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Bayesian inference for the distribution of grams of marijuana in a joint

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ABSTRACT

Background: The average amount of marijuana in a joint is unknown, yet this figure is a critical quantity for creating credible measures of marijuana consumption. It is essential for projecting tax revenues post-legalization, estimating the size of illicit marijuana markets, and learning about how much marijuana users are consuming in order to understand health and behavioral consequences.
Methods: Arrestee Drug Abuse Monitoring data collected between 2000 and 2010 contain relevant information on 10,628 marijuana transactions, joints and loose marijuana purchases, including the city in which the purchase occurred and the price paid for the marijuana. Using the Brown–Silverman drug pricing model to link marijuana price and weight, we are able to infer the distribution of grams of marijuana in a joint and provide a Bayesian posterior distribution for the mean weight of marijuana in a joint.
Results: We estimate that the mean weight of marijuana in a joint is 0.32 g (95% Bayesian posterior interval: 0.30–0.35).
Conclusions: Our estimate of the mean weight of marijuana in a joint is lower than figures commonly used to make estimates of marijuana consumption. These estimates can be incorporated into drug policy discussions to produce better understanding about illicit marijuana markets, the size of potential legalized marijuana markets, and health and behavior outcomes.

1. Introduction

Knowing the average weight of a joint turns out to be a key factor in major drug policy debates that are active today. A handful of states have legalized marijuana production and possession and several other jurisdictions are actively debating legalization. Some of the arguments cited in favor of legalization include an increase in tax revenue derived from legal marijuana sales and the reduction of revenues to drug trafficking organizations. The average weight of a joint turns out to be an important factor in assessing these two issues. Official government estimates of drug usage and expenditures hinge on having a good estimate of the average weight of marijuana in a joint (Office of National Drug Control Policy, 2014).

We actually have little information on how much marijuana an average user consumes and, therefore, projecting how much revenue can be diverted from Mexican drug trafficking organizations and how much revenue might flow into state coffers post-legalization turns out to be challenging. While there are multiple ways to consume marijuana, joints continue to be a common method for consuming marijuana. Schauer et al. (2016) found in a nationally representative consumer panel that for half of marijuana users who responded joints were the preferred method of marijuana use and 89% of respondents reported having smoked a joint at some time in their lives. Some sources for understanding drug use ask about the number of joints smoked rather than weight of loose marijuana. Therefore, in order to obtain good estimates of the quantity of marijuana consumed we need to know how much marijuana is in those joints on average. Perhaps as important as the point estimate for the average weight, a good understanding of the uncertainty around the estimate can prevent policymakers from placing too much confidence in their projections.

A number of studies reported that the typical weight of a marijuana joint ranges from 0.3 to 0.5 g (Kilmer and Pacula, 2009). Using self-report purchase data from arrestees who purchased either 1 g or 1 joint of marijuana between 2000 and 2003, Kilmer et al. (2010) estimate that the average weight of a joint was 0.46 g (95% CI: 0.43–0.50). Mariani et al. (2011) had marijuana users measure out an amount of oregano comparable to what they would ordinarily consume and estimated that joints average 0.66 g of marijuana (with a standard deviation of 0.45g!), but the relative density of oregano to marijuana is unknown. Many discussions among users

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in online forums frequently cite figures between 0.5 and 1.0 g per joint. Gettman (2015) suggests that 0.75 g is the norm and his informal web survey of *High Times* readers indicated that 80% believed that their joints were between 0.5 and 1.0 g. For comparison, the typical cigarette has about 1 g of tobacco.

Kilmer et al. (2010) note a few reasons why their estimate of 0.46 g may have been an overestimate. First, drug dealers tend to be on the light side when selling "one gram" so a reported purchase of 1 g was likely a bit less than 1 g. However, we have no data to verify this or understand the distribution of weight of "one gram" of marijuana. Second, the price per gram for a transaction in grams is estimated at a (marginally) higher "market level" than is the price per gram for a single joint. Price as a function of weight is often modeled as a power function so that the price per gram will tend to be lower for larger quantities (Brown and Silverman, 1974; Caulkins and Padman, 1993). The Kilmer et al. (2010) analysis did not use the power function, but we remedy that in this paper with a richer model that allows for volume discounting.

In this paper we take advantage of a high quality dataset on information collected from arrestees as part of a US Department of Justice initiative that tracked trends in illegal drug markets. Conveniently, arrestees are asked how much they paid for their drugs and what they purchased. Some arrestees report the weight of loose marijuana purchased and the purchase price, while other arrestees report the number of joints purchased and the purchase price. We use a Bayesian analysis to infer the average weight of a joint by modeling marijuana prices, accounting for variation in price by location and time, and using those prices effectively to impute the unobserved joint weights.

2. Data and methods

This section provides an introduction to the data and a description of our model.

