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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

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Competing interests

None to declare.

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.”

Keywords

Cannabis; Extracts; Potency; Prices; Legalization; Drug policy

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).

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 price vs. average potency for each extract product sold in June 2016. (There is one plotting point for each product name, not one point for each item sold.) Fig. 1 reveals few patterns; therefore, we exploit key words in the free text product-name field to search for more homogeneous sub-groups within this broad extracts-for-inhalation product type and to understand what types account for the cluster of products that combine high potency with low price. (We exclude the small number of high-CBD observations, defined here as those with greater than 1% CBD, which tend to be more expensive and have lower THC potency.)

Based on the literature, inspection of store menus, and reading the most common product names, we identified categories that were usually distinct (i.e., relatively few product names spanned categories). These categories are not perfect: words such as “shatter” and “wax” are often used interchangeably. Nonetheless, our data-driven approach suggested eight categories. For each we developed a set of search words (e.g., “shatter” or “budder” for shatter type products). The search function included a wildcard in front and behind the search word so searching on “wax”, for example, identified products called “earwax” and “wax-pucks”.

In general, only products whose names included search words for just one category were categorized. However, special rules were written for common overlaps. For example, “hash oil” was placed with other oils, and “cartridge oil” with other cartridge observations. However, a product that has both “hash” and “cartridge” in its name is left un-categorized since it is unclear what kind of product it is. Examples include “X-Tracted Hashplant Wax 0.5g”, “Fire Alien OG Live Resin Wax(0.5 g)”, and “DD Purple Jolly Rancher Dab Oil 0.5g”. (Each of these examples had fewer than 20 transactions in June 2016) Approximately 74% of all product names (accounting for about 63% of all extract transaction items) could be placed within a specific category, with the remaining observations in the “other” group. See Table 2.

Fig. 2 replicates Fig. 1 for these eight categories of extracts and reveals some patterns in price and potency.

Categories that appeared similar in Fig. 2 in terms of price and potency in that one month also tended to have similar trends in price and potency over time. For example, hash and kief both experienced decreases in potency over time, whereas wax, shatter, and resin all have high potency rates that are stable over time.

It is inconvenient to work with eight categories, and some keywords distinguishing among these eight are synonyms or near-synonyms; e.g.; hash and kief; and wax and shatter. For others; differences are mainly about packaging: some “dabs” can be thought of as single-serving packages of wax or shatter. Cartridges are an interesting intermediate case. They may contain the same variety of oil as when the oil is sold separately; but as we show shortly; they appear to sell at a higher average price; perhaps because of that packaging. Further; as these are slang-like words; definitions are not always clear and usage may vary. Notably; although hash/kief is made from what is often called resin in Europe; in Washington the term “resin” seems to be used to refer to a solid waxy concentrate similar to wax or shatter.

We collapse these eight into four broader categories (Table 3): 1) “cartridge”, 2) “oil”; 3) wax, shatter, dabs, and resin; and 4) hash and kief.

The wax/shatter/resin/dab segment is the largest (55% of categorized observations) and the fastest growing. The average number of transactions per store per day of a wax/shatter/resin product grew from 5 in June of 2015 to 17 a year later. Cartridge/oil transactions – the 2nd largest segment – also increased, but more in keeping with the rate of growth in Washington’s legal cannabis market overall (from 7 to 12 transactions per store per day).

This illustrates the value of partitioning extract observations. The number of extract transactions overall grew by 100% (from 15 to 30 transactions per store per day), but if someone harboring particular concerns about the health consequences of dab/shatter/wax/resin only had access to that figure, they would have underestimated the growth (240%) in the submarket of greatest concern to them.

Prices declined rapidly until the summer of 2015 for all categories of extract products, and afterwards continued declining but at slower rates. Prices in the cartridge and oil categories fell the most even though their average potency increased steadily from 50% to closer to 75%, whereas potency for the other two categories peaked and then decreased slightly, albeit at quite different levels. Wax/shatter/resin potency levels remain around 65% THC, whereas hash/kief have significantly lower potency.

Trends over time in wholesale and retail prices for usable marijuana and extracts

Retail prices of flower have fallen significantly since legalization (Caulkins, 2017; Smart et al., 2017). Price declines may stem from some combination of new production and processing technologies, mastery of existing processes, economies of scale, and greater competition. Policymakers pay attention to prices because they directly impact revenue from ad valorem taxes and indirectly affect health outcomes by influencing consumption. The

econometric literature typically finds that demand for cannabis is relatively inelastic. Point estimates of the elasticity of demand are often somewhere in the neighborhood of −0.5, meaning that a 10% decline in retail price would increase consumption by about 5% (Davis, Geisler, & Nichols, 2016; Gallet, 2014; Ouellet et al., 2017; Pacula & Lundberg, 2013). Price responsiveness can vary by group. For example, Williams (2004) find that youth are more sensitive to price, and Pacula and Lundberg (2013) report that the evidence, though thin, suggests that falling prices increase not only the prevalence of use but also its intensity, with regular users being more price sensitive than occasional users. These patterns would be consistent with demand being more price responsive for those who spend a larger share of their disposable income on the product, as one might expect.

