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

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

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Legalization of medical and adult-use (recreational) cannabis products in Colorado has permitted the formation of a large industry with sales of $1.31 billion in 2016. These sales generate significant tax revenue for the state. I estimate the revenue maximizing sales tax rate on cannabis products using data on sales of cannabis edibles for the adult-use market in Colorado between 2014 and 2016. I use a random coefficient logit model to estimate demand parameters that provide marginal costs, equilibrium prices, and welfare. This allows for the simulation of different rates to determine the revenue maximizing sales tax rate. I find this rate to be 47.6%.

JEL: H21, H30, H71, K34, L66

Keywords: Cannabis, Taxation, Revenue, Public Finance, Tax Law

Legalization of cannabis has expanded considerably in recent years. Thirty-one states and the District of Columbia have legalized cannabis use for medicinal purposes. Nine states and the District of Columbia have legalized adult-use (recreational) cannabis for individuals 21 and older. A significant number of states have 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 to have reached $5.4 billion in 2015

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and $6.7 billion in 2016 (Huddleston Jr., 2016). Recent expansion to California, Maine, Massachusetts, Nevada, and Vermont means that over one fifth of the US population lives in a state which permits legal adult-use cannabis (Borchardt, 2017). Implementation of taxes on cannabis products will have important implications for policymakers. This paper utilizes a random coefficient logit model to estimate the revenue maximizing sales tax rate on cannabis.

Colorado contributes a large share to total US sales. Figure 1 displays total sales in Colorado for 2014-2016. Sales in medical and adult-use cannabis totaled approximately $996 million in 2015 and $1.31 billion in 2016. Growth in sales are largely driven by the adult-use 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. Sales of adult-use cannabis in Colorado faced a 10% special sales tax rate in addition to the 2.9% state sales tax between 2014 and 2016[1]. 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[2]. The tax rate on retail cannabis was changed effective July 2017. The special sales tax rate was raised from 10% to 15%, while retail cannabis was 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.

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 additionally requires a business license. The application fee for a retail marijuana store is $4,500 as of May 2017. 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 adult-use cannabis.

[1] C.R.S. § 39-26-106; § 39-28.8-202
[2] C.R.S. § 39-28.8-302

have nevertheless implemented policies which suggest positive valuation of these sources of welfare. Colorado cites “individual freedom” as a reason for legalizing adult-use 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

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. Michael Grossman utilizes cigarette demand functions from Becker, Grossman and Murphy (1994) to predict a revenue maximizing tax of $1.26 per pack in 1993 (Grossman et al., 1993). Jackson and Saba (1997) expand on Grossman's 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[3]. An excise tax of $1.10 suggests an effective sales tax rate of 75.9%.

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 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[4] [5]. This suggests a revenue maximizing sales tax rate of approximately 96%. Tax revenue may depend significantly on consumer's ability to evade taxes. Goolsbee, Lovenheim and Slemrod (2009) 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 eas-

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

[4]The World Bank Economics of Tobacco Toolkit, Design and Administer Tobacco Taxes. http://www.worldbank.org/en/topic/health/publication/economics-of-tobacco-toolkit

[5]http://www.who.int/tobacco/economics/taxation/en/

ily. 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. 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 is explored in Miravete, Seim and Thurk (2017). 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

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 reports 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. Legal History

Cannabis products were not federally prohibited in the United States prior to the twentieth century. Cannabis and its extracts were available at drug stores and suggested for a variety of ailments in states which permitted its sale. Cannabis extracts were first recognized in the US Pharmacopeia in 1851 as a part of the effort to set standards on the production and use of medicines. Federal regulation of cannabis began with the Federal Food and Drugs Act of 1906. The act required that substances included in the US Pharmacopeia be labeled to identify their contents.

Strong opposition to cannabis grew in the early twentieth century. Consumption of

Silver Bow and Yellowstone delegations both deplore these international complications (Bonnie and Whitebread, 1970).” The Federal Bureau of Narcotics (FBN) Commissioner Harry J. Anslinger personally blamed Mexico for the dispersion of cannabis use at this time. Anslinger presided over the FBN and is one of the primary individuals responsible for the de facto prohibition of cannabis in the United States in the 1930’s.