2.1. ADAM – Arrestee Drug Abuse Monitoring

The Arrestee Drug Abuse Monitoring (ADAM) Program is a jail-based interview that asks arrestees about their substance use, drug market transactions, and additional information such as their treatment experiences, employment status, and housing stability. The information is only used for research purposes and results are not shared with law enforcement officials. At the end of the interview arrestees are asked to take a urinalysis test. The program was formerly known as Drug Use Forecasting and was converted to the probability-based ADAM in 2000 when attempts were made to obtain representative samples of male arrestees (not just those arrested for drug offenses). In the early 2000s ADAM was operational in over 35 counties with more than 20,000 arrestees agreeing to participate each year (U.S. Dept. of Justice, National Institute of Justice, 2002). Funding for the program was eliminated beginning in 2004 and a smaller version of the program (ADAM II) was resuscitated in 2007 with only 10 counties exclusively focused on adult males. By 2011 ADAM II had shrunk to five counties and after 2013 was eliminated, again (Kilmer and Caulkins, 2014).

Our analysis is based on a subset of ADAM data consisting of reported marijuana price and quantity from 24,910 arrestees between 2000–2003 and 2007–2010 in a total of 43 counties (but only 10 counties participated in all 8 years). ADAM is not nationally representative and so, as a result, our analysis reflects the ADAM population rather than the nation. Arrestees reported marijuana in terms of grams or ounces, but also in terms of the number of bags, blunts, or joints. For this study we used data only on marijuana measured in grams ($n = 5845$), ounces ($n = 8027$), or joints ($n = 2230$). We converted all ounce measurements to grams. Of those cases, 4 were missing measurements of weight or quantity, 21 were missing price, and 1 had price given as \$0. We eliminated these cases from the dataset.

We further narrowed the dataset to focus only on those drug quantities most relevant for learning about the amount of marijuana in a joint. Quantities of a half kilogram of marijuana or 50 joints and their associated prices are more likely to have been procured from a distributor rather than a retail sale. If we include them, then our analysis would lean more heavily on parametric assumptions and risk greater bias. Therefore, we focused the dataset on quantities of less than 10 g of marijuana (64% of loose marijuana quantities) and less than 10 joints (98% of quantities of joints).

For loose marijuana, the recorded price per gram varied between \$0.14 and \$1200 with a median price of \$7.05. A price of \$1200 for a gram of marijuana is simply not credible. In fact, prices in excess of \$40 for a gram are highly suspicious, likely the result of errors in the data collection or data entry. As a result we dropped cases less than \$1.25 per gram (the smallest 1%) or greater than \$40 per gram (the largest 3%), eliminating 315 cases from the dataset. The resulting median price per gram remained \$7.05 with 80% of the values falling between \$2.82 and \$20 per gram.

The recorded prices per joint ranged from \$0.25 to \$525 with a median price of \$3.33. Again errors in data collection or data entry are likely responsible for values like \$525. We dropped 32 cases with prices per joint less than \$1 (1% of cases) or greater than \$20 per joint (0.5% of cases). The resulting median price per joint remained \$3.33 with 80% of the values falling between \$1.67 and \$10. The final dataset included price data and weight data on 8492 reports of loose marijuana and 2136 reports of joints.

Table 1 shows a summary of the number of arrestees in our ADAM dataset with complete weight and price data from quantities of less than 10 g and less than 10 joints and without suspiciously large or small prices.

We can use these figures to obtain an estimate of the average weight of a joint. Since the average price per gram in our dataset is \$6.81 and the average price of a joint is \$3.50, then we should expect the average weight of a joint to be 3.50/6.81 = 0.51 g. This simple estimate does not account for several key issues including variation in the price by location, variation in price across years, and volume discounting. In fact, the Bayesian analysis described next has 0.51 falling well outside the 95% posterior interval, indicating that properly accounting for time, place, and quantity discounting impacts the estimate. To illustrate this, if we restricted the analysis to loose marijuana purchases of 5 g or less (instead of 10 g or less) then the average price per gram would be \$9.30 not \$6.81 and the resulting naïve estimate of the weight of a joint would be 3.50/9.30 = 0.38 g. This shows the importance of factoring in quantity discounts. At the same time we do not want to simply discard the data points pertaining to 5–10 g purchases because they contain useful information about variation in prices across locations and over time. Instead, we adjust for quantity discounts within a model described in the next section.

2.2. Bayesian inference for marijuana weight

We first consider the data on arrestees reporting loose marijuana transactions. Let p_{ijk} be the price paid for marijuana weighing w_{ijk} grams as reported by arrestee i in city j in year k. Price as a function of weight is commonly modeled with the Brown–Silverman drug pricing model, by a power relationship of the form

$$p_{ijk} = e^{\beta_j} e^{\alpha_k} w_{ijk}^{\gamma} \quad (1)$$

where β_j and α_k are location and year factors respectively that scale the price for regional variation and inflation (Brown and Silverman, 1974; Caulkins and Padman, 1993; Kilmer et al., 2010). Caulkins