INSTITUT NATIONAL DE LA STATISTIQUE ET DES ETUDES ECONOMIQUES
Série des Documents de Travail du CREST
(Centre de Recherche en Economie et Statistique)

n° 2001-02

The Illicit drug Market : Paradoxical Effects of Law Enforcement Policies

S. PORET[1]

---

[1] CREST-LEI et EUREQua-Univesité de Paris 1.
Address : CREST-LEI-ENPC, 28 Rue des Saints-Pères, 75007 PARIS. E-mail : poret@ensae.fr

Résumé

Cet article propose une modélisation du réseau de distribution des drogues illicites organisé verticalement avec des trafiquants et des revendeurs. L'hypothèse clé est la non linéarité des coûts de transaction liés au risque encouru par les vendeurs de drogues. On étudie les effets d'une politique de mise en œuvre des lois anti-drogues plus sévère sur les prix de gros et de détail des drogues selon le membre du réseau de distribution poursuivi par les autorités répressives. On montre que ces effets sont différents selon le vendeur qui subit la répression et qu'ils peuvent être opposés à un objectif habituel de la politique anti-drogues, à savoir, la diminution de l'usage des drogues illicites. Ces résultats peuvent expliquer en partie l'échec de la « guerre aux drogues » menée aux Etats-Unis dans les années 1980.

Mots Clés : drogues illicites, coûts de transaction, mise en œuvre des lois, relation verticale.

Classification JEL : D43, K42, L13.

The Illicit Drug Market: Paradoxical Effects of Law Enforcement Policies.

Sylvaine Poret*

November 2000

Abstract

This paper presents a model of a vertically organized distribution network of illicit drugs with traffickers and retailers. The key assumption is the non-linear transactions costs related to the risk undergone by illicit drugs sellers. We study the effects of a stricter drug law enforcement policy on the wholesale and retail prices of drugs according to the identity of the member of the distribution network pursued, trafficker or retailer. We show that these effects are different according to the seller who undergoes the repression and that they can be opposite to an usual objective of the anti-drug policy, namely, the decrease of the number of consumers. These results could partially explain the failure of the "war on drugs" in the United States in the 1980s.

Keywords: illicit drugs, transaction costs, law enforcement, vertical relationship.

JEL classification: D43, K42, L13.

*CREST-LEI and EUREQua-University of Paris 1. CREST-LEI, ENPC, 28 rue des Saints-Pères 75007 Paris. E-mail: poret@ensae.fr

1 Introduction

Anti-drug policies sometimes appear to have unexpected effects. For instance, in the United States, in the 1980s, arrests for drug violations rose dramatically, especially those related to heroin, cocaine, and their derivatives. This "war on drugs" coincided however with an increased availability of both heroin and cocaine. In fact, as shown in a study of Johnston et al. (1992), cited by Lee (1993), following a rise of arrests and penalties for drug violations, a steadily growing percentage of high school seniors in that period reported that cocaine and heroin "would be fairly easy or very easy for them to get". The perceived availability of cocaine rose by 20 percent and that of heroin by 50 percent. At the same time, cocaine and heroin import prices had fallen steadily (Caulkins, 1995).[1] Grossman (2000) has shown with prices based on purchases made by drug enforcement agents that the real price of one pure gram of cocaine fell by 81 % between 1981 and 1997. Most of this decline took place in the 1980s. Thus, during a period in which trafficking in cocaine and heroin was an increasingly risky trade involving severe penalties, supply increased and drug prices declined. According to Reuter (1997), "This failure of cocaine and heroin prices to rise with tougher enforcement is a major analytic and policy puzzle".

This policy of large allocations of resources to law enforcement expenditure puts in practice a traditional precept which recommends a tougher anti-drug law enforcement policy in order to diminish the market size. Indeed, one of the assumptions about the dynamics of markets for dependency-creating and expensive drugs made by American drug policy analysts and law enforcement agencies is that more stringent drug law enforcement raises drug prices (Reuter and MacCoun, 1995). This assumption relies on the fact that the seizures realized by the anti-drug law enforcement agents diminish the supply and thus increase the market price. This analysis grounds on the assumption that the illicit drug market behaves like a legal market and ignores the strategic effects which can interfere with the law enforcement policy.

The present paper points out some of these effects and analyses their impact on the drug prices. The objective is to isolate some effects related to strategic behaviors of drug sellers and to show how these effects can explain a part of the paradoxical

[1] The analysis of data on retail prices is more difficult, because the quality and thus the price of a drug differ a lot with the date and the place of purchase. Nevertheless, according to Reuter (1997), cocaine and heroin prices have fallen steadily since 1981.

results of some anti-drug law enforcement policies.

