Defeating Crime? An Economic Analysis of Cannabis Legalization Policies

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Abstract

Can legalization of cannabis eliminate related organized crime? Consumer choices for cannabis in a risky environment are modeled to determine the provision of marijuana, under both prohibition and legalization. Although a legalization policy may crumble the profits from illegal providers driving them out of business, it also increases marijuana 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 objective while limiting cannabis consumption.

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1 Introduction

Most of current prohibition policies, which target the suppliers of illegal marijuana and their consumers, are poorly effective at controlling demand. With 183 million users worldwide, marijuana is the most popular illegal drug on earth (UNODC, 2017).[1] In the absence of legal offer, criminal networks respond to the demand. On the supply side, marijuana 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. As Parey and Rasul (in press) suggest using a forensic economics approach, these figures might even be largely underestimated.[2] In line with the rising evidence that legalizing cannabis would actually be more effective than prohibition in terms of reducing crime and violence (Morris et al., 2014; Gavrilova, Kamada, and Zoutman, 2017; Dragone et al., 2018; Chang and Jacobson, 2017), this paper explores alternative legalization policies.

A first natural idea is to legalize the market by using pricing tools, which can also be used to regulate and tax marijuana consumption. Our theoretical analysis shows that selling legal marijuana 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 mafia organizations. These networks will thus be able to respond to the competition by legal suppliers of cannabis by lowering the price they propose and still make a profit. Hence legalization may instead increase significantly the consumption of "low-cost" illegal cannabis, with all the negative externalities this would entail for societies. We therefore explore a policy that combines pricing tools through the sale of legal cannabis – to

[1] 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).

[2] Using consumption data on complementary legal inputs to illegal cannabis consumption, the authors 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.

push the criminals out of the market – and repressive tools – to limit the subsequent increases in consumption.

To be more specific, in our model the demand 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. We highlight that neither traditional repressive measures nor more "innovative" pricing tools through legalization are satisfactory policies. The former 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. The latter help to eradicate criminals' activities at the cost of substantially increasing consumption.

This binary vision, opposing legalization to repression, involves a policy trade-off, which may lead to undesirable social and political outcomes. We explore how to overcome such a trade-off by combining marijuana pricing with repression tools, and suggest a Policy Mix. The latter allows policy makers to fight the black market for cannabis by creating a legal alternative. Our Policy Mix 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, to decentralize predetermined consumption targets. We do not discuss the optimality of the targets. We derive optimal tools to reach them while eradicating crime. Policy applications and comparisons to the U.S. market for marijuana highlight the complementarities between repression and legalization and question current policies. For example, based on evidence from the US, with a 1% probability of arrest and a USD $4,000$ fine for illegal purchase, a legal price around USD 560 per ounce would evict illegal suppliers from the market and decrease overall consumption by 12%. 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 diverse repressive measures on illegal consumers and suppliers in order to regulate the sale of cannabis. Section 5 calibrates the model based on evidence from the U.S. marijuana 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 marijuana use, the seventies showed a wave of decriminalization. In the United-States, possessing small amounts (usually up to 1 ounce) of marijuana 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 marijuana stalled in the eighties, victims of the war on drugs.

With the rising concerns about the legitimacy and efficiency of this war, policy changes in favor of liberalizing cannabis regained momentum at the end of the nineties. There has hence been 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 would be imitated by eight other American states, the District of Columbia, and in 2018 by Canada, South-Africa and Georgia. Finally the state of New York should legalize it in 2019.

Legalization policies implemented so far are quite diverse. In the US, ten states and the District of Columbia have legalized the use of recreational marijuana, while possessing marijuana remains a felony in other states such as Arizona (see further detail in Appendix A). Moreover, sanctions, and fine levels, may differ a lot between two states having the same marijuana laws. For example in Arizona, there is no guideline for punishment regarding small amounts of marijuana 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 marijuana is legal although the terms of policies differ from province to province.[3] In Uruguay, cannabis production and distribution was legalized in 2017 with the state having allowed farms to grow cannabis for the local market, citizens to run cannabis cooperatives, as well as selected pharmacies to act as dispensaries for both medical and recreational marijuana.[4] There has been a flourishing literature on the impacts of the recent cannabis legalization policies.

[3]For example, in Québec, marijuana 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 marijuana sales through privately run stores.

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

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 than of psycho-pharmacological effects of drug use on crime. Prohibition promotes violence, by reducing marginal cost of crime and raising its marginal benefit (Miron 1999, 2003), which increases incentives to engage in criminal behavior (MacCoun and Reuter, 2001). Moreover, prohibition sets a favorable environment for market cartelization. This 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, reduced-form analysis highlights the positive effects of cannabis liberalization on violence and 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 could outweigh the expected undesirable effects regarding criminality associated to drug addiction. Dills, Goffard, and Miron (2017) show that liberalizing marijuana does not necessarily lead to a rise in crime. Overall crime in Colorado decreased in areas where marijuana dispensaries were added (Brinkman and Mok-Lamme, 2016). In particular, marijuana legalization could be responsible for a drop in local rapes and property crimes (Dragone et al., 2018). The benefits of liberalization policies extend to trans-border crime. This affected particularly the states bordering Mexico where the legalization of cannabis for medical purpose has decreased drug-trafficking related crime rates (Gavrilova et al., 2017).

2.2 Impacts on drug consumption

A first immediate effect of legalization is to increase the availability and proximity of marijuana to adult consumers (provided supply is large enough) and to make it less accessible to under-age consumers. Jacobi and Sovinsky (2016) explore the idea that legalization reduces the searching cost for marijuana and removes the stigma inherent to the illicit consumption. Using a structural approach, they extrapolate that legalizing recreational marijuana would thereby entail an increase in its use around 48%. This is also supported by Austin et al. (2017), who show that marijuana 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. From this viewpoint, and perhaps in contrast to what conventional wisdom dictates regarding addiction to psychotropic substances, marijuana users may be considered as rational economic agents sensitive to variations in prices and risk. In fact marijuana is different from other psychotropic substances in the sense that it is not very addictive and it is almost impossible to overdose with it (National Academy of Sciences 2017). 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 marijuana as it raises demand (Pacula et al. 2010).

However, liberalization does not necessarily result in the consumption-driven social harm one may expect and, in particular, to increased consumption among the youth, on the contrary,[5] – nor to the socially undesirable effects regarding other substance use, public health and road hazard for this population (Dills, Goffard, and Miron, 2017). Using a synthetic control approach, Hansen, Miller, and Weber (2018) demonstrate that states having legalized marijuana do not experience significantly higher alcohol- and cannabis-related traffic fatalities.

2.3 Tax instruments

Some studies have focused on the potential tax revenue from a regulated market for marijuana. Caputo and Ostrom (1994, 1996) suggest the cannabis market could generate substantive public resources and model an optimal government policy for newly legalized commodities. In the case of the US Jacobi and Sovinsky (2016) show that tax policies could raise revenue around US$ 12 billion, while controlling marijuana consumption.

Indeed cannabis consumers are sensitive to price -with price elasticities of demand ranging between -0.67 and -0.79 (Davis, Geisler and Nichols 2016). A government may reduce increases of consumption following legalization by controlling the price through taxation. 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 potentially new users. Van Ours and Williams (2007) show that low cannabis prices are associated with early initiation into cannabis use, with a price elasticity between -0.5 and -0.7. This may also have spillover effects on the use of other psychotropic substances, as suggested by Williams et al. (2004) and Kerr et al. (2017), who shed light on the economic complementarity between alcohol and marijuana use among college students.

[5] 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).

Prohibition and legalization policies have been studied so far as two alternatives. Prohibition aims at limiting the consumption of cannabis but at the costs of violence and cartelization of the illegal market, which fuels powerful criminal networks. In contrast, legalization allows to regulate the market and tax the consumers but at the costs of increasing consumption of cannabis, which may generate negative externalities in terms of public health. Our contribution to the literature is to study the effects of a novel mix policy, which combines pricing tools through the implementation of a legal market of cannabis with sanctions against consumers and suppliers of illegal cannabis. We start by analyzing the equilibrium under the status-quo.

3 Prohibition equilibrium

This section describes the market equilibrium under prohibition. Marijuana 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 marijuana are characterized by negative (positive) θ parameters, reflecting the whole population spectrum. In the absence of legal provision of cannabis, consumers can only purchase from the illegal sector of the economy, with returns from consumption given by $d\theta v$. θv denotes the value of consumption considering a hypothetical legal sector. The discount factor d captures the fact that individuals have higher payoff to consume cannabis if they can purchase legally rather than illegally, such that $0 < d < 1$. Indeed products sold by criminal networks, which are uncertified, are likely to be diluted or of bad quality. Moreover, purchasing from the illegal sector may entail a personal cost in terms of ethics or social stigma, which is also captured in 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 $\mathcal{L}_{\text{illegal}} = [-p - F, \theta dv - p; q, 1 - q]$.

To model individuals' gains and losses from given payoffs, we follow Tverky and Kahneman's Cumulative Prospect Theory (CPT).[6] While expected utility theories focus on final wealth, CPT rather models variations in outcome from a given *status quo*. It enables us to compare outcomes from purchasing marijuana illegally with a "legal option" – not consuming marijuana under prohibition, purchasing legal marijuana under legalization.[7]

Further, CPT allows to consider people's poor ability to deal with probabilities (Kahneman and Tversky, 1972). For instance, they tend to overestimate the odds of rare salient events, while they would underestimate the odds associated to more usual events. In our framework, individuals choosing to purchase cannabis on the black market face a low 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 percep-

[6]This theory is probably the most prominent among nonexpected utility theories.

[7]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.

tion of probabilities. 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 (respectively negative) outcomes –that is not getting arrested with probability $1-q$ –(respectively getting arrested with probability q). As calibrated by Tversky and Kahneman (1992) the weighting function admit the following functional form:

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

The reference level of wealth is 0, which is what the agent earns if he/she does not consume at all. Applying CPT, the lottery $\mathcal{L}_{\text{illegal}} = [-p-F, \theta dv - p; q, 1-q]$ is therefore of 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.

$$u(x) = \begin{cases} x^{\alpha} \text{ , if } x > 0 \\ -\lambda(-x)^{\alpha} \text{ , if } x \leq 0 \end{cases} \tag{2}$$

where $\alpha \in (0,1)$ and $\lambda \geq 1$. This value function enables to account for agents' different risk attitudes depending on whether they face gains (risk-aversion) or losses (risk-seeking).

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:

$$w^{+}(1-q)u(\theta dv - p) + w^{-}(q)u(-p-F) = 0 \tag{3}$$

We show in the Appendix B that θ^{I} exists and is unique when q is not too large. When the probability of being detected is large, risk averse individuals do not purchase the commodity, and prohibition shows the intended effects. On the contrary, for a small probability of being detected, prohibition fails to eliminate illegal consumption. This is particularly consistent with our specification derived from Prospect Theory: biconcave value functions model risk-averse behaviors for gains and proportionally risk-seeking behaviors for losses, such that if the probability of a loss is relatively small, individuals tend to purchase the commodity more.

Substituting the Tversky and Kahneman (1992) value function in (3) Appendix E.2 shows that the marginal consumer is characterized by:

$$\theta^I = \frac{1}{dv}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+p)+p\right] \tag{4}$$

such that 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:

$$D^I(p) = \int_{\theta^I}^{+\infty} g(\theta)d\theta = 1 - G(\theta^I) \tag{5}$$

where θ^I is solution of equation (3). We deduce that the (absolute value) of the price elasticity of demand is:

$$\epsilon_{D^I,p} = \frac{-D^{I\prime}(p)p}{D^I(p)} = \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d\theta^I}{dp}p \tag{6}$$

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

$$\frac{d\epsilon_{D^I,p}}{dq} = \frac{d\{\frac{g(\theta^I)}{1-G(\theta^I)}\}}{d\theta^I}\frac{d\theta^I}{dq}\frac{d\theta^I}{dp}p + \frac{g(\theta^I)}{1-G(\theta^I)}\frac{d^2\theta^I}{dpdq}p. \tag{7}$$

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 of unregulated and untaxed criminals.

