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An Analysis of the United Kingdom's Cannabis Market Using Crowdsourced Data

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This article contributes to the growing literature on the use computer mediated communications to research illicit markets. In it, we conduct an analysis of the British cannabis market using data crowdsourced from a publicly available platform, *PriceofWeed.com.* Crowd-sourced transaction data presents some new insights into the British cannabis market. First, this study has tracked the trafficking flow of cannabis within the UK. Second, it shows the extent to which a quantity discount is granted to consumers. Third, it discusses purchasing habits of cannabis users. Conclusions suggest new areas of application of crowdsourcing to research hard to reach and deviant populations.

Introduction

In recent years, social media data emerged as an important, additional source of information for social science research. Gantz and Reinsel[1] estimated that by 2020 the global volume of digital data will be 35 zettabytes (3.5×10^{22} bytes), a figure that is 44 times the volume of the total digital data that was available in 2010. The ease of uploading information means that more digital data is now created every two to seven days than what was generated and recorded in the entirety of humankind until 2003 (Griffiths, 2012). These huge streams of data represent an unprecedented source of information to examine problems that have historically been difficult to study.

This article contributes to a growing literature on the use of social media and computer mediated communications to research crime-related problems and deviant populations [2]. We conducted an analysis of the British cannabis market using data

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[1] Gantz and Reinsel, 'The Digital Universe Decade – Are You Ready?'

[2] Williams, Burnap, and Sloan, 'Crime Sensing with Big Data'; Gerber, 'Predicting Crime Using Twitter and Kernel Density Estimation'; Holt and Blevins, 'Examining Sex Work from the Client's Perspective'; Holt, 'Identifying Gaps in the Research Literature on Illicit Markets On-Line'.

crowdsourced from a publicly available platform, *PriceofWeed.com*. The results provide insights to cannabis trafficking flows, dealers' behaviors, and consumers' purchasing habits in the United Kingdom that would not be possible or very expensive to develop using traditional data sources.

This article proceeds as follows: First, we discuss what research strategies of illicit drug markets. Second, we show crowdsourcing drug prices can serve as a valid additional data source. Third, we illustrate how crowdsourced data mined from priceofweed.com can be a viable in terms of predicting prices, by triangulating the data with other, publicly available sources. Fourth, we demonstrate how the *Price of Weed* data can be used to understand trafficking flows, the degree to which discounts are given for quantity sold, and the purchasing habits of buyers. Finally, we discuss the benefits, limitations, and future applications of our approach.

Researching Illicit Drug Markets

Researchers have studied illicit drug markets in various ways, including analyzing collated data sets, examining court documents, conducting ethnographies and qualitative interviews [3], analyzing seizures [4], and surveying drug users [5]. Each approach has it benefits and limitations. Ethnography, court documents, and qualitative interviews allow researchers to conduct a nuanced examination of local drug markets, behaviors of the different participants, and social and cultural norms regulating the local drug market. Some scholars even resorted

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[3] Decker and Chapman, *Drug Smugglers on Drug Smuggling*; Potter, *Weed, Need and Greed*; Murphy, 'Drug Court as Both a Legal and Medical Authority'.

[4] Farrell, 'The Global Rate of Interception of Illicit Opiates and Cocaine 1980-1994.'; Burgdorf, Kilmer, and Pacula, 'Heterogeneity in the Composition of Marijuana Seized in California'; Stevens, *Drugs, Crime and Public Health*.

[5] Hughes and Stevens, 'What Can We Learn From The Portuguese Decriminalization of Illicit Drugs?'; MacDonald, 'Illicit Drug Use in the UK'.

to video footage of narcotics transactions extracted from the closed-circuit television to have

a less intrusive observation of drug dealers' behaviors[6]. Nonetheless, the main limitations

shared by these approaches is that they are, generally, time consuming, expensive, and lack

generalizability across marketplaces. Given that markets' components and characteristics,

including actors, roles, social and cultural norms within[7], are variable, the analysis of any

given market may not lead to comparative conclusions that are applicable to multiple markets

or markets of a given region.

In response, to develop generalizable findings on drug shipment volumes, one

strategy researchers have employed is to measure drug seizures, which are a function of the

quantity of drug shipped into a country[8]. As such, seizure data can be used to estimate the

national and international supply of illicit drugs. However, the quantity of drugs seized is not

a straightforward indicator of supply; seizures are the outcome of several factors including

the relative skill of the interdictors, the care taken by smugglers, and whether the jurisdiction

is a known transshipment point[9].

Many developed and developing countries estimate drug use prevalence through

periodic surveys of students and their general population[10]. Prevalence measures, regarded as

the best available indicator to understand how well a country is doing in controlling illicit

drugs[11], dominate the literature. However, population surveys have well-known limitations

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[6] Moeller, 'Video-Recorded Retail Cannabis Trades in a Low-Risk Marketplace'; Piza and Sytsma,
    'Exploring the Defensive Actions of Drug Sellers in Open-Air Markets'.

[7] Ritter, 'Studying Illicit Drug Markets'.

[8] Farrell, 'The Global Rate of Interception of Illicit Opiates and Cocaine 1980-1994.'; Giommoni,
    Aziani, and Berlusconi, 'How Do Illicit Drugs Move Across Countries?'

[9] MacCoun and Reuter, *Drug War Heresis: Learning from Other, Vices, Times, & Places*.

[10] Mounteney et al., 'The Drug Situation in Europe'.

[11] Kilmer, Reuter, and Giommoni, 'What Can Be Learned from Cross-National Comparisons of Data
    on Illegal Drugs?'

such as nonresponse by those who frequently use drugs, misreporting by those who do report use, and unwillingness by many users who do respond to disclose their use[12].

