Three Essays on Applied Microeconomics

Inauguraldissertation zur Erlangung des akademischen Grades
eines Doktors der Wirtschaftswissenschaften
der Universität Mannheim

vorgelegt von
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im Frühjahrs-/Sommersemester 2024

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Tag der Disputation:	15.07.2024

Ackowledgements

First of all, I want to thank Michelle Sovinsky. I was very lucky to have her as a supervisor. She showed me how to think about research questions and how to tackle them. I could not be more grateful, Michelle. By example, you really teach how to make meaningful contributions in this field, as a researcher, a colleague, and a person. I am very excited to continue working together. Likewise, I also want to thank the mentors that I had the pleasure to have: Laura Grigolon, Kevin Remmy, and Bernhard Ganglmair. Your guidance, comments and advice helped me grow as a researcher. A special thank you to Tania Guerra Rosero, an amazing co-author, colleague, and friend.

I am very happy for the team we had at Michelle's chair: Matilde Cappelletti, Jakob von Ditfurth, and Alejandro Medina. Thank you for all your support and comments. Moreover, I have seen how you overcome every obstacle your papers faced, and it is inspiring. I am sure you are all going to do great.

I am grateful for the administrative support from Golareh Khalilpour, Nina Kraus, Ulrich Kehl, Marion Lehnert, Caroline Mohr, Sylvia Rosenkranz, and the CRC Team. Moreover, I gratefully acknowledge the financial support from the Deutsche Forschungsgemeinschaft (DFG) through CRC TR 224 (project A02). I extend my gratitude to the institutions that provided the data for this dissertation: Uruguayan Drug Observatory and Ecuador's Superintendencia de Compañías.

I also thank every single person from my cohort: Giovanni Ballarin, Suzanne Bellue, Jacopo Gambato, Tommaso Gasparini, Lukas Mahler, Laura Montenbruck, Oliver Pfäuti, Jasmina Simon, and Jonathan Stäbler. Between beers, lunches, and economic discussions, we had so much fun.

And most importantly, I am very thankful to my family. Despite the distance, I always felt their support and love. This is also yours.

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Introduction

This dissertation contains three chapters in the field of applied microeconomics. Specifically, they address research questions about the demand for (il)legal marijuana and firms' responses to financial audits.

In the first chapter, I assess the effect of recreational marijuana legalization on the black market's presence by studying Uruguay's marijuana market. This country's legalization aimed to reduce the drug trafficking market's presence and societal costs. However, post-legalization, a third of Uruguayan marijuana users still buy from drug dealers. In this chapter, I estimate a novel demand model in a post-legalized environment that includes access selection/limitations, alternative choices regarding the source (legal or drug trafficking), and individual-level prices. I use these estimates to identify tools that steer the demand to the legal market. Counterfactuals show that a 10% price reduction increases legal marijuana use by 9%, but primarily driven by new users. Reducing access to the drug trafficking market decreases the use of both legal and illegal marijuana, emphasizing access's role in demand. In contrast, widespread legal marijuana access leads to a 17% increase in legal use, with half coming from the drug trafficking market. Understanding consumer substitutions between (il)legal options is crucial for policies targeting black market reduction.

I the second chapter, joint with Tania Guerra Rosero, we analyze if the government should harness private agents to deliver public services. We assess this in the context of the tax administration in Ecuador where the government collaborates with third-party auditors to increase tax compliance. Large firms in Ecuador are required to have third-party audits of their yearly balance sheets and income statements. Auditors review the financial statements and prepare a tax compliance report for the Ecuadorian Tax Agency. We exploit a reform that significantly reduced the asset threshold determining the audit obligation and first document a large bunching response. Second, we provide suggestive evidence that bunching firms reduce their assets through reductions in the debts of their clients (accounts receivable) and in the short-term debts with their suppliers (accounts payable). Third, we use a donut-hole Regression Discontinuity Design to explore the effects of the audits on the audited firms. Our results indicate that firms reduce their reported costs and expenses by 24% and compensate for this with a reduction in reported revenues of 23%. Firms also reduce their net income by 32%. This suggests that governments should not rely on private agents to conduct tax audits.

In the third chapter, I assess the price elasticities of different forms of marijuana (inhalants and edibles) and how these elasticities vary based on potency preference. Using individual-level data from surveys conducted between 2020 and 2022 in Canada, I estimate a two-level nested logit model where individuals first decide whether to use marijuana and then select the form (edible or inhalant). The results indicate a positive correlation between marijuana forms' valuations and reveal that individuals with a preference for high THC potency obtain a lower utility for edibles over inhalants. Additionally, the

study finds that edibles exhibit larger own-price elasticities, in absolute terms, compared to inhalants. Regarding inhalants, individuals with a preference for high THC potency are less price sensitive than individual without this taste. These findings can be useful for public policy when designing pricing strategies in curbing excessive consumption of more potent and harmful marijuana products.

Chapter I

Beyond Legalization: Access and Use of (Non-)Drug-Trafficking Marijuana

1 Introduction

Marijuana ranks as the most prevalent illicit substance worldwide, with roughly 5% of the population aged 15 to 64 using it in the past year (United Nations Office on Drugs and Crime, 2021) and a global market value of around USD 40 billion. Several countries have embraced or are deliberating the legalization of recreational marijuana use. Policymakers predominantly advocate legalization as a tool to diminish the presence of the drug trafficking market. In this regard, Uruguay became the first country to legalize recreational marijuana in 2013, with the primary objective of curbing the drug trafficking market and the high level of violence associated with it (Queirolo et al., 2019). Uruguay's framework permits its citizens to procure recreational marijuana through licensed pharmacies, social cannabis clubs, or home cultivation, all under the regulatory purview of the Institute of Regulation and Control of Cannabis (IRCCA). Notably, despite this policy shift, around a third of users in the country still resort to the drug trafficking market, obtaining marijuana directly from drug dealers. Understanding this demand behavior and proposing different tools to steer the demand is crucial, especially in countries where the black market's violence and the associated social costs are very high.

This paper analyzes the effect of legalization on the drug trafficking market's presence, while incorporating the role of access. I estimate how consumers substitute between legal and illegal sources, when the legal market is more accessible or the drug trafficking market is more challenging to access. Understanding the proper tools in order to steer the demand is critical for public policy, especially in a market where promoting consumption is not desired. For this, I propose a novel demand model where an individual, conditional on her level of access, chooses between drug trafficking marijuana, legal marijuana, or no marijuana use. Modeling access is motivated by the evidence that not every individual knows how to obtain marijuana from dealers and/or that not every individual can obtain marijuana from legal sources due to geographical constraints. Moreover, individuals who know how to obtain illegal drugs may be more interested in using marijuana or vice versa. My demand model also allows for this potential correlation between access and use.

To empirically identify the substitution patterns, I mainly use the VII National Survey on Drug Use in the General Population 2018 (NSDUGP), performed by the Uruguayan Observatory of Drugs, after all the legal marijuana sources opened. It contains individual-level socio-demographics and drug use information. The sample represents 1.8 million individuals of the Uruguayan population (with a total population of 3.4 million). In particular, this survey allows me to observe the main sources of marijuana that individuals use and the accessibility to the drug trafficking market. Past-12-month marijuana users (around 14 percent of the sample) also reported where they mainly obtained the marijuana: from drug dealers, pharmacies, social clubs, self-cultivation, resellers, etc. The data indicate that around a third of users bought marijuana (in)directly from *dealers* in the drug trafficking market. In addition, every surveyed individual reported information regarding accessibility to drug dealers. That allows me to define that 65 percent of the sample has access to the drug trafficking market. Lastly, with department-level data,[1] I can observe the size of the legal market. I use this information to define access, at the individual level, to the legal and drug trafficking market.

I build a model based on random utility maximization in which an individual selects whether to have access to the drug trafficking market or not. This selection depends on individual-level socio-demographics and department-level crime information. Moreover, access to legal marijuana is exogenous for the individual and depends on the individual's geographic location. With this, choice sets are generated for every individual, given that not everybody is able to obtain illegal marijuana and/or lives in a location where legal marijuana is an available option. Considering the individual's choice set, she chooses one of the following as differentiated products: drug trafficking marijuana (if available), legal marijuana (if available), or no use of marijuana (always available), according to her indirect utility. These choices will depend on individual-level socio-demographics, prices, and department-level information. Importantly, I allow for a correlation between the individual's access selection and the marijuana use decision through the (un)observable individual's attributes. Individuals who know how to get an illegal drug (i.e. through a known drug dealer) may be more interested or comfortable regarding using (any) marijuana. At the same time, individuals who enjoy using marijuana may be interested in accessing the drug trafficking market to obtain an additional (and illegal) marijuana option or other illegal drugs. My model captures the potential correlation of these two decisions.

Regarding results, I find that incorporating access selection in the model is crucial for accurately capturing substitution patterns. I find a stronger negative price effect with respect to a model that does not consider access selection or restrictions. Moreover, given individual-level data, I estimate how different (individual) socio-demographics and department-level attributes affect access selection and the marijuana alternatives choice. Furthermore, I find a positive correlation between the selection of having access to illegal drugs and the marijuana use decision. The correlation is not only through the observed individual socioeconomic attributes but also through the unobservables. In particular, the model shows a positive correlation between the unobservables of 0.4. This implies, for example, that reducing the likelihood of accessing the drug trafficking market would result in a reduction in the use of any marijuana. In other words, if illegal drugs are harder to get, individuals will be less interested in using marijuana, whether it comes

[1] Uruguay is divided into 19 *departments*, which are (political) subdivisions of the territory.

from the drug trafficking market or not.

The government could apply policies to enhance (decrease) accessibility to the legal (drug trafficking market) market. I performed counterfactuals that show different tools to steer the demand toward the legal market. First, given limited access to legal sources, I show that a legal price reduction may be inefficient for attracting drug trafficking users. Cross-price elasticities are low, resulting in this policy primarily creating new users while only marginally reducing the drug trafficking market. In particular, a 10 percent price reduction for legal marijuana leads to a 9 percent increase in its use, primarily due to new users. Second, decreasing access to the drug trafficking market reduces the overall marijuana use rate (not only the drug trafficking marijuana use rate). This suggests that when individuals lose contact with illegal drugs or dealers, they will be less likely to use marijuana, regardless of the source. This is driven by the estimated positive correlation between the (un)observables that affect the access selection to drug trafficking marijuana and the marijuana use decision. In the third counterfactual, in contrast, making legal marijuana accessible to all individuals results in a 17 percent increase in its use, with half of this increase involving drug trafficking users transitioning to the legal alternative. Limited legal access creates a situation where individuals who would easily switch to a legal option do not, as it is unavailable to them. This analysis provides valuable insights into how substitution occurs in a market where promoting substance use is not desirable. The novel ingredients of my demand model, combined with the comprehensive data, generate proper estimates to address this policy challenge.

In the last two decades, recreational marijuana use has been mostly studied as an illegal behavior in an illegal market. Moreover, in the last years, new studies have focused on the legal marijuana market. However, the literature considering a black market within a post-legalization market is scarce. To the best of my knowledge, Perrault (2022) is the only empirical article with a demand that considers a black market after legalization but has no information about consumer choices and assumes perfect access to both sources. In contrast, to estimate the effect of marijuana legalization, Jacobi and Sovinsky (2016) incorporates access selection in their demand model but does not distinguish between different (il)legal sources of marijuana. Hence, my paper stands as the first one that uses observed individual choices to estimate a demand where drug trafficking and legal marijuana are potential options, while also accounting for limited access to these alternatives.

This paper is organized as follows: Section 2 presents the related literature; Section 3 describes the institutional background; Section 4 explains the data used in this paper; Section 5 and 6 proposes the demand model and the econometric specification; Section 6 discusses the results; Section 8 shows the counterfactuals; and Section 7 presents the conclusions.

2 Related Literature

In recent years, with the ongoing discussions surrounding the legalization of recreational marijuana, there has been a significant increase in research on marijuana use. My paper is related to three different strands of the economic literature regarding this substance: (i) marijuana demand after legalization or decriminalization, (ii) legal marijuana market analysis, and (iii) the relationship between crime and marijuana legalization. Furthermore, this article is also aligned with research on demand estimation involving limited/consideration sets.

First, with the decriminalization or legalization of marijuana, researchers have primarily examined its potential increase in use. Existing evidence suggests that following decriminalization policies, overall marijuana use rises (Miron and Zwiebel, 1995; Pacula et al., 2010; Williams et al., 2011). However, it's crucial to note that legalization differs significantly from decriminalization. These two approaches vary in terms of accessibility, the associated costs of illegal behavior, and their impact on drug dealers. Jacobi and Sovinsky (2016) is the first article to estimate the impact of legalization on marijuana use, predicting an increase in both intensive and extensive usage margins, where accessibility plays a role. Moreover, Miller et al. (2017) also finds an increase in the demand among college students in Washington (even among underage students) after its legalization. This increase could be attributed to reduced usage risks, lower prices, and improved accessibility (Perrault, 2022). These findings shape the debates on marijuana legalization. Such debates are critical since marijuana use can potentially elevate the likelihood of using harder drugs like cocaine or heroin (Van Ours, 2003; Bretteville-Jensen and Jacobi, 2011). However, existing literature primarily studies marijuana demand but not its sources, such as whether it originates from drug trafficking or the legal market. This novel analysis holds significant value for policymakers, as it aligns with their goal of curbing demand and ensuring a well-executed roll-out. In the current literature, Perrault (2022) proposes the only demand model that accounts for distinct marijuana sources as differentiated products. However, unlike this paper, it is estimated without observed choices and assumes all individuals have access to legal and illegal marijuana.

Second, in recent years, many studies have focused on the marijuana market directly as legal without considering the existence of a black market. With data from Washington, Hansen et al. (2017) assess the effect of taxation on the responses throughout the supply and consumption chain. Hollenbeck and Uetake (2021) suggests that legal marijuana is not overtaxed, with the majority of these taxes mainly carried by consumers. Additionally, regarding tax revenues, Miller and Seo (2021) shows that legal marijuana can cannibalize other legal substances' demand, while Hansen et al. (2020) analyzes the effect of a potency-based tax. Moreover, Thomas (2019) studies how inefficient the systems of license quotas are in the recreational marijuana market in Washington. Lastly, Perrault (2022) suggests that marijuana quality can serve as a tool to redirect demand toward the legal market. Nevertheless, no study has analyzed demand steering to the legal market where access to marijuana sources plays a role.

Third, a relatively new branch of the literature examines the effect of marijuana legalization on crime that arises from the prohibition of this substance. This potential effect is a significant motivator for legalization, particularly in areas where illicit drug production is significant. Studies have reported reductions in various crime rates following legalization (Dragone et al., 2019; Brinkman and Mok-Lamme, 2019), but with minimal effects on youth crime (Dills et al., 2017). Such effects have also been observed in U.S. states bordering Mexico, where the legalization or decriminalization of the marijuana supply chain weakened criminal structures (Gavrilova et al., 2019). Moreover, Hao and Cowan (2020) analyzes an increase in marijuana possession arrests in neighboring states of Colorado and Washington, attributing it to a spillover effect following recreational legalization. However, no evidence is available on how crime and interactions with drug dealers influence the demand for marijuana in a post-legalized environment.

Lastly, by allowing for limited access, this project also extends the literature on limited choice/consideration sets. Jacobi and Sovinsky (2016) is the first article to model access to marijuana and use, while controlling for correlations, but does not consider sources (such as the drug trafficking or legal market). Several other articles, including Sovinsky Goeree (2008); Gaynor et al. (2016); Ho et al. (2017), explore situations where not all products are readily accessible to consumers (imperfect access) or where consumers may not be aware of all available products (imperfect information). This perspective is particularly relevant when considering illegal substances. Notably, this article is the first to define and differentiate limited access to marijuana based on its source.

The literature that considers a post-legalization black market in the marijuana demand is still very scarce. Overall, to the best of my knowledge, Perrault (2022) is the only empirical article that considers the presence of two options (illegal and legal) and analyzes the effect of legalization on the black market's marijuana prices and quality but has no information about consumers' sources. Particularly, the data and framework I employ in this article enable me to introduce a novel demand model that is estimated using observed consumer choices, while also considering limited access to drug trafficking and legal marijuana.

3 Institutional Background

3.1 Legalization of recreational marijuana in Uruguay

In Uruguay, a significant shift in marijuana legislation occurred in 1974 when the possession of a personal use amount was decriminalized under *Law 14,294*. However, production and commercialization remained prohibited. Then, in December 2013, Uruguay made history by becoming the first country to fully legalize recreational marijuana throughout its entire territory.[2] This landmark change was brought about by *Law 19,172*, which empowered the government to regulate the recreational consumption, production, and distribution of marijuana.

This policy change was proposed and mainly pushed by Uruguayan President José Mujica.[3] Three primary objectives drove this initiative. First, the government sought to resolve the legal inconsistency of the prior law, where use was not criminalized, but commercialization was. Second, the government expected to enhance public safety by reducing drug trafficking-related violence and crimes. This objective held particular significance in a South American context, where the adverse consequences of drug trafficking, such as violence, disproportionately affect the global South (United Nations Office on Drugs and Crime, 2023). Less developed regions face challenges like limited opportunities, resources, and law enforcement, making their residents more susceptible to involvement in drug cultivation, production, and distribution, further exacerbating drug-related issues. Finally, it aimed to use regulation as a public health measure.

The legislation, *Law 19,172*, was proposed directly from President Mujica's office as a *top-down* policy, deviating from the typical process involving initial engagement with activists, as seen in other countries. Around sixty percent of Uruguayans initially opposed this policy (Cifra Consultores, 2013). However, the government successfully pushed for this drug policy because citizens began to view marijuana legalization as a means to curb drug trafficking-related crimes and violence (Queirolo et al., 2019). This context differs from the approaches in other countries, where legalization is primarily proposed as a health policy (by regulating demand, supply, and quality) or a tool to raise taxes. In several Latin American nations, including Uruguay, various drugs are produced and then trafficked abroad, resulting in a pervasive drug trafficking market and the presence of *narcos*, generating a heavy toll on society. For instance, in 2014, an estimated 50 percent of violent deaths were linked to gang rivalries in the drug trafficking market (Ministerio del Interior, 2014).

The Uruguayan government capitalized on the fact that 40 percent of the population perceived 'delinquency' as the foremost issue in the country (Latinobarómetro, 2013) and presented this drug policy as an effective tool to undermine *narcos* by reducing their influence. In a June 2013 interview, President Mujica stated: *"The real problem is not marijuana but drug trafficking because consumption already exists in our society. If we do not seize the market from the drug traffickers, we induce the multiplication of the criminal world (...)"* (El Universo, 2013).

3.2 Sources of legal recreational marijuana

Uruguay's legalization framework provides three distinct sources for individuals to access marijuana for recreational use: authorized pharmacies, social cannabis clubs, and

[2] Canada followed suit in 2018, becoming the second country to legalize recreational marijuana. As of 2023, recreational use has been legalized at the state level in 23 states in the United States.

[3] José Mujica served as President from 2010 to 2015.

personal cultivation at home. The Institute of Regulation and Control of Cannabis (IR-CCA) oversees and regulates the availability and distribution of marijuana through these channels.

