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Research paper

Big data on a big new market: Insights from Washington State's legal cannabis market☆

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ABSTRACT

Introduction: Voters in eight U.S. states have passed initiatives to legalize large-scale commercial production of cannabis for non-medical use. All plan or require some form of "seed-to-sale" tracking systems, which provide a view of cannabis market activity at a heretofore unimagined level of detail. Legal markets also create a range of new matters for policy makers to address.

Data: Publicly available data were obtained on approximately 45 million individually priced items purchased in the 35 million retail transactions that took place during the first two and a half years of Washington State's legal cannabis market. Records include product type (flower, extract, lotion, liquid edible, etc.), product name, price, and potency with respect to multiple cannabinoids, notably THC and CBD. Items sold can be traced back up the supply chain through the store to the processor and producer, to the level of identifying the specific production batch and mother plant, the firm that tested the product, and test results.

Method: Data visualization methods are employed to describe spatial-temporal patterns of multiple correlated attributes (e.g., price and potency) broken down by product. Text-analytic methods are used to subdivide the broad category of "extracts for inhalation" into more homogeneous sub-categories. To understand the competitiveness of the legal cannabis market in Washington we calculate the Herfindahl-Hirschman index (HHI) for processors and retailers.

Results: Cannabis prices fell steadily and proportionally at the processor and retailer levels. Retail and wholesale price maintained a roughly 3:1 ratio for multiple product types after some initial fluctuations. Although a wide range of edibles are sold, they account for a modest share of consumer spending; extracts for inhalation are a larger and heterogeneous market segment. The HHI indicates the cannabis market is highly competitive at the processor level, but less so for retail markets at the county level.

Conclusions: Washington's state-legal cannabis market is diverse and rapidly evolving in terms of pricing, products, and organization. Post-legalization, researchers and policy makers may need to think in terms of a family of cannabis products, akin to how we think of new psychoactive substances and amphetamine-type stimulants, not a single drug "cannabis."

Introduction

In November 2012, voters in the U.S. states of Colorado and Washington approved propositions making them the first jurisdictions to legalize (with respect to state law) not just home cultivation and possession, but also large-scale commercial production, distribution, and sale of cannabis products for recreational use. After a period of regulatory design, the first licensed stores opened in January 2014 (in Colorado) and July 2014 (in Washington).

These events triggered considerable research on topics including teen-accessible marketing and promotion (Bierut, Krauss, Sowles, & Cavazos-Rehg, 2017), health outcomes (e.g., Kim & Monte, 2016), effects on treatment providers (Sobesky & Gorgens, 2016), public opinion (Subbaraman & Kerr, 2016), public understanding (Mason, Hanson, Fleming, Ringle, & Haggerty, 2015), local policy response to state legalization (Dilley, Hitchcock, McGroder, Greto, & Richardson, 2017), and strategies for regulation (Carnevale et al., 2017; Jensen & Roussell, 2016; Subritzky, Pettigrew, & Lenton, 2016).

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Table 1
Major product types observed in June 2016.

Product Type	Use Method(s)	Average Price	1st Quartile	3rd Quartile	Average THC Potency	1st Quartile	3rd Quartile	Market Share
Extract for Inhalation	Smoked, vaporized, "dabbed", or added to other products	$34.24	$23.51	$38.1	69.66	65.1	78.6	22%
Solid Infused Edible	Eaten	$21.1	$7.58	$30.73	–	–	–	7%
Liquid Infused Edible	Drunk	$29.1	$17.54	$34.61	–	–	–	3%
Usable Marijuana	Smoked, vaporized	$22.05	$9.36	$28.06	20.47	18.2	22.99	66%
Marijuana Mix Infused	Smoked, vaporized	$16.84	$11.22	$18.85	–	–	–	1%
Infused Topicals	Applied to skin	$31.33	$17	$39.58	–	–	–	1%
Marijuana Mix Package	Smoked, vaporized	$13.61	$6.59	$14.14	19.31	16.1	21.3	1%

There is also considerable interest in the resulting evolution of price and potency of cannabis products. Even before legalization, high-potency products were becoming more popular (Ben Lakhdar, Vaillant, & Wolff, 2016; Mehmedic et al., 2010), raising concerns about possible health impacts (Freeman et al., 2018; Hall & Lynskey, 2016; van der Pol et al., 2014; Weiss, Howlett, & Baler, 2017), especially considering the variety of methods in which higher potency products can be consumed, including dabbing and eating (Loflin & Earleywine, 2014; Krauss et al., 2015). Multiple studies have shown that cannabis consumption is sensitive to price (Ben Lakhdar et al., 2016; Gallet, 2014; Pacula & Lundberg, 2013), and Smart, Caulkins, Kilmer, Davenport, and Midgette (2017) show that for traditional cannabis flowers ("usable marijuana" in Washington State parlance), reported potency positively affects price. Some analysis has been completed on the cannabis market in Washington, including estimating the market demand (Kilmer et al., 2013) and baseline use patterns (Pacula, Jacobson, & Maksabedian, 2016), but past research focused on the illicit market, retail sales only, and/or did not break down the analysis by product types as we do here.