A new line of research has been opened by the recent diffusion of anonymous online drug marketplaces (also known as drug cryptomarkets). Several scholars have resorted to quantitative methods measuring the economic performances of these markets[13] or observing forum threads where buyers, vendors, and administrators discuss cryptomarket issues[14]. Nonetheless, despite cryptomarkets' potential to change the way illicit drugs are bought and sold, they only represent a tiny fraction of the illicit drug market[15].

Given some of the limits of alternative data sources, several researchers use drug prices as a metric to extrapolate information about drug market dynamics. The three main sources of data on drug prices are (1) synthesis reports by national and international agencies such as the United Nations Office on Drugs and Crime (UNODC); (2) transaction-level data from law enforcement agencies such as the US Drug Enforcement Administration; and, (3) self-report data collected from drug users, where respondents report characteristics of their transaction such as how much they spent, what they bought, and the quantity purchased[16].

Accordingly, exploiting information on the cost of illicit drug transactions is particularly appealing as price data are relatively abundant. Moreover, transaction data can be

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[12] Bowman-Bowen and Menard, 'Survey Design Elements as Influences on Estimates of Self-Reported Illicit Substance Use and Other Illegal Activities'; Giommoni, Reuter, and Kilmer, 'Exploring the Perils of Cross-National Comparisons of Drug Prevalence'.

[13] Aldridge and Décary-Hétu, 'Not an "Ebay for Drugs"'.

[14] Moeller, Munksgaard, and Demant, 'Flow My FE the Vendor Said'.

[15] Kruithof et al., 'Internet-Facilitated Drugs Trade. An Analysis of the Size, Scope and the Role of the Netherlands'.

[16] Caulkins, 'Price and Purity Analysis for Illicit Drug: Data and Conceptual Issues'.

disaggregated geographically and temporally to investigate specific patterns[17]. Given its versatility, pricing information has been used in a large array of applications including estimating the elasticity of demand[18], predicting the number of overdoses[19], understanding how traffickers respond to law enforcement interventions[20], and estimating a country's expenditure on illicit drugs[21].

Recently, a data source that tabulates user's self-reported expenditures, the publicly accessibly, clear-web website PriceofWeed.com, has attracted attention among North-American scholars. This website crowdsources data on cannabis transactions, including how much users spent, what kind of cannabis product they bought, and the quantity and perceived quality purchased. This data has been used to examine the consequences of cannabis legalisation in California[22], the effect of law enforcement on cannabis price[23], the elasticity of cannabis demand[24] and even to inform on the financial implications of the legalisation of cannabis in Canada[25]. Data on cannabis prices crowdsourced from the PriceofWeed.com,

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[17] Moeller, 'Video-Recorded Retail Cannabis Trades in a Low-Risk Marketplace'; Sifaneck et al., 'Retail Marijuana Purchases in Designer and Commercial Markets in New York City'; Wilkins, Reilly, and Casswell, 'Cannabis "tinny" Houses in New Zealand'.

[18] Olmstead et al., 'The Price Elasticity of Demand for Heroin'; Bretteville-Jensen, 'Drug Demand – Initiation, Continuation and Quitting'.

[19] Scott et al., 'High-Frequency Drug Purity and Price Series as Tools for Explaining Drug Trends and Harms in Victoria, Australia'; Unick et al., 'The Relationship between US Heroin Market Dynamics and Heroin-Related Overdose, 1992–2008'.

[20] Kuziemko and Levitt, 'An Empirical Analysis of Imprisoning Drug Offenders'; Caulkins and Reuter, 'How Drug Enforcement Affects Drug Prices'; Reuter and Kleiman, 'Risks and Prices'.

[21] RAND Corporation, 'What America's Users Spend on Illegal Drugs'.

[22] Caulkins and Bond, 'Marijuana Price Gradients Implications for Exports and Export-Generated Tax Revenue for California after Legalization'.

[23] Thies, 'The Relationship Between Enforcement and the Price of Marijuana'; Lawson and Nesbit, 'Alchian and Allen Revisited'.

[24] Davis, Geisler, and Nichols, 'The Price Elasticity of Marijuana Demand'.

[25] Office of the Parliamentary Budget Officer, 'Legalized Cannabis: Fiscal Considerations'.

however, has never been examined outside of the USA and Canada. This article shows the potential of crowdsourced data on cannabis prices in a country that, contrary to the US, has less nuanced sources of drug prices, with only a few composite estimates which are publicly available. Our analysis contributes to the current research on the UK's cannabis market by providing several insights into cannabis flows, dealers' behaviours and consumers' purchasing habits using data crowdsourced from the PriceofWeed.com.

Crowdsourcing the Price of Cannabis

Crowdsourcing is a process that solicits help from a large pool of actors to support a project, either by contributing funds, skills, or information to help realize a goal, usually in exchange for promised recompense.[26] As with any other social media platform, crowdsourcing allows users to create and share information with each other. However, unlike other forms of social media, such as Twitter or Facebook, crowdsourcing defines precise tasks – such as "solve this problem," "fund this product," or "contribute knowledge for this project" – that require support to complete.

The *Price of Weed*'s raison d'être is to crowdsource answers to the question: "What is marijuana really worth [in a particular location]?" The site encourages users to provide the prices paid for the benefit of the community, as to understand what the true value of the cannabis purchased is at any given location. By submitting information about their latest transactions, users contribute to the understanding of what the optimal price should be in their area. Users then provide information about their latest transaction for the same reason people contribute to Wikipedia. Users do not get any compensation for writing and editing Wikipedia articles except improved self-esteem through their contribution to the knowledge-

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[26] Estellés-Arolas and González-Ladrón-de-Guevara, 'Towards an Integrated Crowdsourcing Definition'; Gupta and Brooks, *Using Social Media for Global Security*.

base of the Wikipedia community. In the same way, people submitting information about cannabis purchases are happy to contribute and improve the knowledge-base of the cannabis user community.

The *Price of Weed*'s homepage presents a data input form where users can submit their last purchase of marijuana (see Figure 1). The form asks the user to provide information about the location of the transaction, which is pre-populated based on the user's IP address; quantity, with units including 1, 5, 10, 15, 20, 25 grams, an ounce, a half ounce, a quarter of an ounce, and an eighth of an ounce; quality, with categories being low, medium, high; marijuana strain; and the purchase price. Below the data input form, the website reports a map showing the price of marijuana per ounce. Beneath the map, the platform shows the average price per ounce for high and medium quality marijuana in the location of the user's purchase. Finally, the website reports the latest submissions reported by anonymous users, providing up-to-date information on location, price, quantity, quality, and date of sale. All prices are reported in US dollars (USD), although users may use different currencies for their submissions. Information on specific cannabis strain types, although collected, is not reported by the platform and therefore is not obtainable using data scraping techniques.

Figure 1: Data input form and home page of the PriceofWeed.com website

Source: PriceofWeed.com

Figure 2: Information reported by the PriceofWeed.com website

Source: PriceofWeed.com

We gathered a real-time dataset of price entries for the UK from February 2015 through June

2016 by scraping the data from the *Price of Weed* on a daily basis.[27] The *Price of Weed* website, in fact, does not provide the entire dataset but only the latest 15 transactions per country, meaning that daily collection is necessary in order to ensure that all records are collected. The data collection produced an initial sample of 2,146 entries. To create a standard point of comparison, we converted the prices, reported in United States Dollars (USD/ $) to what they would be at the gram amount. Observations with prices lower than $0.30 per gram and higher than $35 were dropped given their abnormal deviance from the mean. All transactions were then converted from USD to Great British Pounds (GBP/ £) using the daily exchange rate provided by the Bank of England. The final dataset contains 2,009 observations. Table 1 shows the descriptive statistics for different transactions.

Table 1. Descriptive statistics of the *Price of Weed* data

Quantity (grams)	Count	Average (GBP)	Min (GBP)	Max (GBP)	Standard Deviation (GBP)
1	468	11.0	4.7	34.9	3.8
3.5	303	19.8	5.2	100.4	10.5
5	235	37.9	3.2	132.9	18.2
7	170	50.7	2.6	200.6	24.2
10	95	48.8	6.3	250.3	50.1
14	123	84.4	3.3	225.0	41.4
15	7	65.0	13.0	183.7	67.8
20	13	25.8	13.0	129.7	32.0
25	5	47.5	16.8	98.9	35.2
28	590	160.7	29.5	501.0	72.9
Total	**2009**	**69.4**	**2.6**	**501.0**	**75.6**

Source: Authors' elaboration on PriceofWeed.com data

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[27] A web scraper is custom-built software that collects data from websites containing the sought after data, in this case information on cannabis price. The scraper extracts data from those pages and collects all the information into a database.

This data shows the large variation in the sample which is not unexpected. Illicit drug prices per unit of measure may vary from transaction to transaction, between places, and over time. Variability does not reduce the data's analytical purchase, and is common in licit marketplaces as well. For instance, the retail price of oil can show different values within the same city and is far more expensive in some parts of the world than in others; nevertheless, it is common to speak about "the price of oil." Whether speaking about the "the price of oil" or "the price of drugs," it is not important that drugs/oil are sold everywhere at the same price, rather it is important that prices are sufficiently linked thereby making it possible to identify a benchmark value[28].

Comparing the *Price of Weed* data to other sources

We checked the validity of the price data collected by comparing it to alternative available sources of data on drug price. In their review, Bryan et al identify three main sources of data for drug prices in the UK [29]:

1) Data generated by the National Crime Agency (NCA) and forensic services;

2) a survey of drug and alcohol services, police forces and service user groups conducted by the charity DrugWise (previously known as DrugScope);

3) and, a survey of drug users by the Independent Drug Monitoring Unit (IDMU).

The data provided by the NCA are collected and collated from police forces throughout the UK, who obtain information using a variety of means, including test purchases, prisoner interviews, and informants' reports. The NCA does not publish the data itself but does

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[28] Moore et al., 'Monograph No. 09: Heroin Markets in Australia: Current Understandings and Future Possibilities'.

[29] Bryan, Del Bono, and Pudney, 'Licensing and Regulation of the Cannabis Market in England and Wales: Towards a Cost-Benefit Analysis'.

provide them in standardized format to international bodies such as the United Nations Office on Drugs and Crime (UNODC) and the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA).

DrugWise is a charity that offers advice and support to organizations in the drug sectors. DrugWise has surveyed local social workers, Drug Action Team staff, and police officers working in drug squads. The interviews were conducted mainly by telephone but also email and face-to-face. Average prices from the surveys are published on the DrugWise webpage.[30]

The Independent Drug Monitoring Unit is a company that monitors the state of the drugs market in the UK and provides expert witnesses in court cases. They conduct an annual survey which collects information on drug consumption and prices paid by drug users who volunteer to take the survey (mainly online). For 2015, the year used in our comparison of the main drug price data sources in the UK to the data collected from the *Price of Weed*, the sample is composed by 333 observations collected in twelve different regions in the UK[31].

Several issues complicate our ability to directly compare these three official data sources and the *Price of Weed* data. First, these sources do not publish in detail methods of data collection or authentication. However, from the information provided, it is clear that the methods used differ widely for each dataset. Each data provider uses varying sampling strategies whereby they conduct interviews differently, and survey distinct geographical areas.

Second, cannabis is not a standardised product, so research on "cannabis" may include a wide array of products, which are not studied similarly across the datasets. For

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[30] http://www.drugwise.org.uk/how-much-do-drugs-cost/

[31] The regions surveyed are: London, South East, South West, Midlands, Wales, Yorkshire and the Humber, North West, North East, Scotland, Ireland, and others.

instance, the IDMU collects information for seven different types of cannabis whereas EMCDDA, UNODC, and DrugWise report a much more limited selection.