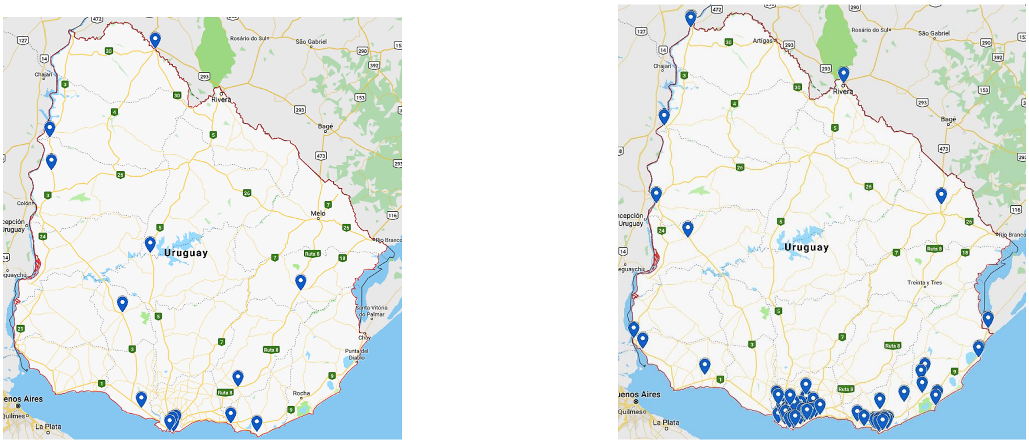
To become a legal marijuana user in Uruguay, individuals must undergo a mandatory registration process. This registration is exclusively available to Uruguayan citizens or those with legal citizenship or permanent residence; tourists are not eligible. The registration process is cost-free and requires specific documentation, including a valid Uruguayan identity card (either natural or legal citizenship) and proof of residence. To complete the registration, individuals must visit designated facilities under the National Postal Service of Uruguay, where they can submit their documents. As of 2018, there were 27 authorized locations spread across the country to facilitate this process.

Home cultivators of marijuana in Uruguay are allowed to cultivate a maximum of 6 plants in their residence, with their annual production not exceeding 480 grams. As of 2018, 9,995 individuals had officially registered as home growers. These registered users had an average age of 36 years old, and roughly three-quarters of them were male. Notably, a significant portion of these registered home growers resided outside the capital city of Montevideo in 2018 (Instituto de Regulación y Control del Cannabis, 2018). However, it's worth noting that various studies indicate that a substantial portion of self-cultivators operate without official registration (Aguiar, 2018; Baudeau, 2018; Cruz et al., 2018). Evidence suggests that nearly half of the individuals who engage in home cultivation of marijuana do so without being formally registered. It's important to emphasize that the government does not prioritize enforcement measures against unregistered cultivators, as they are not seen as contributing to an increase in the drug trafficking market. Consequently, there is minimal enforcement for compelling individuals to undergo registration for home cultivation.

The second authorized source for obtaining legal marijuana in Uruguay is through cannabis social clubs. These clubs are permitted to cultivate a maximum of 99 plants, and the overall production of the club cannot exceed 480 grams per member annually. To establish a cannabis social club, there are specific requirements in place. Each club must have a minimum of 15 members and a maximum of 45 members. Additionally, a technical agent is mandatory to ensure that the club complies with all the requirements set by the regulatory institute. The registration of cannabis social clubs commenced in October 2014, and as of September 2018, the country had 107 clubs distributed across 11 different departments. These clubs collectively had a total membership of 2,703 individuals. On average, each club had approximately 25.3 members, and notably, approximately 80 percent were male, with an average age of 32 years old (Instituto de Regulación y Control del Cannabis, 2018).

Moreover, the third authorized source for obtaining legal marijuana in Uruguay is through authorized pharmacies, a system that commenced mid-2017. This initiative has gained notable attention and evolved significantly. As of September 2018, Uruguay had 14 pharmacies across the nation that were licensed to sell recreational marijuana. These pharmacies experienced significant demand, as evidenced by 28,181 registered buyers within the first year of implementation. Each pharmacy buyer was subject to a monthly acquisition limit of 40 grams, a regulation enforced through a fingerprint verification system, prioritizing privacy by eliminating the need for personal identification. These pharmacies are supplied exclusively by licensed producers, further ensuring the quality and legitimacy of the product. While the distribution of the pharmacies extends beyond Montevideo, the capital city remains a focal point, hosting most of these establishments. Consequently, more than half of the registered buyers are residents of Montevideo. The demographic profile of these buyers revealed a distinct trend, with nearly half of them falling within the age range of 19 to 29 years old (Instituto de Regulación y Control del Cannabis, 2018). This age distribution may indicate a significant engagement of young adults in Uruguay's burgeoning legal marijuana market.

Figure 1 offers a visual representation of the geographic distribution of authorized pharmacies and cannabis social clubs as of September 2018. Notably, a predominant concentration of these sources is evident in the south, where the population is densely clustered in the capital city, Montevideo (see Figure A1). Even though the locations are correlated with highly populated zones, some areas do not have any legal source of marijuana. This is particularly significant for those residing outside the metropolitan areas. For individuals who find themselves at a distance from these authorized outlets, the only legal source is to engage in self-cultivation. This motivates my model of limited access to legal sources.



(a) Authorized pharmacies

(b) Cannabis social clubs

Figure 1: Locations of legal sources 2018 (Instituto de Regulación y Control del Cannabis, 2018)

4 Data

The primary dataset used in this paper is the VII National Survey on Drug Use in the General Population 2018 (NSDUGP). This survey was designed and coordinated by the Uruguayan Observatory of Drugs within the National Secretariat of Drugs. Conducted between September and December 2018, the NSDUGP includes individual-level data, such as socio-demographic attributes and information on drug use. Among the notable features explored are drugs' accessibility and use prevalence. The survey has a sample size of 4,720 individuals within the age range of 16 to 65 years. The dataset is nationally representative of 1.8 million individuals within the broader Uruguayan population, which totals 3.4 million inhabitants.[4]

Table 1 provides an overview of the socio-demographic characteristics. As the table shows, 45 percent of the individuals are male, while 82 percent identify as white. The average age of the respondents is 39, with 26 percent having attended college and 18 percent falling into a high socioeconomic status (defined by the public institutes involved in the survey). Additionally, a substantial majority, comprising 80 percent of the sample, reported their health status as good or very good. Furthermore, concerning the geographical distribution of the sample, 50 percent of individuals were residents of the capital city, Montevideo, while the remaining individuals resided in the country's interior departments. This distribution closely mirrors the population's geographic distribution.

Socio-demographics attributes	Mean	Min	Max
Male	0.45	0	1
Age (years)	39.41	15	65
White	0.82	0	1
Black	0.11	0	1
High school	0.49	0	1
Technical school	0.10	0	1
College	0.26	0	1
Unemployed	0.07	0	1
Middle level SES	0.51	0	1
High level SES	0.18	0	1
Good or very good health	0.80	0	1
Members in household	3.01	1	11
Lives in:			
Montevideo	0.50	0	1
Interior city (>20 thou.)	0.39	0	1
Interior city (<20 thou.)	0.11	0	1
Observations	4,720		

Table 1: Socio-demographics - NSDUGP

Table 2 summarizes individual drug usage patterns and accessibility to such substances. Findings from the survey indicate that 14 percent of respondents reported marijuana use within the past year, with 8 percent reporting use in the last month. Among those who had ever used marijuana, constituting 28 percent of the sample, the average age of initiation was 21 years. The survey extends its inquiry to include harder substances

[4]Given the age bracket of the surveyed individuals and the sample selection of the departments, it does not represent the total population of the country.

like cocaine and cocaine paste.[5] The annual prevalence rate of use for these hard drugs is 2 percent. Regarding drug accessibility, 76 percent of the individuals reported possible access to marijuana, while 61 percent indicated similar ease of access to (paste) cocaine. Additionally, 9 percent of respondents reported being offered the opportunity to purchase marijuana by a dealer, and 31 percent believe the often use of marijuana is risky for their health which may disincentive the consumption. Finally, respondents reported the number of friends and relatives using cocaine (paste), with an average response of 1.03.

Drug use and accessibility	Mean	Min	Max
Used marijuana ever	0.28	0	1
Used marijuana in the last 12 months	0.14	0	1
Used marijuana in the last 30 days	0.08	0	1
Age of first marijuana use	20.7	7	64
Used cocaine (paste) in the last 30 days	0.02	0	1
It is possible to obtain marijuana	0.76	0	1
It is possible to obtain cocaine (paste)	0.61	0	1
Was offered marijuana (to buy)	0.09	0	1
Believes often use of marijuana is risky	0.31	0	1
# friends/relatives that use cocaine (paste)	1.03	0	10
Observations	4,720		

Table 2: Drug use and accessibility information - NSDUGP

Besides individual attributes and marijuana use, for this paper, it is relevant to observe the source of marijuana, accessibility to this substance's sources, and prices. This information is explained in the following subsections and is a key ingredient for estimating the demand model.

4.1 Legal or drug trafficking marijuana

Given the main objective of *Law 19,172*, the Uruguayan Observatory of Drugs conducted this survey not only to assess the country's drug use rates but also to evaluate the effectiveness of the legalization of recreational marijuana and its legal sources. To achieve this, the survey gathered information from the individuals who had used marijuana in the past 12 months, specifically focusing on how they obtained the marijuana they often used. Users can be categorized based on whether the marijuana they often used originated from the legal market or the illicit drug trafficking market.

Table 3 provides the list of the marijuana sources. Users were asked to indicate their most frequently utilized source among these options. Then, legal marijuana encompasses any marijuana originating (directly or indirectly) from self-cultivation, pharmacies, or social clubs.[6] Conversely, drug trafficking marijuana comprises marijuana originally ob-

[5]As common in these surveys and given the sensitive topics, individuals were provided with written assurance that none of their answers would be used against them and that anonymity would be guaranteed.

[6]Non-registered home cultivation or buying from a legal user may technically be considered illegal.

tained (directly or indirectly) from drug dealers. There are two *types* of marijuana in the market: "prensado," which is lower quality and often referred to as brick marijuana, and "cogollo," which refers to the marijuana bud (Figure A2 shows pictures of these marijuana *types*). Marijuana buds are the flowers and the consumable parts of the plant. It's worth noting that before the establishment of legal marijuana sources, self-cultivation was the sole legitimate means of acquiring non-drug trafficking marijuana.

Legal marijuana sources	**Drug trafficking marijuana sources**
(1) I am a self-cultivator	**(1)** I bought *prensado* (brick marijuana) from a drug dealer.
(2) I am a club member	**(2)** I bought *cogollo* (marijuana bud) from a drug dealer
(3) I bought in a pharmacy	**(3)** Someone bought *prensado* (brick marijuana) for me from a drug dealer
(4) I bought to someone that cultivates or is a club member	**(4)** Someone bought *cogollo* (marijuana bud) for me from a drug dealer
(5) Someone bought for me in a pharmacy	**(5)** Drug trafficking marijuana was given/shared
(6) Someone bought for me to a self-cultivator or club member	
(7) Legal marijuana was given/shared	

Table 3: Sources of marijuana - NSDUGP

Table 4 presents an overview of the distribution of individuals who reported using marijuana within the past 12 months, categorized based on their primary source of marijuana. Specifically, marijuana users are classified as legal market users if their primary source of marijuana is one from the legal market or drug trafficking users if they primarily obtain marijuana from dealers. The 2018 survey reveals that 60 percent of users were legal market users, while 33 percent identified as drug trafficking users. Lastly, 7 percent of users lacked information about its source. In the marijuana demand literature, it is important to highlight that this individual-level classification is a completely novel feature, made possible by the detailed information collected by the NSDUGP.

Marijuana users	Freq.	Perc.
Legal users	370	60
Drug trafficking users	204	33
Unknown (Shared/Given)	43	7
Total	617	100

Table 4: Marijuana users - NSDUGP

However, it operates within a "gray" market framework that does not impose the typical social costs of the illicit drug trafficking market. This paper focuses on the origin of the used marijuana.

4.2 Access to marijuana

4.2.1 Access to drug trafficking marijuana

Access to marijuana from the drug trafficking market is not perfect, as not every individual possesses the knowledge or means to obtain it. Only those who successfully have access can make the decision to use it or not.

The NSDUGP asked individuals how easy it is for them to obtain marijuana.[7] However, it is not possible to distinguish if they are referring to legal or drug trafficking marijuana. The survey question refers to *any* marijuana. Consequently, to precisely define access solely to the drug trafficking market, more specific information is necessary.

The NSDUGP collects information from both marijuana users and non-users, allowing the assessment of an individual's potential to acquire marijuana from drug dealers. Table 5 summarizes this information. I assume that an individual has access to the drug trafficking market if they meet any of the following criteria: (i) indicate that obtaining cocaine (paste)[8] is possible, (ii) have used cocaine (paste) within the last 12 months, (iii) have been offered marijuana for purchase in the last 12 months, or (iv) have used drug trafficking marijuana. Among the respondents, 61 percent reported the possibility of obtaining cocaine (paste), with 2 percent reporting use within the past year. Additionally, 9 percent of individuals were offered marijuana to buy (most probably by a drug dealer), and 5 percent have used drug trafficking marijuana in the last 12 months. Following this criteria, 65 percent of the sample has access to the drug trafficking market.[9] Moreover, the definition of access to the drug trafficking market largely hinges on the ability to obtain cocaine (paste). These individuals are more likely to be in direct contact with drug dealers or knowledgeable about engaging with them. Moreover, it is reasonable to assume that if a dealer offers cocaine (paste), they can also provide access to drug trafficking marijuana.

Information about drug trafficking access	Percent
Is possible to obtain cocaine (paste)	61
Used cocaine (paste) in past 12 months	2
Was offered marijuana to buy	9
Used drug trafficking marijuana	5
Has access to the drug trafficking market	65
Used drug trafficking marijuana given access	18
Observations	4,720

Table 5: Drug trafficking market access - NSDUGP

Furthermore, individuals that fit into my definition of drug trafficking access also

[7]A similar question was mainly used by Jacobi and Sovinsky (2016) in order to define marijuana access.

[8]Cocaine paste or coca paste, which is highly popular in South America and predominantly used by low-income populations, typically contains a cocaine concentration ranging from 40 to 80 percent.

[9]Note that certain conditions may overlap within the same individuals.

reported that it was *possible* to obtain *any* marijuana (see Table B1). This validates the fact that individuals who have access to the drug trafficking market are able to obtain marijuana.

4.2.2 Access to legal marijuana

Access to legal marijuana is not perfect as well, as shown previously in Figure 1. With the NSDUGP, it is not possible to define access to the legal market at the individual level. Consequently, I establish access to the legal market for individuals residing in departments with a substantial number of legal marijuana users. In particular, I use the number of legal (registered) users per thousand inhabitants older than 18 years old. I consider this a better indicator of accessibility than the number of authorized pharmacies or clubs per department. They can be highly correlated, but the number of registered users can capture cases of two neighboring cities from different departments, where one may have a high number of legal sources and the adjacent city does not. Departments that have zero or a low number of legal users can easily signal limited or even non-existent accessibility to legal marijuana.

Table 6 shows the number of pharmacy buyers and club members per thousand inhabitants aged 18 or older. I define that a certain department does not have access to legal marijuana if it has 5 or fewer pharmacy buyers per thousand inhabitants older than 18 years old. This threshold is relatively low and the next department with a higher number is relatively distant from it. More interestingly, the departments below this threshold exhibit a zero prevalence rate of legal marijuana (see Table B2). Then, given this definition, individuals residing in Colonia, Florida, San José, and Tucarembó have no access to legal marijuana. Note that these departments also have zero or a low number of club members per thousand inhabitants older than 18 years old.

Departament	**Pharm. Buyers. (/1,000 inh.)**	**Club Members (/1,000 inh.)**	**Obs.**
Canelones	11.98	1.09	497
Colonia	3.15	1.13	187
Florida	3.88	0.37	235
Lavalleja	13.27	0	222
Maldonado	28.74	4.21	397
Montevideo	17.93	1.31	2,359
Salto	11.45	0.08	231
San Jose	4.97	0	410
Tacuarembó	4.36	0	182
Observations			4,720

Table 6: Legal marijuana users per thousand inhabitants (Instituto de Regulación y Control del Cannabis, 2018)

Consequently, 78 percent of the sample has access to legal sources of marijuana. Using the access definitions for these two marijuana alternatives, it is possible to define individual-level limited choice sets.

4.2.3 Access restrictions

As evidence shows, access is not perfect, not regarding the legal or the drug trafficking market of marijuana. Table 7 shows the sample distribution according to access restrictions. Notably, 53 percent of the sample has access to drug trafficking and legal marijuana. In addition, 25 percent (12 percent) have access only to drug trafficking (legal) marijuana, respectively. Lastly, 10 percent of the individuals do not have access to any marijuana. The table's last column also displays the marijuana use rate of each group. Individuals with full access exhibit the highest usage rate of 20 percent.[10] Within this rate, 12.2 percentage points are generated in the legal market, with the remaining portion sourced from the drug trafficking market.

Access restrictions	**Perc.**	**Marij. use rate**
No access	10	0
Access only to legal marijuana	12	7.6
Access only to drug trafficking marijuana	25	5.9
Full access	53	20.0
Total	100	

Table 7: Access restrictions

Furthermore, Table B4 reviews the individuals' socio-demographic attributes according to their access restrictions. The highest fractions of individuals with a college education and high socioeconomic status have access only to legal marijuana. Note that these individuals may have self-selected not to have access to the drug trafficking market while residing in a department with sufficient legal sources.

4.3 Prices of marijuana

I do not observe the reported price paid from every user, for legal and drug trafficking marijuana. However, the NSDUGP asked marijuana users the price per gram of *cogollo* (marijuana bud) and *prensado* (brick marijuana). Table 8 presents the distribution of these reported individual prices per gram (in Uruguayan pesos, UYU). Naturally, marijuana buds tend to have a higher mean price than brick marijuana, as the latter is generally considered lower-quality marijuana, which is only obtained through drug dealers. Conversely, marijuana bud exhibits a larger standard deviation in price, reflecting the significant variation in quality which is unobserved.

[10] Note that this rate is significantly higher than the country's annual prevalence rate (see Table 2).

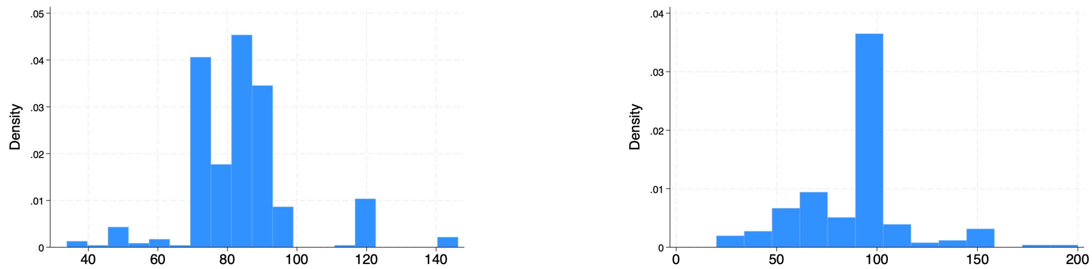
Prices per gram (in UYU)	Mean	S.D.	Min	p10	p50	p90	Max
Brick marijuana *(prensado)*	59.1	33.2	10	20	50	100	150
Marijuana bud *(cogollo)*	123.8	59.9	20	50	100	200	250

1 USD = 32 UYU (2018)

Table 8: Reported prices per gram of brick and marijuana bud

Moreover, the marijuana sold in authorized pharmacies is regulated and is 70 UYU per gram. For users, I use these data to construct an individual-level price per gram for drug trafficking and legal marijuana. First, the price of drug trafficking marijuana is taken as the drug trafficker users' average of their reported illegal marijuana bud price and the brick marijuana price.[11] Second, the price of legal marijuana is taken to be the legal user's average of their reported marijuana bud price and the pharmacy marijuana price.[12] This price construction reflects the market price that users face, whether it is the legal market or the drug trafficking market, and it is not specific to any particular location.

