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Can legalization of cannabis eliminate related organized crime? We model consumer choices for cannabis in a risky environment and determine the provision of cannabis, under prohibition and legalization. Although a legalization policy may crumble the profits from illegal providers driving them out of business, it also increases cannabis use. In contrast, repression decreases cannabis consumption but strengthens the cartelization of criminal networks. Combining legalization with repression can strangle the black market while controlling the demand for cannabis. Based on evidence from the US, policy simulations are used to compute the price of legal cannabis that would achieve this dual objective and highlight the complementarities between repression and legalization. For example, with a 1% probability of arrest and a USD 2000 fine for illegal purchase, a legal price around USD 439 per ounce would evict illegal suppliers and increase the consumption by less that 25%. If the probability of arrest reaches 2%, the eviction price can go up to USD 622 and overall consumption increases by no more than 5:5%.

JEL Classification: I18, K32, K42, L51

Keywords: Cannabis, legalization, crime, policy, regulation

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Defeating Crime? An Economic Analysis of Cannabis Legalization Policies

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June 18, 2019

Abstract

Can legalization of cannabis eliminate related organized crime? We model consumer choices for cannabis in a risky environment and determine the provision of cannabis, under prohibition and legalization. Although a legalization policy may crumble the profits from illegal providers driving them out of business, it also increases cannabis use. In contrast, repression decreases cannabis consumption but strengthens the cartelization of criminal networks. Combining legalization with repression can strangle the black market while controlling the demand for cannabis. Based on evidence from the US, policy simulations are used to compute the price of legal cannabis that would achieve this dual objective and highlight the complementarities between repression and legalization. For example, with a 1% probability of arrest and a USD 2000 fine for illegal purchase, a legal price around USD 439 per ounce would evict illegal suppliers and increase the consumption by

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1 Introduction

Prohibition policies, which target the suppliers or consumers of illegal cannabis, turn out to be poorly effective at controlling demand. With 192 million users worldwide[1], cannabis is the most popular illegal drug (UNODC, 2018).[2] It accounts for half of global drug seizures (UNODC, 2017) and represents a black market worth 142 billion dollars (UNODC, 2005), which is comparable to Hungary's GDP in 2017, or a tenth of Canada's GDP in 2016[3]. In response to this problem and along with evidence of cannabis being less addictive and less risky than other psychotropic substances in terms of overdose (National Academy of Sciences, 2017)[4] some governments have legalized the use of recreational cannabis. This paper investigates to which extent different types of legalization can be implemented to reach a range of objectives set in terms of reduced criminality and consumption.

To reduce criminality a first natural idea is to legalize the market by using pricing tools, which can also be used to regulate and tax cannabis consumption. Our theoretical analysis shows that selling legal cannabis at a competitive price with the smuggling market will not be sufficient to eliminate the criminal networks. Indeed prohibition creates barriers to entry, which has fostered the sector cartelization by criminal organizations. These networks will thus be able to respond to the competition against legal suppliers of cannabis by lowering the price they propose and still make a profit. Hence, legalization at illegal market price may instead increase the consumption of "low-cost" illegal cannabis, with all the negative externalities this would

[1]UNODC reports 192 million people worldwide to have used cannabis at least once in the past year in 2016.

[2]For comparison, this figure represents nearly 1/10 of the population of alcohol drinkers (WHO, 2004) and 1/6 of the population of cigarette smokers (WHO, 2015).

[3]These figures could even be largely underestimated: using consumption data on complementary legal inputs to illegal cannabis consumption, Parey and Rasul (in press) estimate that the size of the cannabis market in the UK could be twice as much as what had been estimated through demand side approaches.

[4]It is almost impossible to overdose with cannabis.

entail for societies. We explore a policy that combines pricing tools through the sale of legal cannabis – to push the criminals out of the market – and repressive tools – to limit the subsequent increases in consumption.

To be more specific, the demand, in our model, comes from (risk averse) individuals who would like to consume cannabis. When the market is prohibited the only option is to turn to a criminal supply, which involves weighing the benefits of consumption against the costs linked to this risky illegal activity. Price is determined by criminals who maximize their profits. Our framework highlights a policy trade-off: prohibition and repression help to control consumption flows but, far from suppressing dealers, they may even increase their market power and the price paid by their clients for their services. In contrast, legalization at black market price helps to eradicate criminals' activities at the cost of substantially increasing consumption. Both types of policies may lead to undesirable social and political outcomes.

We explore how to overcome such a trade-off by combining cannabis pricing with repression tools. The Policy Mix we propose allows policy makers to strangle the black market for cannabis by creating a legal alternative. It is also designed to enable the government to control cannabis consumption by regulating its price. We focus on the legal price, which pushes smugglers out of business. We show how this "eviction" price can be adjusted with repression tools, and/or by increasing the quality of certified legal cannabis relatively to the illegal one. We do not discuss the optimality of the consumption targets but we show how a government may use a pricing strategy combined with sanctions to decentralize the predetermined targets while eradicating crime. Policy applications and comparisons to the U.S. market for cannabis highlight the complementarities between repression and legalization and question current policies. We then enlarge the set of policy objectives, which may explain the heterogeneity of current anti-drug policies.

The rest of the paper is organized as follows. Section 2 describes the evolution of cannabis liberalization measures and positions our paper in the literature. Section 3 presents the set-up of the model, which explains the illegal market structure under *status quo* (prohibition). Section 4 analyses the effects of introducing pricing strategies combined with measures targetting consumers and suppliers in order to regulate the sale of cannabis. Section 5 calibrates the model based on evidence from the U.S. cannabis market and study its implications in terms of price and quantities traded. Section 6 concludes.

2 Cannabis legalization policies: recent evolution and impact review

In response to an increase of cannabis use, the seventies showed a wave of decriminalization. In the United-States, possessing small amounts (usually up to 1 ounce) of cannabis was declassified to a misdemeanor during this period in California, Colorado, Maine, Minnesota, Mississippi, Nebraska, New York, North Carolina, Ohio, Oregon and Washington. Alaska in 1975 declared possession of small amounts of cannabis to be protected under state constitutional right to privacy. Over the Atlantic, the Netherlands took a bold measure by making cannabis available for recreational use in coffee shops. However the attempts to legalize cannabis stalled with the War on Drugs in the eighties.

Rising concerns about the legitimacy and efficiency of this war led to policy changes at the end of the nineties with a second wave of decriminalization laws and the first laws in favor of medical use in the U.S. (see Appendix A). This liberalization movement accelerated in the last decade. In 2012, the Uruguayan government announced plans to legalize and control sales of cannabis to fight drug-related crime. This initiative came along with Colorado and Washington states passing bills legalizing recreational use of cannabis after a referendum. From 2014 onward, these states have been imitated by eight other American states, the District of Columbia, and in 2018 by Canada, South-Africa and Georgia.[5]

Legalization policies implemented so far are quite diverse. In the US, ten states and the District of Columbia have legalized the use of recreational cannabis, while possessing cannabis remains a felony in other states such as Arizona (see further detail in Appendix A). Moreover, sanctions and fine levels differ a lot between two states having the same cannabis laws. 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 $ 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 $ 1,000 fine.

In Canada, retail sale of cannabis is legal although the terms of policies differ from province to province.[6] In Uruguay, cannabis production and distribution were legalized in 2017. Farms are allowed to grow cannabis for the local market, citizens to run cannabis cooperatives, and selected pharmacies to act as dispensaries for both medical and recreational cannabis.[7] There has been a flourishing literature on the impacts of the recent cannabis legalization policies.

2.1 Impacts on crime and violence

The first strand of the literature highlights the costs entailed by drug prohibition. Resignato (2000) shows that most drug-related violent crimes are the consequence of systemic factors entailed by the War on Drugs rather

[5] Bills towards legalizing recreational cannabis have been passed in Alaska (2014), Oregon (2014), California (2016), Maine (2016), Massachusetts (2016), Nevada (2016), Michigan (2018), and Vermont (2018) and the state of New York should legalize it in 2019.

[6] For example, in Québec, cannabis is distributed by a government monopoly, the Société Québécoise du Cannabis (SQDC), which is a subsidiary of the Société des Alcools du Québec (SAQ), the provincial monopoly regulating retail sales of alcohols; while Alberta chose to allow cannabis sales through privately run stores.

[7] Even though Uruguay was the first country to legalize recreational use of cannabis in 2012, public skepticism has slown down the process and distribution of legal cannabis was only implemented in July 2017.

than of psycho-pharmacological effects of drug use on crime. Indeed prohibition increases incentives to engage in criminal behavior (MacCoun and Reuter, 2001). In particular, it promotes violence as almost the only way to solve conflicts and secure market power. Encouraging market strategies based on violence, prohibition reduces the marginal cost of crime and raises its marginal benefit (Miron 1999, 2003). This strengthens cartelization and leads Miron and Zwiebel (1995) to conclude that a free market for drugs would probably do better than prohibition in terms of social costs. The social costs linked to prohibition are exacerbated by "zero-tolerance" policies, which may encourage users to possess higher quantities (Caulkins, 1993).

In line with these arguments, Dills, Goffard, and Miron (2017) show that liberalizing cannabis does not necessarily lead to a rise in crime. Depenalizing possession of small amounts of cannabis enables the police force to focus on other crime, reducing non cannabis-related crime (Adda et. al, 2014). This reallocation outweighs the expected undesirable effects regarding criminality associated to drug consumption. Overall crime in Colorado decreased in areas where cannabis dispensaries were added (Brinkman and Mok-Lamme, 2016). 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 purpose has decreased drug-trafficking related crime rates (Morris et al., 2014; Gavrilova et al., 2017; Chang and Jacobson, 2017). Furthermore legalization policies may dry up criminal profits. 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 on drug consumption

A first immediate effect of legalization is to increase the availability and proximity of cannabis to adult consumers (provided supply is large enough).

Jacobi and Sovinsky (2016) explore the idea that legalization reduces the searching cost for cannabis and removes the stigma inherent to the illicit consumption. Using a structural approach, they extrapolate that legalizing recreational cannabis would thereby entail an increase in its use around 48%. This is also supported by Austin et al. (2017), who show that cannabis legalization induces a rise in consumption early after being implemented, using survey data on undergraduate students at Washington State University. 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).

Legalization may also affect consumer behavior through lowering their risk and the price of drugs available on the market. The idea that individuals are responsive to such changes is supported by Williams (2004). On risk, Adda et al. (2014) show that the experimental depenalization of cannabis possession in the London borough of Lambeth (2001) has caused a rise by 32.5 percent in cannabis-related crime. Accordingly, lower risk faced by consumers following legalization of recreational use may in turn push up prices for illegal cannabis as it raises demand (Pacula et al. 2010). From this viewpoint, cannabis users may be considered as rational economic agents sensitive to variations in prices and risk.

Although increasing consumption, legalization does not necessarily lead to the socially undesirable effects regarding other substance use, public health and road hazard (Dills, Goffard, and Miron, 2017; Hansen, Miller, and Weber, 2018). Legalizing cannabis may even decrease consumption among the youth. According to a federal study on the states of Washington and Colorado experiences, consumption of cannabis among teenagers is estimated to have decreased by 12% following legalization (see the National Survey on Drug Use and Health, Summary of Methodological Studies, 1971-2014 CBHSQ Methodology Report).

2.3 Tax instruments

From a public policy viewpoint, another interest of regulating the cannabis market is to raise tax revenues and to control the consumption using this instrument. Caputo and Ostrom (1994, 1996) show that the cannabis market could generate substantive public resources and model an optimal government policy for newly legalized commodities. In the case of the U.S. tax policies could raise revenue around US$ 12 billion, while controlling cannabis consumption (Jacobi and Sovinsky, 2016).

With price elasticities of demand ranging between -0.5 and -0.79 (Davis, Geisler and Nichols 2016; Van Ours and Williams, 2007), cannabis consumers are sensitive to price. Accordingly, a government may reduce increases in cannabis consumption following legalization by taxing it. From this viewpoint, Becker, Grossman and Murphy (2006) show that policies controlling drug use by taxes are more advantageous than quantity reductions through prohibition. In addition, taxing cannabis consumption may discourage early initiation to cannabis of younger users, who are very responsive to low prices (Van Ours and Williams, 2007).

Prohibition and legalization policies have been studied so far as two alternatives. Our contribution to the literature is to study the effects of a novel Policy Mix, which combines pricing tools through the implementation of a legal market of cannabis and sanctions against consumers and suppliers of illegal cannabis. The next section describes the market equilibrium under prohibition.

3 Prohibition equilibrium

We start by analyzing the equilibrium under the status-quo: Cannabis cannot be obtained legally and consumers need to buy from dealers to meet their demand. They pay a price p to purchase cannabis illegally.

3.1 Demand when there is no legal supply

Potential customers for illegal cannabis are heterogeneous according to their "taste" for the commodity, θ, which is drawn from the distribution $G(\theta)$, twice differentiable, with support $\theta \in \mathbb{R}$ and density function $g(\theta)$. Individuals with distaste (taste) for cannabis are characterized by negative (positive) θ parameters, reflecting the whole population spectrum. In the absence of legal provision of cannabis, consumers can only purchase on the illegal market, with returns from consumption given by $d\theta v$. θv denotes the value of consumption considering a hypothetical legal sector. The discount factor $d \in (0,1)$ captures the fact that individuals have higher payoff to consume cannabis if they can purchase legally rather than illegally. Indeed, illegal products are uncertified and likely to be diluted or of bad quality[8]. Moreover, purchasing from the illegal sector may entail a personal cost in terms of ethics or social stigma, which is also captured by the discount factor d.

Since illegal activities entail a 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 the commodity is: $-p - F$; while the net payoff for an individual who is not caught is $\theta dv - p$. Choosing to consume cannabis illegally may therefore be assimilated as taking part to the lottery $\mathcal{L}_{\text{illegal}} = [-p - F, \theta dv - p; q, 1-q]$.

The seminal paper by Kahneman and Tversky (1972) was the first to show that individuals have a poor ability to deal with probabilities. For instance, they tend to overestimate the odds of rare salient events, while they underestimate the odds associated to more usual events. In our framework, individuals choosing to purchase cannabis on the black market face a low

[8]Quality certification under legalization should involve regulating cropping techniques; in particular the use of pesticides, which is shown to be harmful for health (Subritzky et al. 2017)

probability of being arrested (NGuyen and Reuter, 2012). Getting caught for purchasing cannabis illegally is a rare salient event, whose probability is likely to be overestimated by individuals, even though they may be conscious this probability is relatively low. Conversely, not getting caught is the norm and is not salient; the probability for this event is likely to be underestimated.

Probability weighting functions account for individuals' distorted perception of probabilities. 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) $w(x) \geq x$ ($w(x) \leq x$). In our setting, agents face a binary lottery and the weighting function $w^+(1-q)$ (respectively $w^-(q)$) is applied to probabilities associated to positive (negative) outcomes – that is not getting arrested (getting arrested) with probability $1-q$ (q). The lottery $\mathcal{L}_{\text{illegal}} = [-p-F, \theta dv - p; q, 1-q]$ has expected value

$$w^+(1-q)u(\theta dv - p) + w^-(q)u(-p-F).$$

The values of the different outcomes are given by the function $u(x)$, continuous, strictly increasing in x and such that $u(0) = 0$.[9]. This framework is extremely general. It encompasses 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 encompass Tverky and Kahneman's Cumulative Prospect Theory (CPT), where probability weighting functions are not linear such that $w(0) = 0$, $w(1) = 1$, and for x in the neighborhood of 0 (respectively 1) $w(x) > x$ ($w(x) < x$), and where the value function $u(x)$ is bi-concave with an inflection point in zero and such that $u(0) = 0$. The bi-concave value function enables to account for agents' different risk attitudes depending on whether they face gains (risk-aversion) or losses (risk-seeking). Since it is more realistic we will use this specification in the calibration exercises. However our theoretical results hold in the

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

general case.

The consumer of type θ^I is indifferent between illegal consumption and no consumption if he attributes a zero value to the lottery $\mathcal{L}_{\text{illegal}}$. This agent is characterized as follows:

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

We show in the Appendix B that θ^I exists and is unique.

Any consumer of type $\theta \geq \theta^I$ purchases illegal cannabis. Without loss of generality, the demand for the illegal commodity can then be written:

$$D^I(p) = \int_{\theta^I}^{+\infty} g(\theta)d\theta = 1 - G(\theta^I) \tag{2}$$

where θ^I is solution of equation (1).

We show in Appendix B that the demand for the illegal commodity decreases with the probability of arrest (θ^I increases with q), as we may expect: the risk of being arrested discourages individuals to purchase illegally, which leads to a more positive selection of consumers. In other words, the risk of being arrested, and therefore repression, lowers the demand for illegal commodity, which is the desired effect of prohibition policies.

Similarly θ^I is increasing with p so that a higher price reduces also the demand. However this tool is not available to policy makers under prohibition: the equilibrium price on illegal market results from the interaction between unregulated (and untaxed) criminals.

Finally the absolute value of the price elasticity of demand is:

$$\epsilon_{_{D^I,p}} = \frac{-D^{I\prime}(p)p}{D^I(p)} = \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d\theta^I}{dp}p \tag{3}$$

After differentiating $\epsilon_{D,p}$ with respect to $q \leq 1$, one can check that:

$$\frac{d\epsilon_{D^I,p}}{dq} = \frac{d\{\frac{g(\theta^I)}{1-G(\theta^I)}\}}{d\theta^I}\frac{d\theta^I}{dq}\frac{d\theta^I}{dp}p + \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d^2\theta^I}{dpdq}p. \tag{4}$$

As θ^I increases with p and q, and the cross-derivative of θ^I with p and q is positive, it follows that $\epsilon_{D^I,p}$ increases with $q \in [0,1]$ if the distribution $G(\theta)$ satisfies the monotone hazard rate property. This proves the intuitive result that the price elasticity of demand for cannabis increases with the risk of being caught.

3.2 Cannabis supply under prohibition

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

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

where c represents their constant marginal costs, $\epsilon_{D^I,p}$ is the price elasticity of demand defined in (3) and N is an integer greater than 1. The generalized Cournot competition demand, $D^I(p^N)$, is between the 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 (when $N = 1$) and $p^\infty = c$ in the competitive case when $N \to \infty$.

When the risk q increases, the price elasticity of demand increases, and thus, everything else being equal, the oligopolistic price is lower. Risk-aversion implies that the price imposed by smugglers is lower than the price they would impose to risk neutral individuals with the same expected payoff from consumption.

In a more dynamic perspective, one can endogenize N, the number of criminal organizations on the market. Since K is the level of sunk costs to enter this market, the number of organizations N is the integer 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 on the market, N, thereby increasing the price they charge for their services/commodities, as captured by equation (5) above.[10]

4 Legalization

In order to eradicate organized crime, the government may push the dealers out of business. To do so, a simple idea would be to sell legal cannabis at the same price as the price of illegal cannabis sold on the black market: $p^L = p$. Yet, we can show easily that this policy will increase consumption without necessarily eradicating crime. Indeed, if it is possible to purchase the commodity at price $p^L = p$ without risk, the marginal consumer becomes such that $\theta v - p = 0$:

$$\underline{\theta}^L(p) = \frac{p}{v} \tag{6}$$

Comparing the legal threshold $\underline{\theta}^L(p)$with (1), for any given price p, when there is no risk of detection (i.e., so that $q = 0$) then $\theta^I_{q=0}(p) = \frac{p}{dv} > \underline{\theta}^L(p) = \frac{p}{v}$ $\forall d < 1$. Since θ^I increases with the risk of detection, q, the legal demand threshold is always lower than the illegal one: $\underline{\theta}^L(p) < \theta^I(p)\ \forall p > 0$. This is very intuitive since, for a given price, the value of consuming legal cannabis is higher than illegal one (d<1) and there is no risk under legal purchase.

[10]It is also worth noting that the criminals might face different demands. If the oligopolistic criminals can identify them, they will apply different prices to these different populations. As is standard with third degree price discrimination, groups endowed with the largest price elasticity will get the smallest price. In contrast captive consumers (i.e., groups with low price elasticity) face higher prices.

Moreover, a government setting $p^L \leq p$ (for example $p^L = p$, as suggested by Québec's Minister of Health in 2017[11]) ignores the fact that the illicit retailers may be able to respond by lowering their price. In addition to increasing consumption, such a policy does not necessarily eradicate organized crime. To determine the pricing scheme to legalize the market of cannabis the government, a Stackelberg leader, needs to take into account that the criminals will react to its policy. The model is solved by backwards induction.

4.1 Reaction to the sale of the legalized commodity

We start by computing the demands for legal and illegal cannabis as functions of the relative prices of legal and illegal cannabis and other attributes (i.e.risk associated to illegal consumption and discounted quality). After the government announces a price $p^L \geq 0$ for legal cannabis, an individual purchasing legally has a payoff of $\theta v - p^L$. Agents such that $\theta \geq \frac{p^L}{v} \equiv \theta^0$ prefer to purchase cannabis legally over not purchasing at all. Since $\theta v - p^L$ is the reference wealth for an individual deciding between legal and illegal consumption, such a decision may be modeled by the lottery $[p^L - p - \theta v - F, p^L - p + \theta v(d-1); q, 1-q]$. The threshold type, $\theta^L(p, p^L)$, indifferent between legal and illegal consumption, is solution to :

$$w^+(1-q)u\left(p^L - p + \theta v(d-1)\right) + w^-(q)u\left(p^L - p - \theta v - F\right) = 0 \qquad (7)$$

Appendix C shows that 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 than illegally. In this model, legalization selects high types of consumers, i.e. consumers who have the highest preference for cannabis, such that quality and absence of risk are chosen above price difference.

Recall that θ^I defined in (1) is the threshold above which an individual

[11]See the interview in the newspaper La Presse, September 21, 2017.

prefers to purchase illegally than not to purchase. Two cases may occur following legalization, as shown in Appendix D.

1. The legal price is low enough and legalization shows the intended effect of kicking the illegal dealers out of the cannabis market. Formally:

$$w^{+}(1-q)u(dp^{L}-p) \leq w^{-}(q)|u(-p-F)| \tag{8}$$

   In this case, $\theta^L \leq \theta^0 \leq \theta^I$: the black market is eradicated and $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$ new cannabis consumers appear.

2. The legal price is high:

$$w^{+}(1-q)u(dp^{L}-p) > w^{-}(q)|u(-p-F)| \tag{9}$$

   The above condition describes an environment where $\theta^I < \theta^0 < \theta^L$. In this framework, the residual demand faced by the criminal networks is:

$$D^I(p,p^L) = \int_{\theta^I(p)}^{\theta^L(p,p^L)} g(\theta)d\theta. \tag{10}$$

Under legalization, a high-type segment of the formerly black-market customers are captured by the newly legalized market. Under legalization, individuals with higher valuation for cannabis turn to the legal market and pay attention to quality, while they neglect it under prohibition, where they cannot quality discriminate. This change of preference is also in line with the Prospect Theory (Kahneman and Tversky, 1979). Indeed, when the reference level of wealth changes, individuals change their preferences and accept gambles they would not accept otherwise – and conversely.

To keep some consumers, the criminals adjust their price, p. Let $p^N(p^L)$ be the solution of (5) computed with the direct price elasticity of the demand $D^I(p,p^L)$ defined in (10), $\varepsilon_{D^I,p} = -\frac{\partial D^I(p,p^L)}{\partial p}\frac{p}{D^I(p,p^L)}$, which depends on p^L .

The price reaction function of the smugglers is the solution of the following equation:

$$p(p^L) = \begin{cases} p^N(p^L) & \text{if } \; c \leq p^N(p^L) < dp^L \\ \varnothing & \text{otherwise} \end{cases} \tag{11}$$

Accordingly, as long as the illegal providers are active, i.e. have positive profits, their reaction price is increasing in their marginal costs to operate, c, 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 lower the relative payoffs of illegal consumption as compared to legal one (the lower d) and the lower the legal price, p^L, the lower θ^L defined in (7) and the more difficult it is for the criminals to attract consumers by decreasing their prices.[12]

After the dealers have responded to the sale of legal cannabis, if the price differential between both markets is high enough, we may have the case where $\theta^I < \theta^0 < \theta^L$: the black market survives.

Limiting the legal quantity offered has the same effect and, in practice, legalization might even cause a boom in the black market. This is what happened in California, as reported by the New-York Times on April 27, 2019. In an environment where the cannabis industry was already well implanted under prohibition and where the Medical Marijuana Laws had made the grey economy prosperous, legalization combined with a high entry cost to the legal market caused a boom in the black market cannabis economy.

To resolve this issue, the next section studies a simple legalization policy using pricing tool to drive illegal providers out of business. For the sake of realism we focus on situations where criminals are initially active in equilibrium.

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

4.2 Eradicating organized crime through legalization

We consider a policy in which cannabis is sold on the legal market at a low enough price such that illegal providers get non positive profits, which destroys their economic incentives to operate. This requires that their reaction price is pushed below their marginal costs, i.e. $p(p^L) \leq c$.

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 respectively in equations (1) and (7), with $p = c$:

$$\begin{cases} w^+(1-q)u(\theta dv - c) + w^-(q)u(-c-F) = 0 \\ w^+(1-q)u\left(\underline{p}^L - c + \theta v(d-1)\right)) + w^-(q)u\left(\underline{p}^L - c - \theta v - F\right) = 0 \end{cases} \tag{12}$$

We deduce that $\underline{p}^L = v\theta^I(c)$.

Note that this result applies to any initial structure of the market: monopolist, oligopolistic or competitive. Irrespective of the initial market conditions, if the government wants to drive illegal providers out of business, it has to apply a price smaller than $\underline{p}^L$, so that their mark-up vanishes after they respond to the policy.

Since $\theta^I(c)dv - c > 0$ it follows that $d\underline{p}^L - c > 0$. Therefore $\underline{p}^L > c$: the threshold price imposed by the government to eliminate illegal suppliers is higher than smugglers price under perfect competition, c. Nevertheless, in equilibrium the demand, which is now legal, is

$$D^L(\underline{p}^L) = \int_{\theta^L(\underline{p}^L, c)}^{+\infty} g(\theta)d\theta = 1 - G\left(\theta^L(\underline{p}^L, c)\right) = 1 - G(\theta^I(c)) = D^I(c) \tag{13}$$

This result is summarized in the next proposition.

Proposition 1. *To drive illegal suppliers of cannabis out of business the legal price of cannabis should be set below the threshold price* $\underline{p}^L$*, which yields the same level of consumption as under perfect competition among illegal* *suppliers:* $D^L(\underline{p}^L) = D^I(c)$.

Discussion of Proposition 1 We have shown theoretically that eliminating oligopolistic criminals by legalizing the retail market for cannabis necessarily increases the demand for cannabis.

Such a policy-tradeoff was observed in the beginning of the 19th century when the Dutch government controlled the opium market in the East-Indies, imposing a state monopoly and providing licences to consumers in what was called *opiumregie*. Although the aim was to regulate the market and better tax it, it had to face the tradeoff of 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 operate at lower prices (Van Ours, 1995). The idea to regulate drug markets through pricing policies is of course not new but the design of a policy to overcome this trade-off is novel.

Canada is one of the few countries to date that has implemented cannabis legalization explicitly as a policy to fight drug-related crime. Since the federal government gave to the Provinces the responsibility of implementing this 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 multiple forms.

In Québec, for example, one cannot home-grow cannabis and retail cannabis sales are organized by the government. The *Société Québécoise du Cannabis (SQDC)*, a subsidiary of the provincial society for alcohols, offers cannabis in 13 physical stores and online.[13] The products are classified by potency and strain type – Indica, Sativa, and Hybrid. Dried flower products are priced between CAD 8 and 10 per gram. This figures are consistent

[13] 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).

with the suggestion by the Québec Ministry of Health to set the price of the newly legalized cannabis at black market price – i.e. setting $p^L = p$. However, this policy did not take into account the responses of smugglers on the black market, nor the risk- and quality-premia factors affecting their price-setting. As a consequence, the average black market price fell to below CAD 6 per gram (CAD 180 per ounce), as recorded Mid March 2019 by the crowd-sourced website priceofweed.com.

In Alberta online retail sales are managed by a government monopoly, while physical sales are left to private-licensed stores. Although Alberta allows home-cultivation -up to four active plants for personal use-, prices for dried flowers on Alberta's online cannabis shop are slightly higher than in Québec, corresponding to higher illegal prices – approximatively CAD 40 per ounce higher than in Québec (based on priceofweed.com). Differences in price across Provinces can also be explained by different environmental factors influencing the production of cannabis and the different structures of the markets.

It is still too early to assess the effects of legalization on overall consumption and on the black market size. However using monetary circulation in Canada, Goodhart and Ashworth (2019) show that the need for cash has decreased in the country following the legalization, which they interpret as a decrease in black market transactions for cannabis purchase. For them, the country is heading towards one of the goals Trudeau had set in 2015: "[keeping] profits out of the hands of criminals" (Liberal Party 2015). Yet in presence of a legal supply shortage, the black market has survived by lowering prices, consistently with the theory. This implies that the overall (legal plus illegal) demand for cannabis has increased in Canada.

Canada has relied on Provinces and Territories to regulate the market structure and the supply capacity as well as cannabis quality requirements (certification) and taxes. Our model offers additional pricing tools to policy makers, which take into account the dynamic responses by the market to the quality differential and to the risk premium when legal cannabis is available. It also provides a framework to predict the *post-legalization* rise in consumption and cost-effective ways to control it.

4.3 Controlling cannabis use and eradicating organized crime: A Policy Mix

Substantial increases in drug consumption may not be desirable for the society, nor politically sustainable. Policy makers need other tools than prices to regulate the demand for cannabis while legalizing the market. Our theoretical framework shows that the eviction price that drives criminals out of business, $\underline{p}^L$, can be adjusted. It increases with re-enforcement of repression such as further controls, arrest and fines to those breaking the law or with measures that affect illegal providers' marginal costs to operate, or the relative discounting factor associated to illegal consumption. This is summarized in the following proposition.

Proposition 2. *The threshold price $\underline{p}^L$, which drives smugglers out of business, increases with the marginal cost c, the probability of arrest q, and the fine amount F, and decreases with the discounting factor d.*

Proof. Comparative statics are derived in Appendix B for the general case and in Appendix E.2 for the Tversky and Kahneman (1992) specification. □

Discussion of Proposition 2 Intuitively, policy instruments affecting q, F, d and c make competing with the legal provision of cannabis more difficult. This is either because consumers have lower expected payoffs if they consume illegally rather than legally, or because illegal suppliers operate with increased marginal costs. The government can therefore price the legal cannabis at a higher "eviction" price, which drives illegal suppliers out of business.

If the fine amount or the probability of getting caught are too low, then legalization will fail as dealers will be able to attract consumers. A seemingly almost costless way to enable a government to increase the policy price $\underline{p}^L$ would be to increase the fine F. However, this may also decrease the probability a caught individual will be able to pay. Enforcing the policy may then become very expensive, crowding the judicial system.

The Canadian *Cannabis Act* (S.C. 2018 c. 16, Section 8) clearly states two of the main policy objectives as "deter[ring] illicit activities in relation to cannabis through appropriate sanctions and enforcement measures" and "reduc[ing] the burden on the criminal justice system in relation to cannabis". This means focusing most of the efforts on punishing the illegal suppliers, i.e. rising the marginal cost noted c in our model, and rising sanctions on consumers F[14], but keeping a low probability of arrest q. Another aim of the Canadian *Cannabis Act* is to "provide access to a quality-controlled supply of cannabis", which translates into a drop in the quality discount parameter d. In our Policy Mix framework, increasing c, F or decreasing d enables a government to set a higher legal price $\underline{p}^L$, which can be used to control the consumption of cannabis following the legalization.

So far we have focused on legalization policies that aim at eradicating criminal activities while controlling the subsequent increase in drug consumption. Nonetheless a government might seek to satisfy other goals than eliminating the black market. In addition to minimizing negative externalities for society associated to illegal and legal drug consumption, a government might consider the fiscal aspect of legalization policies, the employment and turnover of the newly created legal sector or the consumers' surplus. Investigating this larger set of objectives is left to further research.

[14]The punishment for possession of illicit cannabis has risen up to a 5-year prison sentence on an indictable offense

5 Policy Implications

This section applies our theoretical framework and empirical evidence from previous studies to calibrate legal prices for cannabis that would evict criminal organizations from the market. The sensitivity analysis is then used to highlight which policy instruments are the most effective at curbing consumption and crime. It also illustrates the complementarity of legalization and repression tools.

To model individuals' gains and losses from given payoffs, we follow Tverky and Kahneman's (1992) Cumulative Prospect Theory (CPT).[15] Our choice of using CPT is consistent with agents' behavior while considering risky gambles (see Rabin 1998 and Barberis and Thaler 2003 for a literature review). 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. Moreover, Prospect Theory is particularly adapted to this context as it accounts for *framing* effects, i.e. the effects of the environment on decision-making. In our model, for instance, legalization changes individuals attitudes towards illegal cannabis consumption, as higher types, who always consume on the black market under prohibition, are less likely to act illegally once cannabis is legalized.

Using CPT enables us to compare outcomes from purchasing cannabis illegally with a "legal option" – not consuming cannabis under prohibition, purchasing legal cannabis under legalization.[16] Furthermore, this allows to consider people's poor ability to deal with probabilities (Kahneman and Tversky, 1972).

The calibration exercise is based on the functional forms derived by Tver-

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

[16] Although we do not model it specifically, the wealth distribution may be thought as a component of the distribution for θ, which reflects the heterogeneous effects of the prices and punishments implemented.

sky and Kahneman (1992). Tversky and Kahneman (1992) generalize the seminal paper (1979) and calibrate the following weighting and value functions.

$$w^t(q) = \frac{q^{\gamma^t}}{(q^{\gamma^t} + (1-q)^{\gamma^t})^{\frac{1}{\gamma^t}}} \qquad \text{with } t = +, -. \tag{14}$$

$$u(x) = \begin{cases} x^\alpha \text{ , if } x > 0 \\ -\lambda(-x)^\alpha \text{ , if } x \leq 0 \end{cases} \qquad \text{with } \alpha \in (0,1) \text{ and } \lambda \geq 1 \tag{15}$$

Substituting the Tversky and Kahneman (1992) value function in (1) Appendix E.2 shows that the marginal consumer is characterized by:

$$\theta^I(p) = \frac{1}{dv}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+p)+p\right] \tag{16}$$

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

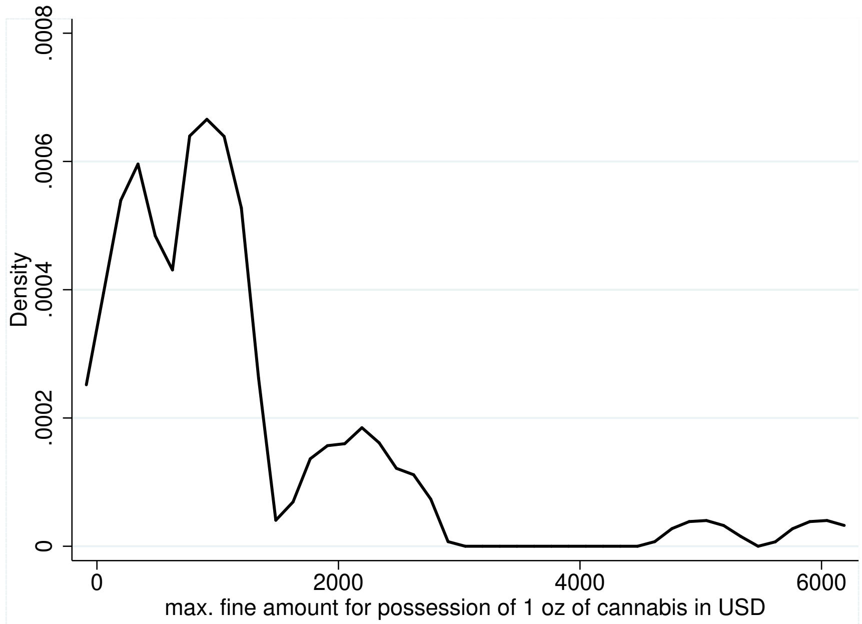
$$\underline{p}^L = \frac{1}{d}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+c)+c\right] \tag{17}$$

5.1 Benchmark values

The exogenous parameters calibrated by Tversky and Kahneman (1992) are $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$ and $\gamma^- 0.69$. By contrast q, F, c, and d are policy parameters, which are affected by investments into different kinds of measures. While the level of fines, F, and the probability of arrest, q, have already been documented in several studies, the parameters c and d require more indirect inference from evidence.

The probability of getting arrested in possession of cannabis in the United-States varies across settings. Nguyen & Reuters (2012) highlight that sex, age, and ethnicity, influence the probability of being controlled by the police, and therefore of being arrested. Still, the authors argue that in most groups,

Figure 1: 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 2016)



the average probability of being arrested is lower than 1%, which we use as a benchmark value for q.

In the United-States, the maximum fines applied for possession of cannabis *on a first offense* vary across states, as represented in figure 1[17](NORML, 2016). 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 in 2016, 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 a decrease in production costs of cannabis thanks to innovation,

[17]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.

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 to approximate the cost of loosing the stocks. These are directly increasing production and distribution costs. Moreover, production and distribution being managed by criminals, there are further hidden costs related to problems such as contracts enforcement, which are difficult to estimate.

Using various assumptions, Caulkins (2010) estimates the cost of production of cannabis to lie between 70$ and 400$ per pound, 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 (2014) estimates the wholesale price of a pound of cannabis under prohibition to be around 3,500$ (i.e. 218.75$ per ounce), and about 10 times smaller under legalization – which is consistent with Caulkins (2010). The LSE Group also reports the typical farmgate price quoted in the media to be around 2,000$ per pound (i.e. 125$ per ounce). A cost-benefit analysis of cannabis legalization by Archambault et al. (2013) uses the value of 5$ per gram (i.e. 141.75$ per ounce). In line with all these studies the illegal marginal cost per ounce is therefore likely to range between 125$ and 218.75$ per ounce.

In a legalized framework, not only innovation might push production costs down for all, but distribution costs on the illegal sector might also decrease, as detection of illegal producers and consumers might become less straightforward. We therefore choose the lower bound, 125$, as our benchmark value for marginal cost of illegal cannabis. 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 we allow for in our sensitivity analysis.

The parameter d describes the discount in value associated to the consumption of illegal cannabis bought on the black market versus legal one, which is certified by health or other regulation authorities. To get an objec-

Table 1: Benchmark values used for sensitivity analysis

Quantity	Benchmark value
λ	2.25
α	0.88
γ^+	0.61
γ^-	0.69
q	0.01
F	1,000
d	0.63
c	125
$\underline{p}^L$	325.78

tive measure for d we focus on the cannabis potency. We approximate d by the difference in THC dosage between cannabis bought legally and illegally. According to ElSohly et al. (2016), the average THC potency of cannabis seizures in the US in 2014 was 11.84%, while around the same time, the THC potency on Colorado's legal market was 18.7%.[18] Based on this difference, a benchmark measure for d could be $\frac{11.84}{18.7} \approx 0.63$.

Table 1 provides an overview of the different parameters. Using our model to predict the eviction price specified in (17), we obtain a benchmark price for legal cannabis of USD 325.78 per ounce. As a comparison, the average price of an ounce of "high quality" black market cannabis has been around 320$ in May 2019 according to the crowd-sourced website priceofweed.com.

5.2 Calibrating the distribution of "taste" for cannabis

We calibrate the distribution of the "taste" for cannabis using our model and the literature on cannabis demand estimation. Van Ours and Williams (2007) estimate the price elasticity of demand to range between -0.50 and -0.70, while Davis, Geisler and Nichols (2016) find a price elasticity between

[18] NBC News (online) 23 March 2015, "Colorado Marijuana Study Finds Legal Weed Contains Potent THC Levels"

-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. 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 (equation (3)) becomes

$$\epsilon_{D^I,p} = \frac{p}{dv}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} + 1\right]\frac{1}{\sigma\sqrt{2\pi}}\frac{e^{\frac{-(\theta^I-\mu)^2}{2\sigma^2}}}{1-\phi(\frac{\theta^I-\mu}{\sigma})} \tag{18}$$

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

$$\varsigma = 1 - \phi\left(\frac{\theta^I - \mu}{\sigma}\right) \tag{19}$$

Using the estimates of ϵ and ς discussed in the literature, we calibrate the parameters μ and σ solving the system defined by equations (18) and (19), 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 2 for μ and σ, as well as the benchmark values for the *post-legalization* increase in consumption implementing the price $\underline{p}^L = 325.78$. As the population becomes more inelastic, the distribution tail becomes fatter and the mean taste lower. The more inelastic the population, the lower the *post-legalization* increase in demand.

5.3 Sensitivity analysis

The sensitivity of the legal price $\underline{p}^L$ to the exogenous parameters γ^+, γ^-, α and λ is discussed in Appendix E.4 and 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.

Table 2: Distribution parameters and *post-legalization* increases in consumption for price elasticities of demand ranging from -0.5 to -0.8

ϵ	$\hat{\mu}$	$\hat{\sigma}$	$\Delta\%D\left(\underline{p}^L\right)$
- 0.5	- 1 093.3	1 689.8	33.67%
- 0.6	- 803.7	1 409.7	41.00%
- 0.7	- 594.4	1 208.0	48.74%
- 0.8	- 438.4	1 057.3	56.60%

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 estimate for the policy price: $\underline{p}^L = 325.78$.

This section studies the effects of investments into further enforcement in repression against illegal suppliers and consumers, which increase the marginal cost of operations for illegal suppliers, c, the probability of arrest, q, and fines to illegal consumers, F. In addition this may decrease the relative valuation of consumption of illegal cannabis, d, which can be further decreased by quality certification. Insights on how sensitive our results are to these policy parameters may be helpful for governments wishing to regulate the price for newly legalized cannabis.

Column 1 of Table 3 presents 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 10\$ per ounce[19] This captures a situation in which controls are very lax and hence are not inflating the marginal cost of operation for illegal suppliers, which becomes close to the estimates given by Caulkins (2010). We also present other cases where intensifying the repression drastically raises the marginal

[19]We simply take the median of the 70\$ to 400\$ interval, 165\$ per pound. We convert this to \$ per ounce, we obtain approximately 10\$.

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

Policy parameters					$\Delta\%D\left(\underline{p}^L\right)$			
c	d	q	F	$\underline{p}^L$	$\epsilon=-0.5$	$\epsilon=-0.6$	$\epsilon=-0.7$	$\epsilon=-0.8$
125	0.63	1%	1000	325.78	33.67%	41.00%	48.74%	56.60%
10	0.63	1%	1000	130.22	56.34%	69.22%	82.87%	96.90%
50	0.63	1%	1000	198.25	48.22%	59.08%	70.57%	82.35%
90	0.63	1%	1000	266.27	40.35%	49.29%	58.73%	68.36%
160	0.63	1%	1000	385.30	27.18%	33.00%	39.12%	45.31%
200	0.63	1%	1000	453.30	20.01%	24.19%	28.59%	33.00%
300	0.63	1%	1000	623.38	3.22%	3.80%	4.47%	5.08%
125	0.25	1%	1000	820.98	-14.24%	-16.96%	-19.56%	-22.14%
125	0.33	1%	1000	621.95	3.35%	3.96%	4.66%	5.30%
125	0.50	1%	1000	410.49	24.50%	29.69%	35.16 %	40.67%
125	0.75	1%	1000	273.66	39.51%	48.24%	57.47%	66.88%
125	0.90	1%	1000	228.05	44.74%	54.75%	65.33%	76.15%
125	0.63	0.1%	1000	218.64	45.83%	56.11%	66.97%	78.10%
125	0.63	0.5%	1000	271.26	39.78%	48.58%	57.87%	67.36%
125	0.63	1.5%	1000	375.57	28.23%	34.29%	40.67%	47.12%
125	0.63	2%	1000	422.69	23.21%	28.11%	33.27%	38.46%
125	0.63	3%	1000	512.17	14.02%	16.87%	19.88%	22.87%
125	0.63	5%	1000	680.83	-2.09%	-2.56%	-2.96%	-3.41%
125	0.63	1%	500	269.17	40.03%	48.88%	58.23%	67.78%
125	0.63	1%	1500	382.39	27.49%	33.38%	39.58 %	45.85%
125	0.63	1%	2000	439.00	21.50%	26.01%	30.76%	35.53%
125	0.63	1%	3000	552.22	10.05%	12.05%	14.17%	16.26%
125	0.63	1%	5000	778.66	-10.69%	-12.78%	-14.77%	-16.77%

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 2.

cost for 1 ounce of cannabis on the black market.

Another parameter whose evolution is hard to predict is d. Indeed, when retail sales for cannabis are legal, new certified products appear: legalization brings product differentiation, driving d down. 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 increase the relative value of illegal cannabis. Starting from our benchmark value, $d = 0.63$, we then consider alternative cases, for d either falling to 0.25 or increasing to 0.90 in Column 2.

Column 3 varies the probability of being caught on the black market, q. Following the implementation of a legal market, it may be more costly than previously to detect consumers of illegal cannabis than 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. Similarly, Column 4 allows for several scenarios starting from the benchmark value of fines, F. For similar reasons, we argue that 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.

As a function of these parameter values, we compute, in column 5, the threshold price, $\underline{p}^L$, which will drive illegal providers out of business. We then predict in columns 6 to 9, the subsequent variation in demand *post-legalization* corresponding to the parameters of taste distributions described in table 2.[20] As highlighted in Table 3, whatever the value for d and c are, the predicted rise in consumption can be stemmed by manipulating q and F,

[20] These are calibrated using the range of price elasticities of demand highlighted by empirical studies.

to which demand is strongly responsive.

Table 4 presents possible options for policies, exploiting variation in several 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* rise in the extensive margin of consumption $\Delta\%D\left(\underline{p}^L\right)$.
Rows 2 to 5 present scenarios in which the government can certify the quality of legal cannabis, such that d decreases to reach 0.5, does not invest a lot in detecting illegal purchases – the probability of arrest q is half the benchmark value – but doubles the fines for illegal purchase. Such a government may choose or not to enforce repression on the illegal side, the marginal cost c varying from 10 – i.e. less than 10% of the benchmark value – to 250 – i.e. twice the benchmark value. Simulations show that the government is able to contain consumption at the *pre-legalization* level when the marginal cost is doubled ($c = 250$).
Row 6 shows that the same consumption objective can be achieved if the government further invests in improving quality of legal cannabis such that $d = 0.25$. Rows 6 to 11 show that investing in quality differentiation (reducing d) seems effective at reducing cannabis consumption for high quality differentiation (i.e. low values of d), but less when illegal and legal products are more similar for consumers.
Rows 12 to 16 show simulations of policies increasing 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 drastically increasing the level of fine may seem to be a cost effective way to limit *post-legalization* consumption, one may question the effectiveness and fairness of setting high fine amounts, as poorer individuals may not be able to pay them. On the other hand, increasing probabilities to be caught may give more weight to statistical discrimination, affecting specific groups.
The fourth part of the table (rows 17 to 21) presents results where the *post-legalization* consumption is contained at the *pre-legalization* level. Although

Table 4: Examples of possible policies and *post-legalization* demand

Policy parameters					$\Delta\%D\left(\underline{p}^L\right)$			
c	d	q	F	$\underline{p}^L$	$\epsilon=-0.5$	$\epsilon=-0.6$	$\epsilon=-0.7$	$\epsilon=-0.8$
125	0.63	1%	1000	325.78	33.67%	41.00%	48.74%	56.60%
10	0.50	0.5%	2000	184.00	49.90%	61.18%	73.11%	85.35%
60	0.50	0.5%	2000	288.08	37.88%	46.22%	55.02%	64.00%
125	0.50	0.5%	2000	336.02	32.54%	39.61%	47.06%	54.62%
250	0.50	0.5%	2000	683.58	-2.33%	-2.86%	-3.30%	-3.80%
125	0.25	0.5%	1000	683.58	-2.33%	-2.86%	-3.30%	-3.80%
125	0.33	0.5%	1000	517.86	13.45%	16.17%	19.06%	21.91%
125	0.50	0.5%	1000	341.79	31.91%	38.82%	46.12%	53.52%
125	0.63	0.5%	1000	271.26	39.78%	48.58%	57.87%	67.36%
125	0.75	0.5%	1000	227.86	39.67%	48.61%	57.94%	67.38%
125	0.90	0.5%	1000	189.88	44.85%	55.07%	65.75%	76.59%
125	0.63	0.5%	1000	271.26	34.88%	41.42%	49.27%	57.18%
125	0.63	1%	2000	439.00	12.90%	15.62%	18.43%	21.14%
125	0.63	0.5%	3000	400.77	17.48%	21.22%	25.08%	28.86%
125	0.63	2%	500	323.01	27.17%	33.12%	39.30%	45.47%
125	0.63	0.1%	5000	290.54	31.35%	38.30%	45.51%	52.76%
125	0.50	1%	3000	695.80	-3.44%	-4.17%	-4.83%	-5.54%
200	0.63	1.5%	2000	663.89	-0.54%	-0.71%	-0.81%	-0.95%
125	0.50	0.5%	5000	668.15	-0.93%	-1.18%	-1.35%	-1.57%
160	0.33	1%	500	636.13	2.83%	3.33%	3.92%	4.46%
25	0.25	1%	2000	677.76	-1.81%	-2.23%	-2.57%	-2.97%
50	0.63	1%	5000	651.12	0.63%	0.69%	0.84%	0.92%
125	0.75	2%	3000	689.99	-2.91%	-3.55%	-4.11%	-4.72%
125	0.63	2%	2000	622.05	3.34%	3.95%	4.64%	5.28%
125	0.63	2%	2500	721.73	-5.75%	-6.93%	-8.03%	-9.16%
10	1.00	0%	-	10	70.85%	87.67%	105.33%	123.42%
25	1.00	0%	-	25	68.60%	84.83%	101.87%	119.34%
50	1.00	0%	-	50	64.87%	80.14%	96.18%	112.59%
75	1.00	0%	-	75	61.19%	75.52%	90.55%	105.93%
100	1.00	0%	-	100	57.55%	70.95%	85.01%	99.37%
125	1.00	0%	-	125	53.96%	66.45%	79.54%	92.90%

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 2.

a lot of these results appear unrealistic, they highlight that a government aiming at eliminating cannabis consumption through legalization would have to invest in a strict repression of either the supply or the demand side, as well as an adequate pricing policy involving relatively high certification on the legal market. Consider, for instance,

a legalization policy combined with significant investments in quality differenciation of legal cannabis ($d = 0.5$) and with increased fines for illegal consumption up to USD 3,000: under this scenario, a retail price for legal cannabis of USD 695.80 per ounce would allow to drive smugglers out of business while decreasing cannabis consumption by 3.49% to 5.54%.

The last exercise illustrates the case of no differentiation between legal and illegal products in an extremely liberal state, where there is no repression, nor investment in quality certification and cannabis is equally priced at marginal cost on both the legal and the illegal markets. The results highlight that when the marginal cost of cannabis is low the consumption of cannabis is likely to double *post-legalization*

6 Conclusion

Designing a policy that both eliminates organized crime and limits a post-liberalization rise in demand is not trivial. Our paper shows that legalizing cannabis using simple pricing tools necessarily results in a substantial increase in consumption – which may not be desirable for societies. If the aim is to control the demand for cannabis, we show that a better policy is to combine legalization with other measures, which allow to adjust the price set by the authorities for legal consumption while fighting against the competition of illegal suppliers. If the legal price of consumption increases and illegal suppliers respond to this by supplying low-costs cannabis, the aggregate consumption rises, feeding a flourishing illegal retail business. From a public and health policy viewpoint this is the worst possible scenario. 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 measures that drive them out of business.

Our paper warns policy makers that legalization policies may have unexpected effects if they are not designed with care. Examples of what can go wrong include situations in which cannabis is legal but extremely expensive or rationed (e.g., Uruguay or Canada). Both scenarios result in flourishing illegal businesses and no significant decrease of criminality. If by contrast the government decides to flood the market with cheap legal cannabis, then illegal businesses will struggle to compete and loose ground, but consumption will significantly increase.

To avoid these problems, our findings highlight the complementarities between legalization and repression, providing policymakers with guidelines to overcome the legalization/repression trade-off. The Policy Mix we propose combines repressive tools against illegal activities and pricing tools to regulate the legal market and reach pre-determined consumption targets while driving illegal suppliers out of business. We show that raising the level of punishment and investing in repression, not only on suppliers but also on users of illegal drugs, allows the government to implement higher legal prices for cannabis while still undermining dealers. This helps to control demand, while driving illegal suppliers out of business. For example, our calibrations based on empirical evidence from the US illustrate that with a 1% probability of arrest and a USD 2000 fine for illegal purchase, if the marginal cost for producing an ounce of cannabis is USD 125 then a legal price around USD 439 per ounce would evict illegal suppliers and contain the increase in consumption below 25% (but there would be no illegal consumption). This legal market would evict the illegal suppliers from the market, create jobs, and allow the government to raise taxes. This is only one example : the increase in *post-legalization* consumption could be further dampened by advertising about better quality and certified legal cannabis, which would decrease the relative value of using illegal cannabis or by increasing the probability of being caught. If the probability of arrest goes up to 2% in the same example, the eviction price can be set at USD 622, which contains the consumption increase below 5.5%.

Further research will extend this model to better capture the large heterogeneity in consumer behavior, in particular regarding their risk aversion, intensive margin of consumption and liquidity constraints to shed more light on post-legalization consumer behavior.

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A Cannabis regulations in the United-States

State	Decriminalization	First MML ballot	MML	First recreational ballot	Recreational	Retail sales
Alabama	-	-	-	-	-	-
Alaska	1975[a]	1998	1998	2004	2014	2016
Arizona	-	1998	2010	2016	-	-
Arkansas	-	2012	2016	-	-	-
California	1975	1996	1996	2012	2012	2017
Colorado	1975	1996	1996	2012	2012	2014
Connecticut	2011	-	2012	-	-	-
Delaware	2015	-	2011	-	-	-
D. C.	2014	-	2011	2014	2015	-
Florida	-	2014	2017	-	-	-
Georgia	-	-	-	-	-	-
Hawaii	-	-	2000	-	-	-
Idaho	-	-	-	-	-	-
Illinois	2016	-	2014	-	-	-
Indiana	-	-	-	-	-	-
Iowa	-	-	-	-	-	-
Kansas	-	-	-	-	-	-
Kentucky	-	-	-	-	-	-

[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 right, was issued. Decriminalization of cannabis came into effect on June 5, 1975. The timeline of cannabis policy in Alaska in then relatively fuzzy: further decriminalization was billed in 1982, then cannabis was recriminalized in 1990, decriminalized again in 2003, to be then recriminalized in 2006; while the textitRavin caselaw would still interact with the criminal state law (Brandeis, 2012). Legalization voted in 2014 ended this confusion.

State	Decriminalization	First MML ballot	MML	First recreational ballot	Recreational	Retail sales
Louisiana[a]	-	-	-	-	-	-
Maine	1976	1999	1999	2016	2017	-
Maryland	2014	-	2017	-	-	-
Massachusetts	2009	2012	2013	2016	2016	2018
Michigan	2018	2008	2008	2018	2018	-
Minnesota	1976	-	2015	-	-	-
Mississippi	1978	-	-	-	-	-
Missouri	2017	-	-	-	-	-
Montana	-	2004	2004	-	-	-
Nebraska	1979	-	-	-	-	-
Nevada	2017	1998	2001	2006	2017	-
New Hampshire	2017	-	2013	-	-	-
New Jersey	-	-	2010	-	-	-
New Mexico	-	-	2007	-	-	-
New York	1977	-	2014	-	-	-
North Carolina	1977	-	-	-	-	-
North Dakota	-	2016	2014	-	2018	-
Ohio	1975	-	2016	2015	-	-
Oklahoma	-	2018	2018	-	-	-
Oregon	1973	1998	1998	2012	2015	2015
Pennsylvania	-	-	2016	-	-	-
Rhode Island	2013	-	2006	-	-	-
South Carolina	-	-	-	-	-	-

[a] Although a bill regulating medical use of cannabis was signed in June 2015, Medical Marijuana Laws have not been implemented yet in Louisiana.

State	Decriminalization	First MML ballot	MML	First recreational ballot	Recreational	Retail sales
South Dakota	-	2006	-	-	-	-
Tennessee	-	-	-	-	-	-
Texas	-	-	-	-	-	-
Utah	-	2018	-	-	-	-
Vermont	2013	-	2004	-	2018	-
Virginia	-	-	-	-	-	-
Washington	1971	1998	1998	2012	2012	2015
Wisconsin	-	-	-	-	-	-
Wyoming	-	-	-	-	-	-

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 $[-p-F, \theta dv - p; q, 1-q]$. His/her reference level is zero as not consuming entails a zero payoff. Therefore, the perceived value the agent associates to the decision to consume illegally is given by: $w^+(1-q)u(\theta dv - p) + w^-(q)u(-p-F)$.

We recall u is a value function which is continuous, derivable, strictly increasing, and such that $u(0) = 0$.

The consumption condition writes as $w^+(1-q)u(\theta dv - p) + w^-(q)u(-p-F) \geq 0$ and an individual is indifferent between illegal consumption and no consumption if the following equation holds:

$$w^+(1-q)u(\theta dv - p) + w^-(q)u(-p-F) = 0 \tag{20}$$

We note θ^I the marginal type solving this equation.

If it exists, θ^I is characterized as follows.

$$\begin{aligned} & w^+(1-q)u(\theta^I dv - p) + w^-(q)u(-p-F) = 0 \\ & \Rightarrow -\frac{u(-p-F)}{u(\theta^I dv - p)} = \frac{w^+(1-q)}{w^-(q)} \end{aligned} \tag{21}$$

Let us note $U(\theta) \equiv -\frac{u(-p-F)}{u(\theta dv - p)}$. The ratio $U(\theta^I)$ is necessarily positive. Indeed, individuals whose type is such that $\theta dv - p < 0$ will never consider buying cannabis illegally at price p (even without risk): so necessarily θ^I satisfies $\theta^I dv - p > 0$. Moreover U is strictly decreasing and convex.

$$\frac{\partial U}{\partial \theta} = dv \cdot u(-p-F)\frac{u'(\theta dv - p)}{u^2(\theta dv - p)} < 0$$

$$\frac{\partial^2 U}{\partial^2 \theta} = d^2v^2 \cdot u(-p-F)u(\theta dv - p)\frac{\cdot u''(\theta dv - p)u(\theta dv - p) - 2 \cdot u'^2(\theta dv - p)}{u^4(\theta dv - p)}$$
$$> 0$$

The strict monotonicity of $U(\theta)$ implies that if θ^I exists, it is unique. $\lim_{\theta \to \frac{p}{dv}^+} U(\theta) = \infty$ and $\lim_{\theta \to \infty} U(\theta) = 0^+$ guarantee the existence of θ^I Differentiating equation (20) yields:

$$\alpha_q \mathrm{d}q + \alpha_\theta \mathrm{d}\theta + \alpha_d \mathrm{d}d + \alpha_p \mathrm{d}p + \alpha_F \mathrm{d}F = 0 \tag{22}$$

where

$$\begin{cases} \alpha_q = -w^{+\prime}(1-q)u\left(\theta dv - p\right) + w^{-\prime}(q)u\left(-p-F\right) & < 0 \\ \alpha_\theta = dvw^+(1-q)u'\left(\theta dv - p\right) & > 0 \\ \alpha_d = \theta vw^+(1-q)u'\left(\theta dv - p\right) & > 0 \\ \alpha_p = -w^+(1-q)u'\left(\theta dv - p\right) - w^-(q)u'\left(-p-F\right) & < 0 \\ \alpha_F = -w^-(q)u'\left(-p-F\right) & < 0 \end{cases}$$

This shows that θ^I increases with p, q, and F; and the cross-derivative of θ^I with respect to p, q, and F is positive. θ^I decreases with d and the cross-derivative of θ^I with respect to d is negative.

C Characterizing the marginal type of 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 reference wealth of $\theta v - p^L$ and the lottery $[-p - F, \theta dv - p; q, 1 - q]$. Therefore, turning to the illegal market over the legal market entails an opportunity cost of $\theta v - p^L$. A potential cannabis consumer deciding between going to the black market or not considers the lottery $[p^L - p - F - \theta v, p^L - p + \theta(d-1)v; q, 1 - q]$, whose value is given by

$$w^+(1-q)u\left(\theta(d-1)v - p + p^L\right) + w^-(q)u\left(-p - F - \theta v + p^L\right)$$

The marginal type of consumer indifferent between legal and illegal consumption solves the following equation.

$$w^+(1-q)u\left(\theta(d-1)v - p + p^L\right) + w^-(q)u\left(-p - F - \theta v + p^L\right) = 0 \quad (23)$$

As earlier, θ^L verifies the following.

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

Let us note $V(\theta) = -\frac{u\left(p^L - p - F - \theta v\right)}{u(p^L - p + \theta(d-1)v)}$. As long as $p^L - p - F < \theta v < \frac{1}{1-d}(p^L - p)$, $V(\theta) > 0$. The left-hand side inequation states that the fine amount being large enough, relatively to the legal price implemented, is a necessary condition for a consumer of type θ^L to exist. Intuitively, if the fine amount implemented is too low, and the price for legal cannabis is too high, then no one consumes legally. The right-hand side of the inequation states that if the quality of legal cannabis is not significantly higher than the quality of black-market cannabis, given the price differential between the two products, then there is no room for a legal market neither. It also shows that there is no black-market if its price is higher than the legal price.

As previously, V is strictly decreasing and convex. The strict monotonicity of $V(\theta)$ implies that if θ^L exists, it is unique. We also have $\theta^L > 0$, as individuals with $\theta < 0$ will never purchase cannabis, whether it is legal or not.

$V(0) = -\frac{u(p^L-p-F)}{u(p^L-p)} \leq 0$ for $F \geq p^L - p$, and $\lim_{\theta\to\infty} V(\theta) = +\infty$. Therefore, by monotonicity, θ^L exists.

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

Indeed, differentiating equation (23) yields:

$$\alpha_q \mathrm{d}q + \alpha_L \mathrm{d}p^L + \alpha_p \mathrm{d}p + \alpha_F \mathrm{d}F + \alpha_\theta \mathrm{d}\theta^L + \alpha_d \mathrm{d}d = 0 \tag{24}$$

with

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

D Static analysis of the consumers

We have shown that, under prohibition, a consumer of type θ^I indifferent between not consuming and consuming illegally is characterized by

$$w^+(1-q)u(\theta^I dv - p) + w^-(q)u(-p-F) = 0$$

Any consumer whose type is higher than θ^I prefers to purchase cannabis from the illegal sector than not to consume cannabis.

In the legalization framework, there is no risk for the consumer facing a decision between consuming legally and not consuming. Thus, the consumer of type θ^0, indifferent between legal consumption and no consumption, is characterized by

$$u\left(\theta^0 v - p^L\right) = 0$$

Because our value function is normalized with $u(0) = 0$,

$$\theta^0 = \frac{p^L}{v}$$

Any consumer whose type is higher than θ^0 will prefer to purchase cannabis legally than not consuming cannabis.

Besides, we have shown that a consumer of type θ^L, indifferent between legal and illegal consumption, is such that

$$w^+(1-q)u\left(\theta^L(d-1)v - p + p^L\right) + w^-(q)u\left(-p - F - \theta^L v + p^L\right) = 0$$

From here, let us now compare the thresholds θ^0, θ^L, and θ^I.

First case: $\theta^L \leq \theta^0 \leq \theta^I$

If $\theta^L < \theta^0$, then we have:

$$\begin{aligned}
&w^+(1-q)u\left(\theta^0 dv - p - (\theta^0 v - p^L)\right) + w^+(q)u\left(-p - F - (\theta^0 v - p^L)\right) < 0 \\
\Leftrightarrow &w^+(1-q)u(dp^L - p) + w^-(q)u(-p-F) < 0 \\
\Leftrightarrow &w^+(1-q)u(dp^L - p) < -w^-(q)u(-p-F)
\end{aligned}$$

This implies that $\theta^0 < \theta^I$.
Indeed, $\theta^I < \theta^0 \Leftrightarrow w^+(1-q)u(dp^L - p) + w^-(q)u(-p-F) > 0$, which contradicts the above.

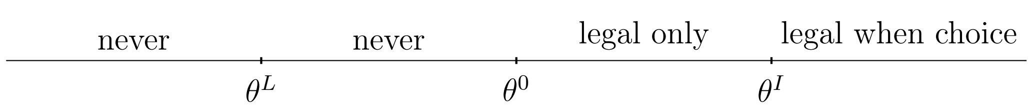
Therefore, an environment in which $\theta^L < \theta^0 < \theta^I$ is characterized by the following condition:

$$w^+(1-q)u(dp^L - p) < w^-(q)|u(-p-F)| \tag{25}$$

This states that if the price on the legal market, p^L, discounted of the quality parameter, is "low enough" then, given a certain level repression and a certain black-market price, the legal market replaces the black market and $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$ new consumers appear.

Note that $p^L = p$ leads to $\theta^L < \theta^0 < \theta^I$ (because then $u(dp^L - p) = u\left((d-1)p\right) < 0$.

Figure 2: Agents continuum when $\theta^L < \theta^0 < \theta^I$



Agents with types lower than θ^0 never purchase cannabis, as they prefer not purchasing cannabis to both purchasing legal and black-market cannabis. Agents with $\theta^0 < \theta < \theta^I$ prefer purchasing legal cannabis compared to black-market cannabis or to not purchasing cannabis at all. They also prefer not purchasing cannabis than purchasing it illegally. Those constitute new customers for the newly legalized cannabis market. Agents such that $\theta^I < \theta$ always purchase cannabis, whether retail sales are legal or not; nevertheless, they purchase cannabis legally when they can.

Second case: $\theta^I < \theta^0 < \theta^L$

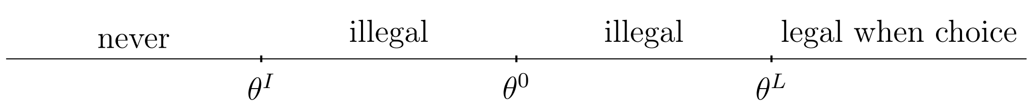
If $\theta^0 < \theta^L$, then we have

$$w^+(1-q)u(dp^L - p) > w^-(q)|u(-p-F)| \tag{26}$$

Symmetrically to the first case, if $\theta^0 < \theta^L$, we necessarily have $\theta^I < \theta^0$.

Here, the discounted 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 and there are no new consumers once a legal market is implemented.

Figure 3: Agents continuum when $\theta^I < \theta^0 < \theta^L$



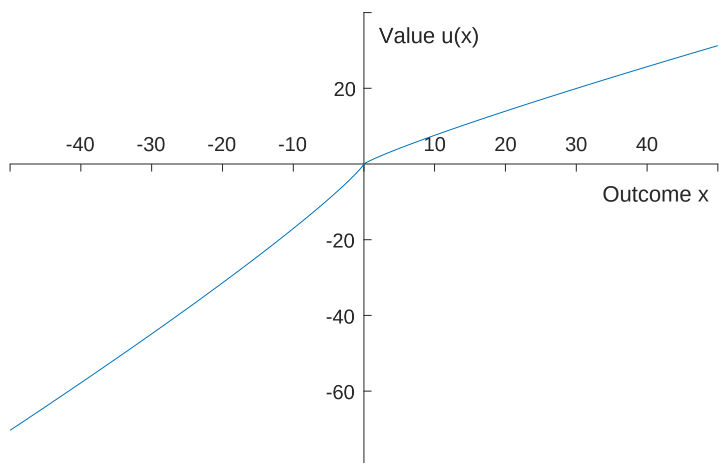
E Application to Tversky and Kahneman (1992) functional form

E.1 Some detail on Tversky and Kahneman (1992) specification

Tversky and Kahneman (1992) suggest a model featuring loss aversion, as well as both 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 biconcave with an inflection point in zero. This describes individuals being empirically risk-averse for gains and risk-seeking for losses; which Kahneman and Tversky (1979) denote as the *reflection effect*.

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



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

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

where $\alpha, \beta \in (0, 1)$ 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 loosing a given amount affects the utility more than gaining the same amount.

In line with Tversky and Kahneman (1992) estimates, we assume $\alpha = \beta$.

The α parameter reflects the curvature and captures how risk averse for gains and risk seeking for losses individuals are.

Probability weighting under CPT is cumulative. Consider the lottery $\mathcal{L} = [x_{-m}, ..., x_0, ..., x_n; p_{-m}, ..., p_0, ..., p_n]$, where $x_0 = 0$, $x_i < x_j$ for $i < j$, and $\sum_{i=-m}^{n} p_i = 1$. The value attributed to the lottery $\mathcal{L}$ is given by:

$$\sum_{i=-m}^{n} \pi_i u(x_i)$$

where

$$\pi_i = \begin{cases} w^+(p_n) & \text{, for } i = n \\ w^-(p_{-m}) & \text{, for } i = -m \\ w^+(p_i + ... + p_n) - w^+(p_{i+1} + ... + p_n) & \text{, for } 0 \leq i \leq n-1 \\ w^-(p_{-m} + ... + p_i) - w^-(p_{-m} + ... + p_{i-1}) & \text{, for } 1-m \leq i < 0 \end{cases}$$

There are only two possible outcomes for a consumer choosing to purchase cannabis illegally in our setting. Therefore, without any loss of generality, we directly apply the probability weights $w^+(1-q)$ and $w^-(q)$ to the two outcomes.

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

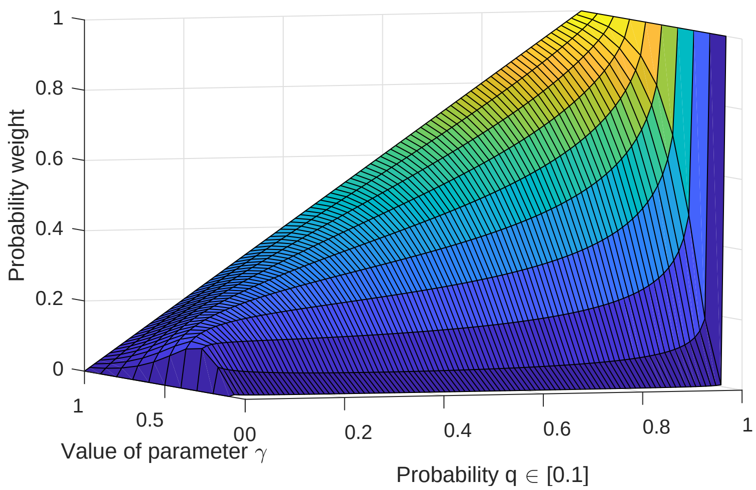
$$w^x(q) = \frac{q^{\gamma^x}}{(q^{\gamma^x} + (1-q)^{\gamma^x})^{\frac{1}{\gamma^x}}} \qquad \text{with } x = +, -.$$

The form of such weighting functions is represented on 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 from the reality 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 $\gamma \in [0.1, 1]$



E.2 Setting a legal price

A consumer considering to consume illegally decides whether to take part to the lottery $\mathcal{L}_{\text{illegal}} = [\theta dv - p, -p - F; 1 - q, q]$ or do nothing and obtain 0. Because not consuming yields the payoff 0, the gross and the net payoffs derived from participating to the lottery are the same and the value associated to the latter is

$$w^+(1-q)u\left(\theta dv - p\right) + w^-(q)u\left(-p - F\right)$$

A consumer indifferent between illegal consumption and no consumption gives a zero value to the lottery $\mathcal{L}_{\text{illegal}}$ and is characterized by the equation

$$w^+(1-q)u\left(\theta dv - p\right) + w^-(q)u\left(-p-F\right) = 0$$

The type θ^I of the consumer indifferent between consuming illegally and no consuming is therefore given by:

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

This implies that:

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

Let us note:

$$\omega(q) \equiv \frac{w^-(q)}{w^+(1-q)}$$

For $x = +, -$, w^x is increasing; which yields $\omega' > 0$.

This implies that:

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

The reference level of wealth for a consumer deciding between the legal and the illegal products changes. Indeed, if the agent decides to go to the legal market, he/she gets a payoff of $\theta v - p^L$ for sure. If he/she decides to go to the illegal market, he/she takes part to the lottery $\mathcal{L}_{\text{illegal}}$. What changes here is then the net payoff derived from participating to the lottery $\mathcal{L}_{\text{illegal}}$. The value given to this lottery is therefore

$$w^+(1-q)u\left(\theta dv - \theta v + p^L - p\right) + w^-(q)u\left(-\theta v + p^L - p - F\right)$$

As previously, the consumer indifferent between the legal and the illegal products gives a zero value to the lottery $\mathcal{L}_{\text{illegal}}$. This agent is therefore characterized by the equation

$$w^+(1-q)u\left(\theta dv - \theta v + p^L - p\right) + w^-(q)u\left(-\theta v + p^L - p - F\right) = 0$$

A policy maker aiming at evicting the criminals out of the market implements a legal price such that all potential consumers, given this price, the black market price, the probability of arrest, the fine, and the discount factor, prefer to turn to the legal market. Dealers are evicted out of the market only once they have no other choice than to price their product at marginal cost or below if they want to attract consumers. Thus, given a marginal cost for illegal production c, and given the parameters q, F, and d, the threshold price $\underline{p}^L$, under which the black market does not survive, is defined by the following system of equations.

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

We deduce that $\underline{p}^L = v\theta^I(c)$ and obtain

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

E.3 Setting the eviction price as a response to the policy parameters

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

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

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

- $$\frac{\partial \underline{p}^L}{\partial d} = -\frac{1}{d^2}\left[\left(\lambda \frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} (F+c) + c\right] < 0$$

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

E.4 Sensitivity analysis to the behavioral parameters

This section presents the sensitivity of the eviction price of of dealers, $\underline{p}^L$, to the exogenous parameters γ^+, γ^-, α and λ.

Tables 5 to 8 present in columns 3 and 4 the sensitivity of the distribution parameters, and in columns 5 and 6 the sensitivity of the eviction price and the subsequent increase in consumption *post-legalization* when implementing the eviction price. The variations of the behavioral parameters are presented in columns 1 and 2.

Overall, the distribution parameters are not very sensitive to the variations in the behavioral parameters: variations of the behavioral parameters by 10% entail variations in the distribution parameters of less than 5%. The policy price seems fairly sensitive to the parameter γ^-: a 10% variation in this parameter causes a change in price up to 15%. This is also true for the parameter α. Finally, the post-legalisation cannabis consumption is not very responsive to small variations in the behavioral parameters (by less than 10%) as it changes by less than 1% for most cases.

Table 5: Sensitivity of legalization price and demand to the behavioral parameters for $\epsilon = -0.5$

parameter	variation	variation in the calibrated outcome $\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
γ^+	+10%	+0.06%	-0.23%	-1.27%	+0.04%
	+5%	+0.02%	-0.14%	-0.71%	+0.05%
	-5%	-0.09%	+0.14%	+0.88%	+0.03%
	-10%	-0.18%	+0.32%	+1.98%	+0.04%
γ^-	+10%	+0.95%	-1.54%	-11.23%	+1.44%
	+5%	+0.41%	-1.06%	-6.05%	+0.07%
	-5%	-0.61%	+1.16%	+7.01%	+0.09%
	-10%	-1.29%	+2.52%	+15.08%	+0.20%
α	+10%	-0.93%	+1.75%	+10.61%	+0.17%
	+5%	-0.46%	+0.86%	+5.24%	+0.08%
	-5%	+0.35%	-0.88%	-5.07%	+0.05%
	-10%	+0.71%	-1.72%	-9.94%	+0.08%
λ	+10%	-0.36%	+0.75%	+4.47%	+0.02%
	+5%	-0.21%	+0.36%	+2.23%	+0.04%
	-5%	+0.10%	-0.41%	-2.21%	+0.08%
	-10%	+0.30%	-0.77%	-4.41%	+0.05%

Notes: Policy parameters are set at benchmark values $q = 0.01$, $F = 1,000$, $d = 0.63$, and $c = 125$. Threshold price $\underline{p}^L$, fine F and marginal cost c are quantities for one ounce of cannabis. $\Delta\%D\left(\underline{p}^L\right)$ is the predicted increase of consumption following a legalization scheme, which drives dealers out of business. The benchmark values for the behavioral parameters are: $\alpha = 0.88$, $\lambda = 2.25$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$. For these parameter values: $\hat{\mu} = -1093.3$, $\hat{\sigma} = 1689.8$, $\underline{p}^L = 325.78$ and $\Delta\%D\left(\underline{p}^L\right) = 33.67\%$.

Table 6: Sensitivity of legalization price and demand to the behavioral parameters for $\epsilon = -0.6$

		variation in the calibrated outcome			
parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
γ^+	+10%	+0.21%	-0.22%	-1.27%	-0.0003%
	+5%	+0.12%	-0.12%	-0.70%	-0.0002%
	-5%	-0.15%	+0.15%	+0.88%	+0.0002%
	-10%	-0.33%	+0.34%	+1.98%	+0.0005%
γ^-	+10%	+1.86%	-1.91%	-11.23%	-0.00%
	+5%	+0.60%	-1.09%	-6.05%	+0.84%
	-5%	-1.17%	+1.19%	+7.01%	+0.003%
	-10%	-2.51%	+2.57%	+15.08%	+0.007%
α	+10%	-1.76%	+1.81%	+10.61%	+0.005%
	+5%	-0.87%	+0.89%	+5.24%	+0.002%
	-5%	+0.29%	-0.98%	-5.07%	+1.08%
	-10%	+1.65%	-1.69%	-9.94%	+0.002%
λ	+10%	-0.74%	+0.76%	+4.47%	+0.001%
	+5%	-0.37%	+0.38%	+2.23%	+0.0006%
	-5%	+0.37%	-0.38%	-2.21%	-0.0006%
	-10%	+0.73%	-0.75%	-4.41%	-0.002%

Notes: Policy parameters are set at benchmark values $q = 0.01$, $F = 1,000$, $d = 0.63$, and $c = 125$. Threshold price $\underline{p}^L$, fine F and marginal cost c are quantities for one ounce of cannabis. $\Delta\%D\left(\underline{p}^L\right)$ is the predicted increase of consumption following a legalization scheme, which drives dealers out of business. The benchmark values for the behavioral parameters are: $\alpha = 0.88$, $\lambda = 2.25$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$. For these parameter values: $\hat{\mu} = -803.7$, $\hat{\sigma} = 1409.7$, $\underline{p}^L = 325.78$ and $\Delta\%D\left(\underline{p}^L\right) = 41.00\%$. Variations of order lower than 10^{-6} are signed but noted 0.00%.

Table 7: Sensitivity of legalization price and demand to the behavioral parameters for $\epsilon = -0.7$

		variation in the calibrated outcome			
parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
γ^+	+10%	+0.57%	-0.22%	-1.27%	-0.00%
	+5%	+0.31%	-0.12%	-0.70%	-0.00%
	-5%	-0.25%	+0.15%	+0.88%	+0.003%
	-10%	-0.57%	+0.34%	+1.98%	+0.007 %
γ^-	+10%	+3.22%	-1.90%	-11.23%	-0.03%
	+5%	+1.74%	-1.03%	-6.03%	-0.02%
	-5%	-2.02%	+1.19%	+7.01%	+0.03%
	-10%	-4.36%	+2.55%	+15.08%	+0.08%
α	+10%	-3.06%	+1.79 %	+10.61%	+0.05%
	+5%	-1.51%	+0.89 %	+5.24%	+0.02%
	-5%	+1.46%	-0.86%	-5.07%	-0.02%
	-10%	+2.85%	-1.69 %	-9.94%	-0.03%
λ	+10%	-1.29%	+0.76%	+4.47%	+0.02 %
	+5%	-0.64%	+0.38 %	+2.23%	+0.008%
	-5%	+0.64%	-0.38%	-2.21%	-0.01%
	-10%	+1.27%	-0.75%	-4.41%	-0.01%

Notes: Policy parameters are set at benchmark values $q = 0.01$, $F = 1,000$, $d = 0.63$, and $c = 125$. Threshold price $\underline{p}^L$, fine F and marginal cost c are quantities for one ounce of cannabis. $\Delta\%D\left(\underline{p}^L\right)$ is the predicted increase of consumption following a legalization scheme, which drives dealers out of business. The benchmark values for the behavioral parameters are: $\alpha = 0.88$, $\lambda = 2.25$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$. For these parameter values: $\hat{\mu} = -601.9$, $\hat{\sigma} = 1198.9$, $\underline{p}^L = 325.78$ and $\Delta\%D\left(\underline{p}^L\right) = 48.74\%$.

Table 8: Sensitivity of legalization price and demand to the behavioral parameters for $\epsilon = -0.8$

		variation in the calibrated outcome			
parameter	variation	$\hat{\mu}$	$\hat{\sigma}$	$\underline{p}^L$	$\Delta\%D\left(\underline{p}^L\right)$
γ^+	+10%	+0.57%	-0.21%	-1.27%	-0.00%
	+5%	+0.32%	-0.12%	-0.70%	-0.00%
	-5%	-0.39%	+0.15%	+0.88%	+0.00%
	-10%	-0.88%	+0.34%	+1.98%	+0.0001%
γ^-	+10%	+5.01%	-1.91%	-11.23%	+0.0002%
	+5%	+2.50%	-1.02%	-6.05%	+0.34%
	-5%	-3.14%	+1.19%	+7.01%	+0.0007%
	-10%	-6.74%	+2.57%	+15.08%	+0.002%
α	+10%	-4.74%	+1.80%	+10.61%	+0.001%
	+5%	-2.34%	+0.89%	+5.24%	+0.0004%
	-5%	+2.16%	-0.81%	-5.07%	+0.30%
	-10%	+4.49%	-1.67%	-9.94%	+0.0002%
λ	+10%	-2.00 %	+0.76%	+4.47%	+0.0004 %
	+5%	-1.00 %	+0.38%	+2.23%	+0.0002%
	-5%	+0.99%	-0.38%	-2.21%	-0.0001%
	-10%	+2.00%	-0.74%	-4.41%	+0.25%

Notes: Policy parameters are set at benchmark values $q = 0.01$, $F = 1,000$, $d = 0.63$, and $c = 125$. Threshold price $\underline{p}^L$, fine F and marginal cost c are quantities for one ounce of cannabis. $\Delta\%D\left(\underline{p}^L\right)$ is the predicted increase of consumption following a legalization scheme, which drives dealers out of business. The benchmark values for the behavioral parameters are: $\alpha = 0.88$, $\lambda = 2.25$, $\gamma^+ = 0.61$ and $\gamma^- = 0.69$. For these parameter values: $\hat{\mu} = -438.4$, $\hat{\sigma} = 1057.3$, $\underline{p}^L = 325.78$ and $\Delta\%D\left(\underline{p}^L\right) = 56.60\%$. Variations of order lower than 10^{-6} are signed but noted 0.00%.