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Weeding out the Dealers? The Economics of Cannabis Legalization

Abstract

We model consumer choices for cannabis in a risky environment and determine the supply of cannabis under prohibition and legalization. While introducing a legal market reduces the profits of illegal providers, it increases cannabis consumption. We show that this trade-off can be overcome by combining legalization with sanctions against users and suppliers of illegal products, and improvements to the quality of legal products. Numerical applications to the US highlight how our proposed policy mix can control the increase in cannabis consumption post-legalization and throttle the illegal market. The eviction prices we predict to drive dealers out of business are much lower than the prices of legal cannabis in the states that opted for legalization, leaving room for the black market to flourish. Analyzing the compatibility of several policy goals put forward in the public debate, including maximizing tax revenue and minimizing psychotropic consumption, we shed light on the less favorable outcomes of recent legalization reforms and suggest a new way forward.

JEL-Codes: I180, K320, K420, L510.

Keywords: cannabis, legalization, crime, policy, regulation.

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1 Introduction

Prohibition policies, which target suppliers or consumers of illegal cannabis, are not very effective at controlling demand. With 192 million users, cannabis is the most popular illegal drug on earth.[1] It accounts for half of global drug seizures and represents a black market worth 142 billion dollars (UNODC, 2017). Prohibition has failed to curb consumption and has fueled criminal activities - drug dealing being the first source of revenue for organized crime; at the same time cannabis is less addictive and less deadly than other psychotropic substances.[2] Governments from advanced and developing countries have decided to legalize the recreational use of cannabis. These legalization reforms have varied widely from one country/state to the next, reflecting different priorities, such as protecting the youth, improving the quality of the products consumed by adults, creating new legal jobs, or raising taxes. However, all reforms share the common goal of reducing criminal activity. We investigate the different ways legalization can be implemented to reach this objective and analyze how the objective of defeating crime may conflict with other objectives, such as raising taxes or decreasing consumption.

Prohibition feeds an international market for drugs, which destabilizes the political economy of drug-producing countries and generates criminality in drug-consuming ones. Yet the costs of violence, instability and repression are generally overlooked by prohibitionists. Barro (2003) argues that legalizing and taxing drugs in advanced economies is a more effective way of controlling the drug market than prohibition. He anticipates that "people would still use drugs (at lower prices), but at least the industry would no longer be connected to criminal activity" (*Business Week*, 03 13 2000). This paper explores a policy of legalization designed to strangle the illegal cannabis market and studies its impact on several outcomes, including price and drug consumption. We model the demand for cannabis from risk averse individuals in a general framework encompassing Expected Utility and Prospect Theory. If the sale of cannabis is illegal, consumers must weigh the benefits of consumption against the costs of participating in an illegal trade. Price is determined by illegal providers who maximize their profits. Our analysis highlights a policy trade-off: although a smart legalization policy may undermine the profits from illegal providers, it also increases cannabis use, which might be a sensitive issue politically.

[1] UNODC (2018) reports that 192 million people worldwide used cannabis at least once in the past year in 2016. This figure could be grossly underestimated: using consumption data on complementary legal inputs to illegal cannabis consumption, Parey and Rasul (forthcoming) estimate that the size of the cannabis market in the UK is twice as large as what has been estimated through demand side approaches.

[2] According to a 2017 meta analysis study of more than 10,000 articles, there are no proven serious adverse effects of moderate cannabis use on the health of adults. It is almost impossible to overdose with cannabis (see Nat. Ac. of Sc., 2017).

In contrast, repression decreases cannabis consumption but strengthens the cartelization of criminal networks and the price paid by their customers.

By illuminating the trade-offs inherent in legalization, our analysis warns policy makers against the unintended consequences of legalization if they neglect the black market responses or if they pursue incompatible objectives. Past reforms have often been disappointing. Canada and Uruguay fell short of eradicating the black market, which was their main objective. In both cases, the willingness of the governments to control consumption led to a severe underestimation of the consumers needs, in terms of both quantity and quality.[3] In California, the legalization reform even fueled the black market while generating only a fraction of the expected tax revenue. Confronted with high prices, due to high taxes in the legal market and new requirements for getting a medical card, many users have turned to illegal cannabis - in total contradiction with the initial objectives of the reform.[4] Our paper provides a general framework to analyze these failures and avoid them in the future.

We start from the simple idea, advocated recently by several policy makers, which is to sell legal cannabis at a price that competes with the black market. The analysis shows that this will not be sufficient to eliminate the black market. Prohibition creates barriers to entry, which foster cartelization of the sector by criminal organizations. These networks are able to respond to the legal competition by lowering their price and still make a profit, as demonstrated in Quebec and Uruguay. Hence, implemented at a competitive price, cannabis legalization may instead increase consumption of "low-cost" illegal cannabis, with all the negative externalities this entails for society. Next we examine a policy mix that combines pricing tools through the sale of legal cannabis – to push the criminals out of the market – and repressive tools – to limit any subsequent increase in consumption.

We show that the eviction price of legal cannabis, which is set to drive illegal providers out of business, can be adjusted with repression and marketing tools. Based on evidence from cannabis markets in the U.S., the policy simulations highlight the complementarities between repression and

[3]In Uruguay, by the end of 2017 only two producers were approved for an annual volume of one ton each, while the market is estimated at between 35 and 40 tons. In addition, the hostility of pharmacists, charged by the State to sell cannabis, has made it even more difficult for users to obtain supplies. Similarly in 2019 in Quebec, public stores were only open from Wednesday to Sunday, "due to the current supply shortages (...) until product availability is more stable" (SQDC's website, www.sqdc.ca, March 19, 2019). Quantity has since increased but not quality. Consumers therefore continue to purchase on the black market.

[4]See https://www.nytimes.com/2019/04/27/us/marijuana-california-legalization.html Thomas Fueller "Getting Worse, Not Better: Illegal Pot Market Booming in California Despite Legalization" *New-York Times* 04 27 2019.

legalization, if a government's objective is to limit the increase in consumption *post-legalization*. For instance, with a 0.1% probability of arrest and a USD 1000 fine for illegal purchase, a legal price around USD 98 per ounce would evict illegal suppliers and increase consumption by 53% to 91%, depending on the elasticity of demand. If the probability of arrest reaches 2%, the eviction price goes up to USD 287 and consumption only increases by 20% to 32.5%. Interestingly, the eviction price can be further adjusted by improving the quality of legal cannabis relative to illegal products. Doubling its relative valuation by consumers would enable a government to set the eviction price at around USD 186 and to limit the rise in consumption to 37% to 63%. This "quality" channel has been neglected by most authorities, including in Canada and Uruguay. Yet, our simulations show that it is quite effective to modulate the eviction price and, thereby, to control consumption *post-legalization*.

Finally, we embed in our theoretical framework a larger set of policy objectives to provide further insight about current policies. We show that prohibition policies are optimal only if a government seeks to minimize total consumption of cannabis and neglects other objectives, such as minimizing the enforcement costs of prohibition. We also show that reducing crime through a regulated market of cannabis sold at the eviction price is compatible with the maximization of consumers' surplus, the minimization of enforcement costs of repression measures, and with the minimization of negative externalities from illegal cannabis consumption. In contrast, the maximization of tax revenues would lead to the co-existence of legal and illegal markets.

The rest of the paper is organized as follows. In Section 2 we describe the evolution of cannabis liberalization measures and position our paper in the literature. In Section 3 we present the set-up of the model, which explains the illegal market structure under *status quo* (prohibition). In Section 4 we analyze the effects of introducing pricing strategies combined with measures targeting consumers and suppliers to drive smugglers out of business and regulate the (legal) sale of cannabis. In Section 5 we calibrate the model based on evidence from the U.S. cannabis market and study its implications in terms of price and increase in consumption *post-legalization*. In Section 6 we enlarge the set of policy objectives to shed more light on current policies before concluding in Section 7.

2 Liberalizing cannabis use: an overview of policy impacts

In response to an increase in cannabis use, the seventies were characterized by a wave of decriminalization measures. In the United-States, possessing small amounts (usually up to 1 ounce) of cannabis was declassified to a misdemeanor in eleven states[5] and Alaska declared possession of small amounts of cannabis to be protected under the state constitutional right to privacy (see Appendix A for a chronology of cannabis laws across states in the US). Across the Atlantic, the Netherlands took a bold step by making cannabis available for recreational use in coffee shops. However, the attempts to legalize cannabis more generally stalled with the *War on Drugs* launched by Ronald Reagan in the eighties. Rising concerns about the legitimacy and efficacy of this war led to a second wave of decriminalization and the first laws in favor of medical use in the U.S. at the end of the nineties. This liberalization movement accelerated in the last decade.

In 2012, the Uruguayan government announced plans to legalize and control sales of recreational cannabis to counter drug-related crime. This initiative occurred as Colorado and Washington states passed bills legalizing recreational use of cannabis, following popular referendums. From 2014 onward, nine other American states and the District of Columbia followed, and in 2018 Canada, South Africa and Georgia also changed their legislation.[6] Legalization policies implemented so far are diverse. In Colorado and Washington states, the reforms have been market oriented, with a clear focus on consumers' needs and taxation. In Canada, retail sale of cannabis is legal although the policies vary across provinces, from Québec's government monopoly to Alberta's privately run stores. In Uruguay the market is under tight public control, which led to sluggish implementation and penury.[7] Based on these examples, a flourishing literature studies the impacts of decriminalization and legalization policies.

[5] California, Colorado, Maine, Minnesota, Mississippi, Nebraska, New York, North Carolina, Ohio, Oregon and Washington

[6] Bills in favor of legalizing recreational cannabis have been passed in Alaska (2014), Oregon (2014), California (2016), Maine (2016), Massachusetts (2016), Nevada (2016), Michigan (2018), Vermont (2018) and Illinois (2019) (see further detail on the US states legislation in Appendix A).

[7] Although Uruguay was officially the first country to legalize recreational cannabis in 2012, public skepticism slowed the process and distribution was delayed until July 2017. Licensed farms are allowed to grow cannabis for the local market, citizens could run cannabis cooperatives, and selected pharmacies acted as dispensaries for both medical and recreational cannabis.

2.1 Impacts of legalization on crime and violence

The first strand of the literature highlights the costs, in term of criminal activities and violence, of drug prohibition. Resignato (2000) shows that most drug-related violent crimes are the consequence of systemic factors linked to the *War on Drugs* rather than of psycho-pharmacological effects of drug use on crime. Indeed, prohibition increases incentives to engage in criminal behavior (MacCoun and Reuter, 2001). It promotes violence as almost the only way to resolve conflicts and secure market power, encouraging market strategies based on violence (Miron, 1999, 2003). This strengthens cartelization and leads Miron and Zwiebel (1995) to the conclusion that a free market for drugs would probably outperform prohibition in terms of social costs. The social costs linked to prohibition are exacerbated by "zero-tolerance" policies, which may encourage users to hold higher quantities (Caulkins, 1993).

In line with these arguments, Dills et al. (2017) show that liberalizing cannabis does not lead to a rise in crime. De-penalizing possession of small amounts of cannabis frees the police to focus on other crime, reducing non cannabis-related crime (Adda et al., 2014). This reallocation effect outweighs the expected undesirable effects of criminality associated with drug consumption. Overall crime in Colorado decreased in areas where cannabis dispensaries were added (Brinkman and Mok-Lamme, 2019). In particular, cannabis legalization could be responsible for a drop in local rapes and property crimes (Dragone et al., 2019).

The benefits of liberalization policies extend to organized crime. In the states bordering Mexico, legalization of cannabis for medical purposes has decreased drug-trafficking related crime (Morris et al., 2014; Gavrilova et al., 2019; Chang and Jacobson, 2017). Furthermore legalization policies have shrunk criminals' profits, weakening their power. In Italy, a legislative loophole leading to an unintended liberalization of cannabis decreased revenues from cannabis sales on the black market by 90-170 million euro (Carrieri et al., 2019).

2.2 Impacts of legalization on drug consumption

Using a structural approach, Jacobi and Sovinsky (2016) explore the idea that legalization reduces the search cost for cannabis and removes the stigma of illicit consumption. They find that legalizing recreational cannabis would increase its use by around 48%. This is supported by Miller et al. (2017), who use survey data on undergraduate students at Washington State University to show that cannabis legalization induced a rise in consumption early after being implemented. Moreover, the ease of access to licit drugs encourages individuals to start consuming cannabis earlier, as shown in the Netherlands by Palali and van Ours (2015).

As consumers react to the risk of being caught while buying cannabis illegally (Jacobson, 2004), legalization is likely to affect consumer behavior by lowering their risk. For example, de-penalizing cannabis possession in the London borough of Lambeth in 2001 led to a significant increase in cannabis possession offences, even though it decreased crime overall (Adda et al., 2014). The reduction in risk faced by consumers following legalization of recreational use may drive up prices for illegal cannabis, as it increases demand (Pacula et al., 2010). In this, cannabis users may be considered rational economic agents, sensitive to variations in prices and risk.[8]

Finally legalization does not seem to lead to the feared socially undesirable gateway effects to other substance use (Dills et al., 2017). On the contrary, cannabis seems to act as a substitute for more powerful and addictive opioids (Powell et al., 2018).

2.3 Legalization and taxation

From a public policy viewpoint, legalization creates a new source of revenue along with the option of controlling consumption levels using tax instruments. Since consumers are price sensitive -with price elasticities of demand between -0.5 and -0.79 (Davis et al., 2016; van Ours and Williams, 2007)-, a government may use taxes to regulate the increase in cannabis use following legalization. Becker et al. (2006) show that policies controlling drug use by taxes are more efficient than quantity reductions through prohibition. Taxing cannabis consumption may discourage early initiation into cannabis use by younger users, who are very responsive to low prices (van Ours and Williams, 2007).

Moreover, cannabis legalization could generate substantial public resources through taxation (Caputo and Ostrom, 1994, 1996). For instance the states of Colorado and Washington collect between USD 200 million and USD 300 million a year in taxes through the cannabis industry. In the state of

[8] Although increasing consumption among the adults, legalizing cannabis seems to decrease consumption among the young, provided legal retailers refuse to sell it to underage consumers. DiNardo and Lemieux (2001) do not find any effect of cannabis decriminalization on consumption among high school students, a result confirmed by a recent study in Oregon Kerr et al. (2017). Furthermore, consumption of cannabis by teenagers is estimated to have decreased by 12% following legalization in the states of Washington and Colorado (SAMHSA, 2014).

Washington, this tax revenue is secured by a substantial degree of market concentration, which results itself from the high taxes set by the authorities (Hollenbeck and Uetake, 2019). In the US, Jacobi and Sovinsky (2016) estimate at around USD 12 billion the tax revenue, which could be raised from country-wide cannabis legalization.

This review of the literature shows that, while prohibition fuels criminality and violence, it also helps contain cannabis consumption. In contrast, legalization leads to a decrease in criminality overall and generates tax revenue, but at the cost of increasing cannabis consumption. We study the theory behind this policy trade-off.

3 Prohibition equilibrium

We start our analysis by studying the illegal market under prohibition. In the absence of a legal option, consumers can only purchase illegal cannabis from dealers, who charge the price p.

3.1 Demand under prohibition

Potential customers for illegal cannabis are heterogeneous. They have different "taste" for the commodity, θ, which is drawn from the distribution $G(\theta)$, twice differentiable, with support $\mathbb{R}$ and density function $g(\theta)$. Individuals who like cannabis are characterized by a positive θ, and those who dislike it, by a negative one. When the illegal cannabis is of quality $v \geq 0$, its value for individual θ is given by θv.

Since illegal activities entail risk, a consumer who purchases black market cannabis is subject to a probability $q \in [0, 1]$ of being caught by the police. If caught, he/she loses the benefit of the commodity, the price paid for it, p, and faces a legal punishment $F \geq 0$ (e.g. fine, prison term). The net payoff of a consumer caught by the police while purchasing illegally is: $-p - F$; while the net payoff for an individual who is not caught is $\theta v - p$. Therefore, choosing to consume cannabis illegally is a lottery $\mathcal{L}_{\text{illegal}} = [-p - F, \theta v - p; q, 1 - q]$. For an individual with characteristic $\theta \in \mathbb{R}$, this lottery has an expected value of

$$w^{+}(1 - q)u(\theta v - p) + w^{-}(q)u(-p - F), \tag{1}$$

where the utility function $u(x)$ is continuous, strictly increasing in $x \in \mathbb{R}$ and such that $u(0) = 0$,[9]

[9] This is a normalization, intuitively reflecting that losses lead to a negative value and gains lead to a positive value.

while the probability weighting functions $w^+(x)$ and $w^-(x)$ are increasing in $x \in [0,1]$, so that $w^+(0) = w^-(0) = 0$ and $w^+(1) = w^-(1) = 1$.

This framework is general. It encompasses the standard Expected Utility approach by setting $w^+(1-q) = 1-q$ and $w^-(q) = q$ and considering an increasing, concave utility function (e.g., CARA). It also encompasses Tversky and Kahneman (1992)'s Cumulative Prospect Theory (CPT), where probability weighting functions are not linear and where the value function $u(x)$ is S-shaped, with an inflection point at zero.[10] The S-shaped value function can account for agents' different risk attitudes depending on whether they face gains (risk-aversion) or losses (risk-seeking). It is particularly adapted to our context as it accounts for framing effects, i.e. the effects of the environment on decision-making.

The consumer of type θ^I, indifferent between illegal consumption and no consumption, is characterized as follows:

$$w^+(1-q)u(\theta^I v - p) + w^-(q)u(-p-F) = 0 \tag{2}$$

We show in Appendix B that $\theta^I > 0$ exists and is unique. Any consumer of type $\theta \geq \theta^I$ purchases illegal cannabis, while consumer of type $\theta < \theta^I$ does not. Without loss of generality, the demand for the illegal commodity can then be written:

$$D^I(p) = \int_{\theta^I}^{+\infty} g(\theta)d\theta = 1 - G(\theta^I) \tag{3}$$

where θ^I is the solution of equation (2).

The following static comparative results regarding the marginal consumer and the price elasticity of demand for illegal cannabis are also derived in Appendix B.

First, θ^I increases with q: the demand for the illegal commodity decreases with the probability of arrest, which is the desired effect of prohibition policies. It discourages individuals from purchasing illegally, which leads to a more positive selection of consumers. Second, θ^I increases with p so that a higher price reduces the demand. However, this is not a policy instrument under prohibition, since the equilibrium price on the illegal market results from interactions between unregulated (and untaxed) criminals.

[10] This theory is the most prominent among non-expected utility theories. While expected utility theories focus on final wealth, CPT models variations in outcome from a given *status quo*.

Finally, the absolute value of the price elasticity of demand,

$$\epsilon_{D^I,p} = \frac{-D^{I\prime}(p)p}{D^I(p)} = \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d\theta^I}{dp}p, \tag{4}$$

increases with $q \in [0,1]$ under the assumption that the distribution $G(\theta)$ satisfies the monotone hazard rate (MHR) property. Since the MHR property is satisfied by most usual distributions, our general framework establishes that, for these distributions, the price elasticity of demand for cannabis increases with the risk of being caught, an intuitive result.