Prejudice was not the only source of growing opposition to cannabis. Many feared the negative consequences of its use. There was relatively low use of cannabis among individuals in eastern states. Early prohibition nevertheless occurred in states including New York, Massachusetts and Maine. Prohibition was driven by fear that cannabis use might increase in narcotics addicts as a result of greater restrictions on opiate and cocaine use. Reports of heinous criminal activity and irreparable health conditions reported by Anslinger and others bolstered the argument for state and federal regulation. Anslinger viewed cannabis use as a societal threat, stating “how many murders, suicides, robberies, criminal assaults, holdups, burglaries, and deeds of maniacal insanity it causes each year, especially among the young, can be only conjectured. The sweeping march of its addiction has been so insidious that, in numerous communities, it thrives almost unmolested, largely because of official ignorance of its effects (Anslinger and Cooper, 1937).” The FBN drafted the Uniform State Narcotic Drug Act in 1931. The act allowed states to include cannabis among substances which faced restrictions on their sale and use. All but two states adopted the Uniform State Narcotic Drug Act by the end of 1936.

Fears regarding the dangers of cannabis lead to further support for federal legislation. Cannabis policy expanded to the federal level with the Marijuana Tax Act of 1937. The act did not explicitly prohibit the sale and use of cannabis. Instead, cannabis was to be taxed at a rate of $1 per transfer of one ounce by a registered physician. Large fines and penalties were imposed for violating the tax act. Individuals in violation could be fined up to $2,000 and face five years in prison (Meier, 1994). The tremendous risk

cannabis as a Schedule I controlled substance. This made it illegal for any individual to manufacture, distribute, or possessNA

cannabis center. Authorization of retail medical cannabis facilities laid the foundation for the future of retail adult-use cannabis facilities.

The process of legalizing adult-use cannabis in Colorado began on November 6th, 2012 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 individ-

in their state for instance. The result has been a wide range of tax policies across states with adult-use cannabis.

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[9]. This implies adult-

licenses permit the operation of a facility which manufactures products with extracts of cannabis such as 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 licensed 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 weeks. 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[12]. 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. Water-based methods use only water, ice, or dry ice. Food-based methods use propylene glycn e who [illegible]
[illegible] past]b based [illegible] use p an[illegible]beob[illegible] ibeo[illegible] [illegible]

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. Contamination testing is conducted on every batch of cannabis products until the production

sale to consumers. Customers must provide valid identification verifying that they are

II. Empirical Framework

A. Market Demand

Consumers demand cannabis edibles based on their 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. 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. As previously stated, the brand of edible may be of particular importance

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, $_{f(j)}$ is a time-invariant fixed effect measuring average consumer preferences for flavor $f(j)$ of product j, $_{b(j)}$

(3) $$U_{ijt} = \quad_{jt}(x_{jt}; \quad_{jt}; p_{jt}; \quad) + \quad_{ijt}(x_{jt}; p_{jt}; \quad_{i}; \quad_{2}) + \epsilon_{ijt}$$

(4) $$_{jt} = \quad p_{jt} + x_{j}^{0} + \quad_{f(j)} + \quad_{b(j)} + \quad_{c(j)} + \quad_{t} + \quad_{jt}$$

(5) $$_{ijt} = (x_{j} \quad (1 + \quad) \quad p_{jt})(\quad_{i})$$

sumers 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 $_{jt}$ is calculated by matching simulated market shares to observed market shares using the contraction mapping suggested by BLP. 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 $z_{jt} = [z_{jt}; z_{2jt}; :::; z_{Rjt}$

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:

$$s_{jt}(x; \ ; p; \ ) + \sum_{r \in J_f} (p_{rt} - mc_{rt}) \frac{@s_{rt}(x; \ ; p; \ )}{@p_{jt}} \tag{11}$$

$$(14) \qquad CS_{it} = \frac{1}{\alpha_j} \ln\left[1 + \sum_{j=1}^{J} \exp(\delta_{jt} + \mu_{ijt})\right]$$

Dividing by α_j 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 adult-use cannabis sales on January 1st, 2014. 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 my estimates due to this event.

