Protection" to "No Protection" for Colorado, Oregon, and Rhode Island. I find that individuals in these states are still afforded an affirmative defense to a cannabis prosecution when they are not registered. Colorado residents are provided an affirmative defense through Article XVIII Section 14 2(a) of the Colorado state constitution. Oregon residents are provided an affirmative defense through Oregon Revised Statutes 475B.913.[53] And Rhode Island residents are provided an affirmative defense through State of Rhode Island General Laws Title 21 Chapter 28.6 Section 8. These provisions are not materially altered or removed by subsequent legislation. I record these states as providing "Some Protection" as a result.

There is no classification under qualifying conditions for patients for laws in Maine, Nevada, New Mexico, Vermont, and the District of Columbia. This may be a result of ambiguous language in these laws which make it difficult to distinguish between "Diagnosed" and "Chronic Pain." The language of these laws

[53] Originally O.R.S. 475.319, renumbered 475B.480 in 2015, renumbered in 2017

closely resembles legislation requiring a diagnosable medical condition for cannabis use. None of these laws explicitly state that undiagnosed chronic pain is a qualifying condition for medical cannabis use. I have not identified anything ambiguous in the relevant laws for Maine, New Mexico, and Vermont which would prevent them from being classified under "Diagnosed." I therefore assume each of these states exhibit the "Diagnosed" classification.

Finally, the names of my classifications are altered for simplicity. Classifications are renamed from "Some protection available if not registered" to "Some Protection," "Only protected if registered" to "No Protection," "Unspecified cause of pain" to "Diagnosed," and "Pain of unknown cause" to "Chronic Pain."

A3. Ch. 2 Additional Results

The influence of including cancer diagnoses and drug overdoses for the samples 1999-2015 and 1996-2016 are included in Tables A3 and A4 respectively. The results are similar to those reported in Table 12, though there is some variation in the significance of some demographic variables. A notable difference occurs in Column (6) of Table A4 in which drug overdoses as well as prison population and the number of police officers are found to be a positive and significant predictor of medical cannabis law. This is consistent with regulators who seek to reduce the instance of drug overdoses by legalizing medical cannabis and constituents concerns regarding imprisonment for cannabis related offenses as well as high law enforcement costs. These results should be interpreted with caution. Drug overdose data is only available between 1999-2015.

Estimation of the determinants of cannabis laws which do not provide any legal protection for unregistered patients and which require a diagnosed medical condition to permit medical use is reported in Table A5. The results offer minimal additional insight into the determinants of medical cannabis legalization. I consider it unlikely that registry provisions and qualifying conditions are important aspects in determining the approval of medical cannabis laws. The legal protection afforded to patients who fail to register with the state still requires a formal recommendation from a physician or a formal diagnosis for medical cannabis use. The legal protection provided to a patient which has received a physician's recommendation but has