Figure 2 shows the distribution of these generated prices for drug trafficking and legal users. The average price for legal marijuana is 83.6 UYU, while 87 UYU for drug trafficking marijuana. For legal marijuana, prices are concentrated between 70 and 90 UYU, whereas drug trafficking prices tend to be concentrated around 90 UYU.



(a) From legal market

(b) From drug trafficking market

Figure 2: Distribution of individual-level marijuana prices (in UYU)
1 USD = 32 UYU (2018)

For the non-users, for each marijuana alternative, I imputed the price using the observed average of four age groups: younger than 20 years old, between 20 and 30 years old, between 30 and 40 years old, and older than 40.[13] Age was the socio-demographic attribute that explained high price variations. This imputation, according to a socio-demographic attribute, follows as performed in Jacobi et al. (2023). Table B5 shows the prices generated for non-users, according to their age. Teenagers and individuals older than 40 have a lower average price for each option. The literature typically focuses on average market or period prices. However, it's crucial to acknowledge that individuals

[11] As shown in Table 3, brick marijuana is only found in the drug trafficking market.
[12] Legal users can buy marijuana buds that were originally produced in legal sources, such as clubs.
[13] For every users from which an input is not observed, I also impute it in this way.

encounter varying scenarios when purchasing marijuana, impacting the price.

5 Model

I consider the following marijuana demand model, where the individual $i = 1, ..., N$, in the department $t = 1, ..., T$, decides whether to have access to the drug trafficking market or not. I model this access selection as being determined by the following utility function:

$$U_{it}^a = \beta^a + \gamma^a X_i^a + \eta^a Z_t^a + \varepsilon_i^a \tag{1}$$

Where, X_i^a is a set of the individual's socio-demographics, which includes age, gender, education, race, and socioeconomic status. Then, Z_t^a is a set of department-specific characteristics that may affect access to illegal drugs, such as crime information. Lastly, ε_i^a is an unobserved term that affects the individual's likelihood of accessing drug trafficking drugs.

In this model, individuals with access to the drug trafficking market can choose to use drug trafficking marijuana or not. On the other hand, legal marijuana is available depending on individual i's location (as mentioned in subsection 4.2.2). I assume that individual i does not decide where to live based on legal sources of marijuana, and instead, accessibility to legal marijuana is exogenous.

Furthermore, conditional on the choice set, individual i, in department t, can choose between $j = 0, 1, 2$: no use of marijuana, use of legal marijuana, or use of drug trafficking marijuana, respectively. Note that legal and drug trafficking marijuana are modeled as differentiated products. This alternative choice is based on the following indirect utility:

$$U_{itj}^u = \beta_j^u - \alpha p_{ij} + \gamma_j^u X_i^u + \eta_j^u Z_t^u + \nu_{itj} + \varepsilon_i^u \tag{2}$$

Where, β_j^u is the constant term for each $j > 0$ (alternative fix effect), p_{ij} is the individual level price for product j, X_i^u is a set of individual-level attributes (such as age, gender, education, race, socioeconomic status, health status and risk adverseness), and market-level attributes Z_t^u that affect the demand choice (such as the number of pharmacy buyers per capital). Finally, ν_{ijt}, a type 1 extreme value error, is the unobserved shock of i of choosing alternative j. Moreover, ε_i^u is the individual's unobserved term of using (any) marijuana. The ε_i^u can be explained as coming from a random coefficient in the constant term: $\beta_{ji}^u = \beta_j^u + \varepsilon_i^u$.[14]

The utility of the outside option is $U_{it0} = \nu_{it0}$. It does not include the ε_i^u since $j = 0$ represents the decision of not using marijuana. Consequently, this allows for a particular substitution of the $j > 0$ alternatives given the unobserved term of use ε_i^u.

In addition, I assume that the idiosyncratic shocks to access and use (demand), ε_i^a and ε_i^u, are distributed according to the following (standardized) multivariate normal

[14] This is similar to Ioannidou et al. (2022) and Crawford et al. (2018) where different financial decisions are allowed to be correlated through the unobserved terms

distribution:

$$\begin{pmatrix} \varepsilon_i^u \\ \varepsilon_i^a \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right) \tag{3}$$

The parameter ρ captures the potential correlation between these unobserved terms. If the correlation is positive, an individual with a higher unobservable propensity to access the drug trafficking market is also more likely to use (any) marijuana. The opposite could also hold: an individual who is highly interested in using marijuana will potentially find their way to obtain drug trafficking marijuana as the only or an additional option of marijuana (or even another illegal drug).

6 Econometric specification

An individual will choose to have access to drug trafficking marijuana if $U_{it}^a > 0$. Then, the probability that individual $i = 1, ..., N$, in department $t = 1, ..., T$, has access to the drug trafficking market is as follows:

$$\phi_{it} = \Pr_{it}(a_{it} = 1) = \int I(\beta^a + \gamma^a X_i^a + \eta^a Z_t^a + \varepsilon_i^a > 0) f(\varepsilon_i^a) d\varepsilon_i^a \tag{4}$$

Where, a_{it} is a dummy that indicates if the individual has access to the drug trafficking market or not, and ε_i^a is distributed normally.

Given the individual's access selection and geographic location, then (s)he will have a limited choice set $\mathcal{C}_\rangle$. An individual will choose alternative $j \in \mathcal{C}_\rangle$ if $U_{itj}^u > U_{itk}^u$, where $j \neq k$. Given the assumptions of the unobserved terms, the probability of individual i, in department t, chooses the good $j \in \mathcal{C}_\rangle$ is:

$$s_{itj\in\mathcal{C}_\rangle} = \int \frac{exp(\beta_j^u - \alpha p_{ij} + \gamma_j^u X_i^u + \eta_j^u Z_t^u + \varepsilon_i^u)}{1 + \sum_{j\in\mathcal{C}_\rangle} exp(\beta_j^u - \alpha p_{ij} + \gamma_j^u X_i^u + \eta_j^u Z_t^u + \varepsilon_i^u)} f(\varepsilon_i^u) d\varepsilon_i^u \tag{5}$$

Where, the type 1 extreme error term, ν_{ijt}, generates the closed-form solution inside the integral. In addition, the probability that individual i in market t chooses the outside option (not using marijuana) is:

$$s_{it0} = 1 - \sum_{j\in\mathcal{C}_\rangle, j\neq 0} s_{itj} \tag{6}$$

Note that if an individual has access to no marijuana, $\mathcal{C}_\rangle = \{0\}$, then (s)he will choose the outside option with certainty. However, the decision of whether to have access to drug trafficking marijuana remains relevant for this individual.

Moreover, the random draws that impact access selection and use are specified as follows:

$$\varepsilon_i^a = \xi_i^a \tag{7}$$

$$\varepsilon_i^u = \rho\xi_i^a + \sqrt{(1-\rho^2)}\xi_i^u \tag{8}$$

Where, $\xi_i^a, \xi_i^u \sim N(0,1)$. So, ρ will capture the correlation of the unobserved shocks of the access selection to drug trafficking marijuana and the use of any marijuana.

I estimate the model by simulated maximum likelihood. Halton draws ($S = 100$) are used to approximate the integrals,[15] and each draw is indexed by s. The joint estimation of these two choice equations is based on the following log-likelihood function:

$$\log\ L = \sum_i \frac{1}{S} \sum_{s=1}^{S} \mathrm{a}_{it} \left(\log(\phi_{its}) + \mathbf{d}_{itj} \log(s_{itjs})\right) + (1 - \mathrm{a}_{it}) \left(\log(1 - \phi_{its}) + \mathbf{d}_{itj} \log(s_{itjs})\right) \tag{9}$$

Where, a_{it} is the dummy that refers to the individual's access selection for drug trafficking marijuana, and $\mathbf{d}_{itj}$ is the dummy for the individual's use of $j \in \mathcal{C}_{\rangle}$.

6.1 Identification

The parameters of the utilities of the access selection to drug trafficking marijuana and the marijuana use decision are estimated due to variation in the data at the individual- and department-level, which corresponds to variation in the probabilities of these two decisions. It is important to note that both the alternative fixed effects and the price coefficient can be identified due to the price variations at the individual level.

Moreover, the parameter ρ can be estimated due to variance in the covariance between unobservables terms that affects the access selection to drug trafficking marijuana and the marijuana use decision. To allow for identification beyond the model nonlinearities, I include exclusion restrictions in the access selection. In particular, I have included two variables that should not affect the utility of using any of the marijuana alternatives. The first variable is the department's number of homicides rate per 100 thousand inhabitants (see Table B2), as a proxy of violence or crime. The presence of drug-related gangs generates the availability of drugs, but also high violence in the locality. It is estimated that half of the homicides are due to drug trafficking conflicts (Ministerio del Interior, 2018), given their search for more territory or power. Furthermore, the second variable that exclusively impacts the likelihood of access is generated with the individual's reported number of friends or relatives that use hard drugs. In particular, with that report, I generate the average per department (see Table B3). This variable would also reflect the department's level of presence of illegal drugs. Higher levels of these two variables are expected to increase the likelihood of the individual's access to the drug trafficking market, without influencing the utility of using marijuana.

[15] According to Train and Winston (2007), these number of draws achieve greater accuracy in mixed logit estimations than 1,000 pseudo-random draws.

7 Results

Table 9, columns (2) and (3) present the coefficients of a model without access restrictions, which is a multinomial logit where every individual has a full choice set: $\{0, 1, 2\}$. Here, there is no access selection to drug trafficking marijuana, and in every department, legal marijuana is available. Moreover, in columns (3)-(5), I show the coefficients of the model with access restrictions proposed in this article: with access selection to drug trafficking marijuana and individual choices sets.

First, the model with access restrictions estimates a larger price coefficient than the model without access restrictions. This is consistent with previous literature considering limited access, as in Jacobi and Sovinsky (2016). Regarding individual attributes, all specifications consistently show that male and college-educated individuals have a higher marginal utility of using marijuana, regardless of the source. However, in the model with access restrictions, college-educated individuals get more utility from using legal marijuana as compared to the drug trafficking option. In contrast, individuals who are older, in good health, and exhibit risk-averse behavior toward marijuana use[16] have a lower marginal utility of using this substance. These negative coefficients on marijuana use utility are even more pronounced when considering drug trafficking marijuana. Two variables have different effects according to the alternative. Individuals who identify as belonging to minority races[17] get less (more) utility from using legal (drug trafficking) marijuana. Furthermore, a high socioeconomic status[18] increases the individual's utility of using legal marijuana but has a negative effect regarding the drug trafficking alternative. In addition, an individual who lives in a department with more pharmacy buyers gets more utility from using legal marijuana.

Being able to obtain marijuana from the drug trafficking (DT) market is not random. As shown in column (5), the same individual-level attributes impact the utility of this access selection. Males and individuals belonging to a minority race have a higher marginal utility from being able to obtain illegal drugs, while older individuals and those with a high socioeconomic status get a lower utility from this selection. Having a college education has a statistically insignificant effect on this selection's utility. As expected, crime, measured through the department's homicides per 100 thousand inhabitants, generates more utility regarding access to illegal drugs. Similarly, the department's average number of friends and relatives who use cocaine (paste) also positively affects the utility of this selection. This implies that departments with higher crime levels and a more significant presence of hard drugs increase an individual's utility regarding having access to the drug trafficking market.

Finally, selection is also in the unobservables, as evidenced by the parameter ρ being positive and statistically significant. In particular, the correlation is equal to 0.4. This

[16]Thinks the often use of marijuana is risky (as described in Table 2).
[17]Black, aboriginal, Asian or other.
[18]The National Institute of Statistics defines three levels: low, medium, and high.

positive correlation underscores the importance of considering access selection into the drug trafficking market in the marijuana use decision. Notably, a similar positive and significant correlation was estimated by Jacobi and Sovinsky (2016), further validating the importance of allowing for this correlation.

	Without Access Restrictions		**With Access Restrictions**		
	Demand		**Demand**		**Access DT**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
price	-0.0625***		-0.0683***		
	(0.0031)		(0.0028)		
	Legal	**Drug-Traff.**	**Legal**	**Drug-Traff.**	
male	0.8353***	0.7827***	0.9656***	0.8160***	0.2820***
	(0.1630)	(0.1956)	(0.0609)	(0.0585)	(0.0223)
college	0.8540***	0.2265	0.9022***	0.2274***	0.0105
	(0.1809)	(0.2604)	(0.0612)	(0.0602)	(0.0283)
minority race	-0.2930	0.2702	-0.2413***	0.2019**	0.1808***
	(0.2208)	(0.2135)	(0.1007)	(0.0854)	(0.0531)
age	-0.0521***	-0.0958***	-0.0625***	-0.1060***	-0.0110***
	(0.0064)	(0.0097)	(0.0023)	(0.0035)	(0.0004)
high SES	0.1731	-0.9974***	0.2024***	-0.9006***	-0.3145***
	(0.1961)	(0.3732)	(0.0906)	(0.0955)	(0.0342)
good health	-0.5081**	-1.0351***	-0.5947***	-1.1308***	
	(0.2130)	(0.2261)	(0.0428)	(0.0633)	
risk adverse	-2.2430***	-2.5138***	-2.4687***	-2.7048***	
	(0.3910)	(0.5426)	(0.2046)	(0.2277)	
pharm buyers pc	0.0507***		0.0146***		
	(0.0130)		(0.0045)		
homicides pc					0.1495***
					(0.0042)
# friends cocaine					0.6824***
					(0.0604)
constant	-2.2220***	0.7550*	-1.4417***	0.7254***	0.8034***
	(0.3704)	(0.4178)	(0.0471)	(0.0534)	(0.0160)
ρ				0.4139***	
				(0.0221)	
Likelihood	1,067		3,280		
N	4,671		4,671		

Note: Standard errors in parenthesis.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 9: Estimation results

Table 10 shows the computed own- and cross-price elasticities of the model with and without access restrictions, regarding legal and drug trafficking marijuana. These elasticities represent the percentage change in demand for the alternatives when there is a one percent increase in the price of the same or a different alternative. The elasticities, ϵ_{jk}, are presented considering the alternative j's demand (in the rows) given a price variation in the k alternative (in the columns). The model with access restrictions yields greater own-price elasticities, in absolute terms, than the model without access restrictions. In the model with (without) access restrictions, the own-price elasticity is -0.97 (-0.83) for legal marijuana and -0.85 (-0.72) for drug trafficking marijuana. Moreover, cross-price elasticities are also crucial for public policy considerations. I find that the model without access restrictions underestimates the cross-price elasticities.

Price elasticites (ϵ_{jk})	Legal marij..	Drug traf. marij.
With access restrictions		
Legal marij.	-0.97	+0.25
Drug traf. marij.	+0.27	-0.85
Without access restrictions		
Legal marij.	-0.83	+0.18
Drug traf. marij.	+0.22	-0.72

Table 10: Price elasticities

8 Counterfactuals

Policymakers have a vested interest in understanding the demand in this particular context to steer it toward the legal and legal marijuana market effectively. When the drug trafficking market experiences a decline in demand, it can result in reduced profits, presence, and violence associated with the illegal drug trade. In addition to the positive externalities of a weaker drug trafficking market, individuals may lose contact with drug dealers. While some individuals may engage with dealers solely to obtain marijuana, it is important to note that dealers can also serve as sources for harder drugs like cocaine, cocaine paste, and heroin. Disrupting the user-dealer relationship may consequently reduce individuals' access to harder drugs, which aligns with the goal of minimizing the negative health effects associated with these substances.

To shift demand away from the drug trafficking market and towards the legal market, the government may consider implementing policies that enhance the accessibility or attractiveness of the legal market or make the drug trafficking market less accessible. Moreover, it is important to mention that curbing the demand is also a government's objective. Some strategies may successfully attract drug trafficking users to the legal market while also increasing the overall marijuana use rate. Introducing new users to the market is not a desirable outcome from the government's perspective. For this reason, it is important to observe how substitutions are performed when using a credible shifting tool.

In particular, first, I analyze a reduction in the price of legal marijuana. Second, I explore how a reduction in drug trafficking presence, determined by department-level variables, influences access to drug trafficking marijuana and the marijuana use decision. Lastly, I introduce legal marijuana as an option within the choice set of every individual and assess the effect of perfect access to this alternative. Given data limitations, it is not possible to precisely anticipate how drug dealers would react to these counterfactual scenarios. In the drug trafficking market, price is unique, and various unobservable factors determine it. However, understanding how the demand reacts to these counterfactuals gives novel and valuable lessons for public policy.

8.1 Legal price reduction

The pricing of legal marijuana is defined by IRCCA, with pharmacies having no control over it. Therefore, implementing price reductions becomes a direct strategy for encouraging more users to transition from the drug trafficking market to the legal one. To achieve this without negatively impacting authorized marijuana suppliers, the government could consider reducing the regulated price.

I perform two legal price reductions: 5 and 10 percent. The results are shown in the Table 11. Column (1) presents the predicted baseline market shares and columns (2)-(3) show the percentage point changes resulting from the respective legal price reductions.

Alternative	**(1)** **Predicted market share** (percentage)	**(2)** **Legal Price ↓ 5%** (Δ percentage points)	**(3)** **Legal Price ↓ 10%**
No use ($j = 0$)	85.4	-0.3	-0.7
Legal marij. ($j = 1$)	9.5	+0.4	+0.9
Drug traf. marij. ($j = 2$)	5.1	-0.1	-0.2
Marijuana use rate	14.6	+0.4	+1

Table 11: Predicted market shares and counterfactuals (legal price reduction)

As expected, the demand for legal marijuana increases following its price reduction. Remarkably, across the various legal price reductions, a significant portion of the shift toward the legal market originates from the outside option (from non-users). It's worth noting that a large fraction of the increase in the legal market share can be attributed to the decrease in the outside option share. For example, with a 10 percent reduction in the legal price, the drug trafficking market share decreases by 0.2 percentage points, while marijuana use increases by a much larger fraction. Given the limited access to legal marijuana, it is impossible to attract potential marginal users (drug trafficking users that may be easily shifted). Moreover, where legal marijuana is already available, attracting these marginal users with lower prices becomes more challenging, given a low cross-price elasticity.

Given the novel ingredients of the model with access restrictions, realistic substitutions are observed (consumers substitute from one available alternative to another available one). However, predictions of the model without access restrictions will underestimate the increase in the overall marijuana use rate, given lower price elasticities. In addition, it will capture non-possible substitutions, considering that without access restrictions every individual has a full choice set (see Table B6). Then, even though some individuals have no access to a certain marijuana alternative, they will have a non-zero probability of choosing it.

8.2 Decreasing access to the drug trafficking market

Another potential tool at the government's disposal for steering the demand is reducing the presence of the drug trafficking market. Various policies could be enacted to target drug-related gangs and organizations directly. In particular, with a diminished drug trafficking market, individuals would be less likely to come into contact with drug dealers when seeking marijuana or other illegal substances.

If drug trafficking is reduced, it should be reflected in two variables considered in the access selection in the model with access restrictions. First, violence and crime, measured through the department's homicide rate, should decrease. A decrease in drug-related conflicts, which typically contribute to violence, would be expected with fewer drug traffickers. However, it's worth noting that approximately half of this measure is attributed to drug-related conflicts, so this aspect needs to be considered in the counterfactual analysis. Secondly, the department's average number of friends and relatives who use hard drugs should also decrease. This serves as a close proxy for the presence of illegal and hard drugs. With drug-related gangs weakened, the availability of illegal drugs would also likely decrease. These two measures are directly or closely related to the drug trafficking of harder drugs. However, if fewer dealers are available due to a reduction in drug trafficking, it should also lead to a decrease in the access and use of illegal marijuana.