3.2 Cannabis supply under prohibition

We model the oligopolistic market for illegal provision of cannabis as a generalized Cournot competition, where a few criminal networks, $i = 1, ..., N$, operate. Assuming symmetrical cost functions: $C_i(q_i) = cq_i + K$ where $K \geq 0$ is the sunk cost to set up the illegal network and $c \geq 0$ is the constant marginal cost of supplying the commodity, we focus on symmetric equilibrium. The generalized Cournot price p^N with N smugglers is such that:

$$\frac{p^N - c}{p^N} = \frac{1}{N}\frac{1}{\epsilon_{D^I,p}} \tag{5}$$

where N is an integer greater than or equal to 1 and $\epsilon_{D^I,p}$ is the price elasticity of demand defined in (4). It is easy to check that, all else being equal, the price in (5) is increasing in the marginal cost of production, c, an intuitive result, and decreasing in N: the higher the number of competing providers the lower their mark-up. The generalized Cournot competition demand, $D^I(p^N)$, is between two extreme cases: $D^I(p^m) \leq D^I(p^N) \leq D^I(c)$ for all $N \geq 1$ where $p^m \equiv p^1$ in the monopoly case and $p^\infty = c$ in the competitive case when $N \to \infty$.

We have established in the Appendix B that the price elasticity of demand, $\epsilon_{D^I,p}$, increases with q. Using (5) we deduce that the oligopolistic price is lower when the risk q increases. Risk-aversion implies that the price charged by smugglers is lower than the price they would impose on risk neutral individuals with the same expected payoff from consumption.[11]

In a more dynamic setting, one can endogenize N. Since K is the sunk cost to enter the illegal market, the maximal number of criminal organizations N that can operate profitably is the integer

[11] Smugglers also face different types of consumers. If they can identify them, they may apply different prices. As is standard with third degree price discrimination, groups with the largest price elasticity get the smallest price. In contrast, captive consumers (i.e., groups with low price elasticity) are charged higher prices.

part of n such that $\pi(n) = K$, where $\pi(n) = (p^n - c)\frac{D^I(p^n)}{n}$ is the firm rent. Therefore, any repressive measure increasing c or K reduces the number of criminal networks active on the market, N, and increases the price they charge (see equation 5).

4 Legalization

To drive the dealers out of business, different policy makers including Québec's Minister of Public Health, Lucie Charlebois,[12] have used the intuitive approach of matching the price of legal cannabis to the black market price: $p^L = p$. We show easily that this policy increases consumption without necessarily eradicating crime.

Let θbv denote the value of consumption for an individual of type θ considering the purchase of legal cannabis of quality bv. The parameter $b \geq 1$, hereafter called "quality differential", captures the fact that, unlike illegal products, legal products are certified and their potency and composition, including pesticide and other chemicals, are known to consumers at the time of purchase.[13] Moreover, purchasing legally alleviates personal cost in terms of ethics and social stigma. Finally, the purchase experience is usually better in a shop than on the street.

If it is possible to purchase cannabis at price $p^L = p$ without risk of getting caught, the marginal consumer indifferent between consuming legal cannabis or not consuming at all is such that:

$$\theta^0(p) = \frac{p}{bv} \tag{6}$$

Comparing the legal threshold, $\theta^0(p)$, with the illegal threshold implicitly determined by (2) for a given price p, we show that the legal demand is higher than the demand for the illegal product: $\theta^0(p) < \theta^I(p)\ \forall p > 0$.[14] For a given price, the value of consuming legal cannabis is higher and there is no risk of being sanctioned, such that the demand for cannabis increases.

Moreover, a government setting a competitive price for legal cannabis such that $p^L = p$, ignores the fact that dealers may lower their price to keep some customers. In addition to increasing consumption, such a policy does not necessarily eradicate crime.

[12]See "Environ '7-8 dollars le gramme' pour du pot légal" by Martin Croteau in *La Presse*, September 21 2017.

[13]Quality certification under legalization usually involves regulating cropping techniques; in particular the use of pesticides, which are shown to be harmful for health (Subritzky et al., 2017).

[14]Indeed, when there is no risk of detection (i.e. $q = 0$) then $\theta^I_{q=0}(p) = \frac{p}{v} \geq \theta^0(p) = \frac{p}{bv}\ \forall b \geq 1$. Since θ^I increases with q, we deduce that: $\theta^I(p) > \theta^I_{q=0}(p) \geq \theta^0(p)\ \forall b \geq 1$ and $q > 0$.

4.1 Response of illegal suppliers to cannabis legalization

To determine a price of legal cannabis that would drive dealers out of business the government, a Stackelberg leader, needs to take into account the impact of response of illegal providers to its policy. As shown in Appendices B through F, all our results hold whether we model behavior under Expected Utility Theory or Prospect Theory. Only the way the marginal consumer is derived under legalization differs slightly in these two frameworks. In Prospect Theory, the marginal type, $\theta^L(p, p^L)$, indifferent between legal and illegal consumption, is the solution of :[15]

$$w^{+}(1-q)u\left(p^L - p - \theta v(b-1)\right) + w^{-}(q)u\left(p^L - p - \theta bv - F\right) = 0, \tag{7}$$

while, if individuals are expected utility maximizers, the marginal consumer is the solution of: $(1 - q)u\left(\theta v - p\right) + qu\left(-p - F\right) = u\left(\theta bv - p^L\right)$. For example, with a CARA utility function $\theta^L(p, p^L)$ is such that $(1-q)u\left(p^L - p - \theta v(b-1)\right) + qu\left(p^L - p - \theta bv - F\right) = 1$, which is similar to (7) but not equal. Appendix C shows that, in both cases, there is a range of legal prices such that $\theta^L(p, p^L)$ exists and is unique. Any individual above this threshold prefers to purchase legally rather than illegally.

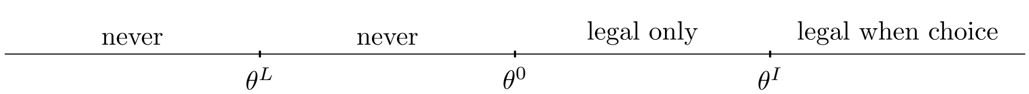
Recall that θ^I defined in (2) is the threshold above which an individual prefers to make an illegal purchase rather than no purchase at all and that θ^0 defined in (6) is the threshold above which an individual prefers to purchase legally rather than not purchase. Let $\tilde{p}^L(p)$ be the value of p^L such that

$$w^{+}(1-q)u\left(\frac{p^L - bp}{b}\right) = -w^{-}(q)u(-p-F), \tag{8}$$

with the probability weighting function being the identity under Expected Utility Theory. Two cases may occur following legalization, as shown in Appendix D.1.

1. $p^L \leq \tilde{p}^L(p)$. The legal price is low enough and legalization shows the intended effect of pushing the illegal providers out of the cannabis market: $\theta^L \leq \theta^0 \leq \theta^I$. In this case, $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$ new cannabis consumers appear.

Figure 1: Consumers choice when $p^L \leq \tilde{p}^L(p)$

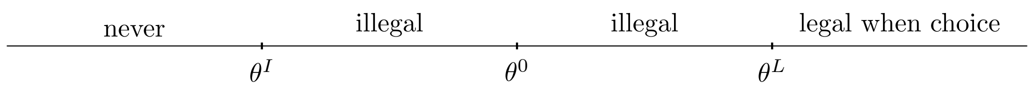


[15] In Prospect Theory individuals deciding between legal and illegal consumption take the certain payoff associated with the legal option, $\theta bv - p^L$, as reference. Engaging in illegal consumption is then modeled as a lottery $[p^L - p - \theta bv - F, p^L - p - \theta(b-1)v; q, 1-q]$ which yields (7).

2. $p^L > \tilde{p}^L(p)$. The legal price is too high to undermine the dealers and $\theta^I < \theta^0 < \theta^L$. In this case, if the illegal providers maintained the same price as under prohibition, the overall demand for cannabis would not change and the residual demand for illegal cannabis would become:

$$D^I(p, p^L) = \int_{\theta^I(p)}^{\theta^L(p,p^L)} g(\theta) d\theta. \tag{9}$$

Figure 2: Consumers choice when $p^L > \tilde{p}^L(p)$



A high-type segment of the former black market customers is captured by the new legal market. Under legalization, individuals with a high valuation for cannabis turn to the legal market and pay attention to quality, while they neglect it under prohibition where products are not certified.

Moreover, to keep some consumers and maximize their profits, illegal providers adjust their price, p. Let $p^N(p^L)$ be the solution of (5) computed with $\varepsilon_{D^I,p} = -\frac{\partial D^I(p,p^L)}{\partial p} \frac{p}{D^I(p,p^L)}$, the direct price elasticity of the demand $D^I(p, p^L)$ defined in (9), which depends on p^L . The price reaction function of the smugglers is the solution of the following equation:

$$p(p^L) = \begin{cases} p^N(p^L) & \text{if } \ c \leq p^N(p^L) < \frac{p^L}{b} \\ \varnothing & \text{otherwise} \end{cases} \tag{10}$$

As long as the illegal providers are active, i.e. have positive profits, their reaction price is increasing in their marginal operating costs, c, and in the price on the legal market, p^L; and is decreasing in the number of active criminal networks in the market, N. Symmetrically, the higher the value of legal cannabis relative to illegal cannabis (the higher b) and the lower the legal price, p^L, the lower θ^L defined in (7) and the more difficult it is for criminals to attract consumers by decreasing their prices.[16]

After the illegal providers respond to the sale of legal cannabis, if the value for money of black market cannabis is sufficiently attractive relative to legal cannabis (i.e., if the price differential between the markets is high enough given the quality differential), we have $\theta^I < \theta^0 < \theta^L$, and the black market survives. Facing competition from the legal market to attract the high segment of the consumer

[16]We show in Appendix C that θ^L increases with p^L, while it decreases with b and p.

distribution, illegal providers push down their prices, which increases the overall demand for cannabis. So far, this has been observed everywhere that cannabis has been legalized.

Proposition 1. *Once legal cannabis is introduced to the market, if the costs of operating on the black market and the repression against illegal purchases are held constant, for any level of quality differential, $b \geq 1$, the overall demand for cannabis increases.*

Proof. See Appendix D.2. □

This proposition highlights that if policy makers only use one instrument in case of legalization, which is to implement a legal market for cannabis by a price setting strategy, then they have to choose between the objective of controlling cannabis consumption with the help of a cartelized illegal market (the *status-quo* in many countries), or implementing a legal market, which increases cannabis consumption.

The flourishing opium market at the beginning of the 19th century illustrates this policy trade-off. To control the opium market in the East-Indies, the Dutch government imposed a state monopoly and provided licences to consumers in what was called *opium regie*. Although the aim was to regulate the market and tax it better, it had to compromise between imposing low prices (getting lower revenues) and having fewer smugglers on the market, or getting higher revenues with a high regulated price, which allowed smugglers to enter the market and compete on price (Van Ours, 1995).

4.2 Eradicating organized crime through legalization

Since many legalization reforms aim to eradicate crime, we now consider a price setting strategy for the legal supply which destroys economic incentives for dealers to operate illegally. The strategy is such that the price of dealers is pushed below their marginal costs after they respond to the policy, i.e. $p(p^L) \leq c$. Let $\theta^I(p)$ be defined in (2). We deduce the next proposition.

Proposition 2. *To drive illegal suppliers out of business, the legal price of cannabis should be set below the eviction price $\underline{p}^L = bv\theta^I(c)$, which, without additional measures, yields the same level of consumption as under perfect competition among illegal suppliers: $D^L(\underline{p}^L) = D^I(c)$.*

Proof. See Appendix E. □

This result is general. Irrespective of the way we model consumers' behavior (i.e. EUT or Prospect Theory) and the initial market conditions (i.e. monopolist, oligopolistic or competitive), if the government wants to drive out illegal providers, it has to apply a price lower than the threshold price $\underline{p}^L = bv\theta^I(c)$, which is such that their mark-up vanishes after they respond to the policy. We refer to the price $\underline{p}^L$ as the *eviction price*. Since $\theta^I(c)v - c > 0$ it follows that $\underline{p}^L > c$: the threshold price for eliminating illegal suppliers is higher than smugglers' marginal cost, c. Nevertheless, in *post-legalization* equilibrium, the demand, which is now legal, is at the same level as if illegal suppliers were pricing at marginal cost under status-quo.

Compared to the status-quo situation of an oligopolistic illegal market, Proposition 2 shows that legalizing the cannabis market through setting the eviction price $\underline{p}^L = bv\theta^I(c)$ would bring the demand of (legal) cannabis to the level of a perfectly competitive illegal market or higher. Public authorities therefore face a trade-off between an increase in cannabis consumption and crime eradication.

4.3 Eradicating organized crime while controlling cannabis use

Increases in drug consumption following legalization may not be desirable for the society, nor politically sustainable. In fact, to date, not a single politician proponent of legalization has disputed this. The increase in cannabis consumption, if anticipated, will prompt opposition to legalization by many citizens, health workers and anti-drug associations. Policy makers need more sophisticated tools to regulate the demand for cannabis *post-legalization*. Our theoretical framework shows that the price that drives criminals out of business can be adjusted.

Corollary 1. *The eviction price $\underline{p}^L$ increases with the marginal costs of illegal providers c, the probability of arrest of illegal consumers q, the associated fine amount F, and the quality differential between legal and illegal cannabis b.*

Proof. See Appendix F □

Intuitively, additional measures affecting c, q, F and b make competing with the legal provision of cannabis more difficult for illegal providers. Combining these four instruments helps contain the increase in cannabis consumption following legalization. This is either because consumers have higher relative expected payoffs if they consume legally, or because illegal providers operate with increased costs. Their economic activities can be throttled more easily such that the eviction price can be set higher. This dampens the increase in demand following legalization. The optimal combination of these instruments is discussed with the objectives of the reforms in Section 6.

5 Policy Implications

In this section we illustrate the implications of the theory, which combines legalization, repression, and investments in quality differentiation, in order to drive illegal providers out of business. The calibration exercise is based on the CPT functional forms derived by Tversky and Kahneman (1992). Our use of CPT is consistent with agents' behavior while considering risky gambles (for a literature review see Rabin, 1998; Barberis and Thaler, 2003). In particular, this theory provides realistic predictions for individual behavior when confronted to risky choices, both inside (Glöckner and Betsch, 2008) and outside (Barberis et al., 2016) the lab.

Tversky and Kahneman (1992) generalize the seminal paper by Kahneman and Tversky (1972), which was one of the first to show that individuals have a poor ability to assess probabilities. They tend to overestimate the odds of rare salient events, while they underestimate the odds of more common events. Probability weighting functions account for individuals' distorted perceptions of probabilities.[17] In our framework, individuals choosing to purchase cannabis on the black market face a binary lottery, with a low probability q of being arrested (Nguyen and Reuter, 2012). The weighting function $w^+(1-q)$ (respectively $w^-(q)$) applied to probabilities associated with positive (respectively negative) outcomes, proposed by Tversky and Kahneman (1992) is:

$$w^t(q) = \frac{q^{\gamma^t}}{(q^{\gamma^t} + (1-q)^{\gamma^t})^{\frac{1}{\gamma^t}}} \qquad \text{with } t = +, -. \tag{11}$$

and the value function is

$$u(x) = \begin{cases} x^\alpha \text{ , if } x > 0 \\ -\lambda(-x)^\alpha \text{ , if } x \leq 0 \end{cases} \qquad \text{with } \alpha \in (0,1) \text{ and } \lambda \geq 1. \tag{12}$$

Substituting (11) and (12) in (2), the marginal consumer is characterized by (see Appendix G):

$$\theta^I(p) = \frac{1}{v}\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} (F+p) + p\right]. \tag{13}$$

[17] These functions are simply increasing mappings $w : [0,1] \mapsto [0,1]$, such that $w(0) = 0$, $w(1) = 1$, and for x in the neighborhood of 0 (respectively 1) $w(x) \geq x$ ($w(x) \leq x$).

The legal price threshold $\underline{p}^L = bv\theta^I(c)$ is then such that:

$$\underline{p}^L = b\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+c)+c\right]. \tag{14}$$

Below we calibrate the eviction price $\underline{p}^L$, as well as the increase in (legal) cannabis consumption at this price and compare it to the level of illegal consumption under prohibition.

5.1 Benchmark values

The exogenous parameters calibrated by Tversky and Kahneman (1992) are $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$. q, F, c, and b are policy parameters, which are affected by investments into different kinds of measures – some are repressive, some are to improve the consumption experience of legal cannabis. While the current level of fines, F, and the probability of arrest, q, are documented in several studies, the parameters c, reflecting the marginal costs of production of illegal suppliers, and b, the higher valuation of legal cannabis, require more indirect inference. Since most studies so far focus on the US, our calibrations are based on US data.

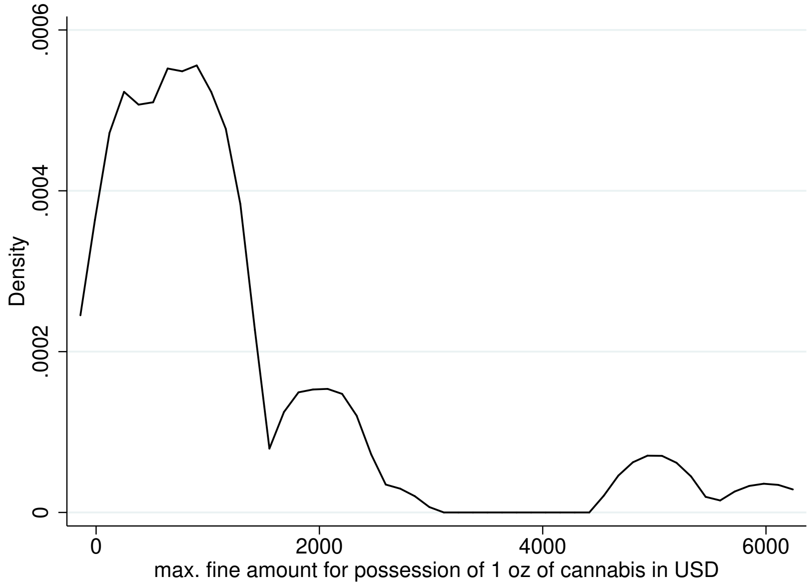
The probability of being arrested in possession of cannabis in the United States varies across settings. Nguyen and Reuter (2012) highlight that sex, age, and ethnicity influence the probability of being stopped by the police, and therefore of being arrested. The authors argue that in most groups, the average probability of being arrested is below 1%, which we use as a benchmark value for q under prohibition. Under legalization, we assume illegal users are more difficult to detect, which drives the probability of arrest down to $q_L = 0.1\%$.

The maximum fines applied for possession of cannabis on a first offense vary also across states, as represented in Figure 3 (NORML, 2020).[18] However, a non-negligible proportion of states apply fines of USD 1,000. This value is also the median value of the fines applied *on a first offense* across the United States as of March 2020, which we use as a benchmark.

The marginal cost of producing and delivering cannabis on the black market, c, is difficult to estimate for several reasons. First, with legalization we expect the cost of producing cannabis to fall due to innovation, which is not trivial to predict. Second, it is difficult to estimate the quantities traded of an illegal commodity, as well as the relative proportion of seizures by law enforcement authorities

[18] Note that we excluded Arizona from the sample, for this state does not set sanctions for possession of small amounts and features a maximum fine of USD 150,000 for the possession of any amount of cannabis.