Legalization could greatly reduce cultivation costs (Caulkins, Kilmer, & Kleiman, 2016; Kilmer, Caulkins, Pacula, MacCoun, & Reuter, 2010). Indeed, wholesale prices have been falling throughout the period of policy liberalization. Washington's voters passed legalization at the end of 2012. That year, the average wholesale price in Washington was about $2800 per pound (WSIN, 2012). By November 2016, the Cannabis Benchmarks spot index – a commodities price index for the American market – had fallen below $1400 per pound. Schaneman (2017) describes a Washington grower who was struggling to find buyers even at a price of $1 per gram ($454 per pound). Dundee Capital Markets (2016) reports that Aphria, a Canadian producer, has production costs of $400–$700 per pound in US dollars while producing 60 g per square foot in its greenhouses. If production costs fell to that typical of tomatoes grown in greenhouses – roughly $4 per square foot – that would work out to only $30 per pound.

It is unclear how declines in production costs might affect (pre-tax) retail prices. The question has a venerable history (Reuter & Kleiman, 1986; Kleiman, 1992). Caulkins (1990, 2007) laid out two extreme models that may bracket the actual relationship. Under the additive model, retail price equals wholesale price plus a constant, so if wholesale prices fall by $1 per gram then so will retail prices. Under the multiplicative model, retail prices are a fixed multiple of wholesale prices, so if wholesale prices fall by 10% then so will retail prices.

Washington State's seed-to-sale data provide a unique opportunity to examine this relationship directly because they follow individual units of cannabis as they move from producer to processor and down to retail sale. By contrast, past analyses based on law enforcement data could be vulnerable to selection biases if, say, retail enforcement focused on places or types of the drug that tended to have higher prices than did wholesale enforcement. For example, if retail prices pertained to sinsemilla in the interior of the United States and wholesale price data came from Mexican "commercial grade" marijuana near the Southwest border that might artificially inflate measured markups.

Technical details pertaining to the database complicate finding the price a producer (farmer) was paid by a processor for a particular unit of cannabis, so the present analysis compares the price customers paid the retail store with the (wholesale) price the retailer paid the processor for that same unit of cannabis. One might view this as a lower-level wholesale

price to distinguish it from producer (farm gate) prices or prices that pertain to transactions between processors.

Fig. 3 plots the average retail vs. processor prices by quarter, a 45° dashed line, and a line representing a constant 3:1 ratio of retail to wholesale prices for usable marijuana (left hand panel) and extracts (right hand panel). Average prices for extracts jumped up and down sharply in the first few quarters. It is not clear whether that is simply because there were so few observations, whether the extracts market had not matured, or whether perhaps some stores were not yet recording data on extracts correctly, but the plotting points for extracts start from Q2 2015 to avoid those early gyrations.

Even though prices fell substantially over this period, retail and wholesale price maintained a roughly 3:1 ratio for both product types after some initial fluctuations in the earliest quarters. Fig. 4 replicates the plot after partitioning extracts into more homogeneous categories. Although these categories vary in both absolute price and extent of price decline, the 3:1 ratio still holds by and large.

Hence, price trends to date in Washington's legal cannabis market have been more consistent with a multiplicative model. One should not leap to the conclusion that if, as expected, production costs continue to fall that decline will necessarily translate into proportional reductions in retail prices. No causal inference can be drawn from the stable-to-date ratio. Prices at the two market levels may have declined in lock step because parallel forces (efficiency gains, increased competition, etc.) operated independently but with equal force at both market levels, not because the decline in processor prices caused the proportionate decline in retail prices.

Market concentration

Market power – meaning a small number of firms controlling a large proportion of sales – is an important variable that determines how firms behave toward competitors and consumers. Reports of consolidation in the industry are common (e.g., Lamars, 2018). Hence, it is of interest to ask at which layers of Washington's legal cannabis market is there much market concentration.

Interviews with market players suggest that processors and producers seem to think that retailers are market makers in Washington State, driving prices and potency (Bao et al., 2017). One producer explained:

> "At the time, there was roughly an infinite amount of growers but limited number of stores. So that gave the stores the power. They thought they'd have 250+ stores at the end of the first year but they had about 100."