TABLE A3—DETERMINANTS OF MEDICAL CANNABIS LEGALIZATION 1999-2015

	Medical Cannabis Legalization					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	-0.0011	-0.0051	-0.0048	-0.0019	-0.0054	-0.0051
	(0.0019)	(0.0044)	(0.0051)	(0.0017)	(0.0043)	(0.0043)
Unemployment Rate	0.0101	-0.0022	-0.0091	0.0049	-0.0058	-0.0127**
	(0.0085)	(0.0066)	(0.0065)	(0.0090)	(0.0063)	(0.0063)
Bachelor’s	0.0070**	0.0058	0.0048	0.0085**	0.0054	0.0059
	(0.0033)	(0.0073)	(0.0088)	(0.0040)	(0.0085)	(0.0084)
Population	-0.0043	-0.0042**	-0.0063**	-0.0043*	-0.0052	-0.0072***
	(0.0027)	(0.0021)	(0.0026)	(0.0022)	(0.0033)	(0.0023)
Population Density	0.0032	0.0113	0.0070	0.0008	0.0105	0.0028
	(0.0034)	(0.0093)	(0.0095)	(0.0029)	(0.0102)	(0.0070)
Elderly	-0.0053	-0.0164*	-0.0232***	-0.0233**	-0.0392**	-0.0404***
	(0.0082)	(0.0084)	(0.0073)	(0.0103)	(0.0167)	(0.0097)
Non-White	0.0002	-0.0006	-0.0017	0.0012	-0.0000	-0.0010
	(0.0008)	(0.0011)	(0.0015)	(0.0013)	(0.0014)	(0.0015)
Female	-0.0159	0.0121	0.0555	-0.0350	-0.0079	0.0314
	(0.0222)	(0.0459)	(0.0670)	(0.0271)	(0.0507)	(0.0528)
Hispanic	0.0017**	-0.0009	0.0000	0.0031***	0.0003	0.0016*
	(0.0008)	(0.0010)	(0.0016)	(0.0008)	(0.0010)	(0.0009)
Republican Control	-0.0754***	-0.0801***	-0.0878***	-0.0657**	-0.0736***	-0.0745***
	(0.0245)	(0.0204)	(0.0234)	(0.0297)	(0.0213)	(0.0204)
Single Party Control	-0.0076	-0.0180	-0.0253	-0.0032	-0.0119	-0.0161
	(0.0198)	(0.0181)	(0.0221)	(0.0184)	(0.0179)	(0.0230)
Religious	-0.0040**	-0.0072***	-0.0105***	-0.0039**	-0.0076***	-0.0110***
	(0.0016)	(0.0015)	(0.0039)	(0.0018)	(0.0016)	(0.0035)
State Budget$_{t-1}$		-0.0748	-0.1040		-0.0534	-0.1055
		(0.0748)	(0.0681)		(0.0658)	(0.0687)
Murder Rate		0.0120*	0.0095		0.0148***	0.0064
		(0.0066)	(0.0071)		(0.0051)	(0.0047)
Alcohol Consumption		0.1026***	0.1604***		0.0922***	0.1471***
		(0.0352)	(0.0344)		(0.0334)	(0.0354)
Cigarette Consumption		-0.0026***	-0.0040***		-0.0030***	-0.0044***
		(0.0005)	(0.0010)		(0.0005)	(0.0011)
Prison Population		-0.0012	0.0051		-0.0053	0.0027
		(0.0068)	(0.0085)		(0.0086)	(0.0099)
Police Officers		-0.0000	0.0004		-0.0001	0.0004
		(0.0003)	(0.0005)		(0.0004)	(0.0004)
AIDS Diagnoses		-0.0026	-0.0029		-0.0028	-0.0014
		(0.0017)	(0.0018)		(0.0021)	(0.0013)
Border Medical Law			-0.0011**			-0.0014***
			(0.0005)			(0.0003)
Cancer Diagnoses				0.0008**	0.0009***	0.0010***
				(0.0003)	(0.0003)	(0.0004)
Drug Overdoses				-0.0001	0.0005	0.0037
				(0.0026)	(0.0038)	(0.0041)
Observations	574	574	574	574	574	574

* This table displays average marginal effects of the logit regression for all medical cannabis laws. Years 1999-2015 are used due to data availability for cancer and overdose rates. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

not registered with the state is likely a small consideration within the policy debate on medical cannabis. Permitting medical cannabis use for chronic pain of unknown causes similarly may be a minor consideration in approving medical cannabis. This is evidenced by states’ decisions not to establish a registry system