Figure 3: Distribution of state maximum fine amounts for possession of 1 ounce of cannabis across the United States (in states where cannabis is prohibited, as of March 2020)



and the stock losses inherent to smuggling activities. These losses directly increase production and distribution costs. Moreover, when criminals are managing production and distribution, hidden costs linked to enforcement of contracts are difficult to estimate.

Using various assumptions, Caulkins (2010) estimates production costs of cannabis post-legalization between 70$ and 400$ per pound (i.e. approximately 80$ and 470$ in 2020), depending on the production method used. However, this estimate does not take into account distribution costs under prohibition, which are likely to be quite large. The LSE Expert Group on the Economics of Drug Policy (Quah et al., 2014) estimates the wholesale price of a pound of illegal cannabis under prohibition to be around 3,500$ (i.e. 218.75$ per ounce, or 237.5$ in 2020), and about 10 times smaller under legalization – which is consistent with Caulkins (2010). The LSE Expert Group also reports the typical farmgate price quoted in the media to be around 2,000$ per pound (i.e. 125$ per ounce). In line with all these studies, the marginal cost of the illegal product is therefore likely to range between 25$ and 125$ per ounce *post-legalization*.

In a legalized framework, we may expect savings from innovation. Moreover, distribution costs in the illegal market may decrease, as detection of illegal producers and consumers might become less straightforward. We therefore choose 50$ as our benchmark value for marginal cost of illegal cannabis under legalization. This corresponds to the first quintile of the interval $[25, 125]$ and accounts, to some extent, for both the high distribution costs specific to the black market and their decrease *post-legalization*. Obviously, this marginal cost of operation by illegal providers can be affected by repressive policies – i.e. investing in detecting illegal producers and retailers – which are allowed to vary in our sensitivity analysis.

The parameter b describes the higher valuation of legal cannabis, which is certified by health or other regulation authorities, relative to cannabis bought on the black market. To get an objective measure for b, we focus on the cannabis potency. We approximate b by the difference in THC dosage between cannabis bought legally and illegally. According to ElSohly et al. (2016), the average THC potency of cannabis seized in the US in 2014 was 11.84%, while around the same time, the THC potency on Colorado's legal market was 18.7%.[19] Based on this difference, a benchmark measure for b could be $\frac{18.7}{11.84} \approx 1.58$. This is clearly an underestimation of the quality gap between legal and illegal products. First of all, legal cannabis can be purchased at different potency depending on the consumer's taste. That is, the variety of products is greater with legalization. Second, the products are certified. Third, the purchase experience is more pleasant and safer in a shop than under cover in the street. Accordingly, the sensitivity analysis will consider several values for b.

Table 1: Benchmark values used for calibration

Variable	Benchmark value
λ	2.25
α	0.88
γ^+	0.61
γ^-	0.69
q_L	0.1%
F	1,000
b	1.58
c	50
$\underline{p}^L$	97.79

Table 1 provides an overview of the different parameters. Using these benchmark values to calibrate the eviction price $\underline{p}^L$ specified in (14), we obtain a benchmark price for legal cannabis of USD 97.79 per ounce. For comparison, we present in Table 2 the legal and illegal prices observed in 7 states of the U.S., in 2018. We report the number of licensed recreational retailers, which we compare to the number of McDonald's restaurants. We also present each state's share of the U.S. legal market for cannabis. These figures give an idea of the degree of liberalization in each state and of the relative

[19] Briggs, Bill. 2015 "Colorado Marijuana Study Finds Legal Weed Contains Potent THC Levels". *CNBC News*, March 23.

position of the black market, which are discussed in Section 6.

Table 2: Legal markets across the U.S.

State	p	p^L	Recreational retailers	McDonald's restaurants	Share of US legal market	Population
AK	298.24	361.57	123	32	0.63%	0.7
CA	256.57	344.45	901	1,279	34.9%	39.5
CO	241.75	143.07	587	209	15.1%	5.6
MA	339.68	354.25	113	170	4.2%	6.9
NV	270.57	295.54	70	134	2.6%	3.0
OR	210.39	127.06	661	130	7.7%	4.2
WA	233.73	$\approx$ 196	512	167	12.8%	7.5

Prices are in USD per ounce, as of fall 2018. The legal price for Washington State is extrapolated from Jeanne Lang Jones and Rob Smith. 2019. "Tight Regulations, High Taxes May Keep Washington State's $1.4B Cannabis Industry from Really Blooming". *Seattle Business*. January. All other legal prices are quoted from New Frontier Data (2019), while black market prices were retrieved from the crowd-sourced website `priceofweed.com`, which was accessed using the Internet archive Wayback Machine. We report the price listed for an ounce of "high" quality cannabis. Numbers of retailers and testing facilities were retrieved from New Frontier Data's "Cannabis Legalized States" interactive map, as of July 2020. The number of McDonald's restaurants in each state was scraped from Google Places, as of August 2020. Shares of the US legal market are projections quoted from New Frontier Data (2017). Population is expressed in million inhabitants, as of 2018.

Finally, to compute the increase in demand following the legalization at eviction price, we need to assess the price elasticity of demand of cannabis. van Ours and Williams (2007) estimate that the price elasticity of demand ranges between -0.50 and -0.70, while Davis et al. (2016) find a price elasticity between -0.67 and -0.79. In line with this empirical evidence, our calibrations allow for a range of price elasticities of demand between -0.5 and -0.8. Assuming that the taste for cannabis θ is normally distributed, we calibrate the distribution parameters of the Gaussian distribution using our model and the literature on cannabis demand. Appendix H.1 shows that the mean value of θ varies between -436.4 and -1090.9 when the elasticity varies between -0.8 and -0.5. This negative average "taste" parameter for cannabis is consistent with surveys in the US reporting negative attitudes towards cannabis consumption on average.

5.2 Effects of policies on post-legalization equilibrium

This section studies the sensitivity of the eviction price and of the post-legalization demand to parameters that can be influenced by policies. Several instruments are considered: reinforcing repression may increase the marginal cost of operations for illegal suppliers, c, the probability of arrest, q, or fines to illegal consumers, F. Moreover, investing in the quality of the legal cannabis, including the diversification of the products (potency, edibles, shopping experience), and in information/education campaigns about the danger of consuming illegal cannabis may increase the relative valuation of consumption of legal cannabis, b.

Table 3: Sensitivity of legalization price (in USD per ounce) and change in post-legalization demand (in percentage)

Policy parameters				Eviction price	Increase in demand			
c	b	q	F	$\underline{p}^L$	$\epsilon = -0.5$	$\epsilon = -0.6$	$\epsilon = -0.7$	$\epsilon = -0.8$
50	1.58	0.1%	1000	97.79	53.18%	65.45%	78.23%	91.49%
15	1.58	0.1%	1000	41.86	64.02%	79.03%	94.72%	111.0%
25	1.58	0.1%	1000	57.84	60.88%	75.09%	89.95%	105.34%
75	1.58	0.1%	1000	137.74	45.72%	56.11%	66.93%	78.1%
100	1.58	0.1%	1000	177.68	38.45%	47.07%	56.01%	65.21%
150	1.58	0.1%	1000	257.58	24.59%	29.91%	35.39%	40.98%
250	1.58	0.1%	1000	417.37	-0.46%	-0.56%	-0.64%	-0.74%
50	0.50	0.1%	1000	30.95	66.18%	81.74%	98.02%	114.91%
50	0.75	0.1%	1000	46.42	63.12%	77.9%	93.36%	109.38%
50	1.00	0.1%	1000	61.89	60.09%	74.1%	88.74%	103.92%
50	2.00	0.1%	1000	123.78	48.31%	59.34%	70.84%	82.73%
50	3.00	0.1%	1000	185.68	37.03%	45.29%	53.87%	62.69%
50	1.58	0.01%	1000	82.06	56.2%	69.22%	82.81%	96.89%
50	1.58	0.2%	1000	111.56	50.59%	62.2%	74.3%	86.82%
50	1.58	0.5%	1000	146.68	44.07%	54.06%	64.45%	75.17%
50	1.58	1.0%	1000	197.33	34.96%	42.73%	50.78%	59.05%
50	1.58	1.5%	1000	243.58	26.95%	32.82%	38.88%	45.06%
50	1.58	2.0%	1000	287.37	19.64%	23.83%	28.14%	32.5%
50	1.58	0.1%	500	88.84	54.9%	67.59%	80.84%	94.56%
50	1.58	0.1%	1500	106.74	51.5%	63.34%	75.68%	88.45%
50	1.58	0.1%	2000	115.68	49.82%	61.24%	73.13%	85.44%
50	1.58	0.1%	3000	133.58	46.49%	57.07%	68.09%	79.48%
50	1.58	0.1%	5000	169.37	39.95%	48.93%	58.25%	67.85%

Notes: Behavioral parameters are set at $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$, and $\gamma^- = 0.69$ as estimated by Tversky and Kahneman (1992). Variation in demand relies on the baseline estimates for the parameters of the distribution of θ corresponding to different price elasticities of demand, as described in Table 6.

The first row presents the benchmark values of the policy parameters in columns 1 to 4, the eviction legal price $\underline{p}^L$, which is around USD 98, and the resulting relative increase in the extensive margin of consumption *post-legalization*. It shows that the increase in demand is predicted to be between 53% and 92% depending on the price elasticity of demand used for the calibrations (in the range between -0.5 and -0.8).

Rows 2 to 7 of Table 3 present several scenarios regarding the marginal cost of operating on the black market. In the first scenario, the marginal cost c chosen is the benchmark value discussed above. In the second scenario, the marginal cost for illegal production and distribution of cannabis drops to 15$ per ounce. This captures a situation in which controls are very lax and hence are not inflating the marginal cost of operation for illegal suppliers, which comes close to the estimates given by Caulkins (2010).[20] We also present other cases where intensifying the repression drastically raises the marginal cost of production on the black market.

Another parameter whose evolution is hard to predict is b. Indeed, when retail sales for cannabis are legal, new certified products appear: legalization brings product differentiation, raising b. Meanwhile, being challenged by a newly legalized market, black market producers and retailers may decide to invest in quality or better services. For instance, consumers who do not want to be seen coming in person to a dispensary, due to social stigma or professional constraints that strictly forbid them to consume cannabis (in the case of truck drivers for example), may turn to a black market delivery service. This will reduce the relative value of legal cannabis. Starting from our benchmark value, $b = 1.58$, rows 8 to 12 consider alternative cases, for b either falling to 0.50[21] or increasing to 3.00.

Rows 13 to 18 vary the probability of being caught on the black market, q. Once a legal market is established, it may become more costly to detect consumers of illegal cannabis than it was under strict prohibition, such that q may decrease. On the other hand, it may be politically more feasible to be tough on consumers of illegal cannabis when there is a legal alternative, such that q may increase.

Rows 19 to 23 allow for several values of fines, F. For similar reasons, it may or may not be easier to implement higher fines with legalization, which is captured by the range of values chosen for the sensitivity analysis. The results highlight that the recommended eviction price, presented in column 4, and the rise in cannabis consumption *post-legalization*, in columns 5 to 8, respond strongly to each policy parameter, c, b, q and F. Some are easier to change than others.

[20] We simply take the median of the 80$ to 470$ per pound interval. We obtain approximately 15$.

[21] For the sake of simplicity, we prove the existence and uniqueness of θ^L under the sufficient condition $b \geq 1$. However it is not necessary. In the particular case considered in the calibration θ^L exists and is unique even if $b = 0.5$.

An intuitive idea to increase the eviction price $\underline{p}^L$, at seemingly low costs, would be to increase the fine F. For example, with a USD 5000 fine for illegal purchase and other parameters set at their benchmark values then a legal price around USD 169 per ounce would evict illegal providers and contain the increase in consumption below 40% to 68%. However, this ignores the fact that high fines are expensive to enforce as they crowd the judicial system.

For similar reasons, it is costly to enforce arrests of users of recreational cannabis. Yet maintaining the probability of arrest to the prohibition level, $q_L = q = 1\%$, entails an increase in the price of legal cannabis up to USD 197 per ounce, which would contain the increase in consumption below 35% to 60%.

Marginal costs of production for illegal providers play a large role in the control of cannabis consumption *post-legalization*. For example, not enforcing repression against illegal providers would entail low production costs at around USD 15 per ounce and push the eviction price of cannabis down to USD 42. This would increase consumption *post-legalization* by 64% to 111%. So maintaining pressure on criminal networks is key to the success of the reform.

An under-explored channel is to strengthen the quality differential between legal and illegal cannabis. It may seem counter-intuitive to invest in quality control and marketing of legal cannabis to promote the *post-legalization* demand. Yet, the eviction price strongly increases with the valuation of quality of legal cannabis, b, such that consumption decreases with it. For example, doubling the relative value of legal cannabis (from 1.58 to 3), pushes the eviction price of cannabis up to USD 186, limiting the increase in consumption to 37% to 63% *post-legalization*. Although this channel is effective at tilting consumption towards the legal sector and controlling it, quality differentiation has been often neglected by governments in different parts of the world. This explains in part these countries' disappointing experience with reform (see more on this below).

The policy scenarios we considered so far only affected one parameter at a time. In practice, these measures can be combined, which, with convex cost functions, is more cost-effective (see Section 6). For instance if the probability of arrest goes up to 1 % *post-legalization* and fines are set to USD 3000, the eviction price can be set at US 422, which maintains consumption at the prohibition level. This is only one example. Other examples and a discussion of the sensitivity analysis of eviction price and *post-legalization* consumption to combined measures can be found in Table 11 in Appendix H.3.

6 Enlarging the set of policy objectives

So far we have focused on policies that try to eliminate the black market while controlling the subsequent increase in consumption, but governments pursue a larger set of objectives when they implement legalization policies. These include restricting access to psychotropic drugs for the youngest users, reducing the negative externalities generated by the consumption of uncertified psychoactive substances, redeploying police forces and relieving congestion in courts and prisons to reduce enforcement costs, increasing consumer surplus, developing a sector that generates legal activities and employment while controlling the quality of products and generating new tax revenues. Although current reforms share most of these objectives, they may have different priorities.

In this section we model a (utilitarian) government's objective function as a linear combination of these objectives and study how they interact. We show that they sometimes reinforce each other, while in other cases they are conflicting. This offers an explanation as to why some reforms have been disappointing in the past.

The timing is as follows.

1. The government chooses the price of the legal cannabis $p^L = (1+\tau)c^L$, where c^L is the marginal cost of producing the commodity legally and τ is the level of excise tax. In other words, it chooses the final price paid by consumers by choosing the tax rate. It also sets the level of repression by influencing, on the demand side, the probability of arrest q and the fine F, and on the supply side, the increase in marginal cost to produce illegally due to repression, $\delta \geq 0$, such that $c = (1+\delta)c^L$. Finally, the government takes measures to boost the quality differential between legal and illegal products, $b \geq 1$.

2. The consumers decide whether to consume or not, and on which market. Depending on the relative prices of legal and illegal products and the quality differential, the black market survives or is eradicated (see Appendix I.1 for more details).

Let's note $e = (F, q, \delta)$ the level of enforcement of repression against consumers and producers of illegal cannabis. The government objective function is:

$$W^G(e, b, \tau) = \alpha_T T(e, b, \tau) - \alpha_C C(e, b, \tau) + \alpha_S S^c(e, b, \tau) - \alpha_\xi \xi(e, b, \tau) \tag{15}$$

where $\alpha_T \geq 0$, $\alpha_C \geq 0$, $\alpha_S \geq 0$, $\alpha_\xi \geq 0$ and where

- $T(e, b, \tau) = \tau c^L D^L \left(p, (1+\tau)c^L | b\right)$ is the revenue from excise taxes on legal cannabis.
- $C(e, b, \tau) = E(\delta, q) - qD^I \left(p, (1+\tau)c^L \middle| b\right) F$ is the enforcement cost net of the fines, with the gross cost of enforcement, $E(\delta, q)$, being increasing and convex in δ and q.
- $S^c(e, b, \tau) = \mathcal{S}^L(p, (1+\tau)c^L|b) + \mathcal{S}^I(p, (1+\tau)c^L|b) - \Psi(b)$ is the sum of the consumer surpluses on the legal and illegal markets, net of $\Psi(b)$, the cost of legal cannabis quality improvement, which is strictly increasing and convex.
  - $\mathcal{S}^L \left(p, (1+\tau)c^L|b\right) = \displaystyle\int_{(1+\tau)c^L}^{\infty} D^L(p, t|b)\mathrm{d}t$ is the net consumer surplus on the legal market.
  - $\mathcal{S}^I \left(p, (1+\tau)c^L|b\right) = (1-q)\int_p^{\bar{p}^I} D^I \left(t, (1+\tau)c^L|b\right) \mathrm{d}t - qD^I \left(p, (1+\tau)c^L|b\right) F$ is the net consumer surplus on the illegal market, with $\bar{p}^I$ being the choke-off price on the illegal market. It is defined as the price p such that equation (8) holds with equality for $p^L = (1+\tau)c^L$.
- Finally the negative externalities generated by the legal and the illegal sectors are increasing in their respective demands: $\xi(\tau, e, b) = \xi_I D^I \left(p, (1+\tau)c^L|b\right) + \xi_L D^L \left(p, (1+\tau)c^L|b\right)$, with $\xi_I \geq 0$ and $\xi_L \geq 0$.

We consider in turn four different objectives that can be decentralized through the choice of enforcement of sanctions against the illegal sector, $e = (F, q, \delta)$, and regulation of the legal sector (b, τ), and study whether they are compatible with the goal of reducing organized crime by setting an eviction price for legal cannabis.

Minimizing negative externalities: $\alpha_T = \alpha_S = \alpha_C = 0$ and $\alpha_\xi > 0$

Because both legal and illegal consumption of psychotropic substances entail health hazards, a government focusing on such externalities minimizes $\xi(\tau, e, b) = \xi_I D^I \left(p, (1+\tau)c^L|b\right) + \xi_L D^L \left(p, (1+\tau)c^L|b\right)$.

Prohibition corresponds to the case in which legal use of cannabis is perceived as having larger negative externalities than illegal use: $\xi_I \leq \xi_L$. Only in this case does the government minimize total consumption, which is best achieved by a criminal monopolist. All else being equal (i.e., for the same investment level in repression) legalization inevitably leads to an increase in demand as shown in Section 4. Therefore, for a given repression budget, prohibition is the policy that minimizes total consumption of cannabis. To shrink the (black market) demand for cannabis, the government should invest in repression. Increasing the sunk costs and the marginal cost of producing illegally pushes the number of illegal providers N down and their prices up. It should also increase the repression against users (i.e., q and F) to decrease the number of people willing to purchase the illegal substance (i.e., to increase θ^I in 3).

In contrast, a government may consider that illegal cannabis is more harmful than legal cannabis for several reasons. The quality of legal products can be certified and health damages reduced. Illegal cannabis can be sold to minors or vulnerable groups, who are at risk of developing psychosis. The ban of sale to the underaged cannot be enforced on the black market: many criminals do not mind who is buying their products, as long as they get paid. Finally, it generates a whole range of criminal activities, including violence, corruption and money laundering (see Section 2). This case corresponds to $\xi_I > \xi_L \geq 0$. Clearly if $\xi_L = 0$, the legalization at eviction price $\underline{p}^L = bv\theta^I(c)$ is optimal. If $\xi_L > 0$, the government seeks to annihilate illegal consumption while controlling legal demand, which is achieved through the policy mix described in the corollary 1.