Some processors reported that immediately after legalization they were obligated to respond to pressure from retailers to make products with high potency as retailers were scarce and therefore had more negotiation power. Fig. 5 seems consistent with this story. It plots over time of the number of licensees for retailers, producers, processors, and integrated producer-processors. (Producer-processors may both grow marijuana and process it from wet flower into intermediate or final products, although our impression is that they generally resemble

producers more than processors.) Fig. 5 shows that the number of retailers did grow more slowly than did the number of processors and producers.

Simple counts do not tell the whole story. Because of craft beers, there are now more than 5000 breweries in the United States, up from fewer than 100 in the 1980s (Tuttle, 2016). However, Bailey (2015) reports that just four firms account for 80–90% of all production.

The Herfindahl-Hirschman index (HHI) is a better measure of market concentration. It is calculated by squaring the market share of each firm competing in a market and summing the resulting numbers. The index can range from close to zero up to 10,000. Low values indicate more competitiveness.

Fig. 6 reports the state-level HHI index for processors and retailers for the three largest classes of cannabis products; the vertical axis is logged so as not to obscure the continuing declines in recent years. All six trends lines show declining market concentration (increasing competitiveness).

The state-level market for usable marijuana was never concentrated. The market for extracts was at first, but it is no longer. Edibles processing was initially highly concentrated; it now falls below 1500 and so in the range customarily referred to as “unconcentrated”. By way of comparison, the federal government has reported that the HHIs for beer and spirits are 2885 and 2180 respectively (or 3.5 and 3.3 after taking logs).[1]

If one views the state as one big retail market, then retailers have less not more market power than processors. However, since retail purchases are generally quite small − usually less than $30 or $40–customers may only buy locally. When the retail HHI is measured at the county level, the median across counties with stores has remained high, falling only from about 5000 to 4000 (3.7 to 3.6 in log terms), but that median is deceiving. The retail HHI in larger counties (King County which includes Seattle, Spokane, etc.) are low; the average is driven up by a few less populous counties that have a single store. The population-weighted average retail HHI has fallen from about 7500 to 1000 (3.9 to3.0 in logged values) for all three product categories.

Yet as Fig. 7 shows for usable marijuana in 2016, that average masks considerable variation across counties by population. (The retail HHI for other products are very similar.) Most of the state’s population lives in counties with unconcentrated retail markets, but many of the less populous counties have high degrees of market concentration at the retail level.

Discussion

It has been common to distinguish cannabis flower from products produced by “mechanical” extraction methods (termed herbal cannabis vs. resin in much of the world and marijuana vs. hashish in North America). Sometimes there were special names for higher potency flower products (sinsemilla vs. commercial grade in North America and skunk or hydroponic vs. herbal in Europe).

[1] https://www.ftc.gov/system/files/attachments/us-submissions-oecd-other-international-competition-fora/oligopoly_us.pdf.

However, that simple, traditional typology fails badly in Washington's legal market. Almost all of the herbal product is high-potency and hash and kief account for a quite small share of the rapidly growing extract market segment, which is dominated by solvent-based extraction (particularly if one views supercritical C02 as a solvent). Furthermore, edibles constitute a non-trivial share of sales, and there are other categories (e.g., cannabis "mixes").

Post-legalization, researchers and policy makers may need to think in terms of a family of cannabis products, akin to how we think of opioids, new psychoactive substances, and amphetamine-type stimulants, not a single drug "cannabis" the way it is possible to think of powder cocaine and crack markets. A non-drug analogy would be thinking about the full suite of dairy products, including ice cream, butter, and yogurt, not just milk or milk and cheese.

This paper took a step toward creating a typology for one part of the cannabis product family, namely extraction products. Partitioning is important since market trends can vary across types of extract products. For example, someone looking only at aggregate data on all extracts might under-estimate growth in sales of "solid" extracts (such as dabs), whose sales have grown faster than have oils and cartridges. There are at least two reasons why the legal industry is embracing extracts. First, just as prescription pills can bring opioids to those who shun injecting drugs, extract-based products can reach customers who dislike smoking. Second, now that owning extraction machines does not create a risk of arrest, there is no reason to discard the THC contained in leaves and other parts of the plant besides flowers. Since most of the plant's weight is in leaves, not flowers, a considerable share of the cannabinoids appear in parts of the plant that could not so easily be brought to market before legalization.

We suspect that Washington State today manifests only the beginning not the culmination of the changes in product form and marketing that legalization will bring. It is not hard to imagine additional product forms emerging that might shake up any current typology, e.g., "bundled" products that combine cannabis with alcohol, tobacco, or other intoxicants. (Washington currently prohibits cannabis products to be mixed with alcohol and tobacco, but this could change). Therefore, we view the present effort as just the beginning of attempts to partition the rapidly evolving cannabis product space.

The curiously stable 3:1 ratio of retail to wholesale prices merits further analysis and replication. It appears to hold across a range of products, but all of our data come from just one jurisdiction and time period. Perhaps the stability of that ratio reflects not something intrinsic to the products or production technologies, but rather something unique to Washington State's regulatory practices, or even the oddities of tax law (Section 280(e)) during this strange time when the cannabis business is state-legal but still prohibited under federal law.

If the multiplicative relationship between wholesale and retail prices were sustained and production costs continue to fall, that might portend quite low pre-tax retail prices in the future. However, we stress that the analysis above is purely descriptive and does not in any

way demonstrate a causal relationship between declines in wholesale prices and corresponding declines in retail prices.

Conclusions and further work

At a high level, the conclusions of this analysis are clear. Legalization induces dramatic changes in cannabis markets, and seed-to-sale monitoring systems offer a window into those changes. Hence, states might want to design these systems in ways that facilitate not only data integrity and administrative functions (collecting taxes, ensuring compliance with testing requirements, etc.), but also the monitoring of market-level aggregates that are of interest to public health.

One limitation is the absence of information on the customer. If customers' identities were known, one could look at individuals' trajectories of purchasing over time and investigate the extent to which frequent purchasers account for a disproportionate share of sales. Indeed, after exploiting seed-to-sale monitoring data the next generation of analysis may want to tap data from companies' "frequent buyer" programs since companies will want to connect different transactions associated with the same repeat customer.

The empirical regularities reported here could prompt some theoretical work. In particular, the surprising stability of the 3:1 ratio of retail to wholesale prices is a puzzle. One story would be that since there are many stores, retail prices ought to equal wholesale prices marked up by enough to cover normal profits and the cost of operating a retail establishment, which one might have expected to be a certain number of dollars per gram. However, since the three to one ratio held even as wholesale prices fell, the markup has fallen sharply in dollars per gram. The next step might be measuring the relationship between retail and wholesale prices in other states. If ratios observed elsewhere are also stable, that calls out for some theoretical explanation.

Many additional analyses could be pursued with seed-to-sale data. For example, it might be fruitful to apply cluster analysis to the inhalant data. It could also be instructive to complement the seed-to-sale data-driven categorization with parallel efforts that draw on other sources of information, such as store menus and the informal literature produced by users, perhaps including social media descriptions of patterns of use.

An interesting challenge would be attempting to replicate the partitioning analysis with edibles, a category that includes various solid products (cookies, caramels, granola, candy cubes, peanut butter cups, etc.) and liquids (lemonade, punch, droppers, and sprays). However analysis of weight, potency, and hence potency-adjusted price per might be considerably more complicated.

Testing practices are another topic of interest. Washington State lets producers pick the lab that will test their products, with limited auditing of reported test results by an independent third party (Young, 2017). This creates incentives for labs to give results that producers like, such as repeatedly sampling until a batch passes a quality control test (e.g., concerning moisture, mold or pesticide residue). Systematic variance of test results across laboratories has raised suspicions among independent analysts and the LCB, and two of the most popular

of Washington's eighteen certified labs have been suspended due to deficiencies in testing practices, including lower than expected contaminant failure and higher average potency tests (Young, 2016, 2017). It would be interesting to see if producers' decisions to switch from one lab to another seem correlated with test results.

More generally, the supply chain above retail can be investigated in ways that have not previously been possible, such as measuring yields per unit area and price markups between growers and processors. The structure of the database complicates such analyses, but their novelty might warrant that effort.

Correlating fine-grained sales data with corresponding data on traffic crashes or emergency room visits could be of interest. The seed-to-sale system reports to the minute when a sale was recorded, so they may expose associations that are hidden in data reported only monthly or quarterly. That detail might also be valuable for teasing out substitution or complementarity with alcohol (c.f., Guttmannova et al., 2016), e.g., if crimes commonly associated with alcohol go up or down immediately after a store changes its menu of cannabis prices.

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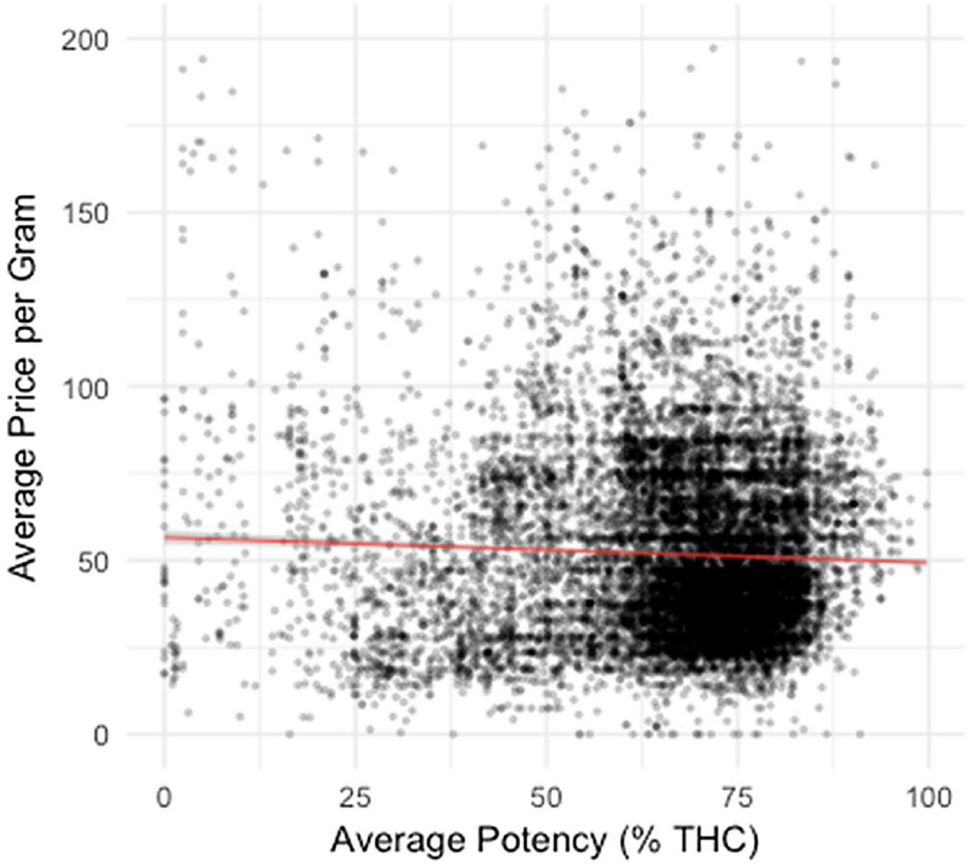

Fig. 1.
Statewide average price and potency of each extract product sold in June 2016.

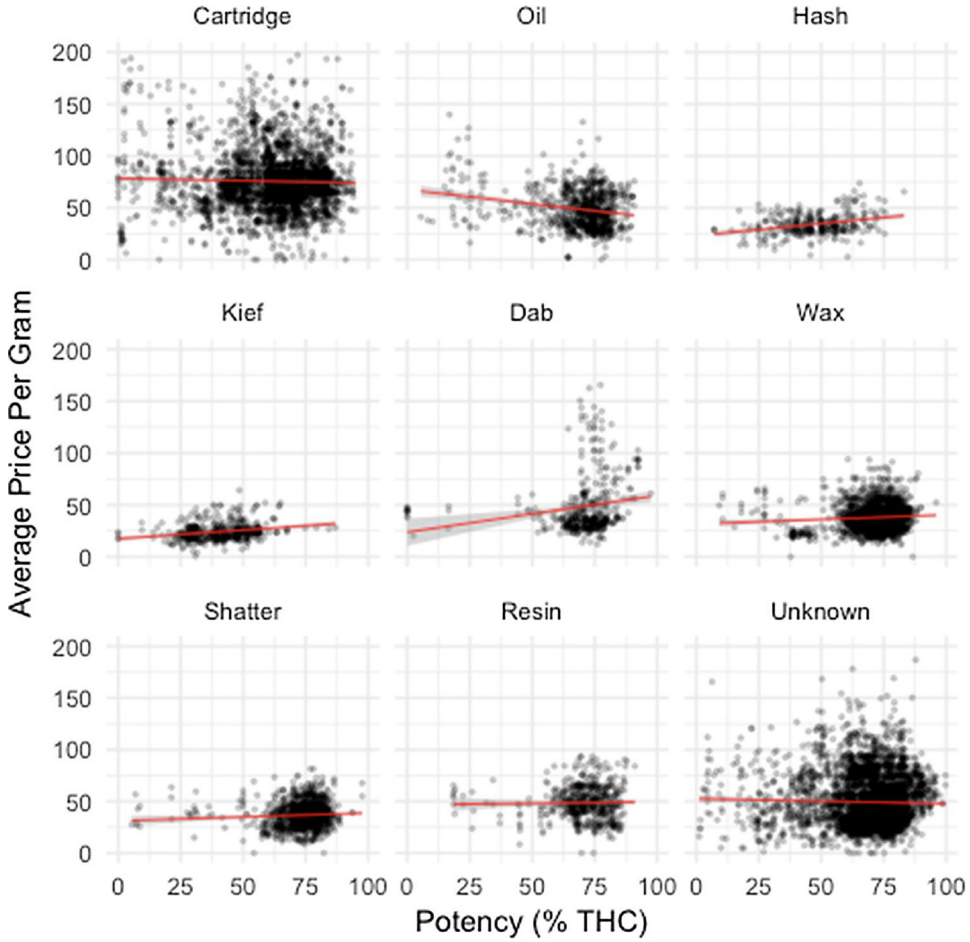

Fig. 2.
Average price and potency for various types of extract products, June 2016.

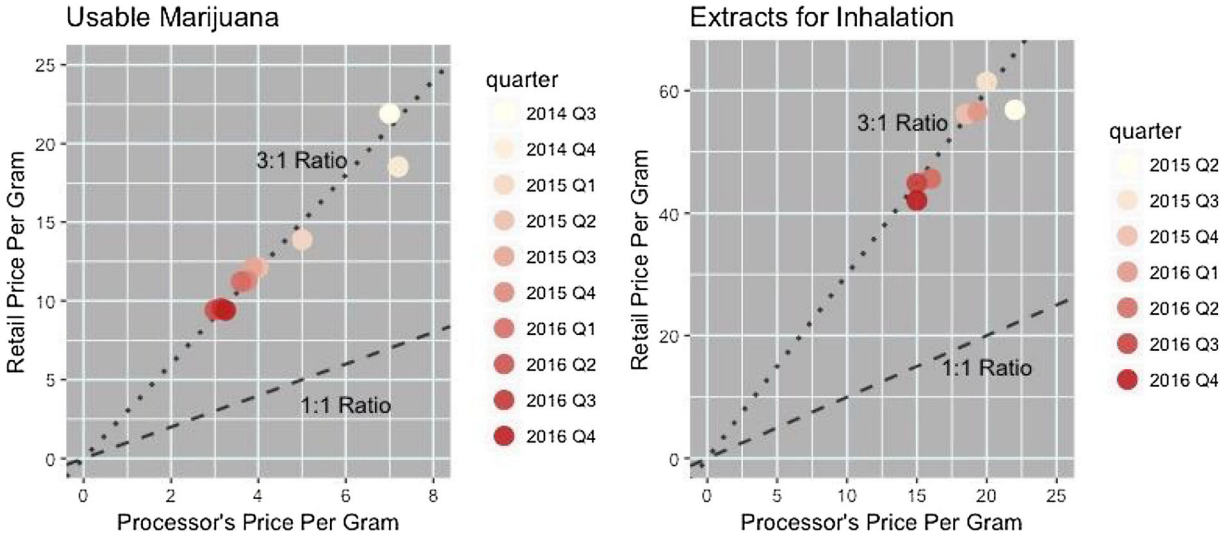

Fig. 3.

Relationship between retail and processor prices for usable marijuana (left panel) and extracts (right panel).

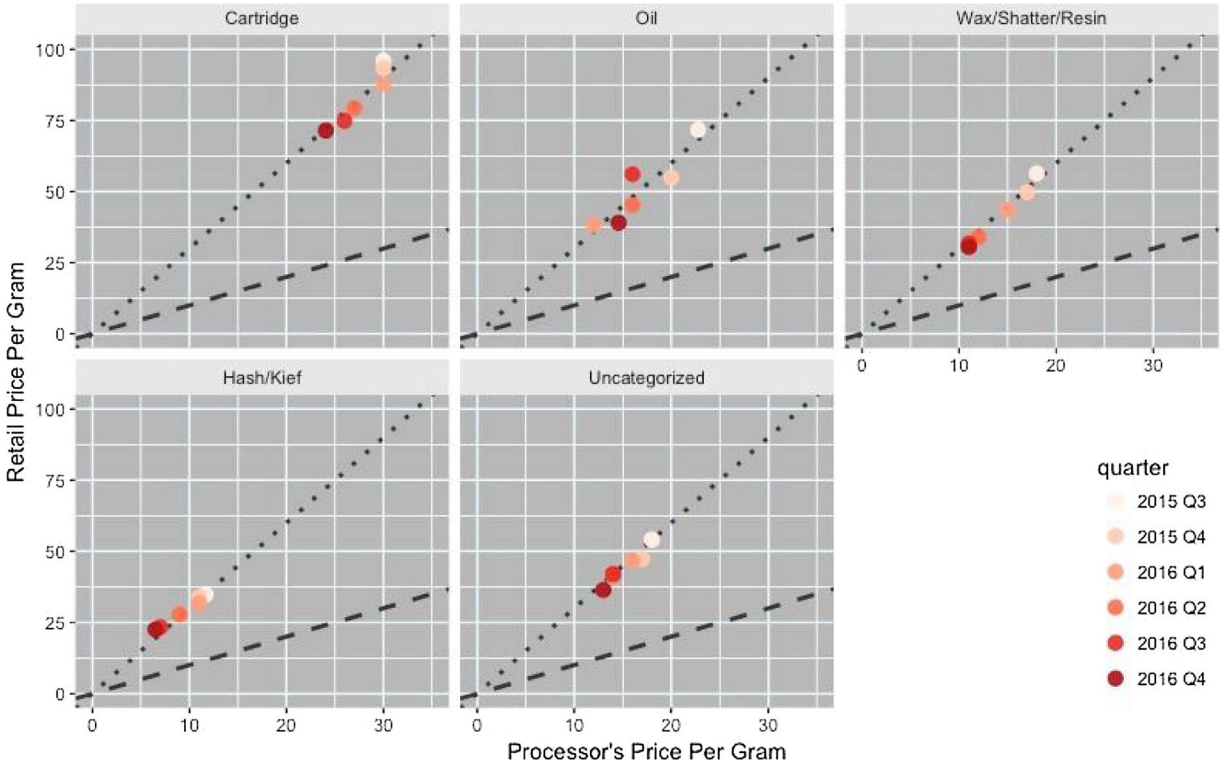

Fig. 4.
Relationship between retail and processor prices for extracts, by subcategory.

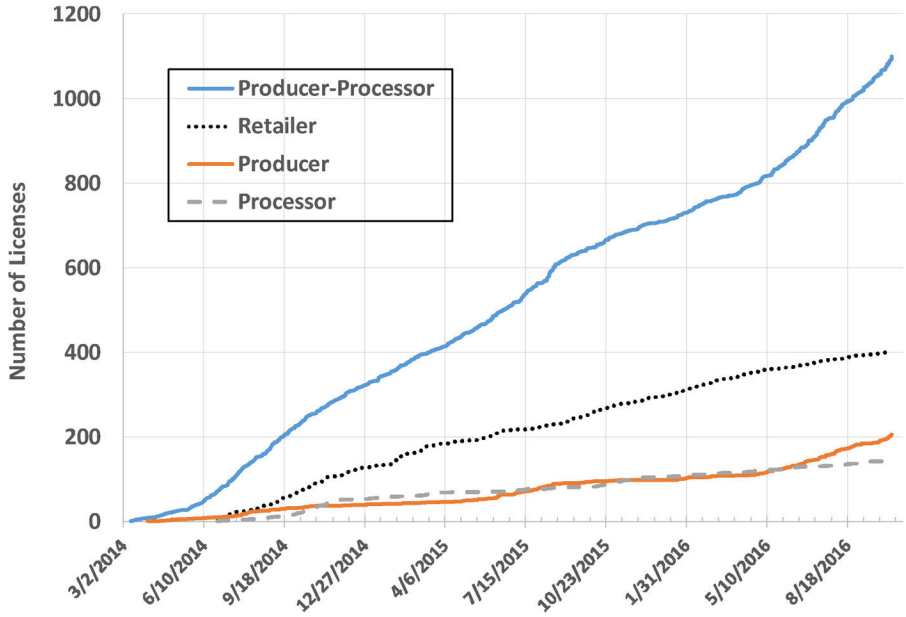

Fig. 5.
Number of licenses for producers, processors & retailers.

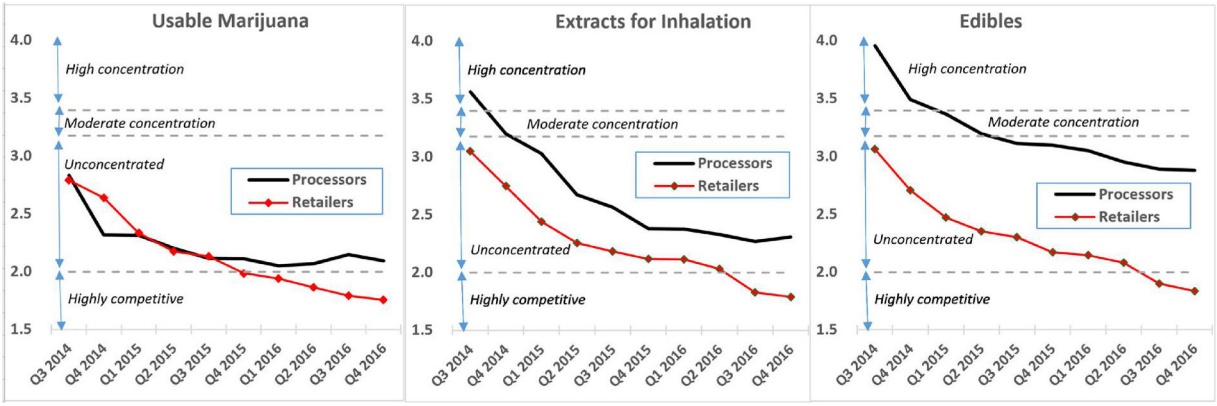

Fig. 6.