Finally as the cross-derivatives of θ^I with p and q are 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. In other words, 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 marijuana. Assuming symmetrical cost functions: $C_i(q_i) = cq_i + K$, 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 ($i = 1, ..., N$), 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:

$$\frac{p^N - c}{p^N} = \frac{1}{N}\frac{1}{\epsilon_{D^I,p}} \tag{8}$$

where c represents their constant marginal costs, $\epsilon_{D^I,p}$ is the price elasticity of demand defined in (6) 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 (8) above.[8]

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 marijuana at the same price as the price of illegal marijuana 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 $\theta v - p = 0$ so that

$$\underline{\theta}^L(p) = \frac{p}{v} \tag{9}$$

Comparing the legal threshold, written as $\underline{\theta}^L = \frac{p}{v}$, with (3), 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 q, the risk of

[8]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.

detection, the legal demand threshold is always lower than the illegal one: $\underline{\theta}^L(p) < \theta^I(p)\ \forall p > 0$. The result holds because, first, the gross consumers' pay-offs are higher under legal than illegal purchase and, second, there is no risk under legal purchase.

Moreover, a government setting $p^L \leq p$ (for example $p^L = p$, as suggested by Québec's Minister of Health in 2017[9]) 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 marijuana 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 marijuana in function of the prices. After the government announces a price $p^L \geq 0$ for legal marijuana, 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 marijuana 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 $[p^L - p - \theta v - F, p^L - p + \theta v(d-1); q, 1-q]$. Therefore, an individual chooses illegal consumption over legal consumption if and only if

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

The threshold type, $\theta^L(p, p^L)$, indifferent between legal and illegal consumption, is solution to :

$$w^+(1-q)u\left(p^L - p + \theta v(d-1)\right) + w^-(q)u\left(p^L - p - \theta v - F\right) = 0 \tag{10}$$

[9]This interview was published on September 21, 2017 in the newspaper La Presse

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 is chosen above price difference.

Recall that θ^I defined in (3) is the threshold above which an individual 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:

$$w^+(1-q)u(dp^L - p) \leq w^-(q)|u(-p-F)| \tag{11}$$

   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:

$$w^+(1-q)u(dp^L - p) > w^-(q)|u(-p-F)| \tag{12}$$

   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:

$$D^I(p, p^L) = \int_{\theta^I(p)}^{\theta^L(p,p^L)} g(\theta)d\theta. \tag{13}$$

Note that in both cases, under legalization, a higher-type segment of the formerly black-market customers are captured by the newly legalized market. This change of preference is consistent with 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. 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.

To keep some consumers, the criminals adjust their price, p. Let $p^N(p^L)$ be the solution of (8) computed with the direct price elasticity of the demand $D^I(p, p^L)$ defined in (13), $\varepsilon_{D^I,p} = -\frac{\partial D^I(p,p^L)}{\partial p} \frac{p}{D^I(p,p^L)}$, which depends on p^L . The price reaction function of the smugglers is the solution of the following equation:

$$p(p^L) = \begin{cases} p^N(p^L) & \text{if } \; c \leq p^N(p^L) < dp^L \\ \varnothing & \text{otherwise} \end{cases} \tag{14}$$

Accordingly, as long as the illegal providers are active, their reaction price is increasing in their marginal costs to operate, c, in the price on the legal market, p^L, in the payoff differential between legal consumption and no consumption, 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 (10) and the more difficult it is for the criminals to attract consumers by decreasing their prices.[10]

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. In the next section we study a simple legalization policy using pricing tool only to weaken illegal providers. For the sake of realism we focus on situations where criminals are initially active in equilibrium.

4.2 Eradicating organized crime through legalization

We consider a policy in which marijuana 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

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

price is pushed below their marginal costs, i.e. $p(p^L) \leq c$. In this case, if the dealers want to break even they apply a price such that the value derived from illegal consumption under legalization is negative for all positive values of θ and, therefore, $\theta^L < \theta^I$. No individual consumes from the black market. However, such a policy increases consumption by $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$, as compared to the case where cannabis is prohibited for the same values of price and repression parameters. The lower p^L, the higher the rise in consumption.

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 (3) and (10), with $p = c$. This yields:

$$\begin{cases} w^+(1-q)u(\theta d v - c) + w^-(q)u(-c-F) = 0 \\ w^+(1-q)u\left(\underline{p}^L - c + \theta v(d-1)\right) + w^-(q)u\left(\underline{p}^L - c - \theta v - F\right) = 0 \end{cases} \tag{15}$$

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

$$\underline{p}^L = \frac{1}{d}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+c) + c\right] \tag{16}$$

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.

Since $\lambda > 0$, $w^-(q) > 0$ and $w^+(1-q) > 0$, $\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{1-\alpha}}(F+c)+c > c$ and it follows that $\underline{p}^L > c$, as $d < 1$. This shows that the threshold price imposed by the government to eliminate illegal suppliers is higher than their price under perfect competition, c. Nevertheless, in equilibrium the demand, which is now legal, is

$$D^L(\underline{p}^L) = \int_{\theta^L(\underline{p}^L, c)}^{+\infty} g(\theta)d\theta = 1 - G\left(\theta^L(\underline{p}^L, c)\right) = 1 - G(\theta^I(c)) = D^I(c) \tag{17}$$

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 dealers:* $D^L(\underline{p}^L) = D^I(c)$*.*

Discussion of Proposition 1 We have shown theoretically that eliminating oligopolistic criminals by legalizing the retail market for marijuana necessarily increases the demand for marijuana. Canada is one of the few countries to date that has implemented cannabis legalization explicitly as a tool to fight drug-related crime. As 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 takes 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.[11] 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 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

[11] 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).