Minimizing net enforcement cost: $\alpha_T = \alpha_S = \alpha_\xi = 0$ and $\alpha_C > 0$

A government may want to minimize the burden for tax payers of the net enforcement cost of repression, $C(\tau, e, b) = E(\delta, q) - qD^I\left(p, (1+\tau)c^L\right)F$. In practice, $qD^I\left(p, (1+\tau)c^L\right)F$, the revenue from arrests, is always lower than the gross cost of enforcement, $E(\delta, q)$. The solution consists in implementing the eviction price $\underline{p}^L = bv\theta^I(c)$. The government avoids investing too much in repression (q and δ should be minimal) as it is costly. It implies that $\theta^I(c)$ in (3) will be low in equilibrium. It also implies that the level of taxes will have to be relatively low at $\tau^{\alpha_C} = \frac{bv\theta^I(c)}{c^L} - 1 > 0$ since $v\theta^I(c) > c \geq c^L$. In other words, minimizing the cost of enforcement in a regulated cannabis market is best achieved by implementing a relatively low eviction price, which means that the subsequent increase in demand for cannabis is large. To manage the demand, the government should encourage investment in quality of the legal products, which increases the eviction price and implies a lower increase in *post-legalization* demand. This obviously comes at a cost, which is not internalized in this objective as it is borne by the private sector (i.e., the firms that sell legal cannabis).

A government concerned with the increase in consumption related to legalization at the eviction price may try to minimize the net enforcement cost, while containing consumption. This is typically the objective of most prohibitionist governments, which corresponds to $\alpha_C > 0$ and $\alpha_\xi > 0$ with $\xi_I < \xi_L$. The problem they solve is to minimize $C(e) = E(\delta, q) - qD^I\left(p, (1+\tau)c^L|b\right)F$ subject to

$D^I(p) \leq \bar{D}$. Since reducing the illegal demand is only made possible by further – costly – investments, for a given level of fine F, the constraint is binding: $D^I\left(p, (1+\tau)c^L|b\right) = \bar{D}$ and the optimal levels of q and δ then satisfy

$$\frac{\frac{\partial D^I\left(p,(1+\tau)c^L|b\right)}{\partial q}}{\frac{\partial D^I\left(p,(1+\tau)c^L|b\right)}{\partial \delta}} = \frac{\frac{\partial E(\delta,q)}{\partial q} - F\bar{D}}{\frac{\partial E(\delta,q)}{\partial \delta}} \tag{16}$$

Equation (16) is a standard result: to optimize the utilization of inputs (here law enforcement resources) the marginal rate of transformation between q and δ in terms of reduction of demand should be equal to their relative marginal cost. Interestingly, everything else being equal, increasing q is more cost effective than increasing δ as the government collects fines when users are arrested. Technically, the Lagrange multiplier of the optimization problem is increasing in the fine amount F. In theory, fixing a very large value for F is a cheap way to control demand. Yet, as mentioned in Section 5, very high fines are not feasible in practice, as most individuals caught would not be able to pay them. This would result in – costly – congestion of the judicial system.

Maximizing consumer surplus: $\alpha_T = \alpha_\xi = \alpha_C = 0$ and $\alpha_S > 0$

If a government focuses on consumer surplus, it should choose a price p^L lower than (or equal to) the eviction price $\underline{p}^L = bv\theta^I(c)$. Indeed, for the same quantity consumed, the surplus of users is larger with a legal option than an illegal one. The government should therefore implement a legalization policy with a price low enough to shut down the illegal market. In the limit, when it has no other objective, it should set the tax at $\tau = 0$, so that $p^L = c^L$. The government should also aim to improve the quality of cannabis products (notably in terms of variety, availability, marketing and packaging). The quality investment that maximizes consumer surplus equalizes the marginal surplus of consumers with the marginal cost of quality improvement: $\int_{(1+\tau)c^L}^{\infty} \frac{\partial D^L(t|b)}{\partial b} \mathrm{d}t = \Psi'(b)$.

Maximizing tax revenue: $\alpha_S = \alpha_\xi = \alpha_C = 0$ and $\alpha_T > 0$

When focusing on tax revenue, the government will choose $\tau^{\alpha_T} > 0$ such that $\frac{\partial T}{\partial \tau} = 0$, assuming an interior solution exists. This is equivalent to:

$$1 - G(\theta^l) = \tau c^L g(\theta^l) \frac{\partial \theta^l}{\partial p^L}, \tag{17}$$

with $\theta^l = \theta^0 = \frac{p^L}{bv}$ if in the initial situation the black market has been eliminated, and $\theta^l = \theta^L$ defined in (7) if not. In Appendix I.2, we develop an example where θ follows an exponential distribution on the positive real line so that we can derive closed form solutions. This simple example highlights that the unconstrained solution (i.e., in the absence of competition by the black market) leads to a larger excise tax than the constrained solution: $\tau_0^{\alpha_T} \geq \tau^{\alpha_T}$,[22] which is intuitive. When the government does not have to deal with competition it can impose higher taxes, as the consumers are captive. Unsurprisingly, the price resulting from the tax optimization problem is generally higher than the eviction price $\underline{p}^L = bv\theta^I((1+\delta)c^L)$.

More generally, when the government aims to maximise tax revenue, a portion of the black market will survive. As in Section 5, we run calibrations to compute the prices in both the legal and the illegal markets when the government focuses on maximizing tax revenues. We use here the same benchmark values as in Section 5 for the repression parameters and the marginal cost on the illegal market. Based on Caulkins (2010) and Quah et al. (2014), we choose $c^L = 25$ as reference. Methodological detail, as well as further examples, can be found in Appendix I.3. Table 4 explores different scenarios in terms of enforcement and quality.

The first column presents the *post-legalization* concentration on the illegal market. Back of the envelop computation, using the Cournot optimality condition with the benchmark black market price and marginal cost valued at USD 320 and USD 50 respectively, yields a concentration on the black market under prohibition of between 0.42 and 0.68, when the price demand elasticity varies between 0.5 and 0.8. We therefore chose 0.55 as a benchmark value for this parameter. Although the concentration on the black market is not a policy parameter *per se*, the legalization may generate changes in the concentration on the black market, which is why we study scenarios where this parameter varies from 0.10 to 1.00. Columns 2 to 5 describe the values of the other policy parameters, whose notations are unchanged. The next two columns provide the equilibrium prices on the black market and on the legal market, while columns 8 and 9 give the overall increase in demand $\Delta D(p, p^L)$, as well as the share of the black market in the total demand, $\%D^I$. Column 10 describes the tax revenue in USD *per capita* and *per annum* derived from state cannabis sales for the specified price and demand on the legal market. The last three columns provide the eviction price, as well as the corresponding increase in demand and tax revenue in USD *per capita* and *per annum*.

The results highlight that in most cases, the price on the legal market maximizing the tax revenue from legal sales is much higher than the eviction price. In this case, the black market survives and, depending on the setting, may account for up to half of the market. The overall extensive margin

[22] They are equal only when $q = 1$.

Table 4: Legalization price and resulting demand when the government maximizes tax revenue

$\frac{1}{N}$	Policy parameters c	b	q	F	Equilibrium prices p	p^L	Demand and revenue $\Delta D\left(p, p^L\right)$	$\%D^I$	R	Eviction scenario $\underline{p}^L$	$\Delta D\left(\underline{p}^L\right)$	$\underline{R}$
0.55	50	1.58	0.1%	1000	95.33	297.47	32.59%	34.73%	341	97.79	103.92%	151
0.55	25	1.58	0.1%	1000	78.60	292.94	28.85%	39.46%	320	57.84	112.88%	71
0.55	125	1.58	0.1%	1000	146.13	311.84	44.57%	18.27%	409	217.63	78.1%	350
0.55	200	1.58	0.1%	1000	200.42	338.15	53.92%	0.0%	491	337.47	54.05%	490
0.10	50	1.58	0.1%	1000	61.33	288.35	25.1%	44.03%	300	97.79	103.92%	151
0.25	50	1.58	0.1%	1000	75.15	292.01	28.09%	40.4%	316	97.79	103.92%	151
0.75	50	1.58	0.1%	1000	105.23	300.20	34.85%	31.77%	353	97.79	103.92%	151
1.00	50	1.58	0.1%	1000	115.05	302.94	37.13%	28.73%	366	97.79	103.92%	151
0.55	50	1.00	0.1%	1000	56.11	67.85	101.83%	0.0%	88	61.89	103.92%	77
0.55	50	1.10	0.1%	1000	55.20	84.04	75.92%	15.23%	103	68.08	103.92%	90
0.55	50	1.30	0.1%	1000	76.13	173.87	44.05%	30.62%	205	80.46	103.92%	115
0.55	50	1.80	0.1%	1000	105.56	393.40	28.03%	36.07%	443	111.41	103.92%	180
0.55	50	1.58	0.2%	1000	92.88	302.42	33.49%	33.16%	351	111.56	100.87%	177
0.55	50	1.58	0.5%	1000	86.81	314.70	35.6%	29.16%	377	146.68	93.19%	240
0.55	50	1.58	1.0%	1000	78.42	331.60	38.19%	23.32%	413	197.33	82.36%	320
0.55	50	1.58	0.0%	-	98.73	290.60	31.28%	36.86%	327	79.00	108.11%	115
0.55	50	1.58	0.1%	100	98.65	295.63	31.07%	36.68%	333	81.68	107.51%	120
0.55	50	1.58	0.1%	500	97.17	296.45	31.74%	35.82%	336	88.84	105.91%	134
0.55	50	1.58	0.1%	1500	93.49	298.51	33.44%	33.62%	346	106.74	101.94%	168
0.55	50	1.58	0.1%	2000	91.66	299.55	34.31%	32.49%	350	115.68	99.96%	185

Notes: The above results are based on a price demand elasticity of 0.8 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

of cannabis consumption is relatively similar between the tax maximizing and the eviction strategies. Interestingly, when the quality on the legal market is not different from the illegal market, the legal price that maximizes tax revenue is relatively close to the eviction price and very little black market survives. In other words, it is case where maximizing tax revenue and eradicating the black market are compatible objectives. However, with a legal cannabis of low quality, the level of tax revenue is very low. We show in Appendix I.3 that these observations are robust to a setting where consumers are not arrested for illegal purchases – i.e. $q_L = 0$.

Discussion of the implementation of reforms This review of legalization reform objectives shows that deflating crime through an eviction price is compatible with the maximization of consumer surplus, the minimization of enforcement cost related to the regulation of cannabis market, and the minimization of health hazards and other negative externalities connected with illegal cannabis consumption. Interestingly enough, current dominant policies of prohibition are optimal only when the government wants to minimize total consumption of cannabis. Justifying prohibition based on our general economic framework requires that public authorities consider health hazards due to legal cannabis consumption equal or worse than for illegal cannabis, and that the costs of prohibition enforcement are neglected. Finally, the maximization of tax revenue will generally conflict with the eradication of the black market. Without reinforcing repression, it leads to higher final prices of legal cannabis than eviction prices, leaving room for illegal providers to operate.

Once it has set its reform objectives, the government should allocate cannabis production and distribution rights to licensed private firms. We have already shown that for reforms to succeed, the quantity, quality, and purchasing experience for legal cannabis must be high. An important and generally overlooked tool the government can use to regulate the cannabis market is to improve the quality of legal cannabis relative to illegal cannabis. To fight the black market, an abundant provision of products of good quality is key. This effort should be increased as governments put more weight on health externalities, consumer surplus, enforcement cost or tax revenue. Since the government is generally a poor grower and an even worse retailer, the private sector may do a better job of meeting customer demand than civil servants. Since it is a basic agricultural crop, the government should license enough producers to maintain a steady supply of cannabis and avoid high markups by the private sector. Production should be tightly monitored through satellite images and drones to avoid having over-production feed the black market. Sanctions in case of misconduct should be harsh. At the same time, the licensed retailers should be sufficiently numerous to give choices to customers and keep a low pre-tax price (as for tobacco retailers in the EU). The final price should be adjusted by the government by setting the level of the excise tax based on its objectives.

Legalization reforms and their discontent

Following citizens' initiative referendums in November 2012, there was legislative change in Colorado and Washington State to end cannabis prohibition in 2013 and 2014. The reforms gave priority to reducing the costs of prohibition, developing a new sector of activity, and generating tax revenue.[23] Since the initial goal was to meet consumers' needs, production, distribution and sale were entrusted to private operators, who invested in market-driven R&D and quality development. A legal industrial sector has since developed: as of today, each of these states accounts nearly three times more recreational cannabis retailers than McDonald's restaurants (see Table 2). This booming legal market

[23]The *Colorado Marijuana Legalization Amendment,* or *Amendment 64*, claims that cannabis legalization is *"in the interest of the efficient use of law enforcement resources, enhancing revenue for public purposes, and individual freedom"*.

generates a substantial revenue, estimated at around USD 1 billion in 2016 in each of these states (for a population of 5.6 million in Colorado and 7.4 million in Washington State).

In Washington State, the level of taxes is high, as are quality requirements. This explains why the black market is still thriving, representing 15 % to 50 % of the cannabis transactions (Arcview Market Research and BDS Analytics, 2019).[24] Nevertheless, a few years after legalization, both states are quite happy with the impact of the reforms on their local finances and economy, while adult consumers enjoy a great variety of high quality cannabis products. These two states had a clear set of compatible priorities that were achieved by combining a market orientation for customers with relatively high taxation.

This is in contrast with the legalization reform in California, whose main objective was to raise substantial new tax revenue. In an environment where the Medical Marijuana Laws had made the grey economy prosperous, the introduction price/quality ratio of the legal cannabis was too high compared to the price/quality ratio on the illegal market. Since the cannabis industry was already well established under prohibition, it reacted swiftly to the legal offer by lowering its prices. It has since grown, absorbing customers who previously were purchasing medical cannabis legally. Illicit transactions account for approximately 80% of the Californian cannabis market.[25] The government of the state is quite disappointed by the reform. A better policy would have been to fix a lower introduction price of legal cannabis (i.e., lower tax rate, at least initially), combined with investments to raise quality, marketing to give a competitive edge to the legal products, and a stronger push back against illegal cannabis producers and consumers, in line with the policy mix we describe in Section 4.

The reform in Uruguay also failed to reach its main objectives, which were to annihilate the black market and strengthen the protection of minors and the safety of adult users, while controlling total consumption. This led the government to create a state monopoly, which delegated the production of cannabis to strictly regulated private companies. To eradicate the black market, Uruguay had initially set the price of legal cannabis at the same level as the black market. However, the government's attempt to control consumption led to a severe underestimation of the size of the market and

[24] Kevin Murphy. 2019. "Cannabis' Black Market Problem". *Forbes.* April 4.. Oregon, which implemented a very liberal reform and where there were, as of 2019, three times more dispensaries as McDonald's restaurants, has been facing a very similar issue (see Natalie Fertig. 2019. "How Legal Marijuana Is Helping the Black Market". *Politico.* July 21.). In this state, low entry barriers, coupled with an extraordinary crop in 2018, have created 6 years worth of oversupply (Oregon Liquor Control Commission, 2019).

[25] Kevin Murphy. 2019. "Cannabis' Black Market Problem". *Forbes.* April 4..

rationing.[26] Thus, several years after the official legalization in 2012, a majority of consumers continue to turn to the black market for their consumption, defeating the initial objective of the reform.

With similar objectives of eradicating the black market and drug-related crime, Canada made the same mistake as Uruguay in underestimating the needs of the consumers of cannabis, both in quantity and in quality. This created rationing and the users had to turn to the black market for their consumption. Since the federal government gave the Provinces the responsibility of implementing the new policy by regulating the retail markets, as well as setting possession, use, and cultivation limits for personal use, the nation-wide legalization policy adopted in 2017 and 2018 took different forms across Provinces.

For instance in Alberta, home-cultivation is allowed[27] and online retail sales are managed by a government monopoly, while retail sales are left to private licensed stores. In Québec, one cannot home-grow cannabis and retail sales are organized by the government. The *Société Québécoise du Cannabis (SQDC)*, a subsidiary of the provincial society for alcohols, provides cannabis both in shops and online.[28] Dried flower products are priced between CAD 8 and 10 per gram by the SQDC, depending on potency and strain type, which is close to the *pre-legalization* black market price ($p^L = p$). As discussed in Section 4, this policy did not anticipate the response of smugglers on the black market and the average black market price in Québec fell to below CAD 6 per gram, as reported Mid March 2019 by the crowd-sourced website priceofweed.com.

It is still too early to assess precisely the effects of legalization on overall consumption and the size of the black market. Using monetary circulation in Canada, Goodhart and Ashworth (2019) show that the need for cash decreased in the country just after the legalization, which they interpret as a decrease in black market cannabis transactions. For them, the country is heading towards one of the goals Trudeau had set in 2015: "[keeping] profits out of the hands of criminals".[29] However, this optimism is contradicted by the recent evolution of the market. Facing a shortage on the supply side, legal providers have focused on increasing their production (i.e. quantity), with no effort to improve the quality or the variety of their products, nor the purchasing experience of the consumers (resulting

[26] By the end of 2017, only two producers were approved for an annual volume of one ton each, while the market has been estimated at between 35 and 40 tons. In addition, the hostility of pharmacists, charged by the State to sell cannabis, has made it more difficult and unpleasant for users to obtain supplies. The authorization of self-cultivation or small producers' clubs, also tightly limited and regulated, has not compensated for the inadequacy of the public offer.

[27] Up to four active plants for personal use.

[28] As of March 2019, SQDC stores only open from Wednesday to Sunday, "due to the current supply shortages (...) until product availability is more stable" (SQDC's website, www.sqdc.ca, March 19, 2019). A year later, SQDC stores' schedule covers the whole week and about 40 stores are expected throughout Québec.

[29] Liberal Party. 2015. "Real change: a new plan for a strong middle class". https://www.liberal.ca/wp-content/uploads/2015/10/New-plan-for-a-strong-middle-class.pdf

in a low b). As a result of this failure to meet consumers' needs, the black market has survived by lowering its prices, which is consistent with the theory, and the stock market prices of the new legal firms have plummeted.[30] Statistics Canada, the national statistical agency, estimates that about 75% of cannabis users still use illegal cannabis. It implies that the overall (legal plus illegal) demand for cannabis has increased in Canada, with a thriving black market. Here again, the failure to anticipate the reaction of the black market to legalization, to predict accurately the rise in demand for legal cannabis and to internalize consumers' demand for quality, led to poorly designed reforms.

7 Conclusion

Designing a policy that both eliminates organized crime and limits the increase in cannabis use *post-legalization* is not trivial. Examples of what can go wrong include situations in which cannabis is legal but too expensive (e.g., California) or rationed and of low quality (e.g., Uruguay or Canada). Both scenarios result in flourishing illegal businesses with no significant decrease in crime. We explore how to avoid such unexpected effects of legalization policies. The policy mix we propose enables public authorities to strangle the cannabis black market by implementing a legal alternative and to control the increase in cannabis consumption *post-legalization*.

Our findings highlight the complementarities between legalization of high quality cannabis (in terms of purchasing experience, variety of the product, potency and purity) and repression, providing policymakers with guidelines to overcome the legalization/repression trade-off. Legalization will be effective at regulating the demand for cannabis if consumers are compelled to buy on a legal market rather than illegally, and, at the same time, if illegal suppliers are targeted by repressive measures that drive them out of business. Raising the level of punishment and investing in repression not only against suppliers, but also against users of illegal drugs, enables authorities to implement higher legal prices for cannabis while undermining dealers.

Although our analysis focuses on how to achieve full legalization by eliminating the black market while containing consumption *post-legalization*, our general framework can be used to study a broader set of objectives. Extensions we discuss show that our policy mix enables governments to reach differ-

[30] Levinson-King, Robin. 2019. "Why Canada's cannabis bubble burst". *BBC News*. December 29. https://www.bbc.com/news/world-us-canada-50664578

ent objectives, such as the minimization of externalities or of enforcement costs, or the maximization of consumer surplus. Again, the analysis highlights the importance of offering high quality legal products to achieve these objectives. Finally, to shed more light on consumption behavior *post-legalization*, future research should account for the large heterogeneity of consumers, in particular regarding their risk aversion, intensive margin of consumption and liquidity constraints.

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Appendix

A Cannabis laws in the U.S.

As of spring 2020, eleven states and the District of Columbia have legalized the use of recreational cannabis and nine additional legalization ballots are expected to take place between November 2020 and November 2022. Cannabis possession remains a felony in other states such as Arizona, where sanctions and fines to enforce the law differ a lot. For example in Arizona, there is no guideline for punishment regarding small amounts of cannabis and possessing 2 pounds or less entails a risk of incarceration of up to 2 years and a fine of up to USD 150,000. In contrast, any amount on a first offense in Iowa is only a misdemeanor punishable by a maximum prison sentence of 6 months and a USD 1,000 fine.

The table below offers a synthetic overview of state cannabis laws across the United States. For each state, we reported the year during which cannabis was decriminalized in the second column. The third column records the year of the first ballot to legalize the use of medical cannabis, i.e. to instate a *Medical Marijuana Law* (MML), while the fourth column gives the year during which such a law was passed. The fifth column lists the year of the first ballot to legalize the recreational use of cannabis, and the sixth column the year of such a law being passed. The final column reports the year of the first legal retail sales of cannabis. Dashes represent the absence of the event described in the corresponding column.

State	Decrim.	1st MML ballot	MML	1st rec. ballot	Rec.	Retail
AL	-	-	-	-	-	-
AK	1975[a]	1998	1998	2000	2014	2016
AZ	-	1996	2010	2016	-[b]	-

[a]Alaska issued a cannabis decriminalization bill on May 16, 1975, which is two weeks before the famous *Ravin* decision, protecting the possession of small amounts under constitutional privacy rights, was issued. Decriminalization of cannabis came into effect on June 5, 1975. The timeline of cannabis policy in Alaska then becomes fuzzy: further decriminalization was billed in 1982, then cannabis was recriminalized in 1990, decriminalized in 2003, then recriminalized in 2006; while the *Ravin* caselaw would still interact with the criminal state law (Brandeis, 2012). Legalization approved in 2014 ended this confusion.

[b] A cannabis legalization initiative is expected to be on the ballot in November 2020 ("Marijuana on the ballot", *Ballotpedia*. Retrieved online May 2020, https://ballotpedia.org/Marijuana_on_the_ballot)

State	Decrim.	1st MML ballot	MML	1st rec. ballot	Rec.	Retail
AR	-[c]	2012	2016	- [b]	-	-
CA	1975	1996	1996	1972	2016	2018
CO	1975	2000	2000	2012	2012	2014
CT	2011	-[d]	2012	-	-	-
DE	2015	- [d]	2011	-	-	-
D.C.	2014	1998	2010	2014	2014	-
FL	-[e]	2014	2016	-[f]	-	-
GA	-[e]	-	-	-	-	-
HI	2020	- [d]	2000	-	-	-
ID	-	-	-	-	-	-
IL	2016	- [d]	2013	-[g]	2019	2020
IN	-	-	-	-	-	-
IA	-	-	-	-	-	-
KS	-	-	-	-	-	-
KY	-[e]	-	-[h]	-	-	-
LA	-[e]	- [d]	2015[i]	-	-	-
ME	1975	1999	1999	2016	2016	-[j]
MD	2014	- [d]	2013	-	-	-
MA	2008	2012	2012	2016	2016	2018
MI	2018	2008	2008	2018	2018	2019
MN	1976	- [d]	2014	-	-	-

[c] Although cannabis use remains a crime under state law, it is decriminalized locally.

[d] *Medical Marijuana* was not on the ballot: instead, it was signed into law after legislative approval.

[e] Although cannabis use remains a crime under state law, it is decriminalized locally.

[f] A cannabis legalization initiative is expected to be on the ballot in November 2022 ("Marijuana on the ballot", *Ballotpedia*. Retrieved online May 2020, https://ballotpedia.org/Marijuana_on_the_ballot)

[g] The recreational use of cannabis was not on the ballot: instead, it was signed into law after legislative approval.

[h] A *Medical Marijuana* bill was presented to the House of Kentucky in January 2020. It is presently under evaluation by the Senate Judiciary Committee (Kentucky General Assembly, *House Bill 136*; retrieved online 2nd May 2020, url: https://apps.legislature.ky.gov/record/20rs/hb136.html).

[i] Although *Medical Marijuana* was signed into law in 2015, it did not become effective before 2019.

[j] The first retail sales were projected for June 2020, but are being delayed due to the covid-19 pandemic (Penelope Overton, 2020. "Pandemic puts launch of Maine's recreational marijuana market on hold". *Portland Press Herald*. April 10. https://www.pressherald.com/2020/04/10/pandemic-puts-maine-adult-use-cannabis-market-on-hold/#

State	Decrim.	1st MML ballot	MML	1st rec. ballot	Rec.	Retail
MS	1978	-[k]	-	- [f]	-	-
MO	2014	2018	2018	- [b]	-	-
MT	-[e]	2004	2004	-[b]	-	-
NE	1979	-[k]	-	-[b]	-	-
NV	2016	1998	1998	2006	2016	2017
NH	2017	- [d]	2013	-	-	-
NJ	-	-[d]	2010	- [b]	-	-
NM	2019	-[d]	2007	-	-	-
NY	1977	- [d]	2014	-	-	-
NC	1977	-	-	-	-	-
ND	2019	2016	2016	2018	-	-
OH	1975	- [d]	2016	2015	-[b]	-
OK	-[l]	2018	2018	-[b]	-	-
OR	1973	1998	1998	2012	2014	2015
PA	-[e]	- [d]	2016	-	-	-
RI	2012	- [d]	2005	-	-	-
SC	-	-	-	-	-	-
SD	-	2006	- [k]	- [b]	-	-
TN	-	-	-	-	-	-
TX	-[e]	-	-	-	-	-
UT	-	2018	2018	-	-	-
VT	2013	- [d]	2004	- [g]	2018	-[m]
VA	-	-	-	-	-	-
WA	2012	1998	1998	2012	2012	2014

[k] A *Medical Marijuana* ballot is expected to be on the ballot in November 2020 ("Marijuana on the ballot", *Ballotpedia*. Retrieved online May 2020, https://ballotpedia.org/Marijuana_on_the_ballot).

[l] A cannabis decriminalization initiative is expected to be on the ballot in November 2020 ("Oklahoma State Question 812, Marijuana Decriminalization Initiative (2020)", retrieved online on Ballotpedia; url: https://ballotpedia.org/Oklahoma_State_Question_812,_Marijuana_Decriminalization_Initiative_(2020)).

[m] As of Spring 2020, a bill implementing retail sales of recreational cannabis is being evaluated by the State House of Representatives (Vermont General Assembly, S.54; retrieved online on 2nd May 2020 https://legislature.vermont.gov/bill/status/2020/S.54).

State	Decrim.	1st MML ballot	MML	1st rec. ballot	Rec.	Retail
WV	-	-	2017[n]	-	-	-
WI	-[e]	-	-	-	-	-
WY	-	-	-	-	-	-

B Characterizing the marginal type of consumer θ^I, indifferent between no consumption and illegal consumption

An individual of type θ deciding between illegal consumption and no consumption considers the lottery $[-p-F, \theta v - p; q, 1-q]$. Not consuming entails a zero payoff. The utility associated with illegal consumption is given by: $w^+(1-q)u(\theta v - p) + w^-(q)u(-p-F)$, where u is a value function which is continuous, derivable and strictly increasing on $\mathbb{R}$, and such that $u(0) = 0$.

The consumption condition is written as: $w^+(1-q)u(\theta v - p) + w^-(q)u(-p-F) > 0$.

Let us define $V_I(\theta) = w^+(1-q)u(\theta v - p) + w^-(q)u(-p-F)$

The marginal individual θ^I, indifferent between illegal consumption and no consumption, is characterized by:

$$V_I(\theta) = 0 \tag{18}$$

Since the value function u from not consuming is such that $u(0) = 0$, this condition is the same, whether θ^I is derived using Expected Utility Theory or Prospect Theory. The only difference is that under Expected Utility Theory, the weighting functions w^+ and w^- are equal to the identity. Since u is a function which is continuous, derivable, strictly increasing on $\mathbb{R}$, it admits a reciprocal function u^{-1} which is also strictly increasing and such that $u^{-1}(0) = 0$. Condition (18) is equivalent to:

$$\theta^I = \frac{u^{-1}\left(\frac{-w^-(q)u(-p-F)}{w^+(1-q)}\right) + p}{v} \tag{19}$$

We deduce that θ^I exists and is unique, with $\theta^I > \frac{p}{v}$ if $q > 0$ and $\theta^I = \frac{p}{v}$ if $q = 0$.

Expression (19) clearly shows that θ^I increases with q, p and F, since the value function u, its reciprocal and the weight functions are strictly increasing.

Finally, we focus on the absolute value of the price elasticity of demand, $\epsilon_{D,p}$, as defined in (4).

[n] Although a bill regulating medical use of cannabis was signed in April 2017, Medical Marijuana Laws have not been implemented yet in West Virginia.

After differentiating $\epsilon_{_{D,p}}$ with respect to q, one can check that:

$$\frac{d\epsilon_{_{D^I,p}}}{dq} = \frac{d\{\frac{g(\theta^I)}{1-G(\theta^I)}\}}{d\theta^I}\frac{d\theta^I}{dq}\frac{d\theta^I}{dp}p + \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d^2\theta^I}{dpdq}p. \tag{20}$$

As θ^I increases with p and q it follows that $\epsilon_{_{D^I,p}}$ increases with $q \in [0,1]$ if the cross-derivative of θ^I with p and q is positive and if the distribution $G(\theta)$ satisfies the monotone hazard rate (MHR) property. We next check under what condition this cross derivative is positive.

Differentiating equation (18) yields: $\sum_{i\in\{p,q,\theta,F\}} \alpha_i \mathrm{d}i = 0$, with

$$\begin{cases} \alpha_\theta = vw^+(1-q)u'(\theta v - p) \\ \alpha_q = -w^{+\prime}(1-q)u(\theta v - p) + w^{-\prime}(q)u(-p-F) \\ \alpha_p = -w^+(1-q)u'(\theta v - p) - w^-(q)u'(-p-F) \\ \alpha_F = -w^-(q)u'(-p-F) \end{cases}$$

In particular, it yields $\frac{\mathrm{d}\theta^I}{\mathrm{d}p} = -\frac{\alpha_p}{\alpha_\theta}$. From this follows that

$$\frac{\mathrm{d}^2\theta^I}{\mathrm{d}p\mathrm{d}q} = \frac{\alpha_p\alpha_{\theta q} - \alpha_{pq}\alpha_\theta}{\alpha_\theta^2}$$

where

$$\begin{cases} \alpha_{pq} = \frac{\partial \alpha_p}{\partial q} = w^{+\prime}(1-q)u'(\theta v - p) - w^{-\prime}(q)u'(-p-F) \\ \alpha_{\theta q} = \frac{\partial \alpha_\theta}{\partial q} = -vw^{+\prime}(1-q)u'(\theta v - p) \end{cases}$$

Since the function u is increasing and the weight functions are positive and increasing, we show that $\alpha_p\alpha_{\theta q} - \alpha_{pq}\alpha_\theta > 0$ as follows:

$$\begin{aligned} &\left[w^-(q)w^{+\prime}(1-q) + w^{-\prime}(q)w^+(1-q)\right] vu'(\theta v - p)\, u'(-p-F) > 0 \\ \Rightarrow & w^-(q)u'(-p-F)\, vw^{+\prime}(1-q)u'(\theta v - p) + w^{-\prime}(q)u'(-p-F)\, vw^+(1-q)u'(\theta v - p) > 0 \\ \Rightarrow & \alpha_p\alpha_{\theta q} - \alpha_{pq}\alpha_\theta > 0 \end{aligned}$$

We conclude that $\frac{\mathrm{d}^2\theta^I}{\mathrm{d}p\mathrm{d}q} > 0$ and that $\epsilon_{_{D^I,p}}$ increases with $q \in [0,1]$ if the distribution $G(\theta)$ satisfies the monotone hazard rate (MHR) property.

C Characterizing the marginal consumer $\theta^L(p, p^L)$, indifferent between legal and illegal consumption

A consumer of type θ deciding between legal and illegal consumption faces a choice between a certain payoff of $\theta bv - p^L$ and the lottery $[-p-F, \theta v - p; q, 1-q]$. Note first that individuals with $\theta \leq 0$ will never purchase cannabis, whether it is legal or not. Second if $\theta v - p \leq \theta bv - p^L$ the only possibility is that the individual buys either the legal product or nothing. Symmetrically if $\theta v - p > 0 > \theta bv - p^L$ the only possibility is that he/she eitherpurchases on the black market or not at all. It implies that a necessary condition for some consumers being willing to purchase cannabis illegally, while others prefer to purchase it legally, is that there exists some $\theta > 0$ such that $\theta v - p > \theta bv - p^L > 0$, or equivalently $\frac{p^L - p}{(b-1)v} > \theta > \frac{p^L}{bv}$. This requires that $\frac{p^L - p}{(b-1)v} > \frac{p^L}{bv}$ or equivalently $p^L > bp$.

C.1 Under Expected Utility Theory

If individuals are expected utility maximizers the marginal consumer, indifferent between legal and illegal consumption, solves the following equation: $(1-q)u(\theta v - p) + qu(-p-F) = u\left(\theta bv - p^L\right)$. Let

$$V_1(\theta) \equiv (1-q)u(\theta v - p) + qu(-p-F) - u\left(\theta bv - p^L\right) \tag{21}$$

If $\theta^L > 0$ exists, it is such that $V_1(\theta) = 0$.

We deduce that for $\frac{p^L - p}{(b-1)v} > \theta > \frac{p^L}{bv}$, $V_1'(\theta) = (1-q)vu'(\theta v - p) - bvu'\left(\theta bv - p^L\right) < 0$ since u' is decreasing (i.e., u is concave) and $1 - q \leq 1$, $\theta v - p > \theta bv - p^L$, $b > 1$. Hence, if $\theta^L > 0$ exists, it is unique. We have that: $V_1\left(\frac{p^L - p}{(b-1)v}\right) = -q\left[u\left(\frac{p^L - bp}{b-1}\right) - u(-p-F)\right] < 0$. Since $V_1(\theta)$ is decreasing for $\theta \in [\frac{p^L}{bv}, \frac{p^L - p}{(b-1)v}]$, to finish the proof we need to find the condition under which $V_1\left(\frac{p^L}{bv}\right) > 0$. Therefore, whenever

$$(1-q)u\left(\frac{p^L - bp}{b}\right) > -qu(-p-F) \tag{22}$$

the equation $V_1(\theta) = 0$ admits a unique solution.

Differentiating equation (21) yields $\alpha_q \mathrm{d}q + \alpha_{p^L}\mathrm{d}p^L + \alpha_p \mathrm{d}p + \alpha_F \mathrm{d}F + \alpha_{\theta^L}\mathrm{d}\theta^L + \alpha_b \mathrm{d}d = 0$ with

$$\begin{cases} \alpha_q = u\left(-p-F\right) - u\left(\theta^L v - p\right) & < 0 \\ \alpha_{p^L} = u'\left(\theta^L v - p^L\right) & > 0 \\ \alpha_p = -qu'\left(-p-F\right) - (1-q)u'\left(\theta^L v - p\right) & < 0 \\ \alpha_F = -qu'\left(-p-F\right) & < 0 \\ \alpha_{\theta^L} = v(1-q)u'\left(\theta^L v - p\right) - bvu'\left(\theta^L bv - p^L\right) & < 0 \\ \alpha_b = -\theta^L vu'\left(\theta^L bv - p^L\right) & < 0 \end{cases}$$

It is straightforward to show that θ^L decreases with q, p, F and b, while it increases with p^L.

C.2 Under Prospect Theory

Under PT the consumer's reference level of wealth is provided by the risk free option, $\theta bv - p^L$. A potential cannabis consumer deciding between buying from the black market or from the legal sector considers the lottery $[p^L - p - F - \theta bv, p^L - p + \theta(1-b)v; q, 1-q]$. Let

$$V_2(\theta) = w^+(1-q)u\left(p^L - p - (b-1)v\theta\right) + w^-(q)u\left(-p - F - \theta bv + p^L\right). \tag{23}$$

The marginal consumer, $\theta^L(p, p^L)$, indifferent between legal and illegal consumption solves $V_2(\theta) = 0$. We have $V_2'(\theta) = -(b-1)vw^+(1-q)u'\left(\theta(1-b)v - p + p^L\right) - bvw^-(q)u'\left(-p - F - \theta bv + p^L\right) < 0$ since $b \geq 1$ and u is strictly increasing.

We have: $V_2\left(\frac{p^L-p}{(b-1)v}\right) = w^-(q)u\left(p - p^L - (b-1)F\right) < 0$ since $p^L > bp \geq p$. The strict monotonicity of $V_2(\theta)$ implies that θ^L exists and is unique whenever $V_2\left(\frac{p^L}{bv}\right) > 0$. This is equivalent to:

$$w^+(1-q)u\left(\frac{p^L-bp}{b}\right) > -w^-(q)u(-p-F) \tag{24}$$

Condition (24) under PT is equivalent to (22) under EUT, where the probability weighting function is the identity. In both cases these conditions imply that $\theta^L > 0$ exists and is unique. It is easy to check that the conditions (22) and (24) are equivalent to $p^L > \tilde{p}^L(p)$ with $\tilde{p}^L(p)$ defined in (8), with the probability weighting functions equal to the identity in the case of EUT.

Differentiating equation (23) yields: $\alpha_{\theta^L}\mathrm{d}\theta^L + \alpha_q \mathrm{d}q + \alpha_{p^L}\mathrm{d}p^L + \alpha_p \mathrm{d}p + \alpha_F \mathrm{d}F + \alpha_d \mathrm{d}d = 0$ with

$$\begin{cases} \alpha_{\theta^L} = -w^-(q)vu'\left(p^L - p - F - \theta^L bv\right) - w^+(1-q)(d-1)vu'\left(p^L - p + \theta^L(1-b)v\right) & < 0 \\ \alpha_q = {w^-}'(q)u\left(p^L - p - F - \theta^L bv\right) - {w^+}'(1-q)u\left(p^L - p + \theta^L(1-b)v\right) & < 0 \\ \alpha_{p^L} = w^-(q)u'\left(p^L - p - F - \theta^L bv\right) + w^+(1-q)u'\left(p^L - p + \theta^L(1-b)v\right) & > 0 \\ \alpha_p = -w^-(q)u'\left(p^L - p - F - \theta^L bv\right) - w^+(1-q)u'\left(p^L - p + \theta^L(1-b)v\right) & < 0 \\ \alpha_F = -w^-(q)u'\left(p^L - p - F - \theta^L bv\right) & < 0 \\ \alpha_b = -\theta^L vw^+(1-q)u'\left(p^L - p + \theta^L(1-b)v\right) - \theta vqu'\left(-p - F - \theta bv + p^L\right) & < 0 \end{cases}$$

It is straightforward to show that θ^L decreases with q, p, F and b, while it increases with p^L.

D Consumers facing legalization

D.1 Consumer choices

Appendix B characterizes the consumer θ^I indifferent, under prohibition, between not consuming and consuming illegally : $V_I(\theta) = w^+(1-q)u(\theta^I v - p) + w^-(q)u(-p-F) = 0$. Any consumer with type higher than θ^I prefers to purchase cannabis on the black market than not to consume cannabis.

Under legalization, the consumer θ^0, indifferent between legal consumption and no consumption, is characterized by $u\left(\theta^0 bv - p^L\right) = 0$. Any consumer with type higher than $\theta^0 = \frac{p^L}{bv}$ prefers to purchase cannabis legally than not consume cannabis.

Appendix C shows that consumer $\theta^L \in \left[\frac{p^L}{bv}, \frac{p^L - p}{(b-1)v}\right]$, indifferent between legal and illegal consumption, solves under

- Expected Utility Theory: $V_1(\theta) = (1-q)u(\theta v - p) + qu(-p-F) - u\left(\theta bv - p^L\right) = 0$
- Prospect Theory: $V_2(\theta) = w^+(1-q)u\left(p^L - p - \theta(b-1)v\right) + w^-(q)u\left(-p - F - \theta bv + p^L\right) = 0$
  With $V_i(\theta)$ $(i = 1, 2)$ decreasing for $\theta \in \left[\frac{p^L}{bv}, \frac{p^L - p}{(b-1)v}\right]$. Any consumer with type higher than θ^L prefers to purchase cannabis legally than illegally.

We next compare the thresholds θ^0, θ^L, and θ^I. Depending on whether the legal price, p^L, is larger than $\tilde{p}^L(p)$ defined in (8) or not (i.e., depending whether condition (24) holds or not), two cases occur.

Condition (24) does not hold ($p^L \leq \tilde{p}^L(p)$): $\theta^L \leq \theta^0 \leq \theta^I$. We have, for $i = 1, 2$, $V_i(\theta^0) = w^+(1-q)u(p^L - bp) + w^-(q)u(-p - F)$, with the weighting functions being the identity function under EUT, while by definition of θ^L, $V_i(\theta^L) = 0$. We deduce that, when condition (24) does not hold, $V_i(\theta^0) < 0 = V_i(\theta^L)$, since the function $V_i(\theta)$ is decreasing in θ, $\theta^L \leq \theta^0$. When the legalization environment is such that an individual θ^L indifferent between legal and illegal purchases is of lower type than an individual θ^0 indifferent between legal purchase and no purchase at all, the individual θ^0 retrieves a negative payoff from illegal consumption.

Finally, since $V_i(\theta)$ is strictly increasing in θ, $\theta^0 < \theta^I \Leftrightarrow V_i(\theta^0) = w^+(1-q)u(\frac{p^L - bp}{b}) + w^-(q)u(-p - F) < 0$. We deduce that $\theta^L < \theta^0 \Rightarrow \theta^0 < \theta^I$. Therefore, the condition $w^+(1-q)u(\frac{p^L - bp}{b}) < -w^-(q)u(-p - F)$, which means that (24) does not hold, characterizes the legalization environment where $\theta^L < \theta^0 < \theta^I$. For instance, this condition is always true if $p^L = p$, as it leads to $u(\frac{p^L - bp}{b}) = u\left((1-b)p\right) < 0$ since $b > 1$. More generally condition (24) does not hold when the price on the legal market adjusted for the product quality, $\frac{p^L}{v}$, is low enough compared to the black market price and the level of repression. In this case the legal market replaces the black market and $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$ new consumers appear as illustrated in Figure 1.

When the probability of arrest and the fine are unchanged, legalization necessarily increases the overall demand for cannabis. Individuals with types lower than θ^0 never purchase cannabis, as they prefer not purchasing cannabis to purchasing both legal and black market cannabis. Individuals with types $\theta^0 < \theta < \theta^I$ prefer purchasing legal cannabis to black market cannabis or to not purchasing cannabis at all. They also prefer not purchasing cannabis to purchasing it illegally. These individuals constitute new customers for the newly legalized cannabis market. The better value for money on the legal market (i.e., the higher b), the lower θ^0 and the more new consumers emerge. Individuals with types $\theta^I < \theta$ always purchase cannabis, whether retail sales are legal or not; nevertheless, they purchase cannabis legally when they can.

Condition (24) holds ($p^L > \tilde{p}^L(p)$): $\theta^I < \theta^0 < \theta^L$. The reasoning is similar to the previous case but the inequalities are inverted. Condition (24) is equivalent to $V_i(\theta^0) > V_i(\theta^L) = 0$ such that $\theta^0 < \theta^L$ when $w^+(1-q)u(\frac{p^L - bp}{b}) > -w^-(q)u(-p - F)$. Similarly $\theta^I < \theta^0 \Leftrightarrow V_I(\theta^0) = w^+(1 - q)u(\frac{p^L - bp}{b}) + w^-(q)u(-p - F) > 0$ such that $\theta^I < \theta^0$ under (24).

Here, the quality adjusted price differential between the legal market and the black market is too high for the legal market to entirely replace the black market, given the black market price and the repression parameters. Consumers with a low valuation for cannabis continue to purchase illegally. If the black market did not react to the legalization policy (i.e., assuming p is fixed), there would be no new consumers once the legal market is created and whatever the value of the quality parameter b, the overall demand for cannabis would remain at $1 - G\left(\theta^I\right)$. In practice and as is shown in Appendix D.2, the criminals react to the introduction of legal cannabis by lowering their prices p, such that θ^I decreases and new consumers, with a lower valuation for cannabis, appear.

D.2 The demand (proof of Proposition 1)

The above analysis reveals the following partial equilibrium result.

Lemma. *Everything else being held constant, including the price on the black market, after a legal cannabis market is established, the overall demand for cannabis either increases, if the price of legal cannabis is not too high ($p^L \leq \tilde{p}^L(p)$); otherwise it does not change.*

The black market responds strategically to the legal market by lowering its price to $p^N(p^L)$, the solution of (5) computed with $\varepsilon_{D^I,p} = -\frac{\partial D^I(p,p^L)}{\partial p}\frac{p}{D^I(p,p^L)}$, the direct price elasticity of the demand $D^I(p, p^L)$ defined in (9), which depends on p^L. The price reaction function of the black market sellers solves the following equation:

$$p(p^L) = \begin{cases} p^N(p^L) & \text{if } \; c \leq p^N(p^L) < \frac{p^L}{b} \\ \varnothing & \text{otherwise} \end{cases} \tag{25}$$

Since θ is distributed on $\mathbb{R}$, as long as $p^L < \infty$, there is a positive demand for legal cannabis ($1 - G\left(\theta^L(p, p^L)\right) > 0$).

If $p^L > \tilde{p}^L(p)$ ($\theta^I < \theta^0 < \theta^L$) and other policy parameters (K, c, b, q, F) are held constant, the demand for the black market product decreases following legalization and the absolute value of the price elasticity of the black market demand increases. Therefore, for any finite legal retail price p^L, the black market price p decreases after legalization and implies that the demand for cannabis increases (θ^I decreases).

If $p^L \leq \tilde{p}^L(p)$ ($\theta^L \leq \theta^0 \leq \theta^I$), it is obvious that the overall demand for legal cannabis increases following legalization. We deduce that legalization always increases the overall demand for cannabis, when the operation costs of illegal providers, the quality differential and the repression of demand on the black market are held constant.

Assuming $\frac{\partial^2 D^I(p,p^L)}{\partial p \partial p^L} > 0$, i.e. an increase in p^L tampers the drop in black market demand following a rise in p, the left side of equation (**??**) is increasing in p^L:

$$\frac{\partial^2 D^I(p,p^L)}{\partial p \partial p^L} D^I(p) - \frac{\partial D^I(p)}{\partial p} \frac{\partial D^I(p,p^L)}{\partial p^L} > 0$$

Yet,

$$\begin{aligned}
&\frac{\partial D^I(p,p^L)}{\partial p} D^I(p) - \frac{\partial D^I(p)}{\partial p} D^I(p,p^L) \\
=&\frac{\partial \theta^L(p,p^L)}{\partial p} g\left(\theta^L(p,p^L)\right)\left[1 - G\left(\theta^I(p)\right)\right] + \frac{\partial \theta^I(p)}{\partial p} g\left(\theta^I(p)\right) G\left(\theta^L(p,p^L)\right) \\
\xrightarrow{p^L \to \infty}& \frac{\partial \theta^I(p)}{\partial p} g\left(\theta^I(p)\right) > 0
\end{aligned}$$

Besides,

$$(1-q)u(\theta v - p) + qu(-p - F) - u(\theta bv - bp)$$

$$w^+(1-q)u(\theta v(1-b) - p(1-b)) + w^-(q)u(-(1-b)p - F - \theta bv)$$

$$\begin{aligned}
&\frac{\partial \theta^L(p,p^L)}{\partial p} g\left(\theta^L(p,p^L)\right)\left[1 - G\left(\theta^I(p)\right)\right] + \frac{\partial \theta^I(p)}{\partial p} g\left(\theta^I(p)\right) G\left(\theta^L(p,p^L)\right) \\
=&\frac{\partial \theta^L(p,p^L)}{\partial p} g\left(\theta^L(p,p^L)\right)\left[1 - G\left(\theta^I(p)\right)\right] + \frac{\partial \theta^I(p)}{\partial p} g\left(\theta^I(p)\right) G\left(\theta^L(p,p^L)\right) \\
\xrightarrow{p^L \to bp}&
\end{aligned}$$

E Proof of Proposition 2

Under Prospect Theory the threshold price, denoted $\underline{p}^L$, below which the criminals exit the market is such that $\theta^L(c, \underline{p}^L) = \theta^I(c)$, where $\theta^I(c)$ and $\theta^L\left(c, \underline{p}^L\right)$ are defined in equations (2) and (7) with $p = c$. Therefore, $\theta^I(c)$ (or equivalently $\theta^L\left(c, \underline{p}^L\right)$) is determined by the following system of equations:

$$\begin{cases}
w^+(1-q)u\left(\theta v - c\right) + w^-(q)u\left(-c - F\right) = 0 \\
w^+(1-q)u\left(\theta v - \theta bv + \underline{p}^L - c\right) + w^-(q)u\left(-\theta bv + \underline{p}^L - c - F\right) = 0
\end{cases}$$

Under Expected Utility Theory, the same reasoning yields the following system of equations

$$\begin{cases} (1-q)u(\theta v - c) + qu(-c-F) = 0 \\ (1-q)u(\theta v - c) + qu(-c-F) = u\left(\theta bv - p^L\right) \end{cases}$$

In both cases, this yields $\underline{p}^L = dv\theta^I(c)$.

The legal demand is at the same level as if illegal suppliers were pricing at marginal cost:

$$D^L(\underline{p}^L) = \int_{\theta^L(\underline{p}^L,c)}^{+\infty} g(\theta)d\theta = 1 - G\left(\theta^L(\underline{p}^L, c)\right) = 1 - G(\theta^I(c)) = D^I(c). \tag{26}$$

F Proof of the corollary of Proposition 1

The price $\underline{p}^L = bv\theta^I(c)$ being linear in the quality differential b and the parameters θ^I and v being positive, it is straightforward that $\underline{p}^L$ increases with b. Regarding the other parameters, comparative statics are derived in Appendix B with $p = c$.

G Application to Tversky and Kahneman (1992)

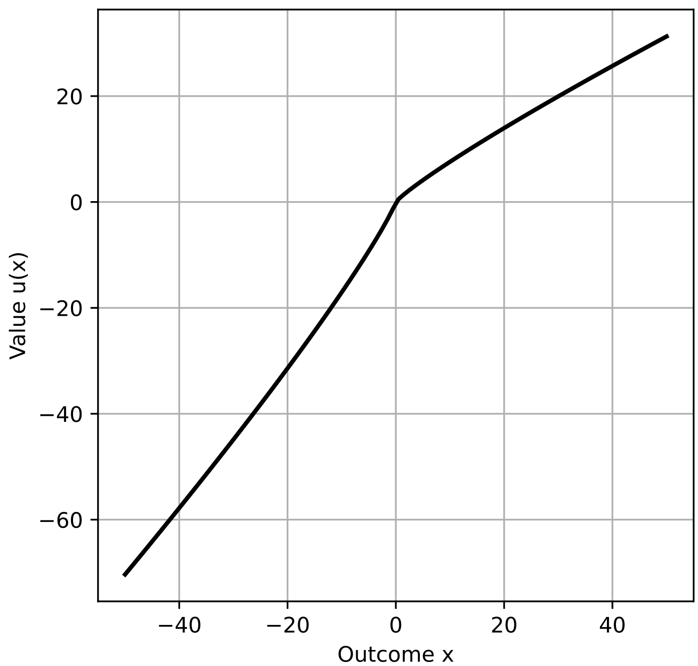
Tversky and Kahneman (1992) suggest a model featuring loss aversion, diminishing sensitivity for gains and losses and diminishing sensitivity regarding probabilities. Agents' appreciation for gains and losses is represented by a value function $u(x)$, which is S-shaped and has an inflection point in zero. This describes individuals being empirically risk-averse for gains and risk-seeking for losses; denoted by Kahneman and Tversky (1979) as the *reflection effect*.

More specifically, the authors calibrate the following functional form for the value function:

$$u(x) = \begin{cases} x^\alpha \text{ , if } x > 0 \\ -\lambda(-x)^\beta \text{ , if } x \leq 0 \end{cases} \tag{27}$$

where $\alpha, \beta \in (0,1)$ reflect the curvature and indicate the degree of risk preference; i.e. the degree of risk-aversion for gains and the degree of risk-seeking in the domain of losses. $\lambda \geq 1$ is the *coefficient of loss aversion*, which reflects that the decrease in utility from a loss is greater than the increase in

Figure 4: Value function as calibrated by Tversky and Kahneman (1992)



utility from a gain of the same amount. In line with Tversky and Kahneman (1992) estimates, we assume $\alpha = \beta$.

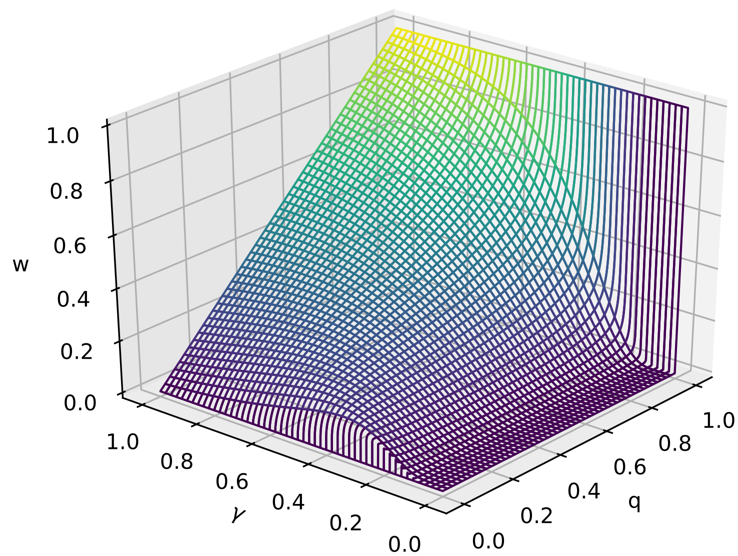
The weighting functions w^+, for gains, w^-, for losses are concave near 0 and convex near 1 to capture diminishing sensitivity for probabilities. Tversky and Kahneman (1992) specify the weighting functions as follows :

$$w^x(q) = \frac{q^{\gamma^x}}{(q^{\gamma^x} + (1-q)^{\gamma^x})^{\frac{1}{\gamma^x}}} \qquad \text{with } x = +, -.$$

The form of such weighting functions is represented in Figure 5. For $\gamma = 1$, $w^x : q \mapsto \frac{q^\gamma}{(q^\gamma + (1-q)^\gamma)^{\frac{1}{\gamma}}}$ is the identity. The closer γ is to 0, the more distorted the probability weights are. When $\gamma \to 0$, the function w^x has an L-shape.

In line with Tversky and Kahneman (1992), we assume that $\gamma^+ < \gamma^-$.

Figure 5: Probability weighting functions for $\gamma \in (0, 1]$



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Eviction price under Tversky and Kahneman (1992)

Substituting the function (27) in (19), the type θ^I indifferent between consuming illegally and not consuming is given by:

$$\theta^I = \frac{1}{v}\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} (F+p) + p\right] \tag{28}$$

This implies that:

$$\frac{\partial \theta^I}{\partial p} = \frac{1}{v}\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} + 1\right] > 0$$

Let us note $\omega(q) \equiv \frac{w^-(q)}{w^+(1-q)}$, which is strictly increasing since w^x is increasing for $x = +, -$. It yields:

$$\frac{\partial \theta^I}{\partial q} = \frac{\lambda^{\frac{1}{\alpha}} (F+p)}{\alpha v} \omega'(q) \left[\omega(q)\right]^{\frac{1-\alpha}{\alpha}} > 0.$$

We deduce that the eviction price $\underline{p}^L = bv\theta^I(c)$ under Tversky and Kahneman (1992)'s specification is:

$$\underline{p}^L = b\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} (F+c) + c\right]. \tag{29}$$

Static comparative of the eviction price

We now study how the eviction price varies when the policy parameters change.

- $$\frac{\partial \underline{p}^L}{\partial F} = b\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} > 0$$

- $$\frac{\partial \underline{p}^L}{\partial c} = b\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} + 1\right] > 0$$

- $$\frac{\partial \underline{p}^L}{\partial b} = \left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} (F+c) + c\right] > 0$$

- $$\frac{\partial \underline{p}^L}{\partial q} = -b\frac{(F+c)\lambda^{\frac{1}{\alpha}}}{\alpha}\frac{\omega'(q)}{\omega^2(q)} > 0$$

Marginal consumer indifferent between legal and illegal consumption

Under the Tversky and Kahneman (1992) specification, one can solve for the type θ^L indifferent between consuming legal and black market cannabis, substituting the function (27) in equation (7). This parameter is given as follows.

$$\theta^L = \left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} b + b - 1\right]^{-1} \left[(p^L - p)\left(1 + \left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}\right) - \left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} F\right] \tag{30}$$

H The policy mix: a numerical application

This Appendix completes the policy implications discussed in Section 5 with further explanations of the calibrations, as well as with further sensitivity analyses of the *post-legalization* equilibrium to the behavioral and policy parameters.

H.1 Calibration of the distribution of "taste" for cannabis

We calibrate the distribution of the "taste" for cannabis using our model and the literature on demand for cannabis, which estimates the range of price elasticities of demand, $\epsilon_{D^I p}$, between -0.5 and -0.8. Let us assume the "taste" for cannabis, $\theta \in \mathbb{R}$, is drawn from a normal distribution $\mathcal{N}(\mu, \sigma^2)$. The expression of the price elasticity of demand in equation (4) becomes

$$\epsilon_{D^I p} = \frac{p}{v}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} + 1\right]\frac{1}{\sigma\sqrt{2\pi}}\frac{e^{\frac{-(\theta^I-\mu)^2}{2\sigma^2}}}{1-\phi(\frac{\theta^I-\mu}{\sigma})} \tag{31}$$

In 2017, 15% of Americans are estimated to have used cannabis in the past year (CBHSQ, 2018). This margin is simply given by:

$$\varsigma = 1 - \phi\left(\frac{\theta^I - \mu}{\sigma}\right) \tag{32}$$

Using the estimates of ϵ and ς discussed in the literature, we calibrate the parameters μ and σ solving the system defined by equations (31) and (32), normalizing $v \equiv 1$ and using the benchmark values for the model parameters summarized in Table 1. Using an iterative solver, we obtain the set of solutions described in Table 6 for μ and σ, as well as the benchmark values for the *post-legalization* increase in consumption implementing the eviction price $\underline{p}^L = 97.79$[31], $\Delta\%D\left(\underline{p}^L\right)$. As the demand becomes more inelastic, the distribution tail becomes fatter and the mean taste lower. The more inelastic the demand, the lower the *post-legalization* increase in demand.

Table 6: Distribution parameters and post-legalization increases in consumption

$\epsilon_{D^I p}$	$\hat{\mu}$	$\hat{\sigma}$	$\Delta\%D\left(\underline{p}^L\right)$
0.5	-690.4	1065.8	53.18%
0.6	-506.3	888.1	65.45%
0.7	-374.8	761.3	78.23%
0.8	-276.2	666.1	91.49%

Notes: Behavioral parameters are set based on Tversky and Kahneman (1992): $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$, $\gamma^- = 0.69$. Variation in demand relies on the baseline estimate of $\underline{p}^L = 97.79$.

The sensitivity of the distribution parameters and of the predictions of the models to the behavioral parameters γ^+, γ^-, α and λ is discussed in Appendix H.2. This Appendix also shows that small variations around the values calibrated by Tversky and Kahneman (1992) induce relatively little change in the predicted policy price $\underline{p}^L$ and subsequent increases in consumption.

[31] This eviction price assumes that, under legalization, the probability of arrest is ten times smaller ($q_L = 0.1\%$) than under prohibition ($q = 1\%$); and that the marginal cost on the black market is USD 50 *post-legalization*.

H.2 Sensitivity analysis of $\underline{p}^L$ to the behavioral parameters

Policy parameters are set at benchmark values $q_L = 0.1\%$, $F = 1,000$, $b = 1.58$, and $c = 50$. Prices and costs are for one ounce of cannabis. $\Delta\%D\left(\underline{p}^L\right)$ is the percentage predicted increase in consumption following a legalization process that drives dealers out of business.

We study the sensitivity of the eviction price, $\underline{p}^L$, to the exogenous behavioral parameters γ^+, γ^-, α and λ. The benchmark values are: $\alpha = 0.88$, $\lambda = 2.25$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$.

Tables 7 to 10 present in columns 3 and 4 the sensitivity of the distribution parameters, and in columns 5 and 6 the sensitivity of both the eviction price and the subsequent increase in consumption *post-legalization*. The magnitude of variations of the behavioral parameters around the benchmark values are presented in column 2.

Table 7: Sensitivity of eviction price and demand to behavioral parameters for $\epsilon = -0.5$

parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
$\gamma^+ = 0.61$	+10%	0.1%	-0.22%	-0.21%	-0.3%
	+5%	0.06%	-0.12%	-0.12%	-0.16%
	-5%	-0.06%	0.15%	0.16%	0.2%
	-10%	-0.14%	0.33%	0.36%	0.46%
$\gamma^- = 0.69$	+10%	0.86%	-1.91%	-7.97%	-2.63%
	+5%	0.47%	-1.03%	-4.51%	-1.41%
	-5%	-0.53%	1.19%	5.86%	1.61%
	-10%	-1.15%	2.57%	13.45%	3.44%
$\alpha = 0.88$	+10%	-0.8%	1.8%	9.66%	2.43%
	+5%	-0.39%	0.89%	4.57%	1.21%
	-5%	0.39%	-0.87%	-4.04%	-1.18%
	-10%	0.77%	-1.7%	-7.54%	-2.33%
$\lambda = 2.25$	+10%	-0.33%	0.76%	2.2%	1.03%
	+5%	-0.16%	0.38%	1.1%	0.52%
	-5%	0.18%	-0.38%	-1.09%	-0.51%
	-10%	0.34%	-0.75%	-2.17%	-1.03%

Benchmark values in column 1 are $\hat{\mu} = -690.4$, $\hat{\sigma} = 1065.8$, $\underline{p}^L = 97.79$ and $\Delta\%D\left(\underline{p}^L\right) = 53.18\%$.

Table 8: Sensitivity of eviction price and demand to behavioral parameters for $\epsilon = -0.6$

parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
$\gamma^+ = 0.61$	+10%	0.22%	-0.21%	-0.21%	-0.34%
	+5%	0.13%	-0.12%	-0.12%	-0.19%
	-5%	-0.14%	0.15%	0.16%	0.24%
	-10%	-0.32%	0.34%	0.36%	0.53%
$\gamma^- = 0.69$	+10%	1.87%	-1.91%	-7.97%	-3.05%
	+5%	1.01%	-1.03%	-4.51%	-1.63%
	-5%	-1.16%	1.2%	5.86%	1.87%
	-10%	-2.5%	2.57%	13.45%	3.99%
$\alpha = 0.88$	+10%	-1.75%	1.81%	9.66%	2.82%
	+5%	-0.86%	0.9%	4.57%	1.4%
	-5%	0.85%	-0.86%	-4.04%	-1.37%
	-10%	1.66%	-1.69%	-7.54%	-2.7%
$\lambda = 2.25$	+10%	-0.73%	0.77%	2.2%	1.2%
	+5%	-0.36%	0.38%	1.1%	0.6%
	-5%	0.38%	-0.37%	-1.09%	-0.6%
	-10%	0.74%	-0.75%	-2.17%	-1.19%

Benchmark values in column 1 $\hat{\mu} = -506.3$, $\hat{\sigma} = 888.1$, $\underline{p}^L = 97.79$ and $\Delta\%D\left(\underline{p}^L\right) = 65.45\%$.

Table 9: Sensitivity of eviction price and demand to behavioral parameters for $\epsilon = -0.7$

parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
$\gamma^+ = 0.61$	+10%	0.37%	-0.22%	-0.21%	-0.39%
	+5%	0.21%	-0.12%	-0.12%	-0.21%
	-5%	-0.24%	0.14%	0.16%	0.27%
	-10%	-0.55%	0.33%	0.36%	0.6%
$\gamma^- = 0.69$	+10%	3.2%	-1.92%	-7.97%	-3.43%
	+5%	1.73%	-1.03%	-4.51%	-1.84%
	-5%	-1.98%	1.19%	5.86%	2.11%
	-10%	-4.27%	2.56%	13.45%	4.49%
$\alpha = 0.88$	+10%	-3.0%	1.8%	9.66%	3.17%
	+5%	-1.48%	0.89%	4.57%	1.58%
	-5%	1.45%	-0.87%	-4.04%	-1.54%
	-10%	2.84%	-1.7%	-7.54%	-3.03%
$\lambda = 2.25$	+10%	-1.26%	0.76%	2.2%	1.35%
	+5%	-0.62%	0.37%	1.1%	0.67%
	-5%	0.64%	-0.38%	-1.09%	-0.67%
	-10%	1.27%	-0.76%	-2.17%	-1.34%

Benchmark values in column 1 $\hat{\mu} = -374.8$, $\hat{\sigma} = 761.3$, $\underline{p}^L = 97.79$ and $\Delta\%D(\underline{p}^L) = 78.23\%$.

Table 10: Sensitivity of eviction price and demand to the behavioral parameters for $\epsilon = -0.8$

parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
$\gamma^+ = 0.61$	+10%	0.58%	-0.22%	-0.21%	-0.42%
	+5%	0.32%	-0.12%	-0.12%	-0.23%
	-5%	-0.38%	0.15%	0.16%	0.29%
	-10%	-0.88%	0.34%	0.36%	0.66%
$\gamma^- = 0.69$	+10%	5.02%	-1.91%	-7.97%	-3.78%
	+5%	2.71%	-1.03%	-4.51%	-2.02%
	-5%	-3.12%	1.2%	5.86%	2.32%
	-10%	-6.72%	2.57%	13.45%	4.95%
$\alpha = 0.88$	+10%	-4.73%	1.81%	9.66%	3.5%
	+5%	-2.33%	0.89%	4.57%	1.74%
	-5%	2.27%	-0.86%	-4.04%	-1.7%
	-10%	4.44%	-1.69%	-7.54%	-3.34%
$\lambda = 2.25$	+10%	-1.99%	0.76%	2.2%	1.48%
	+5%	-0.99%	0.38%	1.1%	0.74%
	-5%	1.0%	-0.38%	-1.09%	-0.74%
	-10%	1.98%	-0.75%	-2.17%	-1.47%

Benchmark values in column 1 $\hat{\mu} = -276.2$, $\hat{\sigma} = 666.1$, $\underline{p}^L = 97.79$, $\Delta\%D(\underline{p}^L) = 91.49\%$.

Overall, the distribution parameters are not very sensitive to the variations in the behavioral parameters: variations in the behavioral parameters by 10% entail variations in the distribution parameters of less than 8% for most cases. The policy price seems fairly sensitive to the parameter γ^-: a 10% variation in this parameter causes a change in price of up to 13.5%. This is also true for the parameter α. Finally, post-legalization cannabis consumption is not very responsive to small variations in the behavioral parameters (by less than 10%) as it changes by less than 2% in most cases.

H.3 Sensitivity analysis to policy parameters

To illustrate how governments may use a combination of policy instruments to regulate the market for cannabis *post-legalization*, Table 11 exploits combined variations in several policy parameters. The first row presents the current benchmark values for the different policy parameters, the recommended legal price $\underline{p}^L$ and the *post-legalization* increase in the extensive margin of consumption. Rows 2 to 5 present scenarios in which the government certifies the quality of legal cannabis, such that b goes up to 2, and does not invest a lot in detecting illegal purchases, such that the probability of arrest q is half the benchmark value, but doubles the fines for illegal purchase (F=2000). At the same time it may choose or not to enforce repression against illegal providers, the marginal cost c varying from 15 – i.e. less than a third of the benchmark value – to 200 – i.e. four times the benchmark value. Simulations show that the government is able to contain consumption at the *pre-legalization* level when the marginal cost is four times the benchmark value ($c = 200$).

Table 11: Sensitivity analysis of eviction price and post-legalization demand

Policy parameters				Eviction Price	Increase in Demand			
c	b	q	F	$\underline{p}^L$	$\epsilon = -0.5$	$\epsilon = -0.6$	$\epsilon = -0.7$	$\epsilon = -0.8$
50	1.58	0.1%	1000	97.79	53.18%	65.45%	78.23%	91.49%
15	2.00	0.05%	2000	56.39	61.17%	75.45%	90.38%	105.85%
25	2.00	0.05%	2000	76.52	57.26%	70.55%	84.43%	98.81%
100	2.00	0.05%	2000	227.5	29.7%	36.22%	42.95%	49.84%
200	2.00	0.05%	2000	428.81	-2.11%	-2.54%	-2.95%	-3.38%
50	1.00	0.05%	1000	56.88	61.07%	75.33%	90.23%	105.68%
50	1.25	0.05%	1000	71.09	58.31%	71.87%	86.03%	100.7%
50	1.58	0.05%	1000	89.86	54.7%	67.35%	80.54%	94.21%
50	2.00	0.05%	1000	113.75	50.18%	61.69%	73.68%	86.09%
50	3.00	0.05%	1000	170.63	39.72%	48.64%	57.91%	67.45%
50	4.00	0.05%	1000	227.5	29.7%	36.22%	42.95%	49.84%
50	1.58	0.05%	1000	89.86	54.7%	67.35%	80.54%	94.21%
50	1.58	0.1%	2000	115.68	49.82%	61.24%	73.13%	85.44%
50	1.58	0.05%	3000	110.55	50.78%	62.44%	74.59%	87.16%
50	1.58	0.2%	500	96.06	53.52%	65.87%	78.75%	92.09%
50	1.58	0.5%	5000	404.51	1.42%	1.7%	2.0%	2.27%
50	2.00	1.0%	2000	392.45	3.21%	3.85%	4.52%	5.15%
100	1.58	1.5%	1500	408.79	0.8%	0.94%	1.12%	1.26%
50	2.00	0.5%	4000	430.44	-2.35%	-2.82%	-3.27%	-3.75%
100	2.25	1.0%	1000	401.54	1.86%	2.22%	2.62%	2.98%
15	2.50	1.0%	2000	396.82	2.56%	3.07%	3.6%	4.1%
15	1.58	0.5%	6000	411.41	0.41%	0.48%	0.58%	0.65%
25	1.25	2.0%	2500	427.67	-1.95%	-2.35%	-2.72%	-3.12%
50	1.58	2.0%	1500	386.59	4.09%	4.9%	5.75%	6.57%
50	3.00	1.0%	1000	374.68	5.88%	7.07%	8.29%	9.5%
15	1.00	0%	-	15.0	69.36%	85.74%	102.88%	120.66%
25	1.00	0%	-	25.0	67.36%	83.23%	99.83%	117.05%
50	1.00	0%	-	50.0	62.42%	77.02%	92.28%	108.11%
75	1.00	0%	-	75.0	57.56%	70.92%	84.88%	99.34%
100	1.00	0%	-	100.0	52.78%	64.93%	77.61%	90.74%
125	1.00	0%	-	125.0	48.08%	59.06%	70.5%	82.32%

Notes: Behavioral parameters are set at values calibrated by Tversky and Kahneman (1992): $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$, and $\gamma^- = 0.69$. Variation in demand relies on the baseline estimates for the parameters of the distribution of θ corresponding to different price elasticities of demand, as described in Table 6.

Rows 6 to 11 show that investing in quality differentiation (increasing b) is effective at reducing cannabis consumption. Even with lax enforcement of arrest of illegal users ($q = 0.05\%$), row 11 shows that limiting the consumption increase *post-legalization* can be achieved by investing in quality differentiation and certification of legal cannabis, such that $b = 4$.

Rows 12 to 16 show simulations of policies which increase repression on the demand side through various intensities of arrests q and fine amounts F, while the other parameters are kept at benchmark values. While increasing the level of fines seems to be an effective way to limit *post-legalization* consumption, high fines may be neither cost-effective nor fair, especially to low income users. Similarly, increased enforcement of arrests combined with statistical discrimination may also result in an uneven burden on some populations.

The fourth part of the table (rows 17 to 25) presents results where the *post-legalization* consumption is contained around the *pre-legalization* level. They highlight that a government aiming at controlling cannabis consumption through legalization would have to invest in strict repression of either the supply or the demand side, as well as in product differentiation, certification and information campaigns. For instance, a legalization policy combined with significant investments in quality differentiation of legal cannabis ($b = 2$) and increased fines for illegal consumption up to USD 4000 would lead to the eviction price of USD 430 per ounce, decreasing cannabis consumption by 2.35% to 3.75%.

The last exercise illustrates an extreme case of no differentiation between legal and illegal products in a liberal state without repression on the demand and supply sides of the market, thus pricing legal cannabis at the marginal cost of production, which is the same on the illegal market. The absence of regulation results in large increases in *post-legalization* consumption, larger than 50% in most scenarios and more than 100% with large price elasticities of demand or low production costs.

I Exploring other tools and policy objectives

I.1 Survival of the black market

After the government chooses the price of the legal cannabis, $p^L = (1+\tau)c^L$, the repression (i.e. the probability of arrest q, the fine F and the increase in marginal cost to produce illegally $\delta \geq 0$), as well as the quality differential between legal and illegal products, $b \geq 1$, the consumers decide whether to consume or not, and on which market. From here, two cases may occur.

1. Taxes are set low enough such that, given the level of repression on both the demand and supply sides and the quality differential, the black market does not survive. In this case τ satisfies $1 + \tau \leq bv\frac{\theta^I\left((1+\delta)c^L\right)}{c^L}$ where $\theta^I\left((1+\delta)c^L\right)$ is defined in (2). Let $\theta^0 = \frac{(1+\tau)c^L}{vb}$ be the agent

indifferent between consuming legal cannabis at price $p^L = (1+\tau)c^L$ and not consuming. The demand for (legal) cannabis is given by: $D^L\left((1+\tau)c^L\right) = 1 - G\left(\frac{(1+\tau)c^L}{vb}\right)$.

2. If the government sets taxes too high, such that $(1+\tau)c^L > bv\theta^I\left((1+\delta)c^L\right)$, then the demand is split between the legal and illegal markets, as follows:

$$D^L\left(p,(1+\tau)c^L|b\right) = 1 - G\left(\theta^L\left(p,(1+\tau)c^L|b\right)\right)$$

$$D^I\left(p,(1+\tau)c^L|b\right) = G\left(\theta^L\left(p,(1+\tau)c^L|b\right)\right) - G\left(\theta^I\left(p\right)\right)$$

where $\theta^I(p)$ is defined in (2) and $\theta^L\left(p,(1+\tau)c^L|b\right)$ in (7). Illegal providers set the black market price p as defined in (5). The price reaction function of the illegal sector is analogous to the best response described in (10) with $p^L = (1+\tau)c^L$.

I.2 Maximizing tax revenue when θ follows an exponential distribution

Let us assume that on the positive real line, θ follows an exponential distribution $G(\theta) \equiv 1 - e^{-\eta\theta}$, with $0 < \eta < 1$, (17) becomes

$$1 = \eta c^L \tau \frac{\partial \theta^l}{\partial p^L}. \tag{33}$$

If the black market has been initially shut down, then (33) yields $\tau_0^{\alpha_T} = \frac{bv}{\eta c^L}$. If the black market is not shut down, with risk-neutral consumers we have $\theta^L = \frac{p^L - p - qF}{(b+q-1)v}$, so that (33) yields: $\tau^{\alpha_T} = \frac{b+q-1}{\eta c^L}v \geq 0$. This is the optimal solution if the demand for cannabis is strictly positive for this level of taxes which requires that $\theta^L(\tau^{\alpha_T}) = \frac{(1+\tau^{\alpha_T})c^L - p - qF}{(b+q-1)v} > 0$. This is equivalent to $\eta < \frac{v(b+q-1)}{qF+p-c^L} \leq \frac{v(b+q-1)}{qF+\delta c^L} = \eta^{\alpha_T}$. We deduce that the unconstrained solution (i.e., in the absence of competition by the black market) leads to a larger excise tax than the constrained solution: $\tau_0^{\alpha_T} \geq \tau^{\alpha_T}$,[32] which is intuitive.

When the government does not have to deal with competition it can impose higher taxes, as the consumers are captive. In both cases, the tax rate increases with vb, the quality of the legal product, and decreases with c^L, the marginal cost of production of legal cannabis, and with η, the distribution of consumers' type parameter. Indeed, a higher η implies that the distribution of taste is skewed towards the low values of θ: few people are willing to pay a high price for cannabis, which implies that the tax rate should be relatively low.

[32] They are equal only when $q = 1$.

Next, we check under which conditions the optimal tax level τ^{α_T} is such that the final price $p^L(\tau^{\alpha_T}) = (1 + \tau^{\alpha_T})\, c^L$ is lower than the eviction price $\underline{p}^L = bv\theta^I((1+\delta)c^L) = b\frac{(1+\delta)c^L+qF}{1-q}$. Let $\eta^{evic} = \frac{(1-q)(b+q-1)v}{b(\delta c^L+qF)+(b+q-1)c^L} > 0$. It is easy to check that if $\eta \geq \eta^{evic}$, then $p^L(\tau^{\alpha_T}) \leq \underline{p}^L$. Under our assumptions, $0 < \eta^{evic} < \eta^{\alpha_T}$. Only when $\eta^{evic} \leq \eta < \eta^{\alpha_T}$ is it possible to maximize tax revenues while simultaneously eradicating the black market through an eviction price.

Based on the number of users of cannabis worldwide, it is unrealistic to assume that the distribution of tastes for cannabis in the general population is skewed towards the low values of θ (i.e., it is unrealistic to consider large values for η). Yet, if $\eta < \eta^{evic} < \eta^{\alpha_T}$, then the price that maximizes tax revenue is higher than the eviction price. In other words, when there is a large demand for cannabis, maximizing tax revenue implies setting the price of the legal products relatively high, such that the black market can survive by selling illegal cannabis at a discount.

I.3 Maximizing tax revenues: a numerical application

This section provides detail on the tax policy application discussed in Section 6. It also presents the results for the other values of the price demand elasticity, as well as other examples, where there is no enforcement on the demand side of the market.

The methodology of this numerical exercise relies on the same principle as in Section 5 and Appendix H, as well as the calibration results of Appendix 6. We use an iterative solver on the system of equations (17) and (10) with $p^L = (1+\tau)c^L$.

Results with elasticities varying from -0.7 to -0.5

We present, in Tables 12 to 14, the results of the numerical exercise from Section 6 for higher values of the demand price elasticity (-0.5, -0.6 and -0.7), as well as another set of results modeling a situation where there are no arrests on the black market. As expected, the more inelastic the demand, the higher the equilibrium prices and the government revenue. The remarks from the main text remain valid here: the price maximizing tax revenue is generally well above the eviction price (except when the quality is the same on both markets) and the corresponding extensive margins of consumption are of the same magnitude.

Table 12: Legalization price and resulting demand when the government maximizes tax revenue ($\epsilon = -0.5$)

	Policy parameters				Equilibrium prices		Equilibrium demand and revenue			Eviction scenario		
$\frac{1}{N}$	c	b	q	F	p	p^L	$\Delta\%D\left(p,p^L\right)$	$s^I\left(p,p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\text{R}}$
0.55	50	1.58	0.1%	1000	122.89	417.78	-0.96%	37.9%	363	97.79	60.09%	119
0.55	25	1.58	0.1%	1000	106.32	413.84	-2.94%	41.13%	348	57.84	65.05%	55
0.55	125	1.58	0.1%	1000	172.96	430.04	5.33%	27.15%	412	217.63	45.72%	286
0.55	200	1.58	0.1%	1000	223.61	442.94	12.14%	14.57%	466	337.47	32.11%	421
0.10	50	1.58	0.1%	1000	68.37	404.99	-7.3%	47.96%	315	97.79	60.09%	119
0.25	50	1.58	0.1%	1000	90.64	410.15	-4.78%	44.05%	334	97.79	60.09%	119
0.75	50	1.58	0.1%	1000	138.60	421.58	0.97%	34.69%	378	97.79	60.09%	119
1.00	50	1.58	0.1%	1000	154.09	425.36	2.91%	31.38%	393	97.79	60.09%	119
0.55	50	1.00	0.1%	1000	53.11	65.03	59.48%	0.0%	65	61.89	60.09%	60
0.55	50	1.10	0.1%	1000	62.68	106.11	24.99%	24.35%	99	68.08	60.09%	70
0.55	50	1.30	0.1%	1000	94.38	237.41	6.56%	34.89%	213	80.46	60.09%	90
0.55	50	1.80	0.1%	1000	137.95	557.87	-4.13%	38.95%	475	111.41	60.09%	141
0.55	50	1.58	0.2%	1000	120.48	424.13	-0.54%	36.86%	372	111.56	58.4%	140
0.55	50	1.58	0.5%	1000	114.49	439.87	0.44%	34.23%	394	146.68	54.14%	191
0.55	50	1.58	1.0%	1000	106.15	461.47	1.63%	30.47%	424	197.33	48.1%	260
0.55	50	1.58	0.0%	1000	126.22	408.95	-1.58%	39.33%	351	79.00	62.42%	89
0.55	50	1.58	0.1%	100	126.28	416.18	-1.77%	39.22%	357	81.68	62.08%	94
0.55	50	1.58	0.1%	500	124.77	416.89	-1.41%	38.64%	360	88.84	61.2%	105
0.55	50	1.58	0.1%	1500	121.01	418.68	-0.51%	37.16%	367	106.74	59.0%	132
0.55	50	1.58	0.1%	2000	119.13	419.57	-0.05%	36.4%	370	115.68	57.9%	146

Notes: The above results are based on a price demand elasticity of 0.5 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Table 13: Legalization price and resulting demand when the government maximizes tax revenue ($\epsilon = -0.6$)

	Policy parameters		Equilibrium prices		Equilibrium demand and revenue			Eviction scenario				
$\frac{1}{N}$	c	b	q	F	p	p^L	$\Delta\%D\left(p,p^L\right)$	$s^I\left(p,p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\text{R}}$
0.55	50	1.58	0.1%	1000	110.50	363.72	9.64%	36.78%	348	97.79	74.1%	129
0.55	25	1.58	0.1%	1000	93.89	359.59	7.11%	40.55%	331	57.84	80.33%	60
0.55	125	1.58	0.1%	1000	160.82	376.65	17.71%	24.02%	403	217.63	56.11%	306
0.55	200	1.58	0.1%	1000	211.81	390.40	26.48%	8.75%	464	337.47	39.2%	443
0.10	50	1.58	0.1%	1000	65.21	352.61	2.91%	46.58%	304	97.79	74.1%	129
0.25	50	1.58	0.1%	1000	83.68	357.08	5.59%	42.76%	321	97.79	74.1%	129
0.75	50	1.58	0.1%	1000	123.60	367.03	11.68%	33.66%	362	97.79	74.1%	129
1.00	50	1.58	0.1%	1000	136.54	370.34	13.74%	30.44%	376	97.79	74.1%	129
0.55	50	1.00	0.1%	1000	51.86	63.69	73.67%	0.0%	68	61.89	74.1%	65
0.55	50	1.10	0.1%	1000	59.24	96.04	41.07%	21.06%	98	68.08	74.1%	76
0.55	50	1.30	0.1%	1000	86.15	208.78	18.41%	33.37%	206	80.46	74.1%	98
0.55	50	1.80	0.1%	1000	123.41	484.03	6.03%	37.93%	454	111.41	74.1%	153
0.55	50	1.58	0.2%	1000	108.07	369.42	10.21%	35.55%	357	111.56	71.98%	152
0.55	50	1.58	0.5%	1000	102.03	383.54	11.54%	32.43%	380	146.68	66.64%	207
0.55	50	1.58	1.0%	1000	93.64	402.94	13.16%	27.95%	412	197.33	59.08%	279
0.55	50	1.58	0.0%	1000	113.88	355.81	8.81%	38.46%	335	79.00	77.02%	97
0.55	50	1.58	0.1%	100	113.87	362.05	8.61%	38.33%	341	81.68	76.6%	102
0.55	50	1.58	0.1%	500	112.38	362.79	9.07%	37.64%	344	88.84	75.49%	114
0.55	50	1.58	0.1%	1500	108.64	364.66	10.22%	35.91%	352	106.74	72.73%	144
0.55	50	1.58	0.1%	2000	106.77	365.60	10.8%	35.02%	356	115.68	71.35%	158

Notes: The above results are based on a price demand elasticity of 0.6 and the corresponding distribution parameters (see Table 6). TThe marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Table 14: Legalization price and resulting demand when the government maximizes tax revenue ($\epsilon = -0.7$)

$\frac{1}{N}$	Policy parameters c	b	Equilibrium prices q	F	Equilibrium demand and revenue p	p^L	$\Delta\%D\left(p, p^L\right)$	Eviction scenario $s^I\left(p, p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\text{R}}$
0.55	50	1.58	0.1%	1000	101.78	325.65	20.84%	35.72%	342	97.79	88.74%	140
0.55	25	1.58	0.1%	1000	85.11	321.32	17.73%	39.99%	323	57.84	96.31%	66
0.55	125	1.58	0.1%	1000	152.34	339.28	30.81%	21.05%	403	217.63	66.93%	328
0.55	200	1.58	0.1%	1000	203.66	353.91	41.68%	3.15%	473	337.47	46.53%	467
0.10	50	1.58	0.1%	1000	62.98	315.69	13.73%	45.27%	300	97.79	88.74%	140
0.25	50	1.58	0.1%	1000	78.78	319.69	16.57%	41.55%	316	97.79	88.74%	140
0.75	50	1.58	0.1%	1000	113.04	328.62	23.0%	32.69%	355	97.79	88.74%	140
1.00	50	1.58	0.1%	1000	124.19	331.60	25.17%	29.55%	368	97.79	88.74%	140
0.55	50	1.00	0.1%	1000	57.06	69.03	86.63%	0.0%	84	61.89	88.74%	71
0.55	50	1.10	0.1%	1000	56.88	89.07	58.1%	18.02%	100	68.08	88.74%	83
0.55	50	1.30	0.1%	1000	80.38	188.68	30.93%	31.95%	204	80.46	88.74%	107
0.55	50	1.80	0.1%	1000	113.15	431.97	16.77%	36.98%	445	111.41	88.74%	166
0.55	50	1.58	0.2%	1000	99.34	330.90	21.58%	34.32%	351	111.56	86.17%	164
0.55	50	1.58	0.5%	1000	93.27	343.94	23.28%	30.75%	376	146.68	79.68%	223
0.55	50	1.58	1.0%	1000	84.87	361.86	25.37%	25.56%	409	197.33	70.53%	299
0.55	50	1.58	0.0%	1000	105.18	318.35	19.78%	37.64%	328	79.00	92.28%	106
0.55	50	1.58	0.1%	100	105.13	323.89	19.57%	37.48%	334	81.68	91.78%	111
0.55	50	1.58	0.1%	500	103.64	324.67	20.14%	36.7%	337	88.84	90.42%	124
0.55	50	1.58	0.1%	1500	99.93	326.63	21.56%	34.73%	346	106.74	87.07%	156
0.55	50	1.58	0.1%	2000	98.08	327.62	22.27%	33.71%	350	115.68	85.4%	171

Notes: The above results are based on a price demand elasticity of 0.7 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Results with $q_L = 0$

We detail in Tables 15 to 18 scenarios where consumers going to the illegal market are not arrested. Since the case where $b = 1$ and $q_L = 0$ yields perfect competition between the legal and the illegal markets, we prefer to present a case where there is very little quality differentiation ($b = 1.01$), rather than no differentiation. When there are no arrests on the demand side, individuals are all the more sensitive to quality. For a government maximizing tax revenue, quality has a large influence on the optimal price: when the quality differential is 1.01, the equilibrium price on the legal market, p^L, is between USD 54 and 57 per ounce, depending on the elasticity; when $b = 1.80$, this price rises up to USD 387 to 549 per ounce.

Table 15: Legalization price and resulting demand when the government maximizes tax revenue and $q_L = 0$, for $\epsilon = -0.5$

	Policy parameters		Equilibrium prices		Equilibrium demand and revenue			Eviction scenario		
$\frac{1}{N}$	c	b	p	p^L	$\Delta\%D\left(p, p^L\right)$	$s^I\left(p, p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\mathrm{R}}$
0.55	50	1.58	126.22	408.95	47.85%	39.33%	351	79.0	62.42%	89
0.55	25	1.58	109.70	405.04	50.94%	42.5%	336	39.5	67.36%	25
0.55	125	1.58	176.18	421.13	38.72%	28.76%	399	197.5	48.08%	260
0.55	200	1.58	226.76	433.97	29.83%	16.4%	452	316.0	34.49%	399
0.10	50	1.58	69.26	395.67	58.67%	49.65%	302	79.0	62.42%	89
0.25	50	1.58	92.55	401.03	54.19%	45.64%	321	79.0	62.42%	89
0.75	50	1.58	142.60	412.89	44.82%	36.03%	366	79.0	62.42%	89
1.00	50	1.58	158.75	416.82	41.87%	32.63%	382	79.0	62.42%	89
0.55	50	1.01	53.84	54.37	61.67%	0.0%	48	50.5	62.42%	42
0.55	50	1.10	64.21	96.67	59.64%	28.81%	83	55.0	62.42%	50
0.55	50	1.30	96.96	228.35	53.35%	37.02%	200	65.0	62.42%	66
0.55	50	1.80	141.64	549.15	45.0%	40.16%	463	90.0	62.42%	108

Notes: The above results are based on a price demand elasticity of 0.5 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Table 16: Legalization price and resulting demand when the government maximizes tax revenue and $q_L = 0$, for $\epsilon = -0.6$

	Policy parameters		Equilibrium prices		Equilibrium demand and revenue			Eviction scenario		
$\frac{1}{N}$	c	b	p	p^L	$\Delta\%D\left(p, p^L\right)$	$s^I\left(p, p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\mathrm{R}}$
0.55	50	1.58	113.88	355.81	61.66%	38.46%	335	79.0	77.02%	97
0.55	25	1.58	97.31	351.71	65.57%	42.15%	319	39.5	83.23%	27
0.55	125	1.58	164.07	368.64	50.12%	25.96%	389	197.5	59.06%	280
0.55	200	1.58	214.98	382.30	38.9%	11.01%	450	316.0	42.15%	421
0.10	50	1.58	66.10	344.17	73.08%	48.57%	289	79.0	77.02%	97
0.25	50	1.58	85.61	348.86	68.37%	44.64%	308	79.0	77.02%	97
0.75	50	1.58	127.66	359.27	58.44%	35.23%	350	79.0	77.02%	97
1.00	50	1.58	141.27	362.73	55.3%	31.9%	364	79.0	77.02%	97
0.55	50	1.01	53.56	54.08	76.15%	0.0%	52	50.5	77.02%	46
0.55	50	1.10	61.00	87.50	74.32%	26.36%	82	55.0	77.02%	54
0.55	50	1.30	88.87	200.65	67.59%	35.88%	192	65.0	77.02%	72
0.55	50	1.80	127.09	476.21	58.57%	39.36%	442	90.0	77.02%	117

Notes: The above results are based on a price demand elasticity of 0.6 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Table 17: Legalization price and resulting demand when the government maximizes tax revenue and $q_L = 0$, for $\epsilon = -0.7$

	Policy parameters		Equilibrium prices		Equilibrium demand and revenue			Eviction scenario		
$\frac{1}{N}$	c	b	p	p^L	$\Delta\%D\left(p,p^L\right)$	$s^I\left(p,p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\text{R}}$
0.55	50	1.58	105.18	318.35	76.13%	37.64%	328	79.0	92.28%	106
0.55	25	1.58	88.56	314.06	80.92%	41.81%	310	39.5	99.83%	30
0.55	125	1.58	155.60	331.86	62.0%	23.32%	388	197.5	70.5%	300
0.55	200	1.58	206.85	346.39	48.29%	5.84%	457	316.0	50.08%	445
0.10	50	1.58	63.87	307.84	88.16%	47.54%	284	79.0	92.28%	106
0.25	50	1.58	80.71	312.06	83.21%	43.69%	302	79.0	92.28%	106
0.75	50	1.58	117.13	321.48	72.72%	34.48%	342	79.0	92.28%	106
1.00	50	1.58	128.96	324.63	69.39%	31.21%	356	79.0	92.28%	106
0.55	50	1.01	55.18	55.71	90.74%	0.0%	60	50.5	92.28%	50
0.55	50	1.10	58.78	81.12	89.67%	24.09%	82	55.0	92.28%	59
0.55	50	1.30	83.18	181.16	82.49%	34.81%	189	65.0	92.28%	78
0.55	50	1.80	116.83	424.77	72.81%	38.6%	432	90.0	92.28%	127

Notes: The above results are based on a price demand elasticity of 0.7 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.

Table 18: Legalization price and resulting demand when the government maximizes tax revenue and $q_L = 0$, for $\epsilon = -0.8$

	Policy parameters		Equilibrium prices		Equilibrium demand and revenue			Eviction scenario		
$\frac{1}{N}$	c	b	p	p^L	$\Delta\%D\left(p,p^L\right)$	$s^I\left(p,p^L\right)$	R	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$	$\underline{\text{R}}$
0.55	50	1.58	98.73	290.60	91.17%	36.86%	327	79.0	108.11%	115
0.55	25	1.58	82.06	286.12	96.89%	41.46%	307	39.5	117.05%	32
0.55	125	1.58	149.39	304.83	74.29%	20.83%	393	197.5	82.32%	320
0.55	200	1.58	200.96	320.27	57.93%	0.93%	471	316.0	58.22%	469
0.10	50	1.58	62.22	280.90	103.8%	46.56%	284	79.0	108.11%	115
0.25	50	1.58	77.08	284.80	98.62%	42.78%	301	79.0	108.11%	115
0.75	50	1.58	109.34	293.51	87.57%	33.76%	340	79.0	108.11%	115
1.00	50	1.58	119.85	296.42	84.04%	30.57%	353	79.0	108.11%	115
0.55	50	1.01	56.78	57.33	105.72%	0.0%	68	50.5	108.11%	54
0.55	50	1.10	57.17	76.48	105.58%	21.99%	84	55.0	108.11%	64
0.55	50	1.30	78.97	166.77	97.96%	33.81%	189	65.0	108.11%	85
0.55	50	1.80	109.22	386.64	87.62%	37.88%	429	90.0	108.11%	138

Notes: The above results are based on a price demand elasticity of 0.8 and the corresponding distribution parameters (see Table 6). The marginal cost on the legal market, c^L, is USD 25 per ounce. The tax revenue in USD *per capita* and *per annum* is given as the product of the difference $p^L - c^L$ with the extensive and intensive margins of consumption. The intensive margin is approximated using Orens et al. (2018) estimates for consumption in Colorado in 2017.