Third, the complete datasets are not publicly available and the only provide point estimates at gram- (EMCDDA and UNODC), eighth- (IDMU), quarter- (DrugWise) and ounce-level (IDMU). Given the lack of harmonisation among the datasets differences among the four sources are expected. However, this exercise can indicate if crowd-sourced values are roughly in line with those reported by other sources.

Table 2 presents the results of this comparison. While prices for *Price of Weed* are based on the users' assessment of the products' quality; it is unclear whether the EMCDDA and the UNODC price estimations reflect lower, medium, upper, or average quality estimates. Accordingly, prices reported in the EMCDDA and the UNODC reports may refer to the average price of cannabis products of low/high potency, or the minimum/maximum price for a gram of cannabis of average quality. Despite the imperfect comparison, the prices per gram reported by the *Price of Weed* data are roughly in line with those reported by the EMCDDA and the UNODC. Among the official data sets, prices for cannabis range from £3.20 to £10 per gram (excluding the UNODC's estimate of £20 for cannabis resin). The price per gram according to the *Price of Weed* data also lies below the upper value of this range.

Table 2. Price of cannabis (GBP) in the UK according to the Price of Weed, the EMCDDA, the UNODC, the IDMU and DrugWise

	Source	Average per gram			An eighth		A fourth		An ounce	
		Low	Medium	High	Medium	High	Medium	High	Medium	High
	PoW[a]		7.2 (±0.2)	7.2 (±0.3)	19.9 (±1.4)	19.6 (±2.4)	47.6 (±3.9)	56.2 (±7.4)	152 (±7.9)	170.9 (±8.6)
EMCDDA	Cannabis herb	3.3		5.7						
	Cannabis resin	3.2		4.3						
UNODC[b]	Cannabis resin	10	10	20						
	Cannabis herb	5	5	10						
	Skunk		5							
IDMU	Black				23.8				107.5	
	Soap-Bar				21.3				75.4	
	Other Moroccan				21.4				92.3	
	Other Hash				31.5				125	
	Skunk				28.3				216	
	Homegrown/Leaf				12.9				67.1	
	Imported Bush				24.1				132.9	
DrugWise	Herbal Cannabis (Standard)							37		
	Herbal Cannabis (High standard)							55		

Price of Weed: 2015/2016; EMCDDA: 2014 (cannabis resin) and 2013 (cannabis herb); UNODC: 2012; DrugWise: 2016; IDMU: 2015.

[a] *We do report value for low quality given the few observations (n.= 84) compared to medium (n. =1,368) and high quality (n. = 557)*

[b] *UNODC considers mean as typical*

The IDMU reports data for an eighth of an ounce (~3.5 grams) and an ounce (~28 grams). Data refers approximately to the same year (*Price of Weed*: 2015/16; IDMU: 2015) but differs in terms of cannabis product. The IDMU reports prices per ounce for several strains that range from £67.10 to a maximum of £216. According to the *Price of Weed,* the average price for an ounce of cannabis is £152 (±£7.90) for medium-quality and £171 (±£8.60) for high-quality. The range provided by the IDMU is wide and lacks nuance; nonetheless, the prices reported by the *Price of Weed* fall within the IDMU range allowing us to see that the prices observed are reasonable when compared to public measurements. The paucity of low-grade cannabis transactions reported in the *Price of Weed* data (there were four) coupled with the fact that that medium- and high-grade products are close in price, could suggest that the quality of product available on market is relatively high overall, supporting the observed trend of relatively small-scale domestic producers competing with each other for market share, and thus providing relatively good quality product[32].

The last comparison is with DrugWise for a quarter ounce of cannabis. DrugWise and *Price of Weed* report prices for different cannabis products but approximately the same year. Despite this, the two datasets seem to report similar results. The minimum price reported by DrugWise is between £27 and £55 per quarter ounce. *Price of Weed* reports an average cost of £47.60 (±£3.90) for medium-quality and £56 (±£7.40) for high-quality cannabis. Crowdsourced values are closer to the upper value and roughly in line with the source of comparison.

As expected, there are differences in the reported prices between the *Price of Weed* data and the other sources surveyed, which could be due to the different year of analysis, product varieties, potency, or variance in the methods of data collection. Prices can change

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[32] Potter et al., 'Global Patterns of Domestic Cannabis Cultivation'.

quite noticeably across years [33] and, as comparative studies in criminology show, idiosyncratic systems of data collection produce different results[34]. One of the main factors limiting the comparison of the *Price of Weed* data with existing data sets is the absence of information about specific types of cannabis products from the *Price of Weed*. In fact, it just reports if the cannabis purchased was of a low, medium, or high quality based on the user's assessment, rather than specifying whether the product is herbal, hash, or some other cannabis product, such as wax. Nonetheless, this does not mean that the *Price of Weed* dataset cannot be used but that it cannot, in its current form, wholly replace some of the nuances the existing sources provide on specific product types.

Results

The next section presents our findings from the *Price of Weed* data in the United Kingdom. They are organized around three themes relevant to understanding the dynamics of drug markets: trafficking flows, quantity discount, and purchasing habits.

Trafficking Flows

Illicit drug prices increase as one moves away from drug import sources[35]. Several studies have used systematic observations on drug prices to infer drug trafficking flows – that is, the route a drug is trafficked along – and to calculate price gradients, that is, changes in price over the trafficking flow. In a series of papers, Chandra and colleagues used drug price

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[33] Bryan, Del Bono, and Pudney, 'Licensing and Regulation of the Cannabis Market in England and Wales: Towards a Cost-Benefit Analysis'; Caulkins and Reuter, 'What Price Data Tell Us About Drug Markets'.