I focus my estimation on sales of adult-use 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 preferences for characteristics in the data. All cannabis products are required to list their composition of cannabinoids measured through potency tests[19]. 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

[19] 1 CCR 212-2-R 1004.5

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 adult-use cannabis as it is the adult-use 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[20]. 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 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

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

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 a th` p. ώ. whose cm poq

istics 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. 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 adult-use cannabis in Colorado[22]. 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 adult-use 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 adult-use market are made to out of state consumers who visit Colorado. I use the population of monthly cannabis users who receive cannabis through the adult-use 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 de-

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

pute 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. The first and second columns display the results of the fixed coefficient logit model[23]. This specification assumes the marginal utility of product characteristics does not vary between consumers. The first column reports OLS logit results. The second column 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 elastici-

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. Adult-use 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. This suggests my estimates provide a realistic measure of marginal cost for the products in the industry. Different sales tax rates are simulated. 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 . 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

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 adult-use cannabis industry based on Light et al. (2014). This results in a measure of market size which is just under half

not use cannabis every month, but may nonetheless be a significant consideration for the

There has been consolidation of firms as a result [26]. 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 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 adult-use industry. Consumers may be encouraged to undertake home cultivation to avoid high

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 adult-use cannabis ranging from 10% - 37%. States have varying motivations for legalizing adult-use 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 adult-use 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 adult-use cannabis policy.

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Tables and Figures

Figure 1.

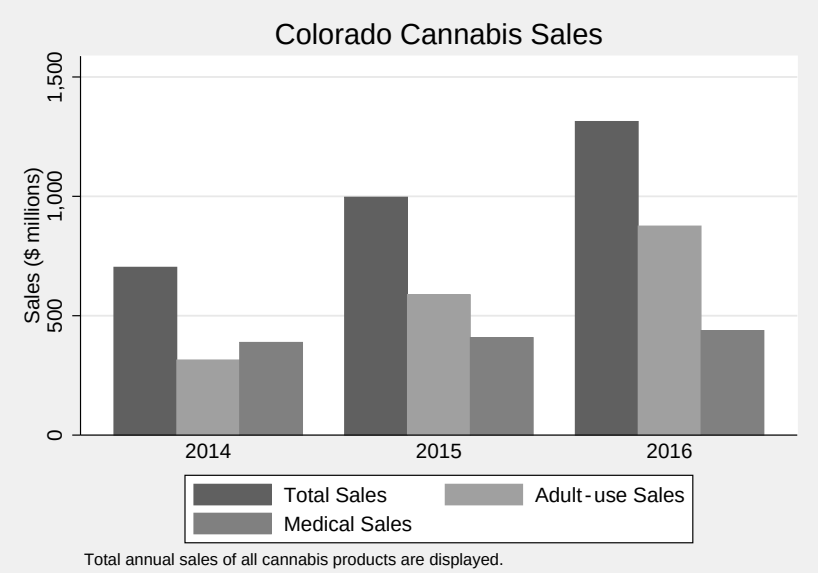

Figure 2.

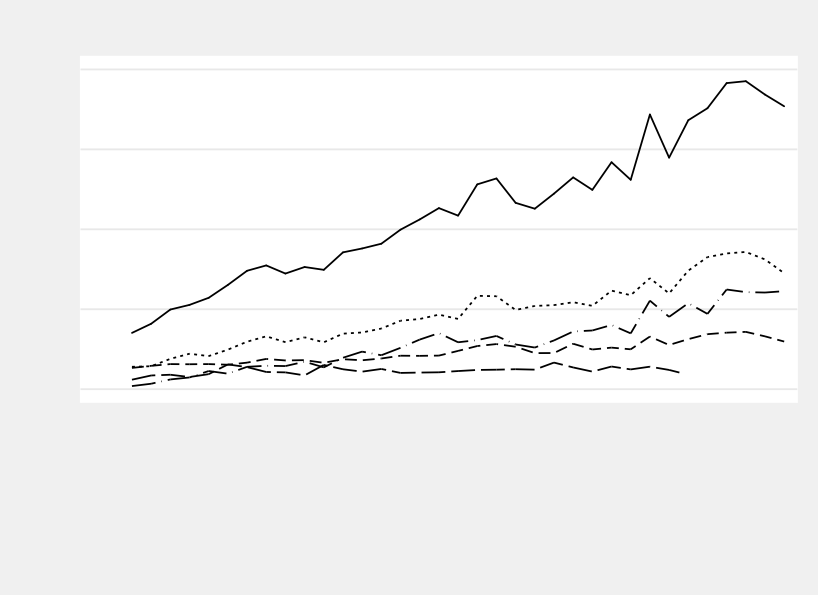

Рисунок 3.

Рисунок 4.

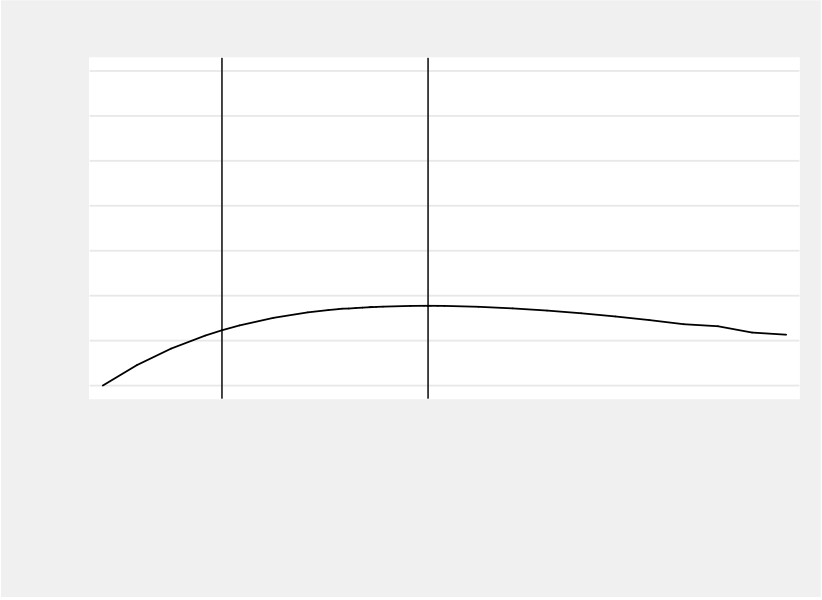

Table 1—Characteristics of Missouri. Estimates are from 2016.

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%
AP AP aęъ ȝ ¾	

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.

Table 3—Demand Estimates

	Fixed Coefficient Logit		Random Coefficient Logit
	(1)	(2)	(3)
Variables	OLS	IV	BLP
Standard Deviation			
$Price$	.	.	0.111**
			(0.0543)
Marginal Utility			
$Price$	-0.00460	-0.188***	-0.275***
	(0.00434)	(0.0660)	(0.0547)
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)
$Constant$	-9.669***	-9.416***	-9.398***
	(0.340)	(0.440)	(0.414)
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

Table 4—Descriptive Statistics: T 10

Item2	.020406		.04001	.05433						
Item8	.020406		.3.04724	.04003	.0233-	.0233-		02301	¿05433	

	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

Appendix

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. IV1 in column (1) corresponds to the sum of THC for all other products in the same class in a market. IV2 of column (1) corresponds to the number of competing products of the same flavor in a market. IV1 of column (2) corresponds to the sum of CBD for all other products in the same class in a market. IV2 of column (2) corresponds to the sum of CBD for all products of the same flavor in a market. And IV3 of column (2) corresponds to the number of competing 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 Regression

Variables	Fixed Coefficient Logit (1)	Random Coefficient Logit (2)
IV1	0.000432***	-0.00283***
	(7.48e-05)	(0.000530)
IV2	-0.0115***	0.000877**
	(0.00398)	(0.000355)
IV3	.	-0.0106***
		(0.00403)
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)
Constant	2.238	1.372
	(1.551)	(1.551)
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 ɹ C ɉffɲcient L ʒit

Table A2—Alternative Specifications Demonstrating Endogeneity

	Random Coefficient Logit		
Variables	(1)	(2)	(3)
Standard Deviation			
Price	0.0926*	0.0992**	0.122**
	(0.0474)	(0.0480)	(0.0601)
Marginal Utility			
Price	-0.261***	-0.230***	-0.323***
	(0.0579)	(0.0549)	(0.0547)
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)
Constant	-8.650***	-8.989***	-9.789***
	(0.484)	(0.417)	(0.414)
Relevance	11.327	11.839	11.839
Exclusion	0.9283	0.3546	0.4056
Observations	7,411	7,411	7,411

* This table [illegible]