Between Main Street and Illicit Markets: Self-Reported Prices and Source Premiums in US Cannabis Markets Markets

Munksgaard, Rasmus

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Munksgaard, Rasmus[2]; Magnussen, Freja Ilsing[3]; Barratt, Monica J.[4]; Ferris, Jason[5]; Puljevic, Cheneal[6]; Winstock, Adam[7].

Abstract

Background: Criminalization and drug enforcement levies a "risk tax" on illicit drugs. Cannabis legalization aims to subvert illicit markets, and a competitive price is one way to achieve this goal. However, drug prices vary not only by legality but also by source (e.g., friends, internet, dispensaries). We examine sourcing premiums to assess whether legal cannabis, in general, is competitive with illegal cannabis.

Methods: We use self-reported cannabis prices in the United States from the Global Drug Survey collected between 2016 and 2021. We analyze the self-reported price of 1-gram of cannabis and the quantity-adjusted price-per-gram to compare the price of cannabis between legal outlets and shopfronts relative to known dealers, friends, and other sources. We use linear regression with state and year dummies adjusting for quantity, age, gender, and cannabis use to assess whether legal markets are a) competitive at the price of 1 gram (N=13,307, N=4,749), and b) remain competitive for larger purchases (N=4, 749).

Results: The price of 1 gram was between $16.7 (other source) and $18.2 (known dealer) from illegal sources, contrasted with $20.1 from shopfronts and

[1] The research team is currently extending the analysis. Early feedback has suggested that the legal/illegal distinction is too narrow and restrictive and does not reflect the fact that what respondents define as "legal sources and shopfronts" can exist in different policy regimes. The analysis will be updated to recognize this problem. Specifically, we will in an additional analysis recode "legal sources and shopfronts" to be reflective of whether there were recreational sales in the state at the time.

[2] Department of Sociology and Social Work, Aalborg University.
[3] Center for Drug and Alcohol Research, Aarhus University, Denmark.
[4] Social Equity Research Centre and Digital Ethnography Research Centre, RMIT University, Melbourne, Vic, Australia; National Drug and Alcohol Research Centre, UNSW Sydney, NSW, Australia
[5] Centre for Health Services Research, The University of Queensland, Australia
[6] Centre for Health Services Research, The University of Queensland, Brisbane, Queensland, Australia; Centre of Research Excellence on Achieving the Tobacco Endgame, School of Public Health, The University of Queensland, Brisbane, Queensland, Australia.
[7] Institute of Epidemiology and Health Care, University College London, London, UK; Global Drug Survey Ltd, London, UK.

legal outlets. Similarly, the quantity-adjusted price ranged from $11.1 (friends) to $12.3 (shopfronts and legal outlets). Introducing an interaction term widened the gap between legal and illegal sources, with a significantly less steep quantity discount on cannabis from known dealers.

Conclusion: Our results suggest that illegal cannabis in the US is priced significantly lower or at the same level as legal cannabis. However, steeper quantity discounts can make legal cannabis competitive on price when purchased in larger quantities.

Keywords: drug markets; cannabis legalization; drug prices; cannabis; drug enforcement; illicit markets

1 Introduction

One of the aims of cannabis legalization is the subversion of illicit markets, which in turn will reduce crime, and divert criminal revenue to the state (Reuter & MacCoun, 2001; Kilmer & Pérez-Dávila, 2023). The price of cannabis is a key measure of this competitiveness. However, comparative analyses of legal and illegal prices are methodologically challenging because there a variation in price within both regulated and criminal markets (Moeller & Sandberg, 2019), driven by source, location, quality, and demographic groups (Wilkins, Romeo, Rychert, Prasad, & Graydon-Guy, 2020). If cannabis legalization is intended to undermine illicit markets, prices of legal cannabis need to be competitive. Yet, if legal prices are too favorable, legalization may increase prevalence and consumption (Pacula & Lundberg, 2014). In this paper we assess whether legal cannabis sources in the US are competitive with illegal ones in terms of price. For this purpose, we use a large and unique dataset of self-reported drug prices from the Global Drug Survey. We examine whether cannabis purchased from legal sources is competitive with cannabis purchased from illegal sources for both the unit prices of 1 gram of cannabis, and as the purchase quantity of cannabis increases. We begin by providing an overview of the literature on the causes and correlates of drug prices, after which we review the literature on drug prices and policy. Thereafter we present the data and analysis.

1.1 Drug prices

Within the "risks and prices" framework the risks imposed by drug enforcement are the primary driver of prices, rather than production or labor costs (Reuter & Kleiman, 1986). Drug enforcement, through different means such as source control and interdiction, therefore, levies a "tax" on producers, traffickers, and sellers that is passed on to the consumer. However, although interdiction and enforcement appear to explain parts of the variation in drug prices between countries (Boivin, 2014), results are mixed when enforcement intensity varies within countries (Caulkins & Reuter, 2010; DiNardo, 1993; Yuan & Caulkins, 1998). In addition to risk, criminalization also keeps

production costs high by impeding technological innovation and efficiency (Caulkins, 2017).

The pricing of illicit drugs is closely related to demand, consumption, prevalence, and crime. Although results may not always be consistent across studies (see for example Gallet, 2014, on the price elasticity of demand), there is substantial evidence that prices exert influence on drug use, as is also the case for tobacco and alcohol prices, with consequences for crime and health (Pacula & Lundberg, 2014). Economists have dedicated substantial efforts to estimating the price elasticity of demand for illicit drugs and have shown that decreasing prices may increase both rates of initiation and use among regular and heavy users (Bretteville-Jensen, 2019; Olmstead, Alessi, Kline, Pacula, & Petry, 2015; Pacula & Lundberg, 2014; Reuter & Caulkins, 1998; van Ours & Williams, 2007). From the perspective of public health, research has emphasized the health implications of price changes to drug use prevalence, overdoses, and medical emergencies (Hyatt & Rhodes, 1995; Weatherburn, Jones, Freeman, & Makkai, 2003). Studies also suggest that increasing drug prices may reduce both property and violent crimes (Sarrica, 2008; Desimone, 2001).

In addition to risk, other factors that influence or correlate with drug prices are purity, quantity, the network position and socioeconomic characteristics of buyers and sellers, the existence of social ties between traders, the mode of exchange, and geographical location. Since drugs vary in purity (Reuter & Caulkins, 2004), studies of substances that often are of varying quality (such as heroin and cocaine) frequently adjust for purity (Caulkins, 2007; Rosenblum, Unick, & Ciccarone, 2014). In cases where the purity of a drug is unknown, a rough proxy for purity may be variations of the same product, such as crack cocaine, heroin types and higher potency cannabis preparations, with prices often varying between these types (Caulkins & Bond, 2012; Munksgaard & Tzanetakis, 2022). As for quantity and network positioning, studies suggest that prices per unit vary between levels of the drug trade, with prices increasing in the last parts of the supply chain (Caulkins & Padman, 1993; Desimone, 2006). Such increases in unit prices have generally been ascribed to the accumulation of risk throughout the supply chain, although Moeller and Sandberg (2015) highlight that quantity discounts might also be a result of mid-level sellers' inclination to reduce prices or "front" drugs to reduce inventory costs. As for sociodemographic factors,

Wilkins et al. (2020) find that prices increase as urbanicity decreases, and that people who use cannabis daily pay higher prices.

Research has also found that social ties and modes of exchange are likely to influence pricing (Moeller & Sandberg, 2019), although results vary. Caulkins & Pacula (2006) observe that free exchanges of cannabis among friends are common, and that public places, ethnicity, and income also explain price variation. Conversely, Wilkins et al. (2020) show mixed results concerning the association between drug source, ethnicity, location, and price. Beyond immediate social networks, Cunliffe et al. (2017) and Moeller, Munksgaard, and Demant (2021) find large differences between online drug markets and police estimates of street prices. Finally, the literature indicates that not only do drug prices vary between countries (e.g., Munksgaard & Tzanetakis, 2022), but they also vary within countries (see for example Caulkins, 1995; Wilkins et al. 2020).

In summary, drug prices and their volatility are crucial to understanding the criminogenic and health effects of illicit markets through the price elasticity of demand. Prices are closely intertwined with policies of enforcement, though the effects are complex. While variation is in part explained by criminalization, scholars have also stressed purity and quantity as determinants or levers of prices, as well as the sociodemographic correlates of prices.

1.2 Price and policy

Within the risks and prices framework, variation in drug prices is a function of enforcement and interdiction (Reuter & Kleiman, 1986). Consequently, depenalization and legalization are expected to lower prices by removing the principal expenses in the drug trade (Caulkins, 2017). To study the relation between price and policy, scholars have used within-country variation in legal and illegal prices, and longitudinal changes in prices following policy changes.

General statistical indicators suggest that drug prices in Portugal did decrease following decriminalization (Hughes & Stevens, 2010). However, using a synthetic control design, Felix and Portugal (2017) found that decriminalization in Portugal did not lead to lower drug prices. As for legalization, several studies examine price

developments under state-level cannabis legalization in the US and federal legalization in Canada. Using longitudinal webscraped data Hunt and Pacula (2017) found an increase in legal prices, varying by cannabis strain, in Colorado and Washington over a period of 4.5 months following legalization of cannabis in these states. Using a large dataset of drug transactions, Pacula, Kilmer, Grossman, and Chaloupka (2010) found that decreased sanctions against use/possession offences increased prices due to an increase in demand. Anderson, Hansen, and Rees (2013) observe price declines after four years of medical marijuana laws. Similarly, Caulkins (2017) observes a consistent decline of more than 50% in cannabis prices in Washington State over two years following legalization (see also Davenport, 2019). Similarly, Meinhofer & Rubli (2021) estimate a 9.2% decline in cannabis prices following recreational cannabis laws using webscraped data. Wadsworth et al. (2023) distinguish between states with active recreational sales and those without, finding that cannabis prices are significantly lower in the former. Thus, while prices appear to increase in the short-term following legalization or sanction reductions, studies suggest that long-term trends follow the expected downward trend.

Whereas unrestricted legalization is likely to decrease prices, taxation can add a "floor" to prices, thus limiting the public health impacts (Grossman, Chaloupka, & Shim, 2002). Taxation of cannabis is a complex policy issue with two general models. The first is an excise tax, typically at the retail level, and the second is taxation by THC levels (Caulkins, Kilmer, Maccoun, Pacula, & Reuter, 2012). The former is the typical model implemented in the US and Canada (Wadsworth, Driezen, Goodman, & Hammond, 2020). However, even in such cases, the price of legal cannabis can still decrease due to efficiency and lower production costs (Davenport, 2019), and Hall et al. (2019) argue that no state has managed to "*[increase] cannabis taxes enough to prevent price declines after legalisation"* (p. 1586).

In summary, removing criminalization of cannabis, either through legalization or depenalization, is expected to lower price through mechanisms such as the reduction of production costs, increased efficiency, and the elimination of risks. Research suggests that in the short-term, prices may increase due to increased demand but decline in the long term. Long-lasting reductions in cannabis prices will have implications for public health, and taxation can reduce the expected dramatic drops in prices.

1.3 This study

The aim of this paper is to assess whether legal prices are indeed competitive with regards to price when compared to other cannabis sources. Using cross-sectional data with self-reported prices covering the US we conduct two analyses. First, we test *whether there are significant differences in cannabis prices across illegal versus legal drug sources at the level of 1 gram*. This analysis assumes that legal and illegal cannabis share the same quantity discount, however, this is not given. In a study of Canadian cannabis prices, Mahamad et al. (2020) find some evidence of varying quantity discounts, and Moeller & Sandberg (2015) suggest that criminalization incentivizes drug sellers to discount substances to reduce inventory costs. If so, we would expect cannabis from illicit sources to exhibit a steeper quantity discount. We therefore further test *whether quantity discounts vary between sources, making illegal cannabis more competitively priced when bought in bulk*.

2 Methods and data

2.1 Sample

We use self-reported cannabis prices submitted to the Global Drug Survey (GDS) in the period from 2016 to 2021. For more than a decade the GDS has conducted an online worldwide self-report survey on drug use. Individuals are eligible to complete the survey if they are aged 16 years or older and have used at least one drug in the past 12 months. Details about the GDS's methodology, including survey design, recruitment and representativeness have been previously described (Barratt et al., 2017; Winstock et al., 2022). In 5 out of 12 years (GDS2017, GDS2018, GDS2019, GDS2020 and GDS2022), the survey included questions about cannabis prices and drug source in addition to questions about sociodemographic characteristics. The GDS convention is to name a survey after the year in which results are published. Data collection begins in the fall and may continue into the following year when results are made publicly available. For example, data collection for GDS2022 began in November 2021, and concluded in February 2022. When referring to individual surveys we specify the survey (e.g. GDS2022) but in our analysis we reference the survey year (2021).

Our sample consists of persons within the US who reported flower cannabis prices in these surveys. We exclude incomplete cases and drop any unrealistic gram-prices below US$0.50 and above US$100, The GDS regularly revises its survey, and has used two different instruments to measure drug prices, one in which respondents are asked about the price of 1 gram (N = 13,307), and one in which they are asked about both quantity and price (N = 4,749). We analyze these separately. 9.8% and 3.3% of respondents did not report a US state, and we code these as "Unspecified" to retain them for analysis. We restrict the scope of analysis to persons within the US, because it provides the largest national sample and competing cannabis policies at the state-level. We include only prices for flower cannabis (high potency or regular) because refined higher potency products, such as wax, shatter and butane hash oil, are qualitatively different, vary significantly in price, and are difficult to compare (Davenport, 2019).

The analytical samples used in this study (N = 13,307, N = 4,749) exceed the size of most self-report studies on drug prices (e.g., Wadsworth et al. 2020; Wilkins et al., 2020), but we highlight that as the data come from a convenience sample (self-selected to do the survey) the data are not representative and therefore not generalizable to the US population. However, while the GDS is not representative, Barratt et al. (2017) highlight that subgroups of people who use cannabis are quite similar when comparing non-probability and probability samples.

2.2 Variables

Our dependent variable is the self-reported price of cannabis. Over the lifetime of the GDS the phrasing of the questions relating to price questions has changed as shown in Table 1. We draw attention to some crucial changes to the GDS over the years that have analytical implications. While these variations in phrasings all constitute measures of cannabis prices, exactly how drug prices should be measured is an ongoing debate (Golub & Johnson, 2004).

GDS Survey	Survey year	Cannabis source	Price-of-1-gram	Price	Quantity (grams)
GDS2013	2012		"How much do you pay for a gram of cannabis/marijuana?"		"How much do you usually buy at a time?"
GDS2014	2013			"How much do you pay for this amount?"	"How much do you usually buy at a time?"
GDS2015	2014		"How much do you usually pay for a gram?"		"How much do you usually buy at a time?"
GDS2016	2015		"How much do you usually pay for a gram?"		"How much do you usually buy at a time?"
GDS2017	2016	**"Thinking about the last time you bought cannabis, which source did you buy it from?"**	**"How much does it usually cost to buy a single gram of the cannabis type you use most commonly in your country?"**	**"How much did you pay for this amount?"**	**"How much did you buy on this occasion?"**
GDS2018	2017	**"Where did you most commonly purchase cannabis in the last 12 months?"**	**"How much does it usually cost to buy 1 gram of cannabis from [most common source]?"**		
GDS2019	2018	**"Where did you most commonly purchase cannabis in the last 12 months?"**	**"How much does it usually cost to buy 1 gram of cannabis from [most common source]?"**		
GDS2020	2019	**"Where did you most commonly purchase cannabis in the last 12 months?"**	**"How much does it usually cost to buy 1 gram of cannabis from [most common source]?"**		
GDS2021	2020				
GDS2022	2021	**"Where did you most commonly purchase cannabis in the last 12 months?"**		**How much do you usually pay for [quantity] of [cannabis type] from [most common source]?**	**How many grams of [cannabis type] do you usually buy at one time from [most common source]?"**

Table 1: Variations of price-quantity questions asked in the Global Drug Survey. Questions in bold are used in the analysis.

First, only GDS2017 and GDS2022 asked about a quantity and a price, whereas GDS2017-GDS2020 asked about the price-of-1-gram. The price-of-1-gram is not an ideal measure, because it may be subject to an unknown quantity discount and thus bias the results (see section 1.1). That is, a person who usually purchases 0.5 grams will likely report a higher gram-price than a person who usually purchases an ounce, because the price-per-gram decreases with the quantity purchased (Caulkins, 2007). Cursory analysis using the GDS2017 data, which included a question about both usual

purchase size and price-of-1-gram, did indeed show a significant association between the quantity question and price-of-1-gram. On average, respondents report the most recent or an average purchase to be 9.87 grams. Whether this would bias results upwards or downwards is uncertain, because people who purchase large quantities may either over- or underestimate the discount they are receiving. To address this bias, we separately analyze data on the price-of-1-gram and price-per-gram, and we draw attention to the higher quality of data in GDS2017 and GDS2022, for which the results are more credible.

Second, although both GDS2017 and GDS2022 included questions about price and quantity, allowing us to compute the price-per-gram, GDS2017 asked about the *last* purchase rather than *usual* purchase. Research using self-reported transaction level data suggests that recent and average purchases do not differ (Bond, Caulkins, Scott, Kilmer, & Dietze, 2014; Olmstead et al., 2015). Although we cannot test if this holds true in our data given the 5-year period between the use of each of the two phrasings, we rely on previous research and combine *usual* and *last* purchase response (GDS2017 and GDS2022). By controlling for year, we reduce bias introduced by the varied phrasing, though it implies that yearly trends in prices should be interpreted with caution.

Our dependent variables are the price-of-1-gram (GDS2017, GDS2018, GDS2019, GDS2020) and price-per-gram (GDS2017, GDS2022) which we analyze separately. In both cases we can assess whether there are significant differences in price across legal and illegal sources at the 1-gram level, but only the price-per-gram questions allow us to compare quantity discounts across sources. We adjust prices for inflation using the Bureau of Labor Statistics Urban Consumers Consumer Price Index (CPI) and use 2016 dollars as a base. In line with Caulkins and Padman (1993) we log-transform quantity, price-per-gram, and price-of-1-gram. Table 2 shows descriptive statistics for both samples.

Variable	Price of 1 gram	Price-per-gram
	N = 13,445	N = 4,727
Usual price of 1 gram (USD)	12.39 (7.75)	
Price-per-gram (USD)		11.09 (6.73)
Usual purchase quantity		9.87 (9.31)
Source		
Legal source and/or shopfronts	2,279 (17%)	847 (18%)
Friend/friend of friend	5,538 (42%)	1,666 (35%)
Known dealer	4,445 (33%)	1,973 (42%)
Other source	1,045 (7.9%)	263 (5.5%)
Cannabis type:		
Plant	3,375 (25%)	1,066 (22%)
High potency plant	9,932 (75%)	3,683 (78%)
Gender:		
Male	9,743 (73%)	3,647 (77%)
Female	3,273 (25%)	1,037 (22%)
Non-binary	291 (2.2%)	65 (1.4%)
Age	27.17 (11.82)	27.81 (12.34)
Days using cannabis within last year		
1	51 (0.4%)	9 (0.2%)
2-10	753 (5.7%)	231 (4.9%)
11-50	1,783 (13%)	610 (13%)
51-100	1,352 (10%)	489 (10%)
>100	9,368 (70%)	3,410 (72%)
Year		
2016	4,373 (33%)	4,434 (93%)
2017	2,124 (16%)	
2018	4,531 (34%)	
2019	2,279 (17%)	
2021		315 (6.6%)
State		
Unspecified	1,300 (9.8%)	156 (3.3%)
Alabama	109 (0.8%)	35 (0.7%)
Alaska	44 (0.3%)	13 (0.3%)
Arizona	229 (1.7%)	100 (2.1%)
Arkansas	73 (0.5%)	36 (0.8%)
California	1,263 (9.5%)	467 (9.8%)
Colorado	454 (3.4%)	177 (3.7%)
Connecticut	147 (1.1%)	61 (1.3%)
Delaware	31 (0.2%)	12 (0.3%)
District of Columbia	59 (0.4%)	17 (0.4%)
Florida	593 (4.5%)	231 (4.9%)
Georgia	308 (2.3%)	122 (2.6%)
Hawaii	27 (0.2%)	15 (0.3%)
Idaho	74 (0.6%)	28 (0.6%)
Illinois	503 (3.8%)	177 (3.7%)
Indiana	231 (1.7%)	88 (1.9%)
Iowa	120 (0.9%)	45 (0.9%)
Kansas	80 (0.6%)	37 (0.8%)
Kentucky	154 (1.2%)	52 (1.1%)
Louisiana	126 (0.9%)	40 (0.8%)

Maine	73 (0.5%)	37 (0.8%)
Maryland	186 (1.4%)	73 (1.5%)
Massachusetts	390 (2.9%)	155 (3.3%)
Michigan	373 (2.8%)	148 (3.1%)
Minnesota	272 (2.0%)	117 (2.5%)
Mississippi	56 (0.4%)	24 (0.5%)
Missouri	195 (1.5%)	65 (1.4%)
Montana	53 (0.4%)	20 (0.4%)
Nebraska	77 (0.6%)	26 (0.5%)
Nevada	105 (0.8%)	47 (1.0%)
New Hampshire	66 (0.5%)	28 (0.6%)
New Jersey	307 (2.3%)	112 (2.4%)
New Mexico	74 (0.6%)	32 (0.7%)
New York	763 (5.7%)	287 (6.0%)
North Carolina	347 (2.6%)	137 (2.9%)
North Dakota	30 (0.2%)	12 (0.3%)
Ohio	466 (3.5%)	159 (3.3%)
Oklahoma	123 (0.9%)	49 (1.0%)
Oregon	342 (2.6%)	129 (2.7%)
Pennsylvania	558 (4.2%)	206 (4.3%)
Rhode Island	48 (0.4%)	23 (0.5%)
South Carolina	118 (0.9%)	58 (1.2%)
South Dakota	24 (0.2%)	11 (0.2%)
Tennessee	219 (1.6%)	83 (1.7%)
Texas	815 (6.1%)	329 (6.9%)
Utah	140 (1.1%)	56 (1.2%)
Vermont	46 (0.3%)	12 (0.3%)
Virginia	321 (2.4%)	111 (2.3%)
Washington	437 (3.3%)	163 (3.4%)
West Virginia	69 (0.5%)	31 (0.7%)
Wisconsin	268 (2.0%)	90 (1.9%)
Wyoming	21 (0.2%)	10 (0.2%)

Table 2: Descriptive statistics. Mean and SD for continuous variables, N, and percentage for categorical variables. Age is uncentered.

Our key independent variable relates to respondents' most common cannabis source in the past 12 months. During the period of data collection, response options about drug sources have changed alongside general trends in drug markets, namely the emergence of illicit online markets. This necessitated substantial recoding to generate similar categories across years. In addition, some sources (e.g., *"Street/Unknown dealer"*) are rarely reported. We merge the rarely cannabis sources that were either inconsistent across years or rarely offered into *"Other source"* (*"Street/unknown dealer"*, *"Social media/clear web"*, *"Dark web"*, *"Other source"*). For legal sources, the GDS has inconsistently offered either or both *"Legal source or social club"* and *"Shopfronts*

(e.g. adult stores, head shops, coffee shops, smoke shops, cannabis dispensaries)". We treat both as legal sources for cannabis, labelling them as *"Legal source and/or shopfronts"*.

We control for age, gender, high-potency cannabis, and consumption patterns which are all likely correlates of price (Wilkins et al., 2020). As GDS has an age restriction of 16 years, we also subtract 15 years from the respondent age to make the intercept more interpretable. We log-transform the age variable to allow for a non-linear relation between age and price and aid interpretability (Gelman & Hill., 2007). Since GDS2015 the survey has included non-binary and transgender categories (non-binary, different identity, and transgender), though these are not consistent across years. We include self-identified gender as a control variable, but due to the inconsistency in survey phrasing, we use the term "non-binary" to include all those who identify as outside the gender binary. While we exclude non-flower forms of cannabis (edibles, resins et cetera), we differentiate between regular and high-potency flower using a dummy variable. We include the number of days within the last 12 months respondents reported consuming cannabis to control for consumption patterns. Finally, we include year and state as categorical variables to account for variation in prices across states and years.

2.3 Analysis

Our dependent variable is the self-reported price, while our key independent variable is the cannabis source. We aim to test a) whether prices differ between legal and illegal sources, and b) whether quantity discounts differ between legal and illegal sources. To test our hypotheses, we use OLS with state and year-dummies. We control for known predictors of cannabis prices, namely quantity, product type, consumption patterns, age, and gender (Caulkins, 1994; Wilkins et al., 2020). Price questions in the GDS have either concerned the *price-of-1-gram* or *price-per-gram*, and we analyze these separately. Our first research question concerns the price of cannabis at the level of 1 gram and the cannabis source coefficient. The latter question concerns the quantity discount and is assessed using an interaction between source and quantity. We address the first question using both measures, *price-of-1-gram* and *price-per-gram*, and the second question using only *price-per-gram*.

3 Findings

To assess whether the price of cannabis differs across sources at the level of 1 gram we estimate two models. In Model 1 (Price-of-1-gram) our dependent variable is the log of the price-of-1-gram. Conversely, in Model 2 (Price-per-gram) our dependent variable is the log of price-per-gram. In both models we control for cannabis type, gender, age, state, and year. In addition to these control variables, we also include the log of quantity purchased (in grams) in Model 2. In Model 3 we expand Model 2 by adding an interaction between source and quantity. This allows us to test whether quantity discounts differ between legal and illegal sources. Table 3 shows the regression results. The intercepts for each model are on the log scale, and exponentiating them yields estimated 1-gram prices of US$16.8, US$10.2 and US$11.6. Notably, the intercept in Models 1 and 2 represent the same – the price of 1 gram bought from a legal source in the reference year 2016 (GDS2017). For this reason, the large discrepancy between the intercept in the two models is surprising, but we draw attention to the substantial difference in phrasing of questions previously discussed and the lack of a quantity control in Model 1.

	Usual price of a gram (adjusted)	**Price-per-gram (adjusted)**	**Price-per-gram (adjusted, w/ interaction)**
Predictors	*β*	*β*	*β*
(Intercept)	2.82 *** (2.63 – 3.00)	2.32 *** (1.88 – 2.76)	2.45 *** (1.98 – 2.92)
Source (ref: legal source and/or shopfronts)			
Friend/friend of friend	-0.13 *** (-0.21 – -0.06)	-0.10 ** (-0.17 – -0.04)	-0.20 *** (-0.31 – -0.10)
Known dealer	-0.10 ** (-0.17 – -0.04)	-0.02 (-0.08 – 0.04)	-0.20 *** (-0.31 – -0.09)
Other source	-0.19 *** (-0.25 – -0.12)	-0.08 * (-0.16 – -0.01)	-0.21 ** (-0.35 – -0.07)
log(Quantity purchased)		-0.24 *** (-0.27 – -0.22)	-0.30 *** (-0.35 – -0.26)
log(Quantity purchased) * Friend/friend of friend			0.05 (-0.01 – 0.11)
log(Quantity purchased) * Known dealer			0.10 *** (0.05 – 0.14)
log(Quantity purchased) * Other source			0.07 (-0.01 – 0.14)
Cannabis type (ref: plant)			
High potency plant	0.02 (-0.01 – 0.05)	0.12 *** (0.08 – 0.16)	0.12 *** (0.08 – 0.16)
Gender (ref: Male)			
Female	0.13 *** (0.11 – 0.15)	0.02 (-0.02 – 0.06)	0.02 (-0.02 – 0.06)
Non-binary	0.04 (-0.02 – 0.09)	0.01 (-0.08 – 0.09)	0.01 (-0.08 – 0.10)
log(Years older than 15)	0.06 *** (0.05 – 0.07)	0.07 *** (0.05 – 0.09)	0.07 *** (0.05 – 0.09)
Days used cannabis within last year (ref: 1 day):			
2-10 days	-0.16 * (-0.31 – -0.02)	0.18 (-0.26 – 0.62)	0.18 (-0.28 – 0.63)

11-50 days	-0.21 ** (-0.36 – -0.06)	0.21 (-0.21 – 0.63)	0.21 (-0.23 – 0.65)
51-100 days	-0.28 *** (-0.43 – -0.13)	0.19 (-0.24 – 0.63)	0.20 (-0.26 – 0.65)
>100 days	-0.38 *** (-0.54 – -0.23)	0.20 (-0.24 – 0.64)	0.20 (-0.25 – 0.65)
Year (ref: 2016)			
2017	-0.18 *** (-0.20 – -0.15)		
2018	-0.27 *** (-0.30 – -0.24)		
2019	-0.32 *** (-0.36 – -0.28)		
2021		-0.27 *** (-0.35 – -0.19)	-0.27 *** (-0.35 – -0.19)
Observations	13,307	4,749	4,749
R^2 / R^2 adjusted	0.188 / 0.184	0.314 / 0.305	0.319 / 0.309

Table 3: Estimates from OLS regression with standard errors clustered by state. State-dummies not shown. *p < 0.05, ** p < 0.01, *** p < 0.001.

Beginning with control variables, we find that women report paying significantly higher prices than men in Model 1 (β= 0.13, $p < 0.001$), but not in Model 2 (β = 0.02, $p > 0.05$) or 3 (β = 0.02, $p > 0.05$). There is no significant difference between male and non-binary respondents. We found a positive, significant, and consistent association between the age of respondents and price in Model 1 (β = 0.06, $p < 0.001$), Model 2 (β = 0.07, $p < 0.001$) and Model 3 (β = 0.07, $p < 0.001$), suggesting that older individuals report paying higher prices. Given that age is log-transformed, the coefficient may be interpreted so that a 1% increase in age is associated with a 0.06% or 0.07% increase in self-reported price. Model 1 identifies a negative association between frequency of use and price, ranging from -0.16 ($p < 0.05$) to -0.36 ($p < 0.001$), but this relation does not replicate in Models 2 and 3. Conversely, we only observe a premium for high-potency cannabis in Models 2 and 3 (β = 0.12, $p < 0.001$). Finally, Model 1 shows a significant decrease in the price of one gram in 2017 (β = -0.18, $p < 0.001$), 2018 (β =

-0.27, $p < 0.001$), and 2019 ($\beta = -0.32$, $p < 0.001$) relative to 2016. Similarly, Models 2 and 3 show a significant decline in price-per-gram in 2021 relative to 2016 ($\beta = -0.27$, $p < 0.001$).

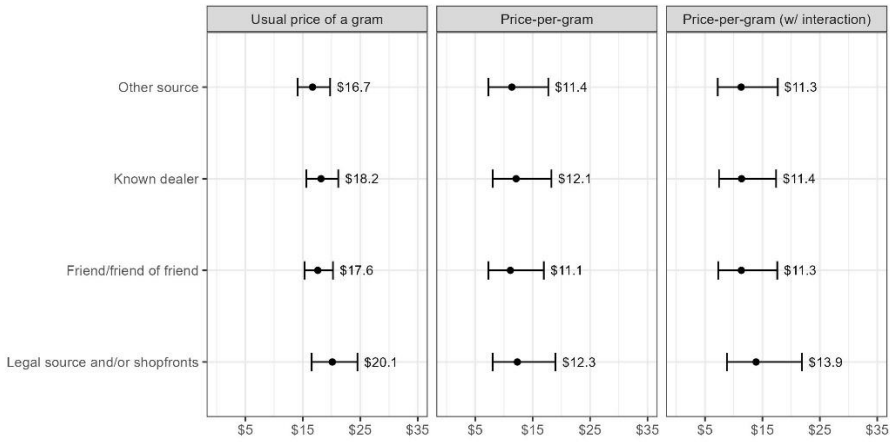

Figure 1: Estimated price of 1 gram across sources holding all covariates at their mean or reference category.

Models 1, 2 and 3 all suggest that illicit cannabis is either sold at a similar price to legal cannabis, or significantly discounted. Figure 1 shows the predicted prices of 1 gram from different sources based on the three models. In Model 1, cannabis purchased through friends ($\beta = -0.13$), through known dealers ($\beta = -0.10$), or other sources ($\beta = -0.19$) is consistently priced significantly lower than cannabis purchased from legal sources ($p < 0.001$). In Model 2, results suggest that cannabis from illegal sources is priced either similar to legal sources or lower. Relative to legal sources, cannabis sourced through friends ($\beta = -0.10$, $p < 0.01$), and other sources ($\beta = -0.08$, $p < 0.05$) is significantly cheaper, but cannabis sourced through known dealers is not ($\beta = -0.02$, $p > 0.05$). Model 2 includes quantity as a covariate, yielding a quantity discount of -0.24 ($p < 0.001$).

In Model 3 we allow the quantity discount to vary across sources using an interaction term. This specification increases price differences at the intercept and estimates a significant price difference between legal sources and friends ($\beta = -0.20$, p

< 0.001), known dealers (β = -0.20, p < 0.001), and other sources (β = -0.21, p < 0.01). The specification further increases the slope of the quantity discount to -0.30 (p < 0.001) for cannabis from legal sources. Cannabis from sourced through friends (β = 0.05, p > 0.05), other sources (β = 0.07, p > 0.05), and known dealers (β = 0.10, p < 0.001) all have a less steep quantity discount, but the difference is only significant in the last case. This relation is illustrated in Figure 2, which shows that while legal cannabis is more expensive in smaller quantities, the steep discount can make it competitive in larger quantities. Thus, allowing for an interaction between source and quantity suggests larger price difference between illegal and legal sources at the intercept.

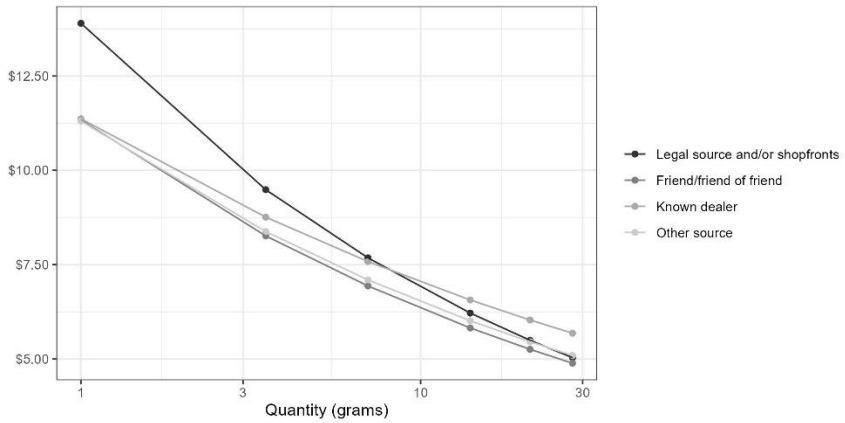

Figure 2: Estimated price-per-gram for different sources at intervals (1, 3.5, 7, 14, 21 and 28 grams) of quantity purchased.

4 Discussion

We found that illegal cannabis across the time period covered in the study was either priced significantly lower or at the same level as legal cannabis in the US. This suggests that illegal cannabis generally remains competitive with legal cannabis on price. Models 1 and 2 show that this is the case whether measured using the price-of-1-gram or the price-per-gram. We found a steeper quantity discount in Model 2 compared to past research (see for example Clements, 2006; Moeller et al., 2021; Munksgaard &

Tzanetakis, 2022). However, Model 3 suggests that legal cannabis appears to be more heavily discounted when purchased in larger quantities, possibly making it competitive on price in larger quantities. These results are not consistent for all illegal sources, however.

Significantly higher prices in legal markets mean that illegal markets remain competitive in terms of price despite their inefficiency and the risk tax (Reuter & Kleiman, 1986). Our results are congruent with past comparative research (Wadsworth et al., 2020), and several factors may explain the difference. First, taxation and the additional costs associated with cannabis sales in legal markets (e.g., medical fees for prescriptions, packaging costs) may keep prices higher (Caulkins et al., 2012; Miron, 2003). Second, the price difference may be indicative of a short-term increase in illegal cannabis prices due to increases in the demand of legal cannabis, similar to what has been observed in past research (Hunt & Pacula, 2017). Third, legal cannabis may be a qualitatively different product either in terms of the value people assign to it, or the quality itself. For example, Sifaneck, Ream, Johnson, and Dunlap (2007) find that "designer marijuana" is sold at substantially higher prices in New York, and Munksgaard and Tzanetakis (2022) find that branded cannabis products diverted from legal markets are sold at a premium in online drug markets. Finally, it is also worth noting that some legal cannabis may be diverted and resold illegally, keeping intact the low production costs but avoiding taxation. In fact, Caulkins and Bond (2012) suggest that legalization within one state could depress illegal prices throughout the US. Although the cannabis industry is tightly regulated (Hansen, Miller, & Weber, 2017; Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017), diversion of products from legal markets has long been observed in the market for illicit tobacco (Joossens, Gilmore, Stoklosa, & Ross, 2016; Joossens & Raw, 2012). Thus, institutional constraints, short-term increases in demand, quality differences and diversion may explain our findings.

Importantly, price is not the only parameter on which legal markets compete. Amlung et al. (2019) show that people who use cannabis "*treat legal cannabis as a superior commodity"* (p. 112). In line with this, research has found that factors such as consistency of product, transparency with regards to potency/quality, selection, and availability are all parameters on which legal markets can compete with illegal ones

(Reuter & Caulkins, 2004; Smart et al., 2017). Finally, Caulkins (2007) highlights that search time may be the most substantial non-monetary cost of drugs, making legal cannabis competitive in areas where venues for legal purchases are easier and/or faster to locate compared to illegal ones. Thus, while illegal cannabis markets appear to remain competitive with legal markets in the US on price, legal cannabis can still be competitive in other aspects.

In addition to our findings concerning legality and price, we also highlight some methodological implications of our findings. When comparing Models 1 and 2 there are large differences in estimated gram prices, even in 2017 in which both questions were used, and some covariates are significant in Model 1, but not in Model 2. As is evidenced in Figure 1, we find that price-quantity questions yield estimates that are much lower, and seemingly more reasonable when compared to past research (e.g., Hunt & Pacula, 2017; Wadsworth et al., 2020; Sifaneck et al., 2007). The omission of quantity as a predictor is the most probable cause of these differences. Notably, we see that when adjusting for quantity in Model 2, frequency of use and gender exhibit insignificant associations to price, and that sourcing premiums are closer to zero or insignificant. This suggests that price differences across these groups may simply be a question of varied purchase sizes, and that quantity is a confounding variable. If so, price estimates should be biased upwards for groups which tend to purchase small quantities, and downwards for those who purchase large quantities, if price is measured based on the *price-of-1-gram* rather than the *price-per-gram*. Specifically, we highlight that the significant price differences between men and women and low- and high-frequency only appear when we are unable to control for quantity purchased. Consequently, we encourage researchers to ask about quantity and price, rather than the price of a single gram.

5 Limitations

As other studies of hidden and criminalized populations, and studies of drug prices in general, the results of this study should be interpreted in the light of several limitations. Firstly, while the size of our samples surpasses that of most self-reported studies on drug prices, this study is limited by the non-probabilistic and self-nominating nature of

GDS (for a comprehensive discussion of these limitations, see Barratt et al., 2017). Consequently, although *"drug markets are dominated by conventional pricing"* (Caulkins, 2007, p. 62), the generalizability of our findings to the US population is limited (Barratt et al., 2017). Secondly, as is evident from the variation in the reported prices of one gram of cannabis across phrasing of price-related questions, the self-reported nature of the GDS data might introduce at least some degree of unreliability to the study. This unreliability might, in part, be attributed to the fact that individuals purchasing illicit drugs often rely on sellers' accounts of the quantity being exchanged, meaning that buyers generally have a somewhat imperfect ability to quantify amounts obtained from non-legal sources (Caulkins, 2007). Thirdly, this study is also limited by factors related to the use of self-reported data more broadly, including the vulnerability to recall bias and social-desirability bias. Lastly, despite utilizing data from several years, the cross-sectional design of GDS prevent us from deriving any causal claims about the relationship between the price and source of cannabis.

6 Conclusion

Using a novel dataset of self-reported price data in the period between 2016 and 2021 (excluding 2020; N = 13,307, N = 4,749), we find that illegal cannabis is either significantly cheaper than legal cannabis, or that there is no significant difference. When respondents are asked about the price of 1 gram, our estimates suggest a price between US$16.7 (other source) and US$18.2 (known dealer) from illegal sources, contrasted to US$20.1 from a legal source. Using a more robust price measure controlling for quantity discounts, we find that the price-per-gram in illegal markets is in the range of US$11.1 (friends/friend of a friend) and US$12.1 (known dealer) contrasted to US$12.3 from legal sources. However, when introducing an interaction between quantity and source, this gap widens with one gram of legal cannabis priced at US$13.9 contrasted to illegal prices in the range of US$11.3 (other sources and friends) and US$11.4 (known dealer). However, we observe a significantly less steep quantity discount sourced from known dealers relative to legal sources and shopfronts, suggesting that as quantities increase legal cannabis is priced similarly as illegal cannabis. These results indicate that illegal cannabis markets remain competitive with

legal markets on price, with similar or significantly lower prices. However, legal cannabis sources cannabis may still remain a more attractive product in the eyes of the consumer.

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