[34] Tonry, 'Is Cross-National and Comparative Research on the Criminal Justice System Useful?'; Aebi and Linde, 'The Epistemological Obstacles in Comparative Criminology'.

[35] Caulkins and Bond, 'Marijuana Price Gradients Implications for Exports and Export-Generated Tax Revenue for California after Legalization'.

information to identify heroin and cocaine trafficking flows across European countries[36] and within the United States [37]. Lahaie et al.[38] found that the price of heroin in France tends to increase moving away from the border with the Netherlands, which is acknowledged to be the main entry route for heroin into Western Europe. Similarly, Caulkins and Bond[39] estimated that the price of marijuana in the United States tends to increase between $325 and $475 per pound per 1,000 miles travelled as the product moves north from the Mexican border.

Prices in the UK cannabis market behave in a similar way: the further away from a southern shipping port, the more a cannabis sells for. Figure 3 plots the average price per gram for 52 cities in the UK against their latitude[40]. This linear model is an approximation, but it fits the data reasonably well ($R = .37$; $p < .001$). The price per unit increases constantly moving from south to north reflecting shipping patterns in the UK. The figure indicates that it is likely that most cannabis shipments enter the UK from the south. Moving from the source of the supply to the north increases traffickers' risk in terms of arrest or seizure given the needs to transport the product, stage the product, and finding a buyer.[41] Accordingly, as we would expect, and as the data reflects, cannabis is more expensive in the northern part of the UK compared to the southern part of the country[42].

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[36] Chandra and Barkell, 'What the Price Data Tell Us about Heroin Flows across Europe'; Chandra, Barkell, and Steffen, 'Inferring Cocaine Flows across Europe'; Chandra and Joba, 'Transnational Cocaine and Heroin Flow Networks in Western Europe'.

[37] Chandra, Peters, and Zimmer, 'How Powdered Cocaine Flows Across the United States Evidence From Open-Source Price Data'.

[38] 'Determinants of Heroin Retail Prices in Metropolitan France'.

[39] 'Marijuana Price Gradients Implications for Exports and Export-Generated Tax Revenue for California after Legalization'.

[40] The analysis considered just those cities for which at least 20 observations has been collected.

[41] Reuter and Kleiman, 'Risks and Prices'.

[42] Caulkins, 'Domestic Geographic Variation in Illicit Drug Prices'.

Several indicators – in particular the Border Force's (the United Kingdom's border and customs agency) seizures of cannabis plants and cannabis products in the last 15 years – has pointed to the decline of the cannabis importation and the rise of UK-based production[43]. Figure 5 suggests that import still likely plays a determinant role in satisfying the internal demand for cannabis in the United Kingdom.

Figure 3. Average price per gram of cannabis across UK and latitude
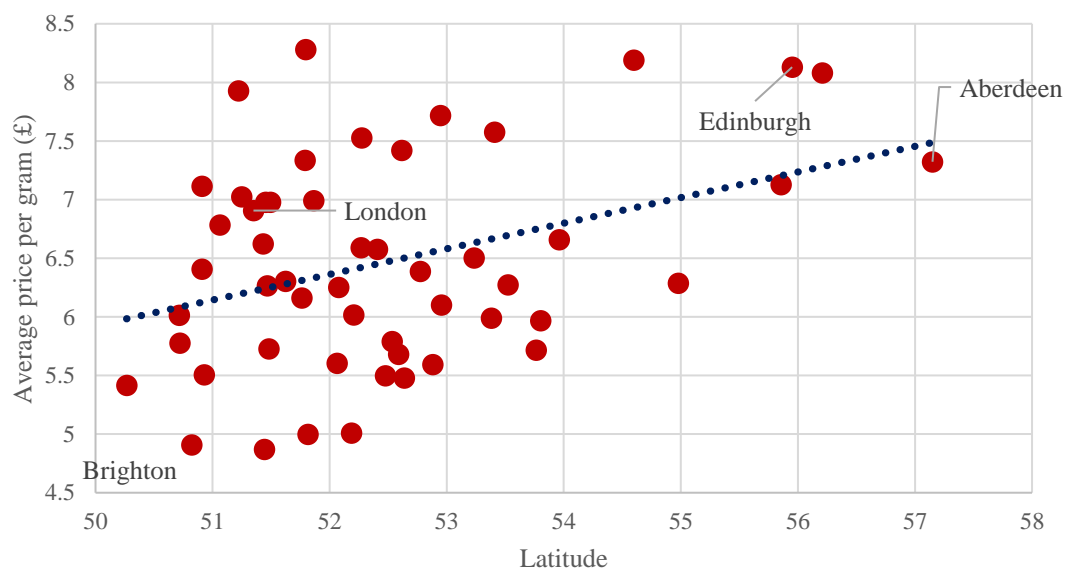
Source: Authors' elaboration on PriceofWeed.com data

Figure 3 suggests that despite the substantial growth of domestic cannabis plant cultivation, large quantities of cannabis are still imported from other countries [44]. The Netherlands, in

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[43] ACPO, 'UK National Problem Profile. Commercial Cultivation of Cannabis 2012'; Potter, 'The Growth of Cannabis Cultivation: Explanations for Import Substitution in the UK'.

[44] EMCDDA, 'Cannabis Production and Markets in Europe'; Potter, 'The Growth of Cannabis Cultivation: Explanations for Import Substitution in the UK'.

particular, has been identified as having a determinant role on the importation of cannabis to the UK[45]. The Netherlands not only exports large quantities of high-quality, domestically produced cannabis to the UK but also works as a staging and distribution hub for the cannabis produced in other countries including Albania, Morocco and Afghanistan[46]. Traffickers can take advantage of the numerous ports of entry in southern Britain, including Southampton, Portsmouth, Dover, Tilbury and Harwich, as well as the Channel Tunnel to transport cannabis loads into the UK[47].