TABLE A4—DETERMINANTS OF MEDICAL CANNABIS LEGALIZATION 1996-2016

	Medical Cannabis Legalization					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	0.0008	-0.0016	-0.0019	-0.0014	-0.0044	-0.0050*
	(0.0017)	(0.0021)	(0.0022)	(0.0016)	(0.0035)	(0.0029)
Unemployment Rate	0.0112**	0.0059	0.0064	0.0106	-0.0014	-0.0074
	(0.0050)	(0.0073)	(0.0075)	(0.0094)	(0.0113)	(0.0120)
Bachelor's	0.0047*	0.0044	0.0048	0.0080***	0.0053	0.0072
	(0.0025)	(0.0031)	(0.0035)	(0.0030)	(0.0061)	(0.0048)
Population	-0.0004	0.0002	0.0005	-0.0044**	-0.0052	-0.0094***
	(0.0019)	(0.0020)	(0.0021)	(0.0021)	(0.0032)	(0.0036)
Population Density	0.0021	0.0063	0.0068	-0.0002	0.0080	-0.0020
	(0.0031)	(0.0044)	(0.0048)	(0.0028)	(0.0100)	(0.0067)
Elderly	0.0026	-0.0038	-0.0029	-0.0216**	-0.0370**	-0.0436***
	(0.0038)	(0.0054)	(0.0056)	(0.0103)	(0.0152)	(0.0106)
Non-White	-0.0005	-0.0007	-0.0005	0.0009	-0.0005	-0.0023**
	(0.0006)	(0.0007)	(0.0008)	(0.0010)	(0.0012)	(0.0012)
Female	-0.0185	0.0034	-0.0002	-0.0264	-0.0008	0.0439
	(0.0201)	(0.0283)	(0.0311)	(0.0233)	(0.0348)	(0.0391)
Hispanic	0.0017**	-0.0006	-0.0007	0.0030***	0.0004	0.0022**
	(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0011)	(0.0010)
Republican Control	-0.0526**	-0.0472*	-0.0470*	-0.0553**	-0.0580***	-0.0628***
	(0.0228)	(0.0248)	(0.0242)	(0.0223)	(0.0214)	(0.0218)
Single Party Control	-0.0033	-0.0055	-0.0036	-0.0007	-0.0050	-0.0094
	(0.0164)	(0.0157)	(0.0157)	(0.0169)	(0.0192)	(0.0166)
Religious	-0.0034***	-0.0040***	-0.0038***	-0.0034**	-0.0067***	-0.0115***
	(0.0012)	(0.0013)	(0.0013)	(0.0014)	(0.0013)	(0.0036)
State Budget$_{t-1}$		0.0188	0.0307		-0.0816	-0.1303**
		(0.0811)	(0.0834)		(0.0513)	(0.0534)
Murder Rate		0.0092	0.0094		0.0114	0.0023
		(0.0058)	(0.0058)		(0.0073)	(0.0064)
Alcohol Consumption		0.0680***	0.0621***		0.0856***	0.1726***
		(0.0195)	(0.0216)		(0.0231)	(0.0399)
Cigarette Consumption		-0.0020***	-0.0019***		-0.0030***	-0.0056***
		(0.0006)	(0.0006)		(0.0006)	(0.0016)
Prison Population		-0.0031	-0.0039		-0.0017	0.0101*
		(0.0083)	(0.0086)		(0.0074)	(0.0061)
Police Officers		-0.0004	-0.0004		-0.0001	0.0006*
		(0.0002)	(0.0003)		(0.0003)	(0.0003)
AIDS Diagnoses		-0.0016	-0.0016		-0.0021	0.0002
		(0.0019)	(0.0019)		(0.0031)	(0.0030)
Border Medical Law			0.0002			-0.0017***
			(0.0003)			(0.0005)
Cancer Diagnoses				0.0008***	0.0009***	0.0013***
				(0.0003)	(0.0004)	(0.0004)
Drug Overdoses				-0.0001	0.0017	0.0065***
				(0.0021)	(0.0019)	(0.0025)
Observations	797	797	797	617	617	617

* This table displays average marginal effects of the logit regression for all medical cannabis laws. Years 1996-2016 are used to consider the impact of including cancer and overdose rates for the full sample. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

or to change the legal protections afforded to unregistered patients,[54] and to alter the nature of qualifying

[54] Washington has never established a patient registry, while Montana chose to eliminate legal protection to unregistered patients for example.

conditions after the initial passage of medical cannabis laws.[55]

The results for recreational cannabis legalization are reported in Table A6. There are only 8 states within the sample which approve recreational use. Insufficient observations make identification of the coefficients difficult. I report results which exclude demographic variables to provide some insight into the nature of these policies. Results with the restricted set of independent variables provide similar insight to the results for medical laws. The percent of a state which is religious, the number of police officers, and the cigarette consumption of a state are negatively related to recreational cannabis policy.

The results for CBD extract laws are reported in Table A7. CBD extracts are permissible in a state which has passed medical, recreational, or CBD extract specific laws. I first consider policies which permit the use of CBD extracts by measuring the determinant of any cannabis law. These results are reported in Columns (1) - (3). Results are similar to those reported for medical cannabis legalization. A notable difference is the insignificance of the political party in control of the state government. This appears to be a consequence of the motivations behind CBD extract legalization specifically. Every state which passed a law only permitting CBD extracts also prohibits medical and recreational use with the exception of Florida. These are states with greater Republican control of the state government. Motivations for these regulators to approve CBD extract laws do not appear similar to those for approving medical or recreational laws. The timing of CBD extract laws appears to be a response to the ambiguity perceived in the 2014 Farm Bill regarding the definition of hemp. The different motivations behind CBD extract specific laws are considered in Columns (4) - (6). The results correspond to the probability a state passes a CBD extract law given that they have not previously passed a medical, recreational, or CBD extract law. This includes every remaining state which had not passed medical or recreational laws with the exception of Nebraska and Idaho. The results show unsurprisingly that these remaining states have greater Republican control of the state government as well as a greater religious population compared to those states which passed medical or recreational laws.

[55]Montana required a diagnosed condition for medical use before permitting chronic pain of unknown cause as a qualifying condition in 2011 for example.