I simulate two reductions in the department's drug trafficking presence through these variables: 50 and 75 percent. Table 12 shows the results of this analysis. Again, column (1) presents the baseline predicted market shares, and columns (2)-(4) indicate the changes in percentage points resulting from the corresponding counterfactuals. The department's average number of friends and relatives who use hard drugs is reduced by either 50 or 75 percent, while the homicide rate is decreased using only the portion attributed to drug-related issues.

Alternative	**(1) Predicted market share** (percentage)	**(2) Drug. Traff. ↓ 50%** (Δ percentage points)	**(3) Drug. Traff. ↓ 75%**
No use ($j = 0$)	85.4	+0.3	+0.8
Legal marij. ($j = 1$)	9.5	-0.2	-0.5
Drug traf. marij. ($j = 2$)	5.1	-0.1	-0.3
Marijuana use rate	14.6	-0.3	-0.8

Table 12: Predicted market shares and counterfactuals (drug trafficking market access reduction)

A reduction in these variables directly impacts an individual's likelihood of accessing the drug trafficking market. This, in turn, results in a reduction in the demand for drug trafficking marijuana. Interestingly, the market share of legal marijuana also decreases.

This arises from the fact that the choice of accessing the drug trafficking market is correlated with using any marijuana alternative. If an individual loses contact with a dealer and illegal drugs, they become less likely to use marijuana, even if a legal option is available. However, it's noteworthy that a reduction in the drug trafficking market share is relatively small. Specifically, a 75 percent reduction in the variables capturing drug trafficking presence results in only a 6 percent decrease (0.3 percentage points) in the drug trafficking marijuana market share.

8.3 Increasing access to legal marijuana market

Finally, the government could increase the accessibility of legal marijuana to attract more users. To achieve this, it should implement policies to encourage potential suppliers to expedite the delivery of marijuana to pharmacies, as bureaucratic obstacles have hindered the supply chain. By enhancing accessibility to the legal market, every individual would have legal marijuana as an option in their choice set, thereby generating a nonzero probability of choosing this alternative.

It is important to note that these counterfactuals are motivated by two facts. Firstly, increased accessibility could be achieved through the authorization and supply of existing pharmacies, which do not require the initial investment as new dispensaries. Secondly, departments without these legal sources have comparable marijuana use rates to other departments with access to sufficient legal sources (see Table B2), indicating that legal supply can meet demand. Table 13 shows the substitutions generated by these assumptions. Column (2) presents how the market shares vary given that every individual has access to legal marijuana (legal marijuana is in every choice set).

Alternative	**(1) Predicted market share** (percentage)	**(2) Perfect access to legal marijuana** (Δ percentage points)
No use ($j = 0$)	85.4	-0.8
Legal marij. ($j = 1$)	9.5	+1.6
Drug traf. marij. ($j = 2$)	5.1	-0.8
Marijuana use rate	14.6	+0.8

Table 13: Predicted market shares and counterfactuals (legal market increase)

As expected, the market share of legal marijuana increases. But interestingly, this increase of 1.6 percentage points (17 percent), half of the substitution comes from users who chose the drug trafficking alternative. This was not the case when reducing the legal price with limited access, where more news users are generated. This particular substitution occurs given that marginal users are quickly attracted to the legal market when it becomes available. In other words, given their (un)observed attributes, some individuals may be just waiting for a legal option in order to switch to it. From the government's perspective, these users should be easy targets. Even though there may be drug trafficking users that would be hard to switch, accessibility may be a key ingredient to diminish the drug trafficking market, with a desirable substitution.

8.4 Discussion of the counterfactuals

Policymakers face the challenge of making the legal marijuana market more attractive while simultaneously curbing marijuana use. The insights gained from the counterfactual analyses provide the following valuable lessons:

1. Limited access to legal sources makes price an inefficient tool for steering demand. Evidence suggests that cross-price elasticity is relatively small.[19]

2. Efforts to reduce access to the drug trafficking market can effectively reduce the overall marijuana use rate. Users and potential users lose their contact with drug dealers, which decreases their inclination to use drugs, including marijuana, whether it is legal or not.

3. Enhancing accessibility to the legal market appears to be the most efficient way to steer demand. The overall marijuana use rate increases, but almost half of the increase is generated by drug trafficking users now choosing the legal alternative.

Policies that enhance access to marijuana may be hindered by a larger incentive to curb the demand or by bureaucratic processes in this new market. However, analyzing the demand in a post-legalized context reveals that the overall marijuana use rate will increase due to policies aimed at steering the demand. Nonetheless, policymakers can adopt strategies to ensure that the increase in marijuana use is mostly generated by reducing the drug trafficking market.

9 Conclusions

Recreational marijuana legalization is often proposed as a tool to diminish the consequences of drug trafficking-related conflicts, which are prevalent in many countries. However, even after the legalization, a significant portion of users may continue to obtain this substance through the drug trafficking market. The slow market transition allows drug dealers to maintain their influence and contact with users.

In this paper, I propose a novel and adequate demand model that considers different aspects of a post-legalized environment, such as access selection/limitations, alternative choice regarding source (as differentiated products), and individual-level prices. By incorporating these ingredients to predict demand, it becomes feasible to identify effective tools for steering demand toward the legal market. This information is valuable for crafting efficient policies aimed at reducing the presence of drug traffickers in the market and

[19] Perrault (2022) also estimates low cross-price elasticities, regarding legal and illegal marijuana.

mitigating their harmful societal consequences. In particular, I find that legal price reduction is an inefficient tool for this objective. However, access plays a crucial role and can be used as a proper tool to generate desirable substitutions that mostly decrease the presence of the drug trafficking market.

Understanding the behavior of a new market is not a simple task, particularly when it comes to a substance with a long history of illegality. Post-legalization, there are many aspects that we need to learn regarding marijuana demand and research should tackle these questions. Considering that the war against drug traffickers has been too long and too costly, it is essential not only to understand the demand for marijuana but also the factors influencing the choice of its source.

Chapter II

Third-Party Audits and Firms' Responses: Evidence for Ecuador

Joint with Tania Guerra Rosero

1 Introduction

Increasing tax revenue in developing countries is key to implementing redistributive policies while reducing dependence on volatile income sources, such as the exploitation of natural resources and foreign aid. Tax enforcement through tax audits can increase tax revenue by detecting and deterring tax evasion. However, auditing a large group of taxpayers is not always feasible because governments are resource-constrained. Can governments collaborate with third-party auditors to expand the monitoring of taxpayers while increasing tax compliance? This is the question that we address in this paper. Harnessing private agents for tax administration purposes has received little attention in public economics. Nevertheless, some countries have implemented policies that involve harnessing private agents. For example, developing countries use large firms and credit card companies to withhold and remit the value-added tax owed by their suppliers (Garriga and Tortarolo, 2024; Brockmeyer and Hernandez, 2016) and local elites to collect taxes (Balán et al., 2022).

In the canonical tax evasion model proposed by Allingham and Sandmo (1972), the evasion decision depends on the probability of detecting evasion and the penalty imposed on evasion. Third-party auditors can increase tax revenue if they change the perceived probability of detecting evasion or if they detect evasion. However, using third-party auditors can be a concern because the value of the audit relies on an independent assessment of the firm. There is a possible conflict of interest on the auditor's side since they are hired by the audited firm. One must acknowledge that auditors might be incentivized to protect the interests of the hiring firm rather than give an accurate picture of its performance (Ronen, 2010). The state capacity of the government is relevant when considering this problem. Audits are more likely to have positive results on middling state-capacity environments (Cuneo et al., 2023), where there is a balance between the auditor's independence problem and the bad behaviors that the auditor can detect.[20] Consistent with these findings, there is a scope for third-party auditors to improve tax compliance, especially in middle-income countries.

This paper studies the reporting behavior of firms in Ecuador that are required to undergo a third-party audit of their balance sheets and income statements.[21] This re-

[20]Cuneo et al. (2023) study the value of internal government audits as a function of state capacity. However, as the authors mention, their conclusions can be extended to third-party audits.

[21]Sole-proprietorship firms are excluded from this obligation.

quirement depends on the size of the firm, regarding its level of total assets. Ecuador is a unique setting to study the use of third-party audits for tax purposes because third-party auditors not only prepare a report that certifies the firm's financial statements but also a tax compliance report for the Tax Agency. The tax compliance report is a comprehensive revision of all accounts reported in the corporate income tax return and auditors are required to state discrepancies between audited and non-audited values. In particular, we exploit a policy that reduced the asset threshold determining the statutory audit obligation from USD 1 million to USD 500 thousand starting in the fiscal year of 2017.[22]

The Ecuadorian setting provides several advantages for our analysis. First, corporate tax evasion is a problem that has been previously documented by Carrillo et al. (2017) and Carrillo et al. (2022). The former paper finds that if the tax agency informs firms about differences between reporting and real tax liability, firms respond by adjusting their costs and revenues. This evidence shapes our expectations regarding the margins that third-party audits can correct. Second, the reform in 2016 dramatically reduced the policy threshold from USD 1,000,000 to USD 500,000 and increased the yearly number of audited firms by around 75%.[23] Third, Ecuador has a high-quality administrative dataset for income statements and balance sheets at the firm level that can be linked to the registry of firms with a rich set of characteristics and to an auditor-audited firm dataset to explore the heterogeneity of the effects.

Our empirical analysis relies on three administrative datasets processed by the Superintendency of Companies, a public institution responsible for supervising Ecuadorian firms. First, we use information from balance sheets, income statements, and corporate income tax returns of the universe of formal firms in Ecuador. This dataset has a rich set of firm-level yearly variables, including assets, liabilities, equity, income, costs, expenses, and tax liability. Second, we use the firm registries from the tax authority and Superintendency of Companies that include characteristics of the firms (e.g. location, industry). Third, we use a matched auditor-audited firm dataset to determine the effectively audited firms. We match firms between the datasets through a unique ID and obtain a panel of assessed firms spanning 2013 to 2019. Fourth, we use business-to-business transaction data from the Tax Agency. Firms registered in the value-added tax in Ecuador are required to present a monthly annex detailing all their transactions with suppliers and clients. We use this dataset to capture the cost of the audits.

We document empirical patterns on the effects of third-party audits by exploiting the discontinuity in the audit obligation imposed by the asset threshold in a donut-hole regression discontinuity design (RDD), as in Benzarti and Harju (2021) and Bachas and Soto (2021). Firms can manipulate the policy threshold by reducing their assets to avoid the audit requirement. As a starting point, we use standard bunching techniques (Saez,

[22]Ecuador adopted the USD dollar as the official currency in 2000. The fiscal year is the same as the calendar year.

[23]Due to the change in the policy threshold, around 14,000 firms are audited each year (17% of the total number of firms), this is an increase of around 6,000 firms.

2010; Kleven and Waseem, 2013) to determine the manipulated area corresponding to the excess and missing mass regions in the bunching approach. We observe a bunching of firms below the threshold that on average reduce their assets by USD 114,000. We also provide suggestive evidence on how firms reduce their assets to elude the audit obligation. Firms adjust their balance statements through variations in accounts receivable (debts of the clients with the firms) and accounts payable (short-term debts of the firm with the suppliers). This finding suggests firms use a *cash flow strategy* rather than engaging in *real responses*.[24]

Next, we exclude the manipulated region defined through the bunching approach and estimate the size of the discontinuity on outcomes of interest around the asset threshold using a donut-hole regression discontinuity design. We mainly focus on revenues, costs, and expenses, the main components of the corporate income tax base. Evidence of a discontinuity in the two outcomes at the policy threshold suggests that audited firms report fewer costs, expenses, and revenues. The discontinuity in the costs and expenses is intuitive since the auditors should correct over-reporting behaviors. In contrast, the discontinuity in revenues is puzzling because one could expect that firms were underreporting their revenues before the audits to lower their tax liability. However, this result is in line with the findings of Carrillo et al. (2017) and Naritomi (2019): if firms need to correct their costs and expenses, they also adjust their revenues to keep constant their tax liability. Our findings suggest that governments should not rely on third-party auditors to conduct tax audits.

This paper contributes to a broad literature on reforms to the tax administration and the effects on compliance (e.g. Basri et al. (2021), but more specifically to the discussion of delegating tax functions to third parties. Previous studies have analyzed the enforcement value of delegating tax collection of indirect taxes to trusted buyers (Garriga and Tortarolo, 2024) or credit card companies (Brockmeyer and Hernandez, 2016) through withholding, and the collection of property taxes to local elites (Balán et al., 2022).

The paper also contributes to the literature analyzing responses of taxpayers to tax audits. Advani et al. (2023) and DeBacker et al. (2018) study the UK and the United States and show a long-run deterrence effect of tax audits on stable income sources in the first case and when third-party reporting is available in the second case. These studies use random audits to study tax evasion; however, a more common characteristic of modern tax systems is size-dependent tax enforcement that targets large taxpayers (Bachas et al., 2019; Almunia and Lopez-Rodriguez, 2018) and it is a feature of our study.

We also speak to the literature on firms' responses to the use of third parties or third-party information to increase compliance (Naritomi, 2019; Pomeranz, 2015) and to size-based policies. Regarding size-based policies in the context of the tax administration, some countries have implemented thresholds for the Value Added Tax (VAT) registration

[24] A real response implies that firms change their true size and a reporting response is achieved through evasion or avoidance. However, our bunching is sharp, suggesting that the response is not real, as argued by Boonzaaier et al. (2019).

and previous work has analyzed responses of firms around the threshold (Liu et al., 2021; Harju et al., 2019; Onji, 2009). Almunia and Lopez-Rodriguez (2018) and Bachas et al. (2019) analyze the responses of firms when tax enforcement targets large firms and find effects on compliance and productivity. Most closely related to our study, Asatryan and Peichl (2016) finds large responses when exploiting three sized-based regulations requiring firms to: comply with international accounting rules, declare taxes on a monthly basis, and register in the VAT.

A large body of literature also studies third-party audits from an accounting perspective. This research has mainly focused on the determinants of the quality of audits like audit partner, tenure and auditor rotation (e.g. Gipper et al. (2017) and Lennox et al. (2014)).

The remainder of the paper proceeds as follows: Section 2 and 3 describe the institutional background and data. We then present our empirical strategy in Section 4 and discuss our results in Section 5. Finally, Section 6 concludes.

2 Institutional Background

2.1 Taxes in Ecuador

The Ecuadorian tax administration relies on two taxes: the value-added tax that generated 47% of the total tax revenue in 2019 and the income tax that accounted for 33%. Firms pay the value-added tax and the corporate income tax. The tax base of the latter is defined as the difference between the revenues of the firm and deductible costs and expenses. The tax rate is flat and was equivalent to 22% till 2017 and has increased to 25% since 2018. The tax rate increases by three percentage points if the firm does not report its shareholding composition and when a shareholder with participation above 50% is a tax resident of a tax haven, lower tax jurisdiction, or preferential tax regime.

During our study period, Ecuador had an income tax advance (*anticipo del impuesto a la renta*). In practice, the tax advance worked as a minimum tax till 2019. It was computed as the sum of 0.4 percent of total assets, 0.4 percent of total taxable income, 0.2 percent of deductible costs and expenses, and 0.2 percent of equity. If the income tax advance exceeded the corporate income tax at the end of the fiscal year, the former became the tax liability of the firm. Since 2020, the tax advance has been voluntary and can be used as a tax credit against the tax liability. It is now computed as 50% of the tax liability of the previous year minus the tax withheld from the taxpayer.

2.2 Statutory audits in Ecuador

Large firms in Ecuador are required to have a third-party audit of their year-end financial statements. Auditors revise if the firm's operations are correctly reflected in the accounting records. They can ask for additional information from the firm's manager to clarify doubts related to the financial statements. Once the revision is done, the auditor prepares two reports. The first one is submitted to the Superintendency of Companies (Supercias), a government agency responsible for supervising all firms in Ecuador.[25] This report contains the certification of the firm's financial statements and the auditor's opinion following the conventions of a regular statutory financial audit. The second is a tax compliance report submitted to the Tax Agency. It contains the auditor's opinion regarding compliance with tax obligations and a document showing discrepancies between the reported value in the tax returns and the audited value (see Figure A3). The tax compliance report is mainly focused on the corporate income tax, although a general revision of the currency outflows tax (*Impuesto a la Salida de Divisas*) and of the transactions of oil and mining firms is also included.

An asset threshold established by the Supercias determines the statutory audit obligation. Firms with assets exceeding the policy threshold in one year must hire a third-party auditor to review the following year's financial statements. In 2016, Supercias reduced the asset threshold from USD 1 million to USD 500 thousand for all firms excluding those with public partners and local branches of foreign firms. The reform was proposed on September 21, 2016, and published in the official gazette on November 11, 2016. Since last-year assets determine if a firm is audited, audited firms in 2016 were the ones whose assets in 2015 exceeded USD 1 million. The policy change implied that firms with assets exceeding USD 500 thousand in 2016 started to audit their financial statements since 2017. Thus, we observe an increase in the number of audited firms starting in 2017.

Supercias authorizes qualified accountants and accounting firms to perform statutory audits. An accounting or related degree and a minimum of years of experience are some of the requirements that auditors have to fulfill. The authorization of Supercias is valid for three years, and after that period, the auditor has to apply for a renovation of her status.

Firms choose their own auditors and the audit partner's tenure is limited to 5 consecutive years.[26] The audit process is shown in Figure 3. For example, if a firm overcomes the threshold in 2016, then it can hire the auditor till September 2017 and inform the auditor's name to Supercias within the next 30 days after hiring. The audit is conducted approximately between February and March of 2018, after the shareholders' approval of the balance sheets and financial statements of 2017. In April 2018, the audited firm presents its financial statements and audited report to the Supercias. Further, the firm presents the corporate income tax (CIT) returns to the tax authority and pays the CIT in the same month. Finally, in July 2018, the auditor presents the tax compliance report to the Tax Authority.

[25] Sole-proprietorship firms are not required to keep accounting records, are not under the control of Supercias and therefore, not required to audit their financial statements. The types of companies that can be created in Ecuador and are monitored by Supercias are mixed capital companies, limited and unlimited liability companies, and limited partnership companies. Supercias also supervises local branches of foreign companies. The Superintendency of Banks regulates companies that offer financial and banking services.

[26] Tenure relation is limited to 3 consecutive years for public interests entities.

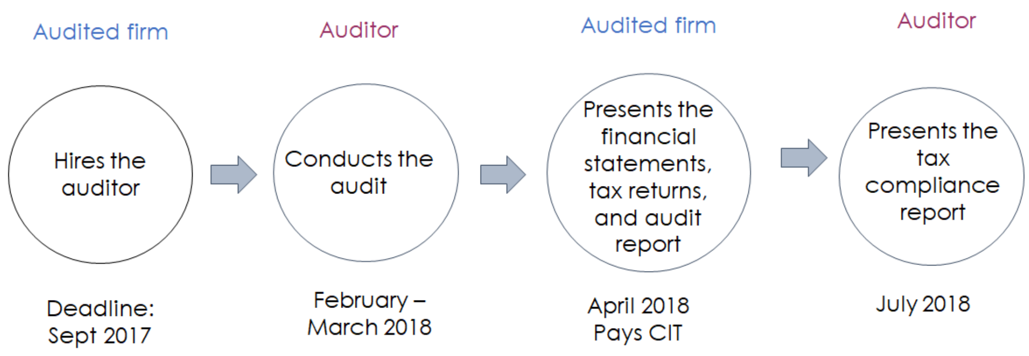


Figure 3: Audit process

Notes: Shows the audit process of a firm that met the audit requirements in 2016.