Given the number of variables in play, identifying the determinants of the price of cannabis is beyond the scope of this article. Future quantitative work should aim at assessing the influence of different factors (e.g. product quality, level of enforcement, etc.) in determining cannabis price. Moreover, since no model can perfectly fit the complexity and heterogeneity of cannabis market, ethnographic and qualitative studies are necessary to add a deeper understanding of local cannabis markets[48].

Quantity Discount

In both licit and illicit marketplaces, customers buying in bulk receive a quantity discount. Merchants use discount prices to attract customers to buy more items and lessen stock, thus passing on the risk of possessing, and potentially losing stock before they are compensated, due to theft, disaster, or any other occurrence which would destroy the value of the stock.

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[45] EMCDDA and EUROPOL, 'EU Drug Markets Report. In-Depth Analysis'.

[46] Burton et al., 'United Kingdom Drug Situation: Annual Report to the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) 2014'; EMCDDA, 'Cannabis Production and Markets in Europe'; EMCDDA, 'European Drug Report 2015. Trends and Development'.

[47] In this analysis we used latitude and not distance from port given the numerous ports present in the UK. There are, in fact, sixteen ports in the South of the UK and each of which can serve as point of entry for the cannabis smuggled onto the island. Latitude is then a better fit in the model.

[48] Adler, *Wheeling and Dealing*.

Risk of arrest for cannabis dealers is probably the main factor explaining quantity discount[49]. A dealer who has an ounce of cannabis has two alternatives: (1) wholesale large quantities to a small group of willing buyers at a discounted overall rate[50], or (2) retail small quantities to a large group of buyers in order to maximize profit. The second alternative increases the exposure to risk of arrest as it involves conducting more transactions, thus increasing visibility to law enforcement and competitors and/or keeping or selling the illicit substance for a relatively longer time period.

The phenomenon of quantity discount has been observed for heroin, cocaine, and cannabis in Australia, Canada, France and the US[51]. There is not, however, information on what kind of quantity discount may be expected in the UK, which we will now show.

Table 3 and Table 4 show the average price per gram for different transactions sizes (a gram, a quarter, a half-ounce and an ounce). Transactions for 10, 15, 20, and 25 grams are dropped because of the paucity of observations as well as an eighth of an ounce and 5-gram transactions because those quantities falling in between a gram and a quarter ounce. Our analysis also excludes low-quality transactions given the low number of observations ($n = 124$).

Both purchases of medium- (Table 3) and high-quality (Table 4) cannabis products show that the greater the quantity of cannabis bought in the UK, the lower the per unit price. The average price for a gram of cannabis of medium-quality is £10.90. The average price for

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[49] Clements, 'Pricing and Packaging'.

[50] Clements and Zhao, 'Economic Aspects of Marijuana'.

[51] Caulkins, 'What Is the Average Price of an Illicit Drug?'; Lahaie, Janssen, and Cadet-Taïrou, 'Determinants of Heroin Retail Prices in Metropolitan France'; Desimone, 'The Relationship Between Illegal Drug Prices at the Retail User and Seller Levels'; Saffer and Chaloupka, 'The Demand for Illicit Drugs'; Clements, 'Pricing and Packaging'; Caulkins and Padman, 'Quantity Discounts and Quality Premia for Illicit Drugs'.

an ounce of cannabis of the same quality is £152.50 (£5.40 per unit). Similarly, the price for

gram transactions of high-quality cannabis is £11.80 while the average price per unit for

ounce transactions is £6.10. This means that the price per unit is 50% cheaper when bought as

an ounce than when bought as a gram.

Table 3. Average price per transaction, price per gram and number of observation for
medium-quality cannabis in UK.

	Average price (GBP)	Price per gram (GBP)	Observations
A gram	10.9	10.9	357
A quarter ounce (~7 grams)	47.6	6.8	104
A half ounce (~14 grams)	82.6	5.9	82
An ounce (~28 grams)	152.5	5.4	338

Source: Authors' elaboration on PriceofWeed.com data

Table 4 Average price per transaction, price per gram and number of observation for high
quality cannabis in UK.

	Average price (GBP)	Price per gram (GBP)	Observations
A gram	11.8	11.8	82
A quarter ounce (~7 grams)	56.2	8.0	63
A half ounce (~14 grams)	91.3	6.5	36
An ounce (~28 grams)	170.9	6.1	237

Source: Authors' elaboration on PriceofWeed.com data

Purchasing Habits

Purchasing habits can heavily influence the estimates of the value of illicit drug markets since those estimates are typically based on retail prices multiplied by estimated volume of sales[52]. Estimates of the size of the illicit drug market are particularly relevant for policy makers and law enforcement agencies as user's spending on illicit drugs may increase crime and fuels corruption[53]. Variation over years in the distribution of the purchase of cannabis can however distort trends of the estimate of the value of the market. For instance, the quantity of cannabis consumed at time t can be the same consumed at time $t + 1$. But if in $t + 1$ users tend to buy cannabis in lower quantities, the estimate of the size of the illicit drug market is biased downward and the trend distorted. Similarly, two regions may have the same market volume with similar tiered pricing but generate different revenues if users have different purchasing habits. One needs to take into account distribution of retail purchase and quantity discount in the estimate of the illicit drug market [54]. The *Price of Weed* platform could represent a useful tool to monitor the typical volume and prices of purchases made by cannabis users.

Table 5 reports the eight most typical purchases observed in the *Price of Weed* dataset and Figure A in the appendix the distribution of cannabis purchases.[55] Most of the transactions are small purchases. The most typical transaction reported is for £10; 41% of all transactions are smaller than £20. Bigger transactions are instead less typical. Purchases of £50, £100, and £65 account for just 12% of the total of the observations. Sixty-six percent of all transactions are below £100.