Table A5—Determinants of Medical Cannabis Registry Provisions and Qualifying Conditions

	No Protection			Diagnosed Condition		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	0.0010	0.0005	0.0011	0.0007	-0.0007	-0.0003
	(0.0013)	(0.0010)	(0.0009)	(0.0015)	(0.0013)	(0.0015)
Unemployment Rate	0.0066	0.0086*	0.0088*	0.0120	0.0099	0.0097
	(0.0054)	(0.0045)	(0.0052)	(0.0083)	(0.0089)	(0.0084)
Bachelor’s	0.0012	0.0035	0.0026	0.0027	0.0034	0.0028
	(0.0021)	(0.0029)	(0.0025)	(0.0024)	(0.0032)	(0.0032)
Population	-0.0009	-0.0001	-0.0000	-0.0039***	-0.0030***	-0.0031***
	(0.0010)	(0.0008)	(0.0009)	(0.0012)	(0.0010)	(0.0012)
Population Density	-0.0037	-0.0019	0.0004	0.0030	0.0059	0.0048
	(0.0027)	(0.0019)	(0.0019)	(0.0029)	(0.0037)	(0.0041)
Elderly	0.0067	0.0125	0.0133*	0.0034	-0.0013	-0.0036
	(0.0062)	(0.0086)	(0.0070)	(0.0048)	(0.0051)	(0.0058)
Non-White	0.0006*	0.0004	0.0003	0.0002	0.0004	0.0001
	(0.0003)	(0.0004)	(0.0004)	(0.0005)	(0.0007)	(0.0008)
Female	-0.0137	-0.0271**	-0.0275**	-0.0104	0.0148	0.0235
	(0.0091)	(0.0128)	(0.0122)	(0.0126)	(0.0242)	(0.0325)
Hispanic	0.0002	-0.0009	-0.0004	0.0016***	0.0008	0.0011**
	(0.0011)	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0005)
Republican Control	-0.0141	-0.0194	-0.0204*	-0.0130	-0.0124	-0.0141
	(0.0112)	(0.0138)	(0.0117)	(0.0163)	(0.0196)	(0.0196)
Single Party Control	-0.0008	0.0028	0.0032	0.0104	0.0163	0.0178
	(0.0081)	(0.0064)	(0.0069)	(0.0134)	(0.0135)	(0.0143)
Religious	0.0010	0.0011*	0.0012*	-0.0009	-0.0018	-0.0021
	(0.0007)	(0.0006)	(0.0007)	(0.0009)	(0.0012)	(0.0014)
State Budget$_{t-1}$		-0.0111	-0.0276		0.1121	0.1022
		(0.0680)	(0.0501)		(0.0772)	(0.0734)
Murder Rate		0.0125***	0.0121***		0.0042	0.0032
		(0.0036)	(0.0041)		(0.0041)	(0.0044)
Alcohol Consumption		0.0190*	0.0298**		0.0532***	0.0650***
		(0.0105)	(0.0123)		(0.0153)	(0.0228)
Cigarette Consumption		-0.0005	-0.0004		-0.0008*	-0.0010
		(0.0004)	(0.0004)		(0.0005)	(0.0007)
Prison Population		-0.0007	0.0005		0.0044	0.0066
		(0.0042)	(0.0049)		(0.0046)	(0.0060)
Police Officers		-0.0000	-0.0001		0.0001	
		(0.0001)	(0.0001)		(0.0002)	
AIDS Diagnoses		-0.0036	-0.0043**		-0.0034*	-0.0037*
		(0.0025)	(0.0021)		(0.0019)	(0.0019)
Border Medical Law			-0.0005**			-0.0004
			(0.0002)			(0.0004)
Observations	978	978	978	863	863	863

* This table displays average marginal effects of the logit regression for medical cannabis laws which only offer legal protection to registered patients or which only allow medical cannabis use for patients with a diagnosed medical condition. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TABLE A6—DETERMINANTS OF RECREATIONAL CANNABIS LEGALIZATION

	Recreational Cannabis Law		
Variable	(1)	(2)	(3)
Republican Control	-0.0287	0.0147	0.0212
	(0.0361)	(0.0342)	(0.0299)
Single Party Control	-0.0214	-0.0399	-0.0510
	(0.0240)	(0.0274)	(0.0341)
Religious	-0.0040**	-0.0037***	-0.0040***
	(0.0017)	(0.0010)	(0.0010)
State Budget$_{t-1}$		-0.0295	-0.0287
		(0.0978)	(0.0958)
Murder Rate		0.0035	0.0013
		(0.0059)	(0.0064)
Alcohol Consumption		0.0264	0.0293
		(0.0272)	(0.0275)
Cigarette Consumption		-0.0050***	-0.0053***
		(0.0018)	(0.0020)
Prison Population		-0.0145	-0.0159
		(0.0114)	(0.0115)
Police Officers		-0.0008*	-0.0007*
		(0.0004)	(0.0004)
Sales Tax		-0.0055	-0.0062
		(0.0051)	(0.0049)
Border Recreational Law			0.0552
			(0.0746)
Observations	238	238	238