3 Data

The empirical analysis relies on three administrative datasets. First, we use the information on balance sheets and income statements of the universe of formal firms in Ecuador available on the website of the Supercias.[27] In the first four months of each year, firms are required to submit the balance sheets and income statements of the previous year to the Supercias. These documents have been approved by the shareholders of each company. We have a rich set of firm-level yearly variables for 2013 - 2019 that includes assets, liabilities, equity, income, costs, expenses, and tax liability.[28]

Second, we use the firm registry of Supercias and the Tax Agency. From this dataset, we obtain information on the organizational form of the firm, date of creation, legal representative, industry, and location. We use the 6-digit industry code from the latter that follows the International Standard Industrial Classification (ISIC).

Third, we use a matched auditor-audited firm dataset that allows us to determine the audited firms between 2013 - 2019. We are able to match companies between the three datasets through a unique ID number.

Finally, transactions between audited firms and auditors can be obtained from business-to-business transaction data. Since 2008, Ecuadorian formal firms have been required to file a monthly transactional annex with information on their domestic and external purchases and sales. Firms required to keep accounting records are required to present the transactional annex.[29] This dataset includes information on clients and suppliers of each firm, the date and amount of the transaction between them.

We exclude mixed capital companies, unlimited liability companies, and local branches of foreign firms unaffected by the policy threshold we study. With this restriction, we lose

[27]We do not have information on sole-proprietorship firms and firms that are not required to keep accounting records. However, they are not subject to the audit obligation.

[28]Even though it is possible to use the years after 2019, we ended our analysis before the COVID-19 pandemic affected economic activity.

[29]Firms that are not required to keep accounting records also need to comply with this annex if they overcome thresholds defined by the Supercias.

around 0.8% of our dataset.

Table 14 presents descriptive statistics for the period before the reform (2013 - 2015). This table has the objective to show where the newly affected firms are located within the distribution of the universe of firms. The first column of the table provides the average of accounting records of the group of firms that were not audited before 2016 but would be audited under the change in the asset threshold. The next columns present the statistics of the entire universe of firms. The newly affected firms have assets that exceed the new threshold (USD 500 thousand) and are below the old threshold (USD 1 million). We observe that these are large firms whose average outcomes are located between the 75th and 90th percentile of the entire distribution.[30]

	Firms with assets >= 500 thd and <1 million	**Mean**	**25%**	**50%**	**75%**	**90%**
		(in thousands of USD)				
Gross Assets	740	1,357	25	52	339	1,305
Liabilities	492	800	0.1	22	197	817
Equity	252	560	0.8	9.5	89	458
Revenues	1,191	1,493	0	36	354	1,597
Costs and expenses	1,151	1,395	0	38	336	1,510
Wage bill	94	80	0	0.5	31	120
Firm-year observations	*18,964*	*216,509*				
Unique firms	*6,321*	*72,170*				

Table 14: Summary statistics, pre-policy reform period

Notes: This table reports summary statistics for accounting records of interest in the pre-policy reform period (2013 - 2015). Values of zero may represent firms that are not active.

In addition, Figure 4 shows the empirical assets distribution in the pre and post-policy reform periods. Before the policy change (Panel A), we do not observe a bunching behavior around the USD 500 thousand asset threshold. However, once the asset threshold determining the audit obligation changed, we notice an excess of firms below the threshold (Panel B).

Firms can be audited by auditing firms or by self-employed auditors with relevant academic degrees (e.g. accountants). In Table B7, we observe important increases in the number of auditors since 2017. There were 25% more auditing parties in 2017 than in 2016 and 47% more between 2018 and 2016. The smaller increase in 2017 is explained due to imperfect compliance with the audit obligation. Auditing firms represent on average 40% of the total auditing agents, however, their participation has decreased since 2016. They audit more firms than the median number audited by self-employed. Further, the median number of audited firms increased for both groups, especially in 2018.

[30]Not all these firms will be audited because they may reduce their assets to avoid the audits.

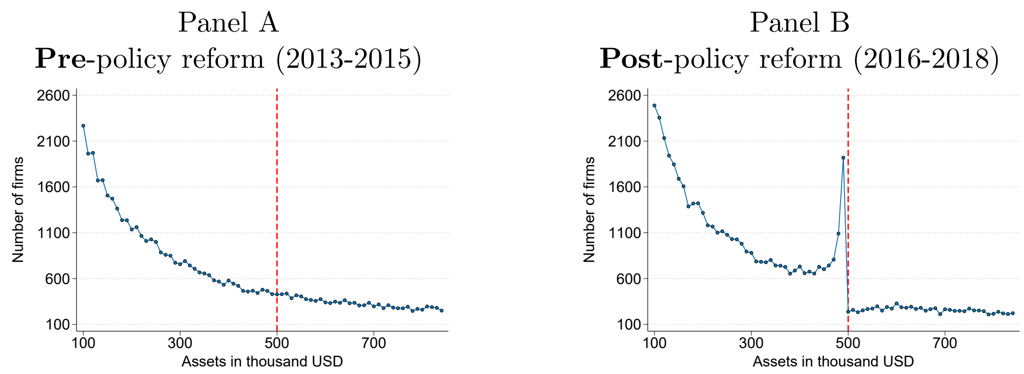


Figure 4: Empirical asset distribution

Notes: To construct the empirical asset distribution before and after the policy reform, we group firms in USD 10,000 asset bins and plot the frequency of firms within each bin. The red dashed line is located at USD 500,000 which is the level of assets that determines the audit obligation since 2016. We did not include 2019 in the post-policy reform graph to have two graphs with observations of three years before and after the implementation of the policy.

4 Empirical Design

The empirical strategy is divided into two parts. First, we define the asset area manipulated by firms that avoid audits. We use standard bunching techniques introduced by Saez (2010) and Chetty et al. (2011), and adapted for the presence of notches by Kleven and Waseem (2013). According to the bunching approach, the manipulated region would correspond to the bunching and missing mass areas.

Second, we identify the effects of the audits on different outcomes of the audited firms by exploiting the discontinuity at the USD 500 thousand cutoff. The level of assets can be manipulated by the firms therefore, we do not use a standard RDD approach. We exclude the firms that bunch around the asset threshold and use a donut-hole RDD as Bachas and Soto (2021) and Benzarti and Harju (2021).

4.1 Defining the manipulated area: Bunching Estimation

We expect to observe firms bunching below the threshold to avoid the audits and a corresponding missing mass above the threshold in response to the new asset threshold. These two regions of the distribution, the bunching and missing mass regions are delimited by a lower bound (a_L) and an upper bound (a_U).

We construct the density we would have observed without the reform that changed the asset threshold. This counterfactual density is estimated by fitting a flexible polynomial to the observed density but excluding observations in the bunching and missing mass regions.

We group observations in asset bins of USD 10,000 and estimate the following regression:

$$n_j = \sum_{i=0}^{p} \beta_i (assets_j)^i + \sum_{i=a_L}^{a_U} \gamma_i 1[assets_j = 1] + v_j \tag{10}$$

Where, n_j is the number of firms in bin j, $assets_j$ is the asset level in bin j and p is the order of the polynomial. The counterfactual distribution is computed as the predicted values of Equation 10 excluding the contribution of the dummies in the area between a_L and a_U.[31]

The bunching mass, B, is the *surplus* of firms in the area between the asset threshold, a^*, and a_L resulting from the comparison of the actual and counterfactual distribution. Thus, B is measured as $\hat{B} = \sum_{j=a_L}^{a*}(n_j - \hat{n_j})$. Similarly, the missing mass, M is measured as the difference between the number of firms that we would have observed above the threshold, in the absence of the threshold, and the number of firms we actually observe, $\hat{M} = \sum_{j>a*}^{a_u}(\hat{n_j} - n_j)$. We define a_L visually at the asset level where firms start to bunch. Further, a_U is the asset level that makes the bunching mass to be equal to the missing mass ($\hat{B} = \hat{M}$) and it is determined through an iterative procedure. We normalize B by the average counterfactual distribution in the bunching region (n_0) to compare our results across different specifications and obtain the excess mass, $b = \hat{B}/\hat{n}_0$.

4.2 Donut-hole RDD

A standard RDD cannot be implemented since the firms can manipulate the assets to avoid the audit obligation. Therefore, we use the bunching technique to determine a donut-hole region formed by the bunching and missing mass regions. Firms in the donut-hole region are excluded before implementing the conventional RDD.

We run a regression model of the following form:

$$log(y_{it}) = \gamma + \delta \mathbb{1}(assets^d_{i,t-1} > 0) + \beta_1 assets^d_{i,t-1} + \beta_2 assets^d_{i,t-1}\mathbb{1}(assets^d_{i,t-1} > 0) + \epsilon_{i,t} \tag{11}$$

Where, y_{it} is the outcome of firm i in year t and $assets^d_{i,t-1} = assets_{i,t-1} - 500,000$ is the asset distance to the cutoff and the running variable. The latter corresponds to period $t-1$ because assets reported in $t-1$ determine if the firm is audited in period t.

Our estimated coefficient of interest is δ since we want to test whether there are statistically significant discontinuities on outcomes of interest around the asset threshold. The optimal bandwidth selection techniques (e.g. Calonico et al. (2020)) do not perform well in our case because our missing mass region is large. Instead, we use alternative bandwidths and report the estimated coefficients for all the cases.

[31] The counterfactual distribution is computed as $\hat{n_j} = \sum_{i=0}^{p} \beta_i (assets_j)^i$.

5 Results

5.1 Bunching at the audit threshold

Figure 5 shows the asset distribution and the estimated counterfactual around the USD 500 thousand threshold based on an 8th-degree flexible polynomial. The estimated parameters are displayed in the top-right corner of the figure. The dashed blue lines are located at the lower bound of the bunching mass area and the upper bound of the missing mass area. The dashed red line marks the location of the policy threshold. The bunching mass is 3.94 larger than the counterfactual distribution. This is because there are around four times more firms in the bunching than the number one would observe without reforming the policy threshold.[32]

We observe that bunching starts at USD 440 thousand and the estimated upper bound of the missing mass region is USD 630 thousand. These two limits of the manipulated region will be excluded in the donut-hole RDD design. We present robustness checks to our main specification in Table B8. Our estimated excess mass is robust to changes in the order of the polynomial, bandwidth, and bin size.

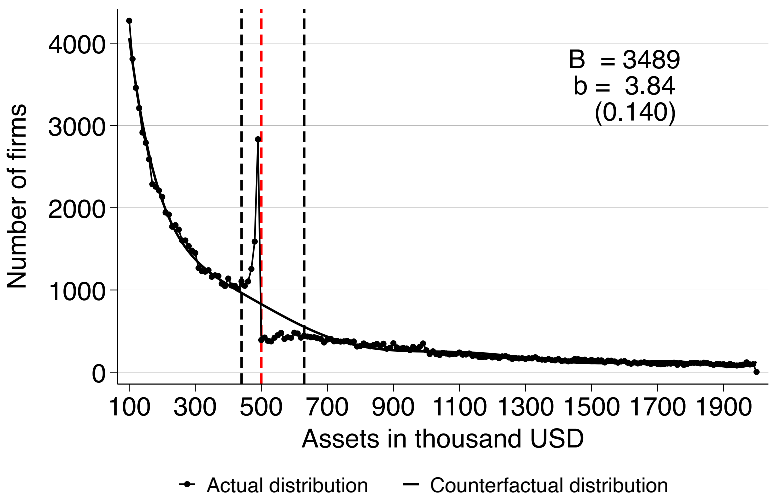


Figure 5: Asset bunching estimation, 2016 - 2019

Notes: The red dashed line is located at the policy threshold (USD 500 thousand), and the black dashed lines are located at the limits of the bunching and missing mass regions. To construct the counterfactual distribution, we group the assets in bins of USD 10,000. We visually determine that bunching starts at USD 440,000 and fit a polynomial of eight order.

The sharp bunching suggests that this is not a real response as explained by Boonzaaier et al. (2019). Thus, we also provide suggestive evidence on how firms that bunch reduce

[32] Figure A4 shows the same exercise by year. Moreover, Figure A5 presents the same exercise for the policy threshold of USD 1 million. We observe that bunching starts at USD 950 thousand and there are five times more firms in the bunching region. It is worth noting that the firms that bunch at the USD 1 million threshold are different firms than those that are the new bunchers under the USD 500 thousand threshold. Moreoover,

their assets in Table 15. *Bunchers* are the firms that in 2015 had assets between USD 500 and USD 750 thousand and in 2016 were located in the bunching region (with assets between USD 440 thousand and USD 500 thousand). *Non-bunchers* are the rest of the firms that in 2015 had assets between USD 500 and USD 750 thousand. We compute the average variation of their balance sheet's accounts between 2015 and 2016 and test if the difference of the variations between the two groups is statistically significantly different from zero.

Bunchers reduce their assets in USD 113 thousand on average. Current assets and current liabilities mainly explain this reduction and accounts receivable (debts of the clients with the firms) and accounts payable (short-term debts of the firm with the suppliers) present the most important variations. This finding suggests firms use a *cash flow strategy* to reduce their assets rather than engaging in *real responses*.

	Average Δ in accounting records 2015 - 2016 USD thousands		
	non-buncher (N=1478)	buncher (N=766)	difference
Δ **Assets**	0.05	-113	113***
Δ Cu. Assets	5.67	-85.02	89.70***
Δ Cash	3.52	-7.92	11.44***
Δ Accounts Rec.	17.20	-54.30	71.50**
Δ LT. Assets	-5.17	-29.04	23.86***
Δ **Equity**	-30.67	-21.67	-8.99*
Δ Capital Stock	3.42	0.65	2.77
Δ **Liabilities**	-7.81	-95.26	87.46***
Δ Cu.Liabilities	-3.29	-71.60	68.32***
Δ Accounts Pay.	-6.31	-59.81	53.50***
Δ LT. Liabilities	-4.48	-20.85	16.38**

Table 15: Responses of bunchers and non-bunchers, 2015 - 2016
Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

One concern is that firms bunch at the left of the threshold because the audit cost is high. To explore this possibility, we use business-to-business transaction data to estimate the audit cost in 2017 for firms affected by the reduction in the asset threshold (firms with assets between USD 500 thousand and USD 1 million in 2017). Audits of financial statements and income statements of 2017 were conducted in 2018, thus, we use transaction data from 2018. We track down all the transactions between audited firms and their auditors in 2018 and sum them up to get an approximation of the total audit cost.[33] Since auditors are prohibited from providing additional services to the audited firms, all

[33]This approach would have some limitations if audited firms postpone their payments of the audits corresponding to one year to the next year. However, this seems unlikely because the audit process finishes in July of each year with the presentation of the tax compliance report.

the transactions that we observe should be related to the audits. Figure 6 shows the mean amount traded between the audited firms and the auditors (audit cost) by asset level in 2017. Surprisingly, the audit cost does not seem to increase with the level of assets, and on average firms spend USD 1971.70 on audits. This is only 0.20% of the total assets for firms with assets equal to USD 1 million and 0.39% for firms with assets of USD 500 thousand.

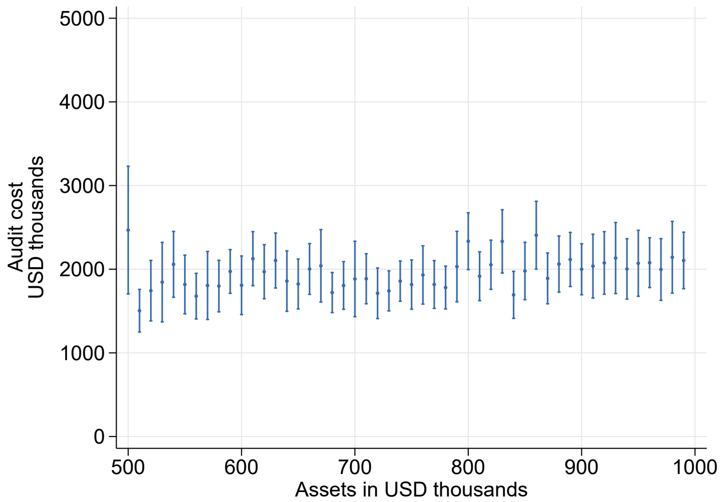


Figure 6: Average audit cost by asset level in 2017

Notes: We group the firms in USD 10,000 asset bins and compute the average amount traded between the audited firm and its auditor for each bin in 2018. We use the transactions of 2018 to obtain the audit cost of 2017 because the audits of the balance sheets and income statements of 2017 were conducted in 2018. We focus on firms with assets between USD 500 thousand and USD 1 million in 2017 since they are affected by the reduction of the asset threshold. The audit cost is winsorized at the 5th and 95th percentiles.

Finally, regarding this bunching behavior, we analyze the heterogeneity of responses across major industries in Ecuador. We observe that the manufacturing industry exhibits the strongest response, likely because it maintains extensive paperwork and may have stronger incentives to avoid stringent monitoring (Almunia and Lopez-Rodriguez, 2018). Conversely, the real estate industry shows the weakest response, possibly due to these firms having a lower proportion of current assets, which makes it more difficult for them to adjust their level of total assets.

5.2 Responses of firms that are audited

Compliance with statutory audits is not perfect. Figure 7 shows the first-stage estimate of the impact of the asset threshold on the probability of being audited (complying with the audit). We plot the probability of being audited for firms by USD 10,000 asset bins in the pre-policy period (hollow circle) and post-policy period (solid circle). We only observe a clear discontinuity in the audit probability that increases by 80 percentage points in the years after the policy is implemented. This probability for the above-threshold firms is

Industry	Bunching Estimator (b)
Retail and Wholesale	4.66
	(0.18)
Manufacturing	5.34
	(0.30)
Construction	4.14
	(0.30)
Agriculture	4.39
	(0.36)
Real estate	2.25
	(0.20)
Transportation	3.82
	(0.27)

Table 16: Bunching estimator across industries

Notes: Across the main industries in Ecuador, we estimate b. Bootstrapped standard errors are in parentheses.

not equal to 1 because there is imperfect compliance with the audit obligation in 2017, as can be seen in Figure A6. Figure A7 shows almost perfect compliance for 2018 and 2019. However, we decided to use a fuzzy donut-hole RDD to include 2017 in our analysis.

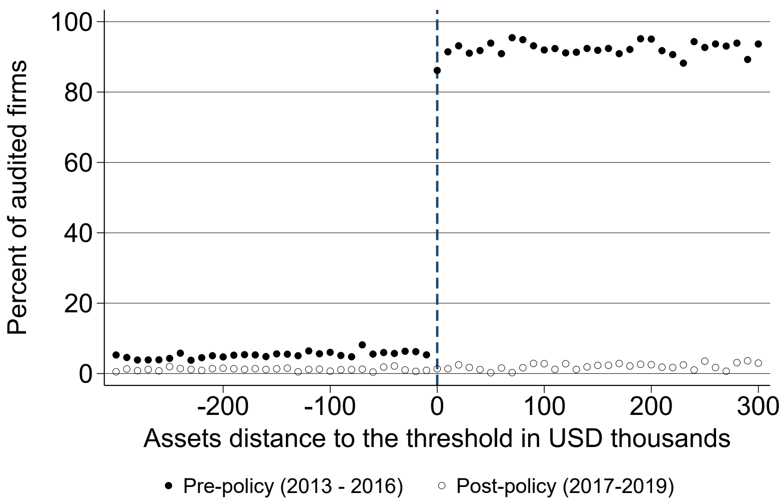


Figure 7: Audit Probability below and above the USD 500 thousand asset threshold

Notes: We group firms in USD 10,000 asset bins and compute the percentage of firms that are audited within each bin. Hollow circles correspond to 2013 - 2015 (pre-policy period) while solid circles correspond to 2017 - 2019 (post-policy period).