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[52] Kilmer et al., 'Bringing Perspective to Illicit Markets'.

[53] Bond et al., 'Are Users' Most Recent Drug Purchases Representative?'

[54] Caulkins, 'Price and Purity Analysis for Illicit Drug: Data and Conceptual Issues'; Caulkins and Reuter, 'What Price Data Tell Us About Drug Markets'.

[55] As a result of the conversion from USD ($) to GBP (£) most of the transactions report several decimals. Since it is impossible that users make purchases of, for instance, 10.34566, all observation are rounded at the nearest number, i.e. 10.

Table 5. Typical purchase of cannabis in UK.

Purchase (GBP)	Observations	Percentage	Cumulative percentage
£10	395	20%	20%
£15	170	8%	28%
£20	155	8%	36%
£5	102	5%	41%
£35	96	5%	46%
£50	90	4%	50%
£100	85	4%	54%
£65	82	4%	58%
…	…	…	…
Total	**2009**	**100%**	**100%**

Source: Authors' elaboration on PriceofWeed.com data

Table 6 reports the eight most common transaction prices and the corresponding amount of cannabis purchased at those price points.[56] The results show a clear concentration in the amount of cannabis that the same monetary transaction can buy but also a considerable variation for some of them. For instance, 89% of those spending £10 in a transaction purchased a gram. Similarly, most of the users spending between £15 and £20 received an eighth of an ounce, and most of the transactions between £65 and £100 were for an ounce of cannabis.

Some observations seem more problematic. According to the data a purchase of £355 can buy anywhere from a gram (1%), 5 grams (60%), to an ounce (15%). Quality does not seem to influence this as medium- and high-quality cannabis show almost the same distribution. It is possible that purchases of high quantities at relatively low prices could be due to a personal connection with a supplier that allows the consumer to get a below market

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[56] The analysis removed purchases of 15g, 20g and 25g due to the low number of observations (*n.* = 16)

price due to "mates rates." Although some transactions present a large variation most of them have clear concentration on some quantities and there is a strong positive correlation between spending and quantity.

Table 6: Most typical purchases in UK and corresponding quantity of cannabis bought

Purchase (£)	A gram	An Eighth	5 Grams	A Fourth	10 Grams	A Half Ounce	An Ounce	Total
10	89%	7%	1%	0%	3%	0%	0%	100%
15	24%	57%	10%	3%	2%	4%	0%	100%
20	24%	67%	6%	2%	1%	0%	0%	100%
5	35%	16%	12%	6%	27%	4%	0%	100%
35	1%	11%	60%	11%	2%	1%	15%	100%
50	0%	7%	50%	29%	6%	6%	3%	100%
100	0%	1%	4%	1%	19%	20%	55%	100%
65	0%	1%	9%	11%	12%	21%	46%	100%

Source: Authors' elaboration on PriceofWeed.com data

Discussion

Crowd-sourced transaction data presents some new insights into the UK cannabis market that traditional data sources are not able to provide. First, this study has shown that there exists trafficking flow illustrated by increasing prices for cannabis within the UK from south to north, which suggests the ongoing presence of foreign product in the UK marketplace. The growth of domestic cannabis plant cultivation is likely to affect this pattern in the future. The analysis presented here offers a tool for law enforcement authorities to monitor this trend and understand the changing nature of the United Kingdom's cannabis market. Second, it shows the extent to which a quantity discount is granted to consumers. As observed for other legal and illegal goods, buying in bulk reduce the price per unit. Cannabis sellers are willing to reduce profits per unit in order to reduce their exposure to risks of arrest. Third, this research indicates the purchasing habits of cannabis users, helping us to understand whether larger or smaller transactions are comparatively common in a given location. Although the dataset is unlikely to be fully representative of the whole cannabis

market, the results suggest that most cannabis transactions are small in terms of price and volume, with £10 buying a gram being the most typical transaction reported.

Crowdsourcing could be used not only to provide a static snapshot of an illicit market, as it the case for the results presented here, but also used as a tool to monitor the market in near real time. Data from crowdsourcing platforms such as the *PriceofWeed.com* could show how buyers, sellers, and traffickers respond to law enforcement interventions or drug policy changes by evaluating shifts in supply, demand, and price. For instance, traffickers can adapt to interdiction programs by shifting to alternative routes. This form of displacement is often referred to as the "balloon effect," and suggests that stronger law enforcement actions in one location will result in the displacement of drug trafficking activities to another location[57]. Similarly, law enforcement actions or changes in drug policy (e.g. reclassification of some substances, changes threshold limits to discern sales from personal use, etc.) can affect users' and dealers' behaviors and push them to sell or buy in bigger or smaller quantities. Given the inability to understand these shifts with existing research products, crowdsourcing is a tool that could supplement the limited data available to law enforcement agencies, public health institutions, policy makers and NGOs on the effect of such interventions, though practitioners should be cautious in using the *Price of Weed* data given its array of limitations.

There are, in fact, significant limitations in the use of the *Price of Weed* data. First, this is not a random or representative sample. The transaction data are self-reported by relatively unknown participants and not a random sample of the cannabis purchasing population [58]. To date, we know little about those who provide information and the data collected might not be representative of the entire cannabis population. We have no

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[57] Friesendorf, 'Squeezing the Balloon?'; Hawdon and Kleiman, *Encyclopedia of Drug Policy*; Reuter, 'The Mobility of Drug Trafficking'.