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 seem to range slightly higher than in Québec, corresponding to higher illegal prices – approximatively CAD 40 per ounce higher than in Québec (based on priceofweed.com). This difference in price across Provinces could be caused by different environmental factors influencing the production of marijuana or 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. They interpret this result as a decrease in black market transactions. For them government 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 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 tools to policy makers as it provides them with a more general pricing approach, which not only accounts for the quality differential, but also for the risk premium as well as the market dynamics involved. 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, $\underline{p}^L$, is not fixed. 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. Appendix B for the general case and Appendix E.2 for the Tversky and Kahneman (1992) specification show that θ^I increases with p, q, and F; and decreases with d. As $\underline{p}^L = v\theta^I(c)$, $\underline{p}^L$ increases with c, q, and F; and decreases with d. □

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 ignores the fact that this also decreases 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[12], but keeping a low probability of arrest q. Moreover the Canadian *Cannabis Act* aims 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 higher legal price $\underline{p}^L$; and thereby control the increase in demand for marijuana following 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 while controlling the demand. In addition to minimizing negative externalities for societies 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. Typically the legalization reform in Colorado has been driven by these economic considerations, whose modeling is left to further research.

[12]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 uses our theoretical framework and empirical evidence from previous studies to calibrate legal prices for marijuana that would evict criminal organizations from the market. Prior to illustrating how the parameters q, F, c, and d impact the legal price threshold $\underline{p}^L$, we set realistic benchmark values for all parameters and conduct a sensitivity analysis of their impact on $\underline{p}^L$.

5.1 Discussion of benchmark values

The parameters calibrated by Tversky and Kahneman (1992), i.e. α, λ, γ^+, and γ^-, are exogenous, whereas 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 marijuana 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, the average probability of being arrested is lower than 1%, which we use as a benchmark value for q.

Similarly, policy enforcement regarding marijuana in the United-States is very diverse, and consequently, the maximum fines applied for possession are too (NORML, 2018). However, a non-negligible proportion of states apply fines of 2000$, which we will use as a benchmark value for F.

A benchmark value for the marginal cost of producing and delivering marijuana on the black market, c , is difficult to establish for two reasons. With more liberalization, we expect more innovation in the future and further decrease in production costs of marijuana, which are 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 risk of getting arrested and loosing the business profits. These are directly increasing production costs. Moreover, production and distribution being facilitated by organized criminals, there are further hidden costs, which are difficult to estimate.

Using various assumptions, Caulkins (2010) estimates the cost of production of marijuana 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 very large. The LSE Expert Group on the Economics of Drug Policy (2014) estimates the wholesale price of a pound of marijuana 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 marijuana 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. In light with these concerns, we choose the lower bound, 125$, as our benchmark value. Obviously this marginal cost of operation by illegal providers can be strongly affected by repressive policies– i.e. investing in detecting illegal producers, retailers and consumers, which we will allow for in our sensitivity analysis.

The parameter d describes the discount in value associated to the consumption of illegal marijuana bought on the black market versus legal one,

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	2,000
d	0.63
c	125
$\underline{p}^L$	439

which is certified by health or other regulation authorities. To approximate d, one could for example consider the difference in THC dosage, or in its volatility, between cannabis bought legally or illegally. According to ElSohly et al. (2016), the average THC potency of marijuana 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%.[13] Based on this difference, a benchmark measure for d could be $1 - \frac{18.7-11.84}{18.7} \approx 63\%$.

Table 1 provides an overview of the different parameters. If we plot these values in the legal price threshold function specified in (16), we obtain a benchmark legal price of 439$ per ounce. As a comparison, the average price of an ounce of black market marijuana has been around 300$ in June 2018 according to the crowd-sourced website priceofweed.com.

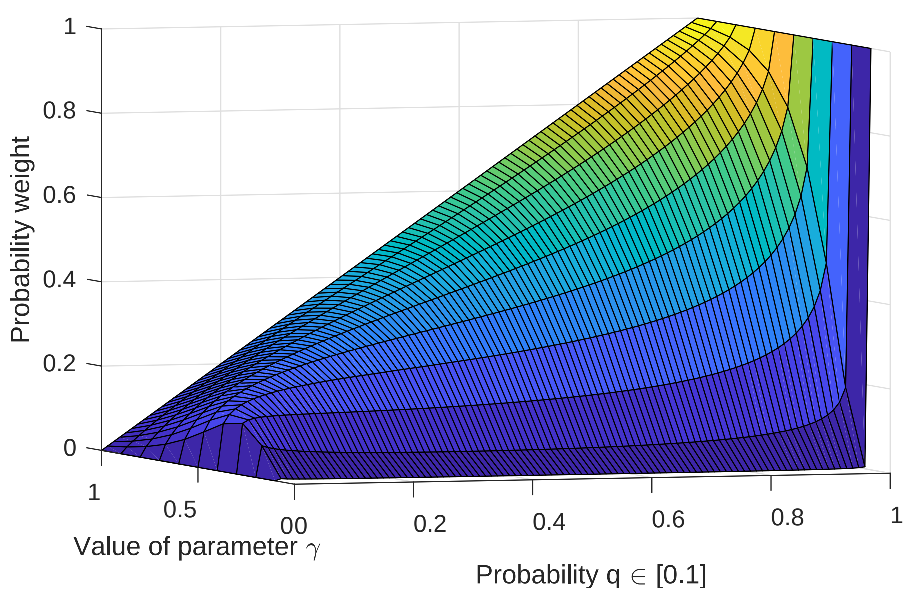
[13] NBC News (online) 23 March 2015, "Colorado Marijuana Study Finds Legal Weed Contains Potent THC Levels"

5.2 Sensitivity analysis

5.2.1 Behavioral parameters

Let us now take a look at the probability distortion function w. For $\gamma = 1$, $w : q \mapsto \frac{q^\gamma}{(q^\gamma+(1-q)^\gamma)^{\frac{1}{\gamma}}}$ 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 has an L-shape. The policy price does not seem much sensitive to γ^+. An increase by 5 percentage points in γ^+ leads to a decrease by 1.5% in $\underline{p}^L$. A decrease in γ^+ by the same amount leads to an increase by 2% in the policy price. Sensitivity to losses is exacerbated by the parameter λ. As a consequence, the threshold price is more sensitive to γ^- than to γ^+. An increase in only 1 percentage point in γ^- yields a decrease in the policy price by 2.6%; while a decrease by the same amount causes an increase in the policy price by 2.7%.

Figure 1: Probability weighting functions for $\gamma \in [0.1, 1]$



Regarding the value function u, the α parameter reflects the curvature and quantifies how risk averse for gains and risk seeking for losses individuals are. If $\alpha = 1$, the right side is the identity and the left side a linear function of coefficient λ. When $\alpha \to 0$, the S-shape of the value function becomes two horizontal lines, one at level λ on the left side of the ordinates, and one at level 1 on the right side. Our result is here quite sensitive to changes in α. *Ceteris paribus*, a 2 percentage point change in α, either positive or negative, leads to a 3% change in the threshold price in the same direction.

Prospect Theory assumes agents are at least as risk seeking for losses as they are risk averse for gains, which is captured by $\lambda \geq 1$. The more relatively risk seeking for losses agents are, the higher the policy price. Indeed, a decrease by 25 percentage points in λ yields a decrease by 7% in $\underline{p}^L$, while the result of an increase by the same amount yields an increase of the same magnitude.

Table 2: Sensitivity of legalization price

α	λ	γ^+	γ^-	$\underline{p}^L$	$\Delta\%\underline{p}^L$	$\Delta\%D$
0.88	2.25	0.61	0.69	439.00	-	+15.57%
0.86	2.25	0.61	0.69	424.67	-3.26%	+18.91%
0.90	2.25	0.61	0.69	453.54	+3.31%	+12.17%
0.88	2.00	0.61	0.69	408.86	-6.87%	+22.60%
0.88	2.50	0.61	0.69	469.6	+6.97%	+8.43%
0.88	2.25	0.66	0.69	432.35	-1.52%	+17.12%
0.88	2.25	0.56	0.69	448.56	+2.18%	+13.34%
0.88	2.25	0.61	0.70	427.63	-2.59%	+18.22%
0.88	2.25	0.61	0.68	450.88	+2.70%	+12.80%

Notes: Policy parameters are set at benchmark values $q = 0.01$, $F = 2,000$, $d = 0.63$, and $c = 125$. Threshold price $\underline{p}^L$, fine F and marginal cost c are quantities for one ounce of marijuana. Variation in demand relies on the estimates by Jacobi and Sovinsky (2016) regarding the shift in demand following legalization (48%) and Davis et al.(2016) regarding the price elasticity of demand for marijuana (-0.7).

These results are summarized in Table 2.

This table also highlights that variations of these exogenous parameters around the values calibrated by Tversky and Kahneman (1992) imply relatively little variation – i.e. less than 7% – of the legalization price, $\underline{p}^L$, a government should implement to push illegal providers out of business.

5.2.2 Policy parameters

We now turn to studying 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, F, sanctioning illegal consumers, or decrease the valuation of consumption of illegal cannabis, d. Insights on how sensitive our results are to these policy parameters may be helpful for governments wishing to regulate the price for newly legalized marijuana.

Column 1 of Table 3 presents two 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 marijuana drops to 10$ per ounce[14] 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).

Another parameter whose evolution is hard to predict is d. Indeed, 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), might 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

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

Table 3: Sensitivity of legalization price and variation in demand

c	d	q	F	$\underline{p}^L$	$\Delta\%\underline{p}^L$	$\Delta\%D$
125	63%	1%	2000	439.00	-	+15.57%
			4000	665.44	+51.58%	-37.27%
125	63%	2%	2000	622.05	+41.70%	-27.15%
			4000	1020.78	+132.52%	-120.18%
125	75%	1%	2000	368.76	- 16.00%	+31.95%
			4000	558.97	+27.33%	-12.43%
125	75%	2%	2000	522.53	+19.03%	- 3.92%
			4000	857.45	+95.32%	-82.07%
125	85%	1%	2000	325.38	- 25.88%	+42.08%
			4000	493.21	+12.35%	+ 2.92%
125	85%	2%	2000	461.05	+ 5.02%	+10.42%
			4000	756.58	+72.34%	+58.53%
10	63%	1%	2000	243.44	-44.55%	+61.20%
			4000	469.88	+ 7.03%	+ 8.36%
10	63%	2%	2000	416.59	- 5.11%	+20.80%
			4000	815.31	+85.72%	-72.24%
10	75%	1%	2000	204.49	- 53.42%	+70.29%
			4000	394.70	- 10.09%	+25.90%
10	75%	2%	2000	349.93	- 20.29%	+36.35%
			4000	684.86	+56.00%	-41.80%
10	85%	1%	2000	180.43	- 58.90%	+75.90%
			4000	348.27	- 20.67%	+36.74%
10	85%	2%	2000	308.77	- 29.67%	+45.95%
			4000	604.29	+37.65%	-23.00%

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 estimates by Jacobi and Sovinsky (2016) regarding the shift in demand following legalization (48%) and Davis et al.(2016) regarding the price elasticity of demand for marijuana (-0.7).

two alternative cases, for $d = 0.75$ and $d = 0.85$ in Column 2.

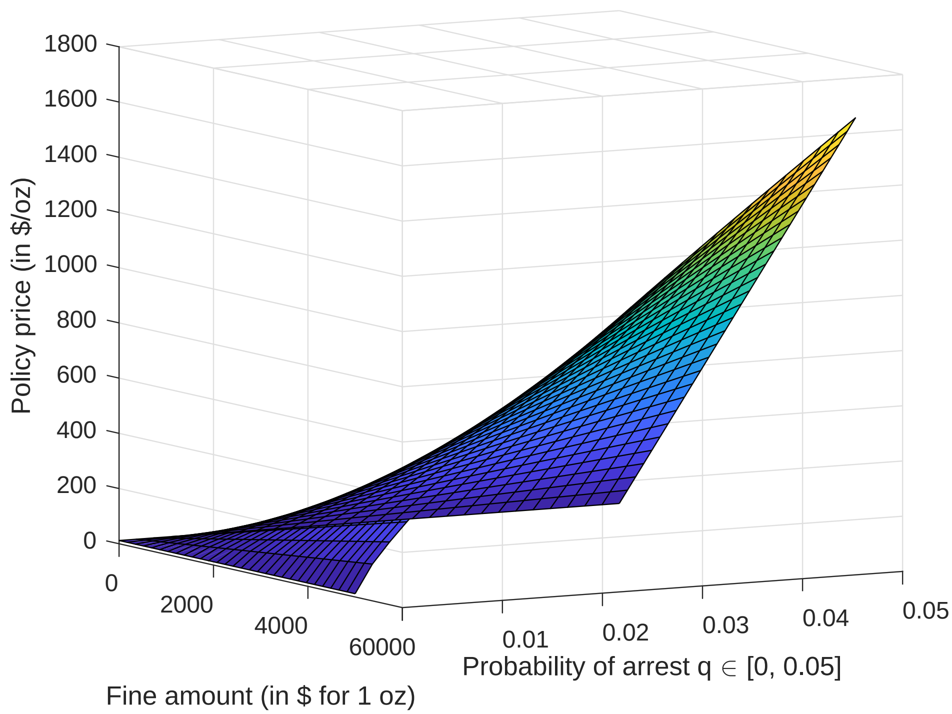
Column 3 varies the probability of being caught on the black market, q, considering doubling the benchmark value, which may be politically more feasible when it is combined with the legalization policy under study than with prohibition. Indeed it is easier to be tough on consumers of illegal marijuana when there is a legal alternative, than when there is none. Similarly Column 4 allows for two scenarios starting from the benchmark value of fines, F, and then doubling it. For the same reasons, it may also be politically easier to implement with legalization.

As a function of these parameter values, we compute, in column 5, the threshold price, $\underline{p}^L$, which would push illegal providers out of business and predict, in column 6, the subsequent variation in demand. This variation is computed on the basis of a pre-legalization black market price of 300$, a demand price elasticity of -0.7 (Davis et al. 2016) and a "legalization-only" shift in demand of 48% (Jacobi and Sovinsky 2016). For example, considering the benchmark parameter values in the first row, we compute the threshold price of such legalization scheme to be 439$. This would increase the consumption of marijuana by around 15%. However, implementing more controls on consumers, such as doubling the amount of fine (second row) or doubling the probability of arrest (third row), has a strong mitigating effect, which decreases strongly the demand (by 37% and 27% respectively) when combined with legalization.

As highlighted by the results in table 3, whatever the value for d and c are, the predicted rise in consumption can be stemmed by manipulating q and F, to which demand is strongly responsive. As shown in figure 2 below, even in the worst scenario, i.e. $c = 10$ and $d = 0.85$, setting a fine amount at 5000$ and a probability of getting caught at 5% is largely sufficient to respond to the rise in demand, since for those values the threshold $\underline{p}^L$ exceeds 1500$ per ounce. This would theoretically annihilate the demand for marijuana as illustrated in figure 3.

Although we leave the cost-benefit analysis for future work, we may conjecture that raising fines and probability of arrest of consumers may require less investment as compared to rising controls on suppliers to affect their

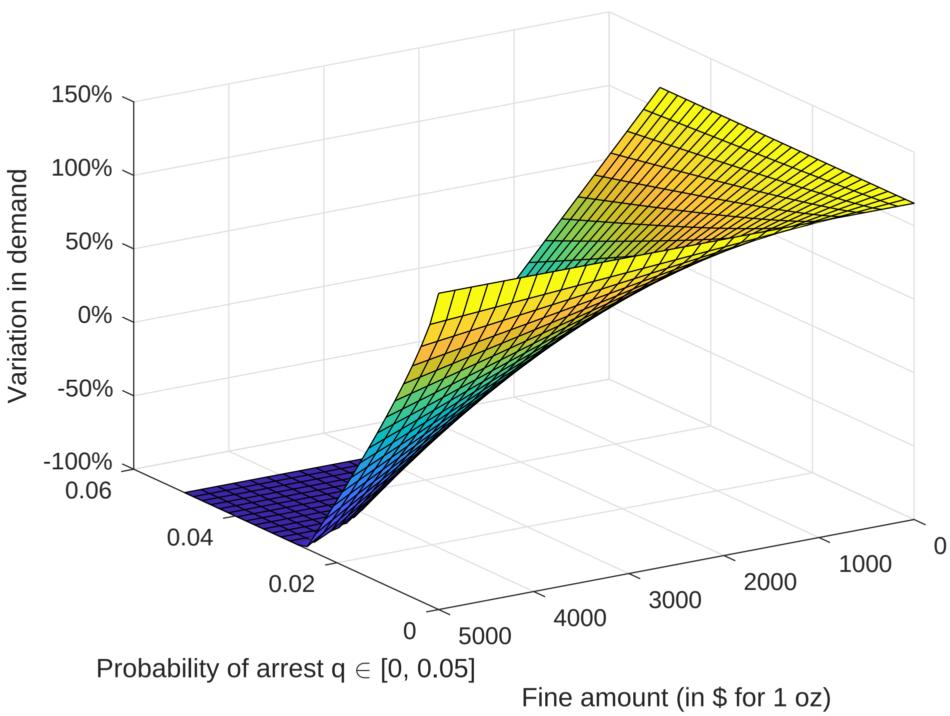
Figure 2: Policy price function for 1 oz of marijuana, with $d = 0.85$ and $c = 10$



Note: Behavioral parameters are set at values calibrated by Tversky and Kahneman (1992): $\lambda = 2.25$, $\alpha = 0.88$, $\gamma^+ = 0.61$, and $\gamma^- = 0.69$.

marginal costs of production, c, or the discount factor of illegal cannabis, d. Rising fine amounts and the probability of arrest is hence likely to be relatively more cost-effective if the aim is to legalize the market while controlling the demand for marijuana. However, political constraints, externalities in terms of public health, crime and other non-monetary costs and benefits for the society, which are likely to be sizable, will be hard to assess.

Figure 3: Variation in demand when implementing the policy price $\underline{p}^L$, with $d = 0.85$ and $c = 10$



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 estimates by Jacobi and Sovinsky (2016) regarding the shift in demand following legalization (48%) and Davis et al.(2016) regarding the price elasticity of demand for marijuana (-0.7).

6 Conclusion

The federal Controlled Substances Act of 1970 describes cannabis as a drug with high potential for abuse and no acceptable medical use. In spite of increasing investments in repression during the War of Drugs, powerful criminal networks still take advantage of the prevailing black market for illegal drugs such as marijuana. As a response to this failure, marijuana use has been liberalized in some states at the end of the nineties, the drug being progressively decriminalized, allowed for medical use, and even legalized. However, these policies had undesirable effects, raising marijuana use in some states or strengthening the position of criminals.

Indeed, designing a policy that both reduces organized crime and limits a post-liberalization rise in demand is not trivial. Our paper shows that legalizing marijuana 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, which is the worst possible outcome. For legalization to be effective at regulating the demand for cannabis, it is thus necessary to both strengthen incentives on consumers to buy legally rather than illegally at the same time as targeting the illegal suppliers by measures that drive them out of business – selling legal cannabis and increasing their marginal costs of production.

Our paper hence warns policy makers that legalization policies may have unexpected effects if they are not designed with care. They may easily push a society to situations, in which cannabis is legal but disproportionately expensive, which would result in flourishing illegal businesses. On the other hand, with cheaper legal cannabis, then illegal businesses would struggle to compete but consumption would significantly increase. In contrast, the Mix policy we propose in this paper 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.

By raising the level of punishment and investing in increased repression, not only on suppliers but also on users of illegal drugs, a government could implement higher legal prices for legal cannabis and compete with dealers.

This would help control demand, while driving illegal suppliers out of business. For example, our calibrations based on empirical evidence on the US market illustrate that with a 1% probability of arrest and a 4000$ fine for illegal purchase, if the marginal cost for producing an ounce of marijuana is 125$ -corresponding to a pre-legalization black market retail price of 300$-then a legal price around 560$ per ounce would evict illegal suppliers and decrease overall consumption by 12%. Our findings highlight the complementarities between legalization and repression, providing policymakers with guidelines to overcome the legalization/repression trade-off.

Further research will extend this model to better capture the large heterogeneity in consumer behavior, in particular regarding their risk aversion and liquidity constraints. Further evidence is also required to fine-tune the calibrations for different types of consumers and shed more light on post-legalization consumer behavior.

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A Marijuana 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 marijuana 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 marijuana came into effect on June 5, 1975. The timeline of marijuana policy in Alaska in then relatively fuzzy: further decriminalization was billed in 1982, then marijuana 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 marijuana 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 is modeled by the lottery $[-p-F, \theta dv-p; q, 1-q]$. His/her reference level when considering this lottery is 0, 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 modeling the preferences of an individual being subject to Prospect Theory. We therefore assume the function u is continuous, derivable, strictly increasing, and biconcave with an inflection point on the y-axis. We normalize losses to lead to a negative value, respectively gains to lead to a positive value, and $u(0) = 0$.

Intuitively, 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:

$$w^+(1-q)u(\theta dv - p) + w^-(q)u(-p-F) = 0 \tag{18}$$

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

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

$$\begin{aligned} & w^+(1-q)u(\theta^I dv - p) + w^-(q)u(-p-F) = 0 \\ & \Rightarrow -\frac{u(-p-F)}{u(\theta dv - p)} = \frac{w^+(1-q)}{w^-(q)} \\ & \Rightarrow -\frac{u(-p-F)}{u(\theta^I dv - p)} > 0 \end{aligned} \tag{19}$$

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 $\theta^I dv - p > 0$. Notice that $\forall \theta > \frac{p}{dv}, U(\theta) > 0$ and that U is strictly decreasing and convex.

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

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

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, for q being small enough.

Differentiating equation (18) yields:

$$\alpha_q \mathrm{d}q + \alpha_\theta \mathrm{d}\theta + \alpha_d \mathrm{d}d + \alpha_p \mathrm{d}p + \alpha_F \mathrm{d}F = 0 \tag{20}$$

where

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

This allows to show 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.

$$w^+(1-q)u\left(\theta(d-1)v - p + p^L\right) + w^-(q)u\left(-p - F - \theta v + p^L\right) = 0 \quad (21)$$

As earlier, θ^L verifies the following.

$$\begin{aligned} -\frac{u\left(p^L - p - F - \theta v\right)}{u\left(p^L - p + \theta(d-1)v\right)} &= \frac{w^+(1-q)}{w^-(q)} \\ \Rightarrow -\frac{u\left(p^L - p - F - \theta v\right)}{u\left(p^L - p + \theta(d-1)v\right)} &> 0 \end{aligned}$$

Let us note $V(\theta) = -\frac{u\left(p^L - p - F - \theta v\right)}{u\left(p^L - p + \theta(d-1)v\right)}$. 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 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 reminds us that the black-market price being higher than the legal price, and of poorer quality, would involve no black market would exist at all.

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 (21) yields:

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

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 consumer continuum on $\mathbb{R}$

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.

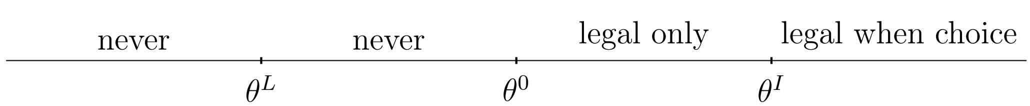
Therefore, an environment in which $\theta^L < \theta^0 < \theta^I$ is characterized by the following condition:

$$w^+(1-q)u(dp^L - p) < w^-(q)|u(-p-F)| \tag{23}$$

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 integrally substitutes to the black market. Moreover, $\int_{\theta^0}^{\theta^I} g(\theta)\mathrm{d}\theta$ 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 4: Agents continuum when $\theta^L < \theta^0 < \theta^I$



Agents whose type is 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 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: $\theta^I < \theta^0 < \theta^L$

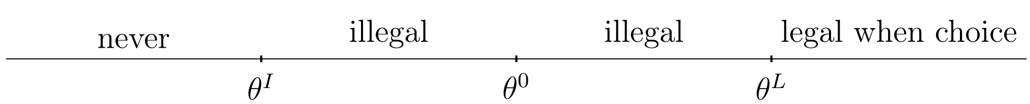
If $\theta^0 < \theta^L$, then we have

$$w^+(1-q)u(dp^L - p) > w^-(q)|u(-p-F)| \tag{24}$$

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 totally overcome 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 legal retail sales for marijuana appear.