* This table displays average marginal effects of the logit regression for recreational cannabis laws. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

TABLE A7—DETERMINANTS OF CBD EXTRACT LEGALIZATION

	Any Cannabis Law			CBD Extract Law		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Household Income	0.0016	-0.0013	-0.0012	-0.0007	-0.0001	-0.0001
	(0.0022)	(0.0024)	(0.0025)	(0.0019)	(0.0021)	(0.0021)
Unemployment Rate	0.0211***	0.0159**	0.0142*	0.0212**	0.0253**	0.0253**
	(0.0059)	(0.0078)	(0.0081)	(0.0091)	(0.0102)	(0.0101)
Bachelor’s	0.0044	0.0054	0.0050	0.0035	0.0008	0.0009
	(0.0036)	(0.0041)	(0.0042)	(0.0030)	(0.0029)	(0.0029)
Population	-0.0025	-0.0014	-0.0002	-0.0012	-0.0056***	-0.0057***
	(0.0019)	(0.0022)	(0.0025)	(0.0018)	(0.0021)	(0.0021)
Population Density	0.0002	0.0054	0.0068	-0.0017	0.0207*	0.0205*
	(0.0041)	(0.0056)	(0.0056)	(0.0095)	(0.0120)	(0.0124)
Elderly	-0.0022	-0.0067	-0.0057	0.0006	-0.0044	-0.0045
	(0.0042)	(0.0070)	(0.0076)	(0.0033)	(0.0047)	(0.0047)
Non-White	0.0004	0.0003	0.0000	-0.0006	-0.0002	-0.0002
	(0.0007)	(0.0009)	(0.0009)	(0.0008)	(0.0013)	(0.0013)
Female	-0.0022	0.0119	0.0025	-0.0067	0.0223	0.0237
	(0.0193)	(0.0299)	(0.0320)	(0.0143)	(0.0187)	(0.0220)
Hispanic	0.0024***	0.0003	0.0001	0.0014	0.0054***	0.0054***
	(0.0007)	(0.0007)	(0.0007)	(0.0013)	(0.0018)	(0.0017)
Republican Control	-0.0288	-0.0392	-0.0468	0.0422*	0.0920**	0.0947*
	(0.0235)	(0.0282)	(0.0289)	(0.0223)	(0.0450)	(0.0491)
Single Party Control	-0.0110	-0.0175	-0.0169	-0.0217	-0.0342	-0.0351
	(0.0201)	(0.0182)	(0.0180)	(0.0136)	(0.0285)	(0.0280)
Religious	-0.0027**	-0.0031**	-0.0029**	0.0013*	0.0029***	0.0029***
	(0.0012)	(0.0012)	(0.0013)	(0.0007)	(0.0006)	(0.0006)
State Budget$_{t-1}$		0.0366	0.0198		0.1233***	0.1265***
		(0.0939)	(0.0924)		(0.0466)	(0.0481)
Murder Rate		0.0082	0.0089		-0.0058	-0.0062
		(0.0067)	(0.0068)		(0.0063)	(0.0070)
Alcohol Consumption		0.0702***	0.0700***		0.0060	0.0057
		(0.0210)	(0.0220)		(0.0152)	(0.0153)
Cigarette Consumption		-0.0015**	-0.0016**		0.0010**	0.0010**
		(0.0007)	(0.0007)		(0.0004)	(0.0004)
Prison Population		-0.0015	-0.0019		-0.0059	-0.0058
		(0.0089)	(0.0090)		(0.0043)	(0.0041)
Police Officers		-0.0005**	-0.0005**		0.0002	0.0002
		(0.0002)	(0.0003)		(0.0003)	(0.0003)
AIDS Diagnoses		-0.0010	-0.0013		-0.0029	-0.0026
		(0.0023)	(0.0024)		(0.0044)	(0.0048)
Border CBD Law			0.0860			-0.0032
			(0.0790)			(0.0246)
Observations	770	770	770	770	770	770

* This table displays average marginal effects of the logit regression for CBD extract laws. “Any Cannabis Law” measures the determinants for CBD extracts legalized through medical, recreational, or CBD extract laws. “CBD Extract Law” measures the determinants for laws which only legalize CBD extracts and do not permit medical or recreational use of THC. Year fixed effects are included in every specification. Standard errors clustered at the state level are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$