Figure 8 plots the effect of the asset threshold on the firm's costs and expenses. We decided to add costs and expenses in one variable because expenses are more relevant for the services sector while costs are important for the non-services sector. We estimate the discontinuity in costs and expenses using Equation 11 and find that firms reduce their reported costs and expenses by 24.3%. The evidence of a discontinuity in the variable at the threshold could indicate that auditors correct over-reporting behavior. We also repeat this exercise for the pre-policy period, our placebo sample, and we find an insignificant discontinuity (Figure A8).

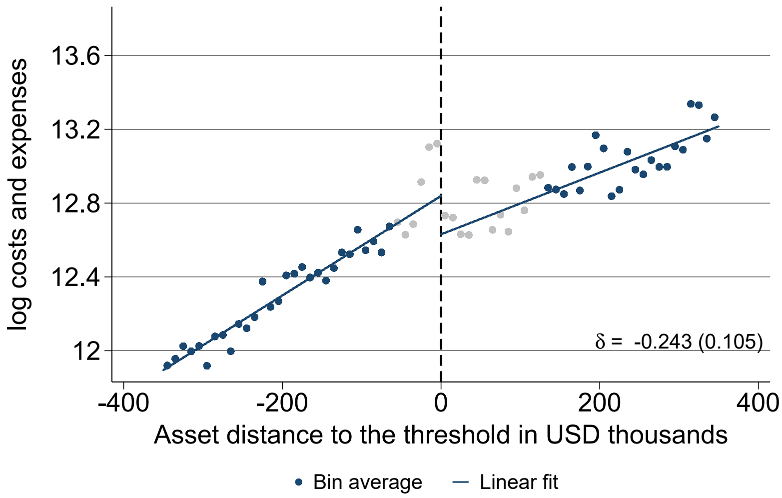


Figure 8: The effect of audits on costs and expenses

Notes: The figure shows the effect of the asset threshold on costs and expenses (in logs). Firms are grouped in USD 10,000 asset bins for the graphs.

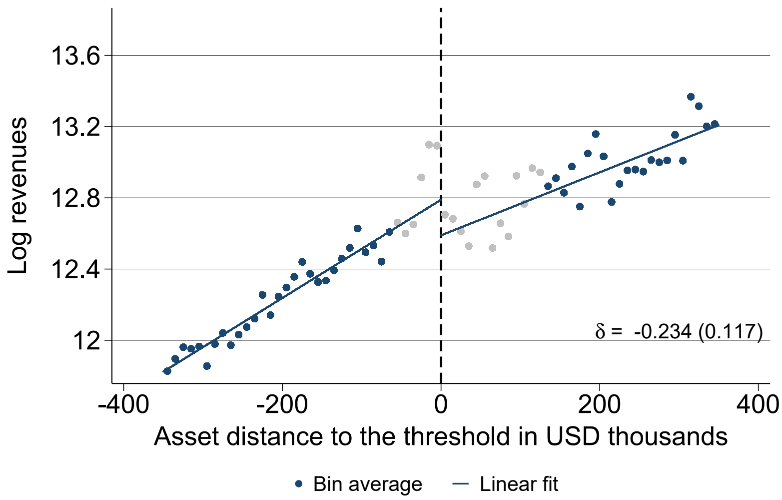


Figure 9: The effect of audits on revenues

Notes: The figure shows the effect of the asset threshold on revenues (in logs). Firms are grouped in USD 10,000 asset bins for the graphs.

Figure 9 plots the response to the audit obligation on revenues. We also estimate a statistically significant discontinuity implying that firms above the threshold reduce their reported revenues by 23.4%. This adjustment is puzzling because one could have expected that firms underreport their sales. However, other studies (Carrillo et al., 2017; Naritomi,

Outcomes (logs)	Costs and Expenses	Revenues	Net income	Wage bill
δ	-0.243**	-0.234**	-0.319**	0.104
	(0.105)	(0.117)	(0.129)	(0.090)
N below	28,050	28,184	22,334	21,940
N above	5,381	5,396	4,273	4,382

Table 17: RDD coefficient for different outcomes
Notes: * p<0.1, ** p<0.05, *** p<0.01.

2019; Asatryan and Peichl, 2016) have found that firms subject to higher enforcement in developing countries adjust the two margins (revenues and costs and expenses) to reduce the impacts on the tax liability.

Table 17 shows the results of the RDD estimation for costs and expenses, revenues, net income, and total expenditure on wages (wage bill). We use the net income as an outcome of interest because it is the corporate income tax base before withholding and deductions. We do not use the tax liability because a large number of firms report 0 as their tax liability. Nevertheless, it is also common for some firms to report 0 net income. This explains the decrease in the number of observations in the RDD estimation for this outcome variable. Audited firms reduce their reported net income by 31.9%. We included the wage bill as an outcome of interest considering that firms in developing countries hire workers but do not pay their social security benefits. However, we do not find any effect on this variable.

In our main specification, we restrict our analysis to observations between USD 150 thousand (left bandwidth) and USD 850 thousand (right bandwidth). The manipulated region that is excluded from the estimation is located between USD 440 thousand and USD 630 thousand, where the upper bound was estimated using the bunching approach. Figures A9 and A10 present the estimated RDD coefficient under different values of the upper bound of the excluded region and of bandwidths. The coefficient is robust to changes in the left bandwidth and the upper bound of the manipulated region; nevertheless, when we reduce the right bandwidth, it is less precisely estimated. This is explained because when assets increase, we observe fewer firms. Thus, changes in the right bandwidth would imply less information is used for the estimation.

6 Conclusions

In this paper, we study whether governments can harness third-party auditors to perform tax audits and increase tax compliance. We first characterize the bunching response to the reform of the asset threshold that determines the audit obligation. The sharp bunching and the fact that firms reduce their accounts payable and accounts receivable suggest that they engage in *cash flow strategies*. We then estimate the audits' effects on the audited firms. Firms reduce both costs and expenses and revenues by 24% and 23%, respectively and their net income by 32%. These results suggest that harnessing third-party auditors to conduct tax audits is not a good policy for the government. First, there is a change in the behavior of firms that reduce their assets to be exempted from the audits, and second, audited firms report fewer costs and expenses but also revenues.

Studies like this provide valuable information for public policy, as firms or individuals may react in unexpected ways. Understanding these reactions offers insights for future policies or adjustments, particularly regarding stronger supervision of firms and tax compliance enforcement.

Chapter III

High Substitutions: A Demand Model of Edible and Inhalable Marijuana

1 Introduction

Globally, marijuana is the most used illicit recreational drug, boasting an annual prevalence rate of use estimated at 5 percent (United Nations Office on Drugs and Crime, 2021). In response to this, numerous jurisdictions, particularly in the United States, along with other countries, have pursued the legalization of marijuana for recreational purposes as a strategic public health measure and to counteract the size of the illegal market, or are actively deliberating this potential policy shift. Canada emerged as a significant player in this landscape in 2018, becoming the second country after Uruguay to fully legalize marijuana in all its territory. Before legalization, dried flowers constituted the predominant form of illicit marijuana, primarily utilized for inhalants. Following the establishment of Canada's legalized marijuana market, significant transformations have occurred, providing consumers with a diverse array of options extending beyond conventional inhalants. This includes a spectrum of products such as edibles, concentrates, vapes, oils, and more (Lee, 2018). Notably, edibles have emerged as the second most popular form of marijuana in Canada, with an increasing trend in usage (Health Canada, 2024a,b). Furthermore, product diversification extends beyond variations in form to include differences in potency. Delta-9-tetrahydrocannabinol (THC), a primary chemical compound responsible for marijuana's psychoactive effects, varies in concentration among products. The legalization framework facilitates the availability of products with diverse THC levels. This new scenario presents interesting avenues for exploration within the marijuana demand literature.

This paper examines individuals' price sensitivity towards various forms of marijuana and how this sensitivity varies based on THC preference. Specifically, I build and estimate a marijuana demand model that accounts for two forms of marijuana (inhalants and edibles), and it also includes THC preference as a determinant. This analysis is crucial for informing public policy, especially considering that higher THC potency in products can carry a higher risk of addiction and (mental) health disorders (Di Forti et al., 2019; Freeman et al., 2021; Addictions, Drug & Alcohol Institute, 2023). Understanding the impact of price on demand, particularly among individuals with a preference for high THC potency, can serve as a tool to discourage excessive consumption. Furthermore, the analysis of the marijuana market post-legalization is a growing area of research, but relatively new. This article contributes a novel demand analysis to this emerging field.

To estimate the substitution patterns, I use data from surveys conducted by a North American cannabis market research firm. These surveys, conducted between 2020 and

2022, provide valuable insights into consumer behaviors and preferences. They include socio-demographic details, geographic information, and crucially, preferred marijuana consumption forms (edible or inhalant), typical payment amounts for marijuana products, and THC potency preferences. Among respondents, 31 percent primarily consumed inhalable marijuana, while 13 percent favored edibles. Additionally, respondents indicated their preferred THC potency for inhalants and edibles. With these reports, I define thresholds to identify a preference for very high THC potency. With these assumptions, I observed that 20 percent of the sample has this taste.

Using this dataset, I estimate a two-level nested logit model. At the top level, an individual decide whether or not to use marijuana. At the bottom level, conditional on use, the individual selects the form of marijuana, either edible or inhalant. In other words, an individual determines whether to use marijuana to experience its psychoactive effects and subsequently selects *how* to consume it. This model allows for correlation across alternatives in the bottom-level nest, through the unobserved terms of their valuations. This correlation is relevant when computing the substitution patterns.

Regarding the results, I find a positive correlation between the valuations of marijuana forms, suggesting the adequacy of the modeling approach. Furthermore, individuals with a preference for very high THC potency show a lower marginal utility for using edibles over inhalants. Additionally, the own-price elasticities are larger, in absolute terms, for edibles compared to inhalants. A 1 percent increase in the price of edibles (inhalants) will decrease its demand by 0.5 (0.43) percent. Cross-price elasticities are relatively small. Finally, I find that individuals with a preference for high THC potency are less price-sensitive regarding inhalants. The own-price elasticity of inhalants is -0.35 for individuals with this preference, compared to 0.45 for individuals without this preference. These findings are relevant for public policy, as more potent marijuana products can pose greater harm to users. Identifying these price elasticities for different forms of marijuana and for individuals with varying THC potency preferences can inform policies aimed at curbing excessive consumption of more harmful products through pricing strategies.

This paper is structured as follows: Section 2 reviews the related literature; Section 3 provides an overview of the institutional background; Section 4 outlines the data utilized in this paper; Section 5 introduces the demand model; Sections 6 and 7 present the findings and the concluding remarks, respectively.

2 Related Literature

Given that several territories have legalized marijuana for recreation, the economics literature has delved into the demand for this substance. This article aligns with the literature's focus on addressing questions emerging from the legal and more sophisticated marijuana market.

The first studies analyzed how the demand changed after decriminalization policies (Miron and Zwiebel, 1995; Pacula et al., 2010; Williams et al., 2011). Then, Jacobi and Sovinsky (2016) became the first article to estimate the impact of legalization on marijuana use, considering that legalization differs to decriminalization. Perrault (2022) assess the effect of legalization but on the equilibrium prices and quality. Furthermore, Jacobi et al. (2023) studies the joint use of recreational marijuana, medical marijuana, and opioids. Understanding the marijuana demand is crucial, even after its legalization, as its use may increase the likelihood of using harder drugs such as cocaine or heroin (Van Ours, 2003; Bretteville-Jensen and Jacobi, 2011).

In addition, in recent years, numerous articles have introduced research questions stemming from the newly legalized marijuana market. Hollenbeck and Uetake (2021) argues that legal marijuana is not excessively taxed, with consumers bearing most tax burdens. Hansen et al. (2017) examines how taxation affects supply and consumption chains. Additionally, Miller and Seo (2021) finds that legal marijuana may reduce demand for other legal substances, while Hansen et al. (2020) explores a potency-based tax's impact. Furthermore, Thomas (2019) investigates the inefficiency of license quota systems in Washington state, generating a restriction to retail entry. Hollenbeck and Giroldo (2022) shows that cannabis entrepreneurs with multiple store licenses earn significantly higher profits per store than single-store entrepreneurs. Regarding product characteristics, Smart et al. (2017) and Caulkins et al. (2018) have studied the relationship between THC potency and price, using publicly available data from Washington State's cannabis traceability system. Lastly, several articles have assessed the effects of different policies in the Canadian legalized cannabis market, including the impact of legalization, store locations and THC labeling on marijuana use (Hammond et al., 2020; Marquette et al., 2024; Fataar et al., 2024; Hammond, 2021; Goodman and Hammond, 2022).

This article fills a gap in the literature by analyzing the demand for inhalable and edible marijuana in a post-legalized environment, while also considering THC preference, making it a novel contribution to the field.

3 Institutional Background

In 2018, Canada became the second country globally, following Uruguay, to legalize recreational marijuana. This landmark decision was enacted through the Cannabis Act, or Bill C-45, implemented in October 2018. The objectives behind legalizing marijuana encompassed safeguarding the health of young individuals, curbing illicit activities, alleviating pressure on the criminal justice system, ensuring a quality-controlled supply, and enhancing public awareness of marijuana-related risks (Government of Canada, 2018).

The Cannabis Act introduced a comprehensive regulatory framework governing marijuana production, distribution, and possession. Key institutions such as Health Canada, Provincial and Territorial Models, and the Canadian Border Services Agency played pivotal roles in overseeing the newly established industry (Government of Canada, 2018). Health Canada assumed critical responsibilities including licensing marijuana producers, setting quality standards, and conducting routine inspections to ensure compliance with federal regulations. Concurrently, provincial and territorial governments were granted autonomy to devise their own regulatory frameworks for marijuana distribution and retail. Finally, the Canadian Border Services Agency was tasked with regulating cross-border marijuana movements, imposing strict restrictions on international transportation while facilitating legitimate possession and consumption within Canada.

Under the Cannabis Act, while the provincial governments oversee the retail sales, the federal government assumed primary responsibility for production, cultivation, processing, licensing, and taxation. Notably, it committed to use marijuana tax revenue to finance public education campaigns and enhance mental health and addiction services.

Before Canada's legalization of recreational marijuana, dried flower or leaf was the dominant product in the marijuana market. However, post-legalization, the landscape has evolved significantly, providing consumers with a diverse array of product types and consumption methods beyond traditional inhalants (Lee, 2018). With the emergence of edibles, beverages, vape products, concentrates, and more, the market has become increasingly diverse. Health Canada's survey on marijuana usage provides a comprehensive insight into the evolving sophistication of the market. Figure 10 shows the product type used by marijuana past-year users. The three most prevalent product types in 2023 were dried flower or leaf (60%), edible cannabis (54%), and vape pens or cartridges (34%), considering that users could select more than one product. Following these were oil for oral use, beverages, hashish or kief, topical products, and concentrates or extracts. Note that the consumption of edibles is experiencing a significant upward trend.

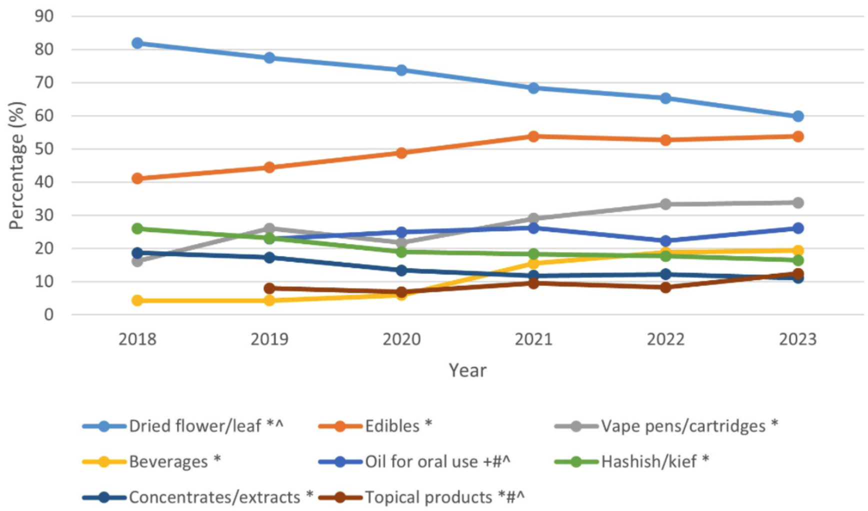


Figure 10: Marijuana products used by past-year users in Canada (Health Canada, 2024a)

In terms of sales from retailers to consumers, edibles also demonstrate significant participation, as depicted in Figure 11. In December 2023, retailers sold approximately 10 million packages of dried cannabis and 5 million packages of edibles. Additionally, cannabis extracts show a comparable level of participation to edibles in terms of the number of packages sold. In the United States, product diversity is also evident and exhibits an increasing trend post-legalization (see Figure A11).

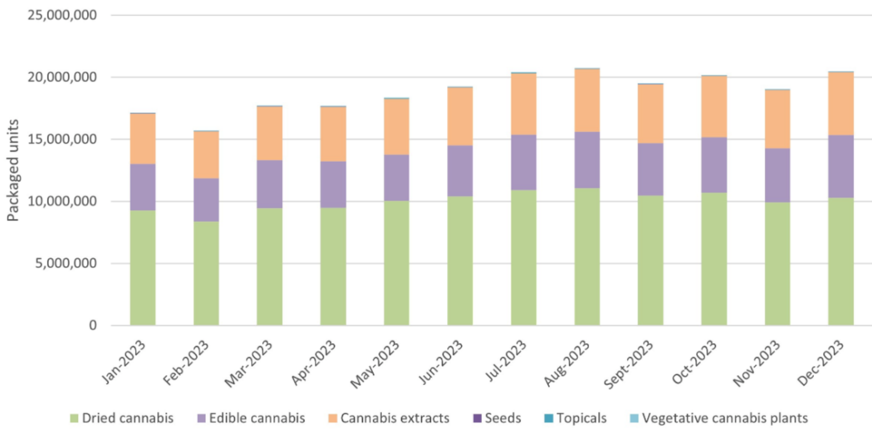


Figure 11: Sales of marijuana by product type in Canada (Health Canada, 2024b)

4 Data

I use a dataset provided by a North American cannabis market research company. This company is a leading firm in its industry. Its core activities involve the collection, analysis, and presentation of critical data related to retailers performance and consumer behavior through comprehensive surveys.

In particular, I use their seasonal surveys which includes individual-level information on consumer behaviors, attitudes, product preferences, sources of marijuana, consumption patterns, and the key drivers influencing cannabis purchases. Here, I analyze six cross-sections conducted between Spring 2020 and Spring 2022 across various Canadian provinces. The total sample comprises 17,110 individuals, with approximately 3.5 thousand individuals observed in each wave (Spring/Fall-year), as indicated in Table 18.

Season/Year	**2020**	**2021**	**2022**	N
Spring	3,506	3,347	3,417	10,720
Fall	3,370	3,470	-	6,840
N	6,876	6,817	3,417	17,110

Table 18: Sample size

Table 19's Panel A presents the socio-demographic characteristics of the observed sample. Among these individuals, 43 percent are male, 57 percent have completed a college education, and 20 percent have some college experience or technical/vocational education. Moreover, 3 percent of the sample identifies as black, while 14 percent self-identify as Asian. The average age of the sample is 47, with a minimum of 16. Finally, 10 percent of the respondents reported that they are unemployed, and 73 percent have a health condition.