In the drug trade, the largest cost incurred by drug sellers is associated with discovery, apprehension, conviction, and punishment. The amount of law enforcement resources and its allocation along the distribution chain would seem to be the primary determinant of narcotic prices. The first strategic effect is associated to transaction costs which are related to the risk of arrest and conviction. The probability of discovery of someone engaged in the narcotics trade is a function of the number of transactions in which he is involved and of the probability of arrest at the time of a transaction. The risk of arrest is large at the point in the chain of distribution where the average quantity of drug transferred in any given transaction is lower and where therefore the number of transactions is higher (Rottenberg, 1968).

The narcotics distribution system is a vertically organized network which can be long or short. In principle, the importer can sell the drug directly to consumers, but in practice, he often sells to wholesalers who in turn sell to retailers. At the retailing level, in industrial countries, narcotics trade can be represented by a pyramidal structure with four levels (Choiseul-Praslin, 1991): the trafficker, whose unique objective is to maximize his profit, is a businessman; the retailer, seeking for a regular income, could sell directly to the consumer, but he usually prefers to deal with a user-retailer, to whom he sells a larger quantity under better conditions; the user-retailer or dealer buys quantities both for his own consumption and to finance it; and finally, at the bottom of the network is the casual or regular consumer.

This market organization suggests that the vertical relationship between sellers at different levels of a vertically organized network is one of the main features of drug markets. This characteristic should thus play a role in the analysis of the effect of the law enforcement policies. In our model, the effect of law enforcement is allowed to be different for each level of the vertical chain toward which the repression policy applies, in order to bring out specific effects related to the seller's position in the drug distribution network.

Among the papers which deal with the effects of law enforcement policies on the drug market, the first one that modeled this market as a vertical structure is due to Chiu et al. (1998). The authors model the market for illegal drugs as one characterized by double marginalization. An upstream monopolist, such as the drug cartel in Colombia, sells wholesale quantities of drugs to local distributors in the US., who are Cournot competitors. The government's objective is to minimize the quantity of retail drugs consumed by its citizens. The authority imposes quantity taxes on the upstream and the downstream firms. These taxes represent the prohibition and the enforcement efforts which effectively raise the production costs. Chiu et al. thus model the drug market as a stage game involving the law enforcement authority, the upstream monopolist, and the downstream oligopolists and consider the location of optimal enforcement efforts. They find that the location of the enforcement effort is irrelevant to the quantity minimization problem. They conclude that "the choice of battlefield on which to fight the war on drugs is likely to be of only secondary importance in choosing effective anti-drugs policy".

Contrary to the first analyses of the drug market in which the criminal activities market is described as a monopoly (Buchanan, 1973),[2] recent observations achieved by Reuter (1983; 1991) and Kleiman (1989)[2] tend to confirm that the retailing networks structure evolved to a non-cartelized oligopoly. For that reason our model considers the illicit drug market as an oligopoly. Traffickers compete on the same territory and they sell on an intermediate market to dealers, who are in competition too.[3]

In all countries, the use and sale of certain drugs (heroin, cocaine, cannabis, synthetic drugs) are prohibited. Prohibition, which follows the total ban principle, has to be distinguished from repression, which is the enforcement of this principle by the authority in charged with the anti-drug law enforcement.

The first paper which studies drug-law enforcement is due to Eatherly (1974). The author discusses the implications of the following two strategies: reducing demand by harassing buyers, or reducing supply by harassing sellers. He concludes that enforcement strategies directed against drug sellers tend to be less effective because sellers can easily convert arrests and sentences into pecuniary terms, that is, an increase of the market price. This often leads to an increase of thefts and crimes committed by consumers. Harassing buyers by nonpecuniary punishment is efficient because nonpecuniary punishment of consumers is not easy to shift onto others so that price decreases. This enforcement strategy "has the advantage of giving the community a mechanism for encouraging users to seek rehabilitation" (Eatherly, 1974, p. 213).

[2] Reported in Kopp (1997).

[3] The model can nevertheless be applied in the case of a chain of monopolists.

Lee (1993) disputes this conclusion, arguing that economic analysis assumes that the illicit drug market behaves like a legal market in spite of the risks and large transaction costs inherent to this market. To examine demand reducing policies, Lee builds a model of an illicit drug market that prominently features penalties on market participants, users and dealers, and he analyses the effects of users repression on supply. A theory of illicit drug markets, in which buyers and sellers face large transaction costs and consumption penalties, is proposed and used to analyze whether harassing users would reduce both consumption and price. Lee assumes perfect competition and also that the risk of transaction gives rise to a constant expected cost per transaction. The analysis implies that a shift toward harassing users would probably not lower both consumption and price, which can explain paradoxes from the decriminalization of marijuana in the 1970s and the "war on drugs" in the 1980s.

There is however a practical objection against harassing consumers. Indeed, it seems now difficult, at least in a lot of Western Europe countries, to pursue drug users who are seen more as victims than as punishable market participants.