In Washington, the state Liquor and Cannabis Board (LCB) regulates the industry, licensing producers, processors, and retailers, and certifying laboratories. The LCB also manages a "seed-to-sale" database that is designed to capture *all* transactions and conversions of cannabis products as they move from producers to processors to labs and retail stores (Miller, 2017). This analysis takes advantage of these data to explore aspects of this new legal market including: 1. How to partition the broad product category "extracts for inhalation" into more insightful subgroupings, 2. The relationship between wholesale and retail prices, and 3. Calculating the Herfindahl-Hirschman index (HHI) to assess competitiveness in the processor and retail markets.

These analyses contribute to the academic literature just described and may be helpful to policy makers. As Schaneman (2018) describes, from the cannabis producers' perspective, "Washington state's cannabis supply continues to swell, flooding the market and causing both wholesale and retail prices to sink" and this has led shop owners and producers to seek changes to Washington's regulations. Grounding analysis and policy response in data is important; a similar story published three years earlier (Schroyer, 2015) reported worries that falling prices would lead to "a 90% failure rate for the 370 licensed producers and processors" and yet, as we show below, the number of licensees continued to grow briskly.

Data and measures

The unit of analysis here is perhaps most properly called an "item-entry" not a "transaction" because one purchase can produce multiple observations (Smart et al., 2017). For example, if a customer simultaneously bought two grams of one type of cannabis flower and one gram of another, that would generate two separate observations in this data set. However, the observations are also not simply items because multiple copies of the same item can appear within a single observation. If that person bought two separate one gram packages of the first type of flower for $10 each, that could appear as a single $20 observation with a "usable weight" of 2 g and a '2' in the "weight" field which, for retail transactions, indicates the number of items in that item-entry. Nonetheless, for brevity we will abbreviate "item-entry" to "item" in the sequel.

Each observation reports the price paid and whether the buyer is a retail consumer, store owner, processor, etc. In July 2015, Washington changed from a 25% tax at each step of the production process to a single retail excise tax of 37%. The pre-July 2015 observations include those taxes, while the post-July 2015 data do not. We inflate retail prices after July 2015 by 37% to match the effective cost to the buyer before state (6%) and local sales tax. Prices are expressed in dollars per gram, calculated as the sale price divided by the usable weight of the cannabis. Potency is defined as the "Total THC" content, calculated as active (decarboxylated) THC, plus 0.877 times inactive (carboxylated) THC-A, to account for changes in mass during decarboxylation (Smart et al., 2017).

The variable "inventorytype" distinguishes ten retail product types. This analysis focuses on the most common: "usable marijuana" which refers to traditional flower with minimal processing, solid and liquid "marijuana-infused edibles" which are cannabis infused food and drink products, and "extract for inhalation" (for simplicity, henceforth referred to as "extracts") which includes a wide range of processed products, including wax, kief, shatter, oils, and distillates for portable vaporizers.

Since the data encompass the *universe* of all legal transactions, not a sample drawn from some larger population, we generally do not test for the statistical significance of differences.

Results

Broader market overview

Table 1 summarizes the major product types, typical consumption methods, item prices, and THC potencies observed in June 2016. Potencies for edibles, infused mixes, and topicals are not reported because of concerns that not all stores may have been entering potency for those products in a consistent manner.

Partitioning extracts for inhalation

One prominent trend observed by Smart et al. (2017) is the increasing market share of extracts for inhalation (hereinafter "extracts"), which differs somewhat from what Daniulaityte et al. (2015) reports for the early years of Colorado's market.

Smart et al. (2017) only analyze in detail price and potency for usable marijuana (i.e., flower), in part because extracts include a heterogeneous amalgam of different product types. For example, cartridges and wax are both included even though they can differ in price, potency, and modality of use (Krauss & Sowles, 2015; Morean, Kong, Camenga, Cavallo, & Krishnan-Sarin, 2015). Fig. 1 plots the average