Furthermore, Table 19's Panel B provides an overview of the geographic distribution of the sample, which closely mirrors the population distribution in Canada. Ontario is the most common province of residence for 27 percent of the surveyed individuals. The second most common province in the sample is Alberta with 18 percent of the respondents, and closely followed by British Columbia and Quebec with 16 and 15 percent respectively. In terms of urbanization, 47 percent of the individuals reported living in a city, while 11 percent resided in the rural area.

	Percent
(A) Socio-demographics	
Male	43
Age (in years)	47
Some college / Trade or Tech graduate	20
College graduate	57
Black	3
Asian	14
Unemployed	10
Has a health condition	73
(B) Geographic information	
Lives in a city	47
Lives in rural area	11
Alberta	18
British Columbia	16
Ontario	27
Quebec	15
Other	24
N	17,110

Table 19: Sociodemographic and geographic information

Table 20 presents the reported marijuana usage within the past 6 months among the surveyed individuals. Within the sample, 44 percent reported using marijuana, and this data also allows us to examine further the forms in which they consumed this substance. Inhalable marijuana was the most common method, with 41 percent of the sample using this form. Additionally, 13 percent of the individuals opted for edibles. It is important to mention that some individuals reported using both forms. However, with the frequency of use I defined which substance was used the most, in order to define if the individual is an inhalant or edible user, as presented.

4.1 Payments on marijuana

For the demand model, information price information is crucial. In the surveys, I observe how much the users usually pay in a purchase. Table 21 reports statistics of these payments reported by inhalant and edible users. The average purchase payment for inhalants

	Percent
Uses marijuana	44
Uses inhalant marijuana	31
Uses edible marijuana	13
N	17,110

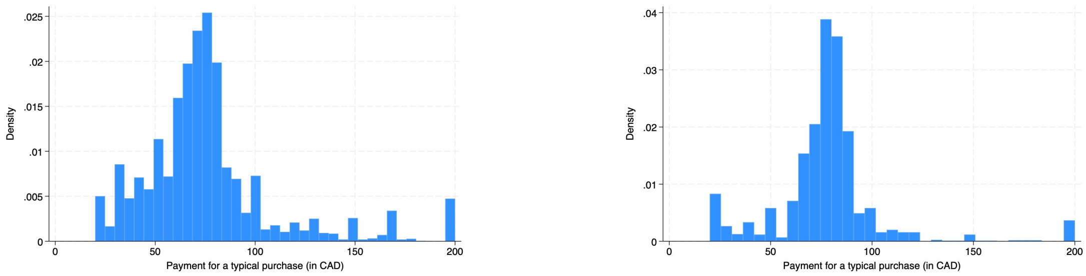
Table 20: Marijuana use (past 6 months) information

in 80 CAD, while for edibles is 72 CAD. Notably, both categories exhibit comparable standard deviations. However, inhalant purchases show a higher median payment.

	Mean	**S.D.**	**p10**	**p50**	**p90**	N
Inhalant - Typical payment	80.0	53.7	25	60	160	4,163
Edible - Typical payment	71.6	52.6	20	50	150	1,638

Table 21: Reported payments for marijuana purchases (in CAD)

Using the observed payments, I undertake predictions for non-users and individuals with missing reports employing a linear lasso method.[34] This predictive model incorporates socio-demographic factors and geographic indicators, encompassing gender, age, education, race, city residence, regional location, and year. Additionally, all potential interactions between these variables are accounted for within the model. The predicted and observed payments, at the individual-level, are presented in Figure 12, by marijuana form.



(a) Inhalants (b) Edibles

Figure 12: Distribution of predicted and observed individual-level payments (in CAD)

4.2 THC preference

A vital component of the model is the individual's THC potency preference in the marijuana consumed. Fortunately, the survey incorporates questions that effectively capture this preference for both inhalants and edibles,[35] providing valuable insights into user

[34] A similar approach regarding non-observed prices have been employed by Jacobi et al. (2023).

[35] Note that this indicates the preferred THC potency. Actual consumption may differ. However, these reports reflect the individuals' preference for a stronger psychoactive effect.

tastes. A fraction of the users answer these questions. When referring to inhalants, THC potency is typically reported as a percentage, representing the amount of THC relative to the total weight. For edibles, THC potency is commonly expressed in milligrams per unit. As illustrated in Table 22's Panel A, 28 percent of respondents indicated a preference for THC concentrations between 0 and 20 percent in their inhalants, while 46 percent preferred concentrations between 21 and 40 percent. Preferences for higher concentrations were less common. Conversely, Panel B of Table 22 details preferences for THC levels in edibles. The most favored concentration ranged between 2.5 and 5 milligrams, preferred by 25 percent of respondents, followed by 5 to 10 milligrams, preferred by 22 percent.

	Percent
(A) Inhalants: Ideal THC potency	
N: 4,276	
0% - 20%	28
21% - 40%	46
41% - 60%	14
61% - 80%	5
81% +	8
(B) Edibles: Ideal THC potency	
N: 4,015	
Less than 2.5 mgs	14
More than 2.5 mgs to 5 mgs	25
More than 5 mgs to 10 mgs	22
More than 10 mgs to 20 mgs	17
More than 20 mgs to 50 mgs	11
More than 50 mgs to 100 mgs	6
More than 100 mgs to 200 mg	3
More than 200 mgs	4

Table 22: Ideal THC level in marijuana products

I assume an individual prefers very high levels of THC if at least one of the following two conditions is met (Addictions, Drug & Alcohol Institute, 2023; Weedmaps, 2024):

- Reports 41% or more as an ideal level of THC in inhalants.
- Reports 20 milligrams or more as an ideal level THC in edibles.

This assumption pertains to 20 percent of the respondents who provided information on their THC preferences. Using this data, I predict preferences for non-users and users who did not report their tastes. Employing a lasso method similar to the payment predictions, this model incorporates socio-demographic factors and geographic indicators, including gender, age, education, race, urban or regional residence, and year, along with all potential interactions between these variables. The predicted latent variable is then ranked to mimic a 20-80 distribution, assuming that 20 percent of the sample prefers higher THC levels. This approach ensures each individual in the sample has a defined preference, while maintaining the observed distribution.

5 The Model

I build a model of marijuana form choice when using this substance. Let there be $i = 1, .., I$ individuals, $m = 1, ..., M$ provinces in Canada, and $t = 1, .., T$ years. Each individual i, in year t and province m, chooses between using marijuana or not: $g = 0, 1$. Conditional on use, there are two alternatives of marijuana according to its form: inhalant and edibles, $j = 1, 2$. The nesting structure is shown in Figure 13.

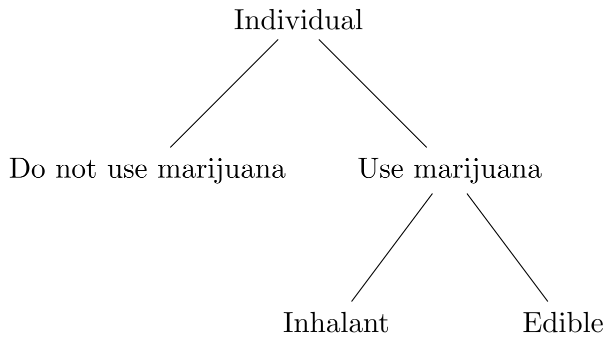


Figure 13: Regimen choice model

I assume that the indirect utility of individual i of choosing j is additively separable into a term that is specific to the marijuana form j (V_{ijmt}), and a component that only varies with the decision to use marijuana g (W_{igmt}). The error component of the indirect utility, ε_{ijmt}, will follow the assumptions of a two-level nested logit, allowing correlation of the valuations across the two marijuana forms.

$$U_{ijmt} = V_{ijmt} + W_{igmt} + \varepsilon_{ijmt} \tag{12}$$

The first component of the indirect utility, V_{ijmt}, is specified as follows:

$$V_{ijmt} = \beta_j - p_{ij}\alpha + THC_i\alpha_j^{THC} + X_i'\gamma_j + \delta_m + \tau_t \tag{13}$$

Where, X_i, is a vector of individual socio-demographics such as gender, age, race, education, and an indicator if the individual lives in a city, THC_i is a dummy that identifies if the individual has a preference for high levels of THC, and p_{ij} is the individual-level price of the marijuana form alternative j. Finally, δ_m and τ_t are province and year fixed effects, respectively.

The second component of the indirect utility, W_{igmt}, is specified as:

$$W_{igmt} = Z_i\gamma_g + \theta_m + \eta_t \tag{14}$$

Where, Z_i, is a vector of individual level characteristics such as: socio-demographics (the same set as in X_i), health status, and employment status. Likewise, θ_m and η_t are province and year fixed effects, respectively.

Note that the 'Use Marijuana' nest ($g = 1$) includes the marijuana forms $j = 1, 2$. In contrast, the nest of not using marijuana ($g = 0$) is a degenerate one with one alternative $j = 0$. Then, utility of not using marijuana is:

$$U_{i0mt} = W_{i0mt} + \varepsilon_{i0mt} \tag{15}$$

At the bottom level, the alternatives of marijuana forms are nested. The distribution of the error components contains the nesting parameter $\lambda \in (0, 1]$. If $\lambda_g = 1$, then the error terms are distributed according an i.i.d. extreme value distribution. If λ gets closer to zero, then the correlation of the unobserved error terms reaches a perfect correlation. Moreover, given random utility maximization and the assumptions of the nested logit, simple closed-form expressions of the choice probabilities are generated. The probability of selecting marijuana form j is the product of two probabilities: the conditional probability of choosing form j from the bottom nest, and the marginal probability that individual i opts to use marijuana:

$$s_{ijmt} = s_{ijmt|g} \cdot s_{igmt}$$

First, within the bottom-level nest, the probabilities of selecting marijuana form $j = 1, 2$ (conditional on use) are:

$$s_{ijmt|g} = \frac{exp(V_{ijmt}/\lambda)}{\sum_{l \in J} exp(V_{ilmt}/\lambda)}$$

And second, in the upper-level, the probability that individual i chooses to use marijuana ($g = 1$) is as follows:

$$s_{i1mt} = \frac{exp(W_{i1mt} + \lambda I_{i1mt}))}{exp(W_{i0mt}) + exp(W_{i1mt} + \lambda I_{i1mt})}$$

Where, I_{i1mt}, the *inclusive value*, is a measure of the expected utility of the two marijuana form alternatives, and brings information from the bottom level to the upper one:

$$I_{i1mt} = log\left[\sum_{j \in J} exp(V_{ijmt}/\lambda)\right]$$

Finally, the probability of choosing not to use marijuana ($g = 0$) is:

$$s_{i0mt} = 1 - s_{i1mt}$$

6 Results

Table 23 presents the estimated coefficients of the bottom level logit, representing the probability of selecting a marijuana form conditional on use. Firstly, the payment coefficient exhibits a negative and statistically significant value. Additionally, individuals preferring very high THC potency show a lower marginal utility when opting for edible marijuana compared to inhalable forms. Moreover, older individuals derive more utility from selecting edibles, whereas the opposite holds true for males. In terms of ethnicity, Asian users experience higher marginal utility when choosing edibles compared to inhalants, while the coefficient for black users is statistically insignificant. Furthermore, individuals with some college education or college graduates demonstrate higher utility when selecting edibles over inhalants. Lastly, the coefficient for residency in a city is positive but statistically insignificant. It is important to note that the bottom level logit includes fixed effects for province and year.

	Marijuana form
Payment	-0.007***
	(0.001)
	Edible (Base: Inhalant)
Prefers very high THC	-0.790***
	(0.070)
Age	0.012***
	(0.002)
Male	-0.200***
	(0.056)
Asian	0.337***
	(0.085)
Black	0.237
	(0.175)
Some college / Trade or Tech graduate	0.227***
	(0.084)
College graduate	0.576***
	(0.070)
Lives in city	0.059
	(0.054)
Province FE	Yes
Year FE	Yes
Number of observations	15,098
Number of individuals (marijuana users)	7,549
Log-likelihood	-4,246.
Alternatives	2

Note: *** p<.01, ** p<.05, * p<.1. Standard errors are in parentheses. The Table shows the result of the bottom-level logit, where the base alternative is Inhalant.

Table 23: Marijuana form choice - Disaggregated nested logit model

Table 24 presents the estimated coefficients for the top level logit, indicating the probability of marijuana use. Firstly, the coefficient of the inclusive value is positive and lower than one (0.84), indicating a positive correlation between the marijuana forms' valuations through their unobserved terms. This will affect the substitutions between these alternatives. Moreover, individuals with a health condition exhibit a higher marginal utility from marijuana use, while the coefficient for unemployed individuals is statistically insignificant. Consistent with previous literature, older individuals and males demonstrate a higher marginal utility for marijuana use. Conversely, black and Asian individuals experience lower utility from using this substance. Additionally, individuals with some college education show a positive marginal utility, whereas college graduates exhibit the opposite. Similar to the bottom level, the coefficient for residency in cities is positive but statistically insignificant. Fixed effects for province and year are also included.

	Marijuana use
Inclusive value	0.836***
	(0.094)
Has a health condition	0.714***
	(0.040)
Unemployed	-0.086
	(0.056)
Age	-0.047***
	(0.001)
Male	0.635***
	(0.036)
Asian	-0.919***
	(0.054)
Black	-0.529***
	(0.103)
Some college / Trade or Tech graduate	0.113**
	(0.051)
College graduate	-0.117***
	(0.045)
Lives in city	0.048
	(0.034)
Constant	1.56***
	(0.091)
Province FE	Yes
Year FE	Yes
Number of observations/individuals	17,110
Log-likelihood	-10,463

Note: *** p<.01, ** p<.05, * p<.1. Standard errors are in parentheses and estimated via bootstrap. The Table shows the result of the upper-level logit, where the decision is to use marijuana or not (past 6 months use).

Table 24: Marijuana use decision - Disaggregated nested logit model

6.1 Substitution patterns

Table 25 displays the calculated own- and cross-price elasticities, indicating the percentage change in demand for one alternative in response to a one percent change in the price of the same or another alternative. For this, I consider payment a strong proxy of price. The elasticities, denoted as $\epsilon_{j,k}$, show the percentage change in demand for product j resulting from a one percent price increase in product k. The table is organized into three columns: column (1) lists the average price elasticities for the entire sample, column (2) for individuals with a preference for high THC potency, and column (3) for those without such a preference. In all columns, the own-price elasticities are greater than minus one, aligning with typical findings in marijuana demand studies. Notably, edibles ($j = 2$) exhibit higher own-price elasticities in absolute terms compared to inhalants ($j = 1$), indicating greater price sensitivity among edible consumers. Cross-price elasticities are relatively small. It is particularly interesting to note that among inhalant users, those with a preference for high THC potency exhibit lower own-price elasticity (-0.34) compared to those without such a preference (-0.45). This finding indicates that users seeking stronger psychoactive effects are less price-sensitive, a fact that could be particularly significant for shaping public policy. For edibles, the cross-price elasticities are remarkably similar regardless of THC preference.

	(1) **Entire Sample**	**(2)** **Preference for high THC**	**(3)** **No preference for high THC**
$\epsilon_{1,1}$	-0.43	-0.34	-0.45
$\epsilon_{2,2}$	-0.50	-0.51	0.50
$\epsilon_{1,2}$	0.10	0.07	0.11
$\epsilon_{2,1}$	0.24	0.32	0.22

Table 25: Average price elasticities

7 Conclusions

Following the legalization of recreational marijuana, the market experiences increased diversity, offering users a variety of consumption methods and potency levels. This shift opens up new avenues for research in empirical industrial organization.

In this paper, I propose a demand model allowing individuals to choose between different forms of marijuana (edible and inhalable), using a two-level nested logit framework. By allowing for correlation between the marijuana form alternatives' valuations, I find that the own-price elasticity of inhalants is lower than that of edibles. Additionally, individuals preferring high THC potency are less price sensitive regarding inhalants, than individual that do not have this preference. These findings shed light on policymakers' efforts to regulate prices and curb excessive demand for potent marijuana products that may be more harmful.

Price can serve as a tool to mitigate demand for products that pose health risks. However, with the evolving sophistication of the legal marijuana market, there is a growing need for ongoing research to provide fresh insights into marijuana demand. The changing landscape of the market, product offerings, and consumer preferences post-legalization underscores the importance of continuous scholarly inquiry in this area.

Appendix

Chapter I Appendix

Uruguay population density

Figure A1: Uruguay population density in 2020 (Geo-Ref, 2021)

Marijuana types

(a) Marijuana brick

(b) Marijuana bud

(c) Pharmacy Marijuana

Figure A2: Marijuana alternatives

Accessibility to marijuana

Able to obtain Marijuana	**No Access to Drug.Traff Market**	**Has Access to Drug.Traff Market**
Possible to obtain marijuana	614	2,960
Impossible to obtain marijuana	248	0
Do not know	811	87
Do not know	1,673	3,047

Table B1: Accessibility to marijuana

Department-level information

Department	Homicides (per 100 thou. inhabitants)	Marij.use rate (annual prevalence)	Legal Marij. use rate (annual prevalence)
Montevideo	16.1	17.5	11.2
Canelones	8.7	13.4	8.4
Colonia	4.6	9.6	0
Florida	7.2	6.4	0
Lavalleja	8.5	6.3	4.1
Maldonado	11.6	10.6	5.9
Salto	9.0	7.4	3.5
San Jose	5.2	7.3	0
Tacuarembó	9.7	6.3	0

Table B2: Department-level information

Department	Average number of friends/relatives that use hard drugs
Montevideo	16.1
Canelones	1.11
Colonia	0.56
Florida	0.64
Lavalleja	0.37
Maldonado	1.07
Salto	1.33
San Jose	1.09
Tacuarembó	0.59

Table B3: Department-level information

Socio-demographics by access restrictions

Socio-deomographic	No access	Only Drug traff.	Only Legal	Full access
		(in percent)		
Male	41	51	36	48
College	18	19	31	27
Minority race	17	22	14	20
Age (in years)	42	38	43	27
High SES	14	13	26	17

Table B4: Socio-demographics by access restrictions

Imputed prices for non-users

Age group	Legal market	Drug trafficking market
Younger than 20 years old	77.3	90.8
Between 20-30 years old	84.6	91.3
Between 30-40 years old	88.6	94.4
Older than 40 years old	73.3	80.7
Average price	78.1	85.9

Table B5: Imputed prices (in UYU)

Legal price reduction with model without access restrictions

Alternative	(1) Predicted market share (percentage)	(2) Legal Price ↓ 5% (Δ percentage points)	(3) Legal Price ↓ 10%
No use ($j = 0$)	85.5	-0.2	-0.5
Legal marij. ($j = 1$)	9.4	+0.3	+0.7
Drug traf. marij. ($j = 2$)	5.1	-0.1	-0.2
Marijuana use rate	14.5	+0.3	+0.7

Table B6: Predicted market shares and counterfactuals with model without access restrictions (legal price reduction)

Chapter II Appendix

Example of tax compliance report

INFORME DE CUMPLIMIENTO TRIBUTARIO **Índice**

RAZÓN SOCIAL: COMPAÑÍA XYZ S.A.
RUC: XXXXXXXXXXXXX
EJERCICIO FISCAL: 2018

ANEXO No. 4
DETALLE DE LA DECLARACIÓN DE IMPUESTO A LA RENTA

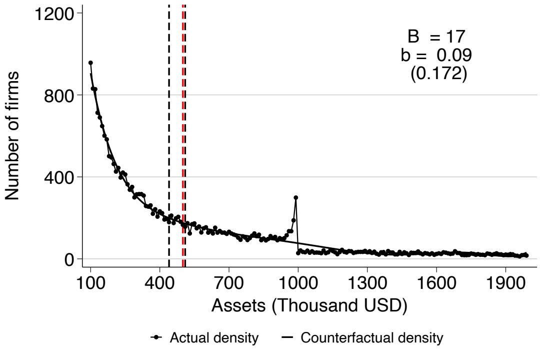
Datos de la declaración del Impuesto a la Renta (a)			Datos de la contabilidad			
Número de Casillero	Nombre del Casillero	Valor declarado	Código de cuenta contable	Nombre de la Cuenta	Valor total del ejercicio fiscal auditado	Diferencias
		{1}	(b)		{2}	{3}={2-1}
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00
		0.00			0.00	0.00

NOTAS :
a. Corresponde al número, nombre y valor del casillero del formulario 101 en el que se efectuó la declaración del impuesto a la renta y presentación de estados financieros para sociedades y establecimientos permanentes. Informar únicamente los casilleros en donde se registraron valores.
b. Los códigos de cuentas deberán ser ingresados al máximo detalle posible, de tal forma que los componentes de cada casillero se puedan identificar claramente.
c. En caso de existir diferencias u observaciones, se debe revelar la explicación de las mismas, tanto al pie de este anexo, como en la parte de Recomendaciones sobre Aspectos Tributarios.