The law enforcement authority can use two law enforcement instruments to fight against such illicit activities as drug trade: resources to arrest and convict sellers and penalties for drug sale. In fact, the law enforcement authority pursues all members of the distribution network, but it is of interest to isolate the effects of the law enforcement when the authority pursues only one type of sellers (traffickers or retailers) in order to bring to the fore specific strategic effects.

The purpose of this paper is to present a model of an illicit drug market characterized by a vertically organized structure and transaction costs related to the repression. For each possible pursued member of the drug distribution network, retailer or trafficker, we analyze the effects of an increase of law enforcement tools on the wholesale and retail prices of the drug.

Considering that the objective of the authority is to minimize the use of drugs, we show that a tougher law enforcement policy can have a paradoxical result: it can actually increase the drug consumption. We also show that the effects of a tougher law enforcement policy differ with the type of seller who undergoes the repression. These results could partially explain the failure of the "war on drugs" set up by the US. government in the 1980s.

We present the model in section 2. Section 3 develops the effects of an increase of repression when the law enforcement pursues only the retailers. In section 4, these effects are determined when the law enforcement pursues the traffickers. We compare the results obtained in section 5 and conclude in section 6.

2 The model

The drug market is made up of consumers, a vertically organized distribution network, and the anti-drug law enforcement authority. These players of the market are presented successively in the following subsections. In the last subsection, we present the stage game involving these different agents.

2.1 The demand

Consumers are characterized by their reservation price θ for one unit of drug, $\theta \in [0, \Theta]$. Consumers are uniformly distributed on the line $[0, \Theta]$, $\Theta > 1$. This product is not perfectly divisible. Each consumer buys 0 or 1 unit of drug. According to a study of Reuter et al. (1990) realized in Washington D.C., a typical dealer realizes 13 sales to 12 customers during one working day and the quantity sold in each transaction corresponds to one dose. Thus, assuming that each consumer buys one unit of drug at each meeting with a seller is realistic.

The parameter Θ represents the number of potential consumers, that is to say, the number of users for a price equal to zero. Notice that the reservation price θ may be a criterion to represent different groups of consumers, according to their degree of dependance towards drug. We do not want to capture the addictive behaviors which concern only a part of users and which were largely developed by the theory of "rational addiction" introduced by Becker (1988; 1991).

Let the individual demand function be: $D(p) = \begin{cases} 1 \text{ if } \theta \geq p. \\ 0 \text{ if } \theta < p. \end{cases}$

The global demand function thus is:

$$D(p) = \Theta - p.$$

where p denotes the price of the drug consumed in the market.

2.2 The drug distribution network

In order to represent the drug distribution network, we consider vertically organized networks with two levels: the upstream level consisting of the traffickers, and the downstream level consisting of the retailers.

Under the assumption that the market is oligopolistic, the market is made up of m identical traffickers, n identical retailers ($m \leq n$), and Θ potential consumers.[4]

Let x_j be the quantity sold by a trafficker j ($j = 1, ..., m$) and x_i the quantity sold by a retailer i ($i = 1, ..., n$). Since we consider only unitary demand at the consumer level, x_i is also the number of consumers served by a retailer, and $x_{ij} = \frac{x_j}{x_i}$ the number of retailers served by a trafficker. Each trafficker thus supplies x_{ij} retailers with a total quantity x_j, each retailer sells to each of the x_i consumers one unit of product. The market is assumed to be symmetric.

The competition on the illicit drugs market is not very intense, especially in small areas.. Moreover, the sellers do not raise directly the drug price. They diminish the quantity of pure product per dose, that is, the quality of the drug sold. Thus we assume that the competition in the intermediate and final good markets is *à la* Cournot (Salinger, 1988).

We don't model the attitude towards risk of the sellers in this paper, because we focus the analysis on the effects of the law enforcement tools and the drug market structure, and we let this analysis for future research. Moreover, being involved in the drug trade can be viewed as a risk-preference behavior, but sellers act to minimize the risk they run. Characterizing the attitude towards risk of drug sellers is thus not obvious. Some experimental studies would be necessary to clarify this discussion.

2.3 The law enforcement policy

The drug trade is prohibited and the authorities set up a law enforcement policy. To deter traffickers and retailers, the anti-drug law enforcement authority can use two tools.

The first one is to spend money on the control of drug dealing. This spending determines the probability q of arrest and conviction at the time of a transaction with

[4] With $n = 1$ and $m = 1$, we obtain results for the case in which the distribution network is a monopoly in chain, that is, when drug sellers are organized in local monopolies, which may happen on some territories, see Gambetta and Reuter (1995).

a customer. For a typical seller, who works two days a week and realizes about 1,000 transactions per year, the probability of arrest at the time of a transaction is around one out of 4,500 (Reuter, 1997), that is to say, q is equal to 0.022 %.