Figure 5: Agents continuum when $\theta^I < \theta^0 < \theta^L$



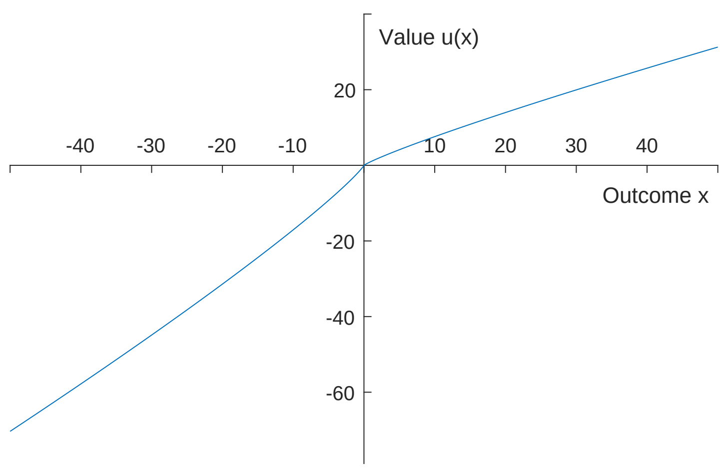
E Application to Tversky and Kahneman (1992) value function

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



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

$$u(x) = \begin{cases} x^{\alpha} \text{ , if } x > 0 \\ -\lambda(-x)^{\beta} \text{ , if } x \leq 0 \end{cases} \tag{25}$$

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.

Empirically $\alpha = \beta$. For computational reasons, we assume $\alpha = \beta$.

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

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

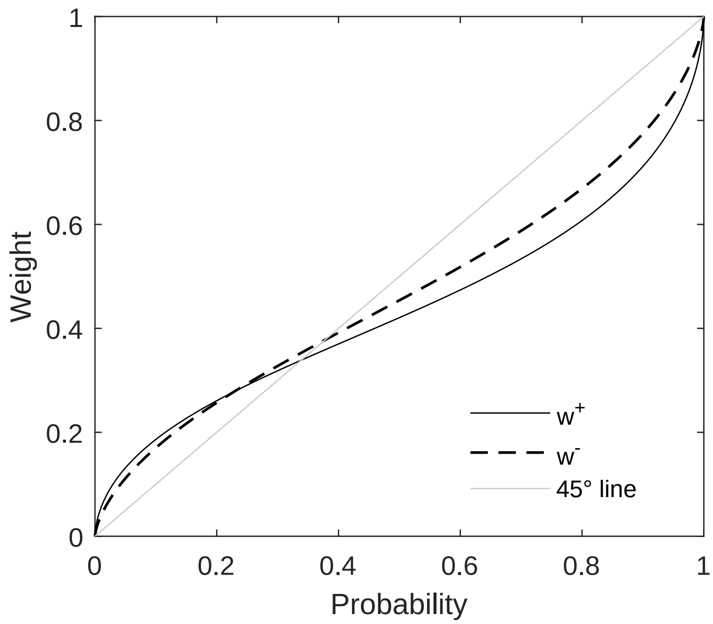
These weighting functions w^+, for gains, w^-, for losses are concave near 0 and convex near 1 to capture diminishing sensitivity for probabilities. For example Tversky and Kahneman (1992) specify the weighting functions as follows :

$$w(q) = \frac{q^\gamma}{(q^\gamma + (1-q)^\gamma)^{\frac{1}{\gamma}}} \tag{26}$$

Where the parameter $\gamma \in (0, 1]$ may slightly differ for the two weighting functions. These weighting functions, as calibrated by Tversky and Kahneman (1992) are represented on figure 7.

There are only two possible outcomes for a consumer choosing to purchase marijuana 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.

Figure 7: Weighting functions as calibrated by Tversky and Kahneman (1992)



E.2 Expression for the 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:

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

Note that:

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

and

$$\frac{\partial\theta^I}{\partial q} = \frac{\lambda^{\frac{1}{\alpha}}(F+p)}{\alpha dv}\left(-\frac{\omega'(q)}{\omega^2(q)}\right)^{\frac{1-\alpha}{\alpha}} > 0$$

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. Criminals are evicted out of the market only once they have no other choice than to price their product at marginal cost. 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.

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

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 Reaction of the eviction price to the policy parameters

We can now straightforwardly study the static comparatives of the eviction price when the policy parameters vary.

- $$\frac{\partial\underline{p}^L}{\partial F} = \frac{1}{d}\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} > 0 \tag{27}$$
- $$\frac{\partial\underline{p}^L}{\partial c} = \frac{1}{d}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}} + 1\right] > 0 \tag{28}$$
- $$\frac{\partial\underline{p}^L}{\partial d} = -\frac{1}{d^2}\left[\left(\lambda\frac{w^-(q)}{w^+(1-q)}\right)^{\frac{1}{\alpha}}(F+c)+c\right] < 0 \tag{29}$$

The probability perception by the agent (noted $\omega(q) \equiv \frac{w^+(1-q)}{w^-(q)}$) varies following a marginal change of actual probability of arrest as:

$$w'(q) = \frac{q^{\gamma-1}\left[(\gamma-1)q + \gamma(1-q)^{\gamma} + (1-q)^{\gamma-1}q\right]}{\left[q^{\gamma} + (1-q)\gamma\right]^{\frac{1}{\gamma}+1}} \tag{30}$$

The change in the eviction price following a marginal increase in q is thus given by:

$$\frac{\partial \underline{p}^{L}}{\partial q} = -\frac{(F+c)\lambda^{\frac{1}{\alpha}}}{d\alpha}\frac{\omega'(q)}{\omega^{2}(q)} > 0 \tag{31}$$