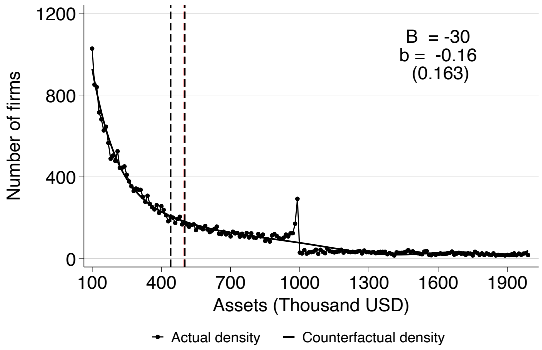
Notes: This appendix of the tax compliance report shows the discrepancies between the reported and audited values. The taxpayer reports the code, the account's name, and the value declared in the corporate income tax return in the first three columns of the table. She reports the accounting code, the account's name, and the audited value in columns four to six. The last column shows the discrepancies (if any) between the value reported in the tax return and the audited value.

Figure A3: Tax Compliance report

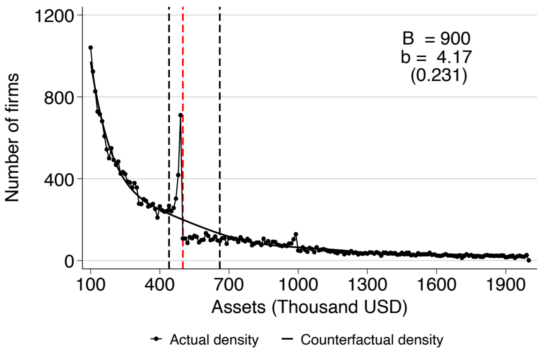
Bunching estimator by years



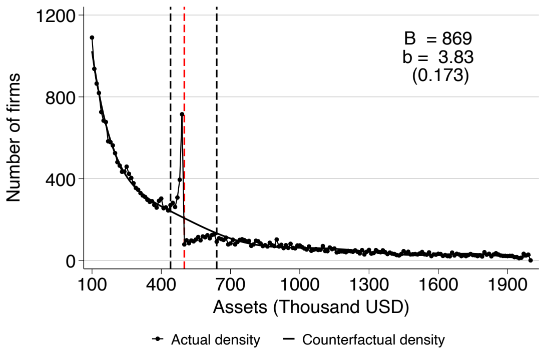
(a) 2014



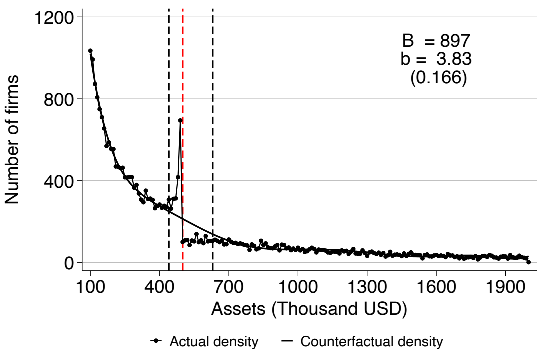
(b) 2015



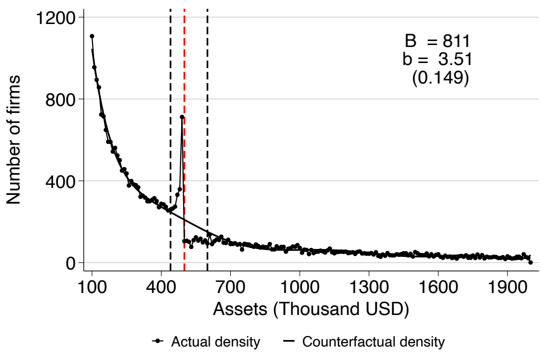
(c) 2016



(d) 2017



(e) 2018



(f) 2019

Figure A4: Bunching by years

Bunching estimation at old threshold

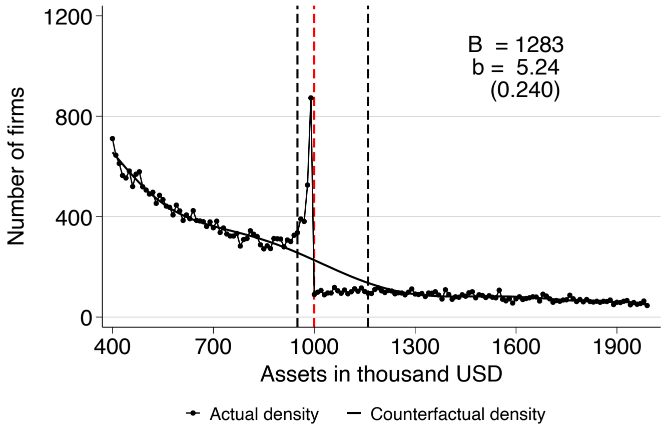


Figure A5: Asset bunching estimation, 2013 - 2015

Notes: The red dashed line is located at the policy threshold (USD 1 million) and the black dashed lines are located at the limits of the bunching and missing mass regions. To construct the counterfactual distribution, we group the assets in bins of USD 10,000. We visually determine that bunching starts at USD 950,000 and fit a polynomial of 8th order. Following standard bunching techniques (Kleven and Waseem 2013), we compute that there are 5.24 more firms than the number of firms we would observe without the asset threshold. Bootstrapped standard errors are in parentheses.

Audit rate in 2017

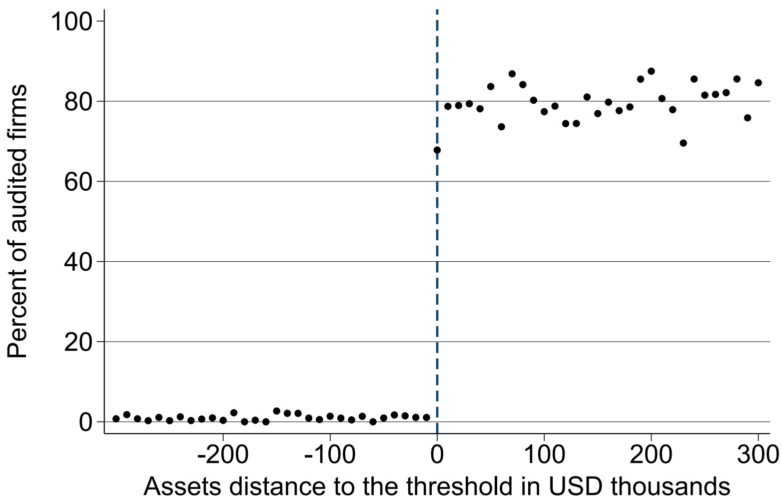


Figure A6: Audit Probability below and above the USD 500 thousand asset threshold in 2017

Notes: The figure shows the audit probability below and above the threshold for firms grouped in USD 10,000 asset bins. The probability for the above-threshold firms indicates that compliance was imperfect in 2017.

Audit rate in 2018 - 2019

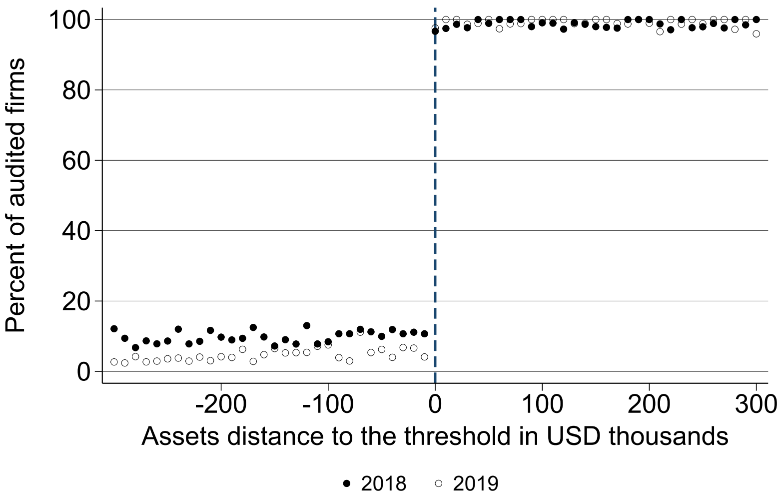


Figure A7: Audit Probability below and above the USD 500 thousand asset threshold in 2018 and 2019

Notes: The figure shows the audit probability below and above the threshold for firms grouped in USD 10,000 asset bins. The probability for the above-threshold firms indicates that compliance was very high in 2018 and 2019.

Placebo: Effects of audits on revenues and costs and expenses in the pre-policy period

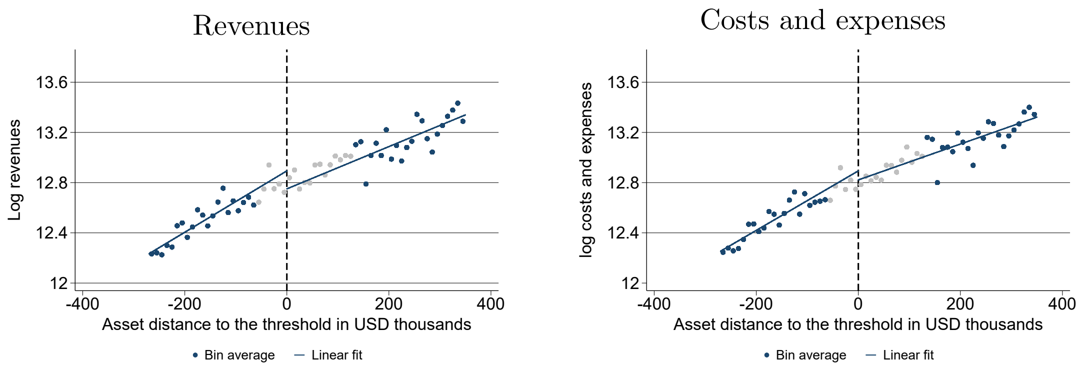
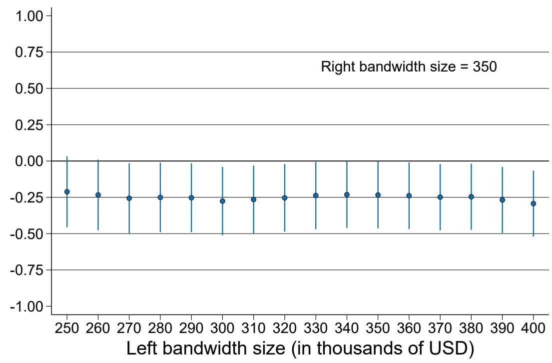


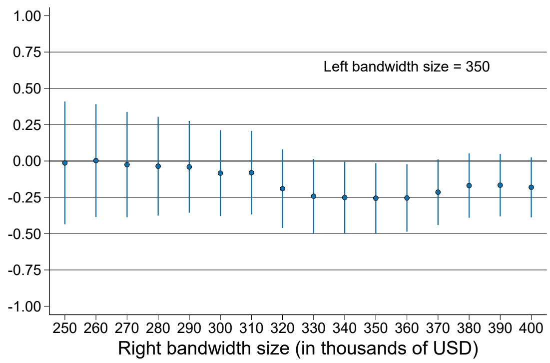
Figure A8: Placebo: Effects of the audit threshold in the pre-policy period

Notes: The figure shows the effect of the asset threshold on costs and expenses (in logs) in the pre-policy period (placebo test). Firms are grouped in USD 10,000 asset bins for the graphs.

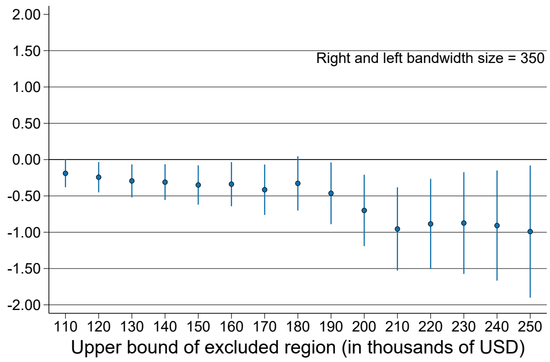
Robustness checks: Revenues



(a) Changes to the left bandwidth



(b) Changes to the right bandwidth

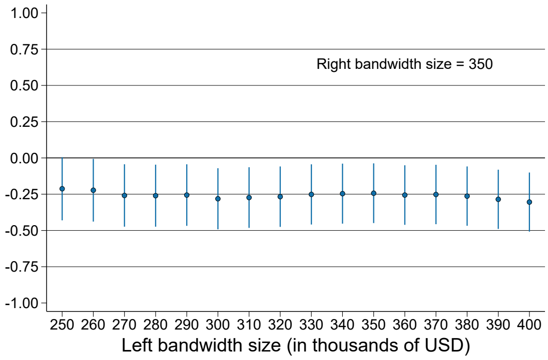


(c) Changes to the upper bound of the excluded region

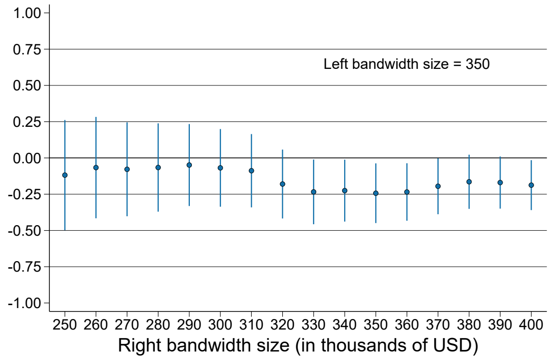
Figure A9: Robustness checks: Discontinuity coefficient of log revenues

Notes: These group of figures shows the estimated discontinuity of revenues (in logs) when we change the left bandwidth, right bandwidth, and the upper bound of the excluded region.

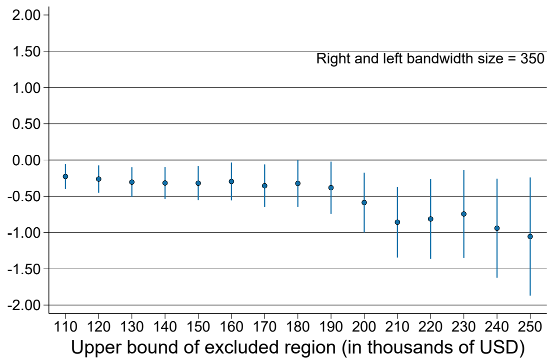
Robustness checks: costs and expenses



(a) Changes to the left bandwidth



(b) Changes to the right bandwidth



(c) Changes to the upper bound of the excluded region

Figure A10: Robustness checks: Discontinuity coefficient of log costs and expenses

Notes: This group of figures presents the estimated RDD coefficient of the log costs and expenses under different values of the upper bound of the excluded region and of the bandwidths.

Auditors and auditing firms

Year	Number of unique auditors	% of auditors that are firms	Median number of firms audited by self-employed	Median number of firms audited by firms
2013	516	40	15	38
2014	549	41	17	42
2015	563	43	16	42
2016	599	41	15	42
2017	754	38	20	46
2018	883	36	29	59
2019	840	40	23	53

Table B7: Descriptive statistics of auditors and auditing firms

Notes: This table presents descriptive statistics of auditors and auditing firms. We can observe a significant increase in the number of auditors between 2016 and 2017 and 2017 and 2018. Firms represent around 40% of the total number of agents doing auditing activities. Still, the median number of firms they audit is greater than the median number audited by self-employed auditors.

Bunching estimator: various specifications

	$b_{2016-2019}$	b_{2016}	b_{2017}	b_{2018}	b_{2019}
Main specification	3.84 (0.131)	4.17 (0.26)	3.83 (0.176)	3.83 (0.164)	3.51 (0.151)
Polynomial order= 7	4.36 (0.209)	4.63 (0.271)	4.41 (0.217)	4.34 (0.187)	4.02 (0.190)
Lower bound = USD 450,000	3.68 (0.120)	4.03 (0.187)	3.78 (0.143)	3.59 (0.133)	3.47 (0.127)
Bin size= 9,000	5.26 (0.554)	5.74 (0.568)	5.34 (0.650)	5.07 (0.671)	4.48 (0.191)

Table B8: Excess mass (b) with different specifications

Notes: This table presents the estimates of the excess mass (b) under different specifications and years. We change the order of the polynomial, the lower bound where the bunching starts and the bin size to show that the bunching is robust to these alternative specifications.

Chapter III Appendix

Product diversity in the United States

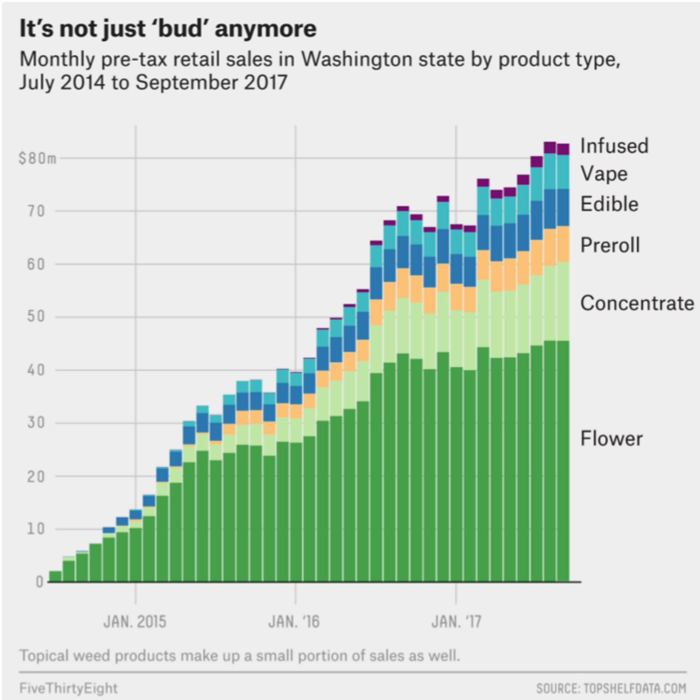


Figure A11: Sales of marijuana by product type in Washington State (Lee, 2018)

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Eidesstattliche Versicherung gemäß §8 Absatz 2 Buchstabe a) der Promotionsordnung der Universität Mannheim zur Erlangung des Doktorgrades der Volkswirtschaftslehre (Dr. rer. pol.)

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   Die eingereichten Dissertationsexemplare sowie der Datenträger gehen in das Eigentum der Universität über.

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