Trends in the Herfindahl-Hirschman index for processors and retailers by product, vertical axis in log values.

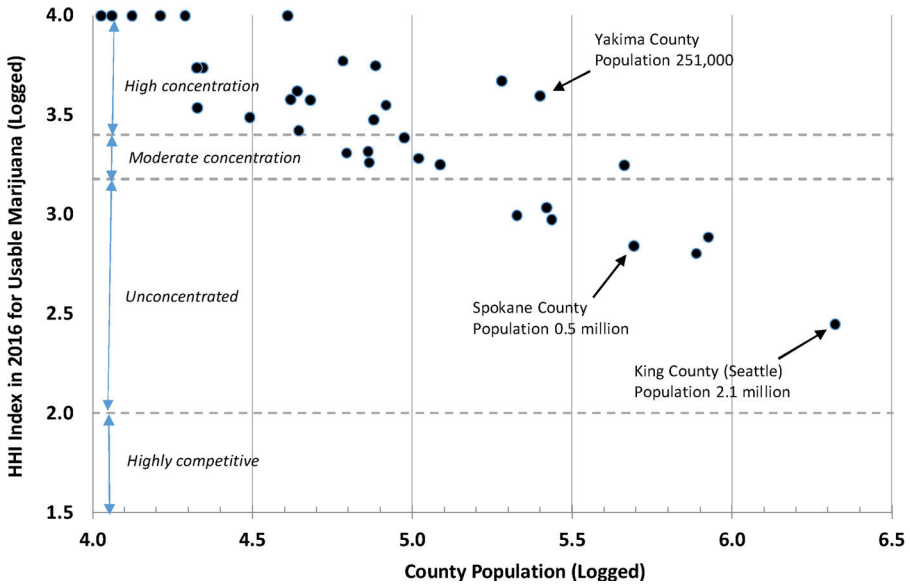

Fig. 7.

Herfindahl-Hirschman index for usable marijuana retailers vs. population, both axes in log values.

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%

Table 2

Categorization schema for extracts based on June 2016 retail sales.

Category	Search word(s)	Three most common product names within that category	Proportion of obs.
Cartridge	cart, vape, pen, vc, refill	The Clear Cartridge; Liberty Reach, 0.5 g PURE Vaporizer Cartridge, Blue Dream; Willy's Wonder 0.5 ml Cartridges	22%
Oil	oil, rso, eso	Jesus (.5 g) Oil; Berry Haze (.5 g) Oil; Pineapple Super Silver Haze (.5 g) Oil	3%
Hash	hash	Bubble Hash 0.5 g; Sugar Hash - 1 g; Monk Hash - 1 g	1%
Kief	kief, keif	Kief, BSH Kief 1 g; BSH Kief 1 g	3%
Dab	dab	Lucid Dabs (1 g); Dabulators 0.25 g; Dabz - Mt Rainier #10;	1%
Wax	wax, budder	Wax 1 g; Blue Dream SugarWax; Supergirl Wax 1 g	19%
Shatter	Shatter, crumble	1 g Girl Scout Crumble (grow state); Concentrate: BHO Shatter 1 g; Wa Woo Cookie Shatter	11%
Resin	resin, rosin	Pineapple Express Live Resin (.5g); Tangie Live Resin (.5g); Middlefork Live Resin (.5g)	4%
Uncategorized	NA	Dutch Hawaiian Frost R.IO6013z 0.5 g Atomizer; The Clear Concentrate; Jedi Kush	36%

Table 3

Extract market broken down by product category for June 2016 (observations with matched product names only).

Product	Use Method(s)	Average Price	1st Quartile	3rd Quartile	Average THC Potency	1st Quartile	3rd Quartile	Market Share
Cartridge	Vaporized	$ 79.56	$65.46	$86.78	68	61	78	34%
Hash/kief	Smoked or added to flower	$ 23.57	$16.92	$28.21	41	30	50	6%
Oil	Vaporized or added to flower	$ 43.13	$29.92	$54.25	72	68	78	5%
Wax/shatter/resin/dab	Flash vaporized (“dabbed”)	$ 30.54	$23.36	$35.77	73	70	78	55%