[58] Ouellet et al., 'The Price of Cannabis in Canada'.

demographic information or an indication of a user's typical consumption. The anonymity granted by the platform encourages users to submit genuine information but, simultaneously, deprives researchers from any sociodemographic or economic information about those using the platform. While it may be technically possible to ask for such information, an increase in requesting potentially identifying information could deter users from participating. Attempting to estimate likely users by analyzing users from other crowdsourcing platforms would not be viable, since the use of these platforms depends on the platforms' purpose and the way in which they collect data (online, telephone, etc.)[59].

However, we know from previous studies that social media platform usage rates vary by sociodemographic and economic conditions. Male, younger people, and certain occupational groups (e.g. managerial, administrative, and professional occupations) have higher participation[60]. This can suggest that participants of the *Price of Weed* website are likely to have relatively high income and being able to buy better products. Conversely, incarcerated and homeless populations, who may have a higher rate of drug use, are likely to be underrepresented in this sample[61]. Clearly, future research should try to better understand the population of individuals participating on these sorts of platforms.

Second, there is no ability to protect against false or inaccurate submissions, potentially input by anyone purposefully or erroneously (i.e. typos). Moreover, there is an issue regarding the independence of the submissions. The same users can report multiple submissions of transactions taking place at different times, however there is no way of determining if this is the behavior observed. The inability for researchers to fully understand the participating population makes it difficult to test for errors and weight for over or under

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[59] Behrend et al., 'The Viability of Crowdsourcing for Survey Research'.

[60] Sloan et al., 'Who Tweets?'; Sloan et al., 'Knowing the Tweeters'.

[61] Ouellet et al., 'The Price of Cannabis in Canada'; Giommoni, Reuter, and Kilmer, 'Exploring the Perils of Cross-National Comparisons of Drug Prevalence'.

representation. We triangulated the crowdsourced data with other traditional sources in order to check its reliability. This comparison was hampered by lack of harmonization among the different datasets. Nonetheless, we have demonstrated that the *Price of Weed* data do not deviate from the ranges reported by these other sources

Third, cannabis is an experience good[62] which means that buyers may have a limited knowledge of the quality of the product before they consume it. Users may have a better knowledge of the product after developing a history of consumption. Moreover, users may view quality relevant to the best they have consumed, with personal baselines for comparison varying widely. Accordingly, the self-reporting nature of the information on quality can be inaccurate and subjective. For instance, what it is considered high-quality cannabis in Edinburgh may be considered as low-quality cannabis in Brighton. Evrard, Legleye, and Cadet-Taïrou[63] asked drug users the perceived quality of cocaine that they were consuming and then analyzed them in a laboratory. They discovered that "users were not good at assessing the actual purity of the cocaine they had used"[64]. Similarly, Decorte[65] concludes that users have an incomplete knowledge of the quality of the substance they use even after its consumption. This can help to explain the little difference in the price per unit for medium- and high-quality cannabis according to the data gathered from the *Price of Weed* website. Additional and more objective information on the concentration of tetrahydrocannabinol (THC), the primary psychoactive cannabinoid in cannabis, and cannabidiol (CBD), the other significant, although non-psychoactive cannabinoid present in

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[62] Caulkins, 'Price and Purity Analysis for Illicit Drug: Data and Conceptual Issues'.

[63] 'Composition, Purity and Perceived Quality of Street Cocaine in France'.

[64] Evrard, Legleye, and Cadet-Taïrou, 402.

[65] 'Quality Control by Cocaine Users'.

cannabis, is needed to make sure that we are comparing similar products[66]. Perhaps more importantly, the last years have seen a proliferation of cannabis products, including marijuana edibles, oils, and vaping products. Future data collection efforts should consider the heterogeneity of cannabis-based products.

Conclusions

The analyses provide encouraging results in the use of crowdsourcing for researching transactions and behaviors within illicit drug markets. Our work has shown that mining the publicly available, crowdsourced data from *Price of Weed* can help researchers understand patterns that are otherwise indiscernible from public reports. In countries like the UK, where such research outputs are lacking, such strategies may present one of the few ways in which researchers can proceed with such inquires. Moreover, this work illustrates that it may be possible to develop crowdsourcing instruments that effectively gather information from some traditionally hard-to-reach and/or deviant populations. Importantly, the information gathered via the internet can be used to extrapolate data regarding the transactions involving higher-level groups, such as wholesalers, that traditional methods often struggle to evaluate[67].

The crowdsourcing platform used in this article is not ideal for researchers, rendering several limitations on the data collected and the inferences made. Accordingly, practitioners and social scientists can respond to their research needs by starting to develop their own crowdsourcing platforms. An optimized platform could provide data also for other substances including new psychoactive substances, synthetic drugs, cocaine, and similar products.

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[66] Martin-Santos et al., 'Acute Effects of a Single, Oral Dose of D9-Tetrahydrocannabinol (THC) and Cannabidiol (CBD) Administration in Healthy Volunteers'.

[67] Gundur, 'Using the Internet to Recruit Respondents for Offline Interviews in Criminological Studies'.

Further considerations could include the need to educate users on the quality and type of the product they are consuming, by providing cues such as photos to help identify products and estimate amounts, descriptions of a product's appearance and aroma, descriptions of the effect after a drug's consumption, or techniques on how to do simple chemical analysis for substance purity. Such efforts are likely to provide a better matching between the reported and actual quality of the product but cannot have the precision of forensic analysis.

      Keeping the ongoing limitations of crowdsourcing in mind, it is a methodology that should be used to complement and augment, rather than replace, conventional sources, such as law enforcement and forensic data, in countries with a tradition of data collection and analysis on illicit markets. Nonetheless, crowdsourcing could provide a starting point for analysis in countries that do not have robust recording practices within criminal justice agencies, acting as a substitute of traditional data sources. In such circumstances, crowdsourcing may provide the drug-related data researchers require to study drug markets in a way that otherwise would not be possible.

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Acknowledgements

Appendix

Figure A. Distribution of cannabis purchase in the UK. *Price of Weed* data