The second tool for the authorities is to introduce a sanction sx paid by the seller in case of arrest and conviction. The sanction is a function of the quantity x transacted and of the unitary sanction s.

The assumption that the sanction is a linear function of exchanged quantities at each transaction may seem too simple, but the quantity transferred at each transaction is a good parameter to characterize the seller's position in the distribution network. This representation of the sanction allows to differentiate traffickers from retailers as in the Anti-Drug Act: $x = 1$ for retailers and $x = x_i \geq 1$ for traffickers. The unitary sanction s characterizes the penalties severity.

Because a seller is arrested at the time of a transaction, there is no possible error made in the enforcement process. We suppose also that the law enforcement authority is able to distinguish between sellers and consumers and between traffickers and retailers.

Repression undergone by the participants induces transaction costs which depend on the probability of arrest. The probability of discovery of an agent involved in the narcotics trade is a function of the capacity of the law enforcement authority to arrest him when he serves a customer, but also of the number of transactions in which he is involved.

The probability of arrest is an increasing function of the frequency of transactions. If the probability of arrest is q for one transaction, it is $1-(1-q)^t$ for one conviction in t transactions. Once he has been arrested, the seller can not continue selling his product.

The risk is supposed smaller for traffickers than for retailers, who realize a more important number of transactions, but they pay a smaller sanction than traffickers when they are arrested, because they sell a smaller quantity to each consumer.

Under these assumptions, the trafficker's expected profit (respectively the retailer's one), when law enforcement agents only pursue traffickers (respectively retailers) is: $E\Pi_j^T(x_j) = w\left[\frac{1-q}{q}\left(1-(1-q)^{x_{ij}}\right)\right] - cx_j - sx_i\left[1-(1-q)^{x_{ij}}\right]$ and

$E\Pi_i^R(x_i) = p\left[\frac{1-q}{q}\left(1-(1-q)^{x_i}\right)\right] - wx_i - s\left[1-(1-q)^{x_i}\right]$ with w the wholesale price and c the unit cost of production.

The first term of these profits represents the total receipts (wx_j and px_i) minus the losses related to the capture and thus the decrease of the supply related to the law enforcement policy.

The last term of these profits means that the transaction costs, which are equal to the sanction (sx_i in the case of traffickers oriented policy and s in the case of retailers oriented policy) times the probability of arrest at the time of the transactions realized by the seller (respectively x_{ij} and x_i). These transaction costs are increasing with the sanction s, with the probability of arrest at the time of a transaction q, and with the number of transactions realized by each seller (respectively x_{ij} and x_i). They are concave with respect to the probability of arrest at the time of a transaction q and with respect to the number of transactions realized (respectively x_{ij} and x_i).

We focus on the effects of the transaction costs and the vertical structure of the drug distribution network. For that purpose, we must neglect the effects on quantities related to the seizure of drug in the market by the anti-drug law enforcement agents. Thus, we assume that the sellers receive the total receipts of the trade. This model thus concentrates on the strategies of sellers who face a law enforcement policy generating transaction costs.

Under this additional assumption, we can rewrite the trafficker's expected profit (respectively the retailer's one), when law enforcement only pursues traffickers (respectively retailers):
$E\Pi_j^T(x_j) = [w-c]\,x_j - sx_i\left[1-(1-q)^{x_{ij}}\right]$ and
$E\Pi_i^R(x_i) = (p-w)x_i - s\left[1-(1-q)^{x_i}\right]$.

By taking into account the increasing and concave transaction costs related to the risk caused by the law enforcement, traffickers and retailers seek to maximize their expected profit. They face the following trade-off: increasing quantities sold to increase their profit (but this increases the number of transactions and thus the transaction costs), or decreasing the number of transactions in order to reduce the risk of arrest or the amount of the sanction by increasing the retail price.

2.4 The game

We model the drug market as a three-stage game involving the m traffickers, the n retailers, and the Θ potential consumers.

At the first stage, the m traffickers sell to some retailers a quantity of units of drug at the wholesale price w, with a constant unit cost of production c.

At the second stage, the n retailers sell to consumers at the retail price p.

At the third stage, consumers purchase one unit of drug if their reservation price θ is higher than the retail price p.

The equilibrium concept is subgame-perfect Nash equilibrium with pure strategies.

We study two different policies. In the retailers oriented policy, the authority only pursues the retailers, whereas it only pursues the traffickers under the traffickers oriented policy.

Each repressive regime gives rise to two different games. We solve successively each of these games by backward induction.

3 Retailers' repression

We first consider the case where the repression concerns only the retailers.

3.1 Equilibrium prices

In the third stage, consumers buy one unit of drug if their reservation price θ is higher than the retail price p.

In the second stage, each retailer maximizes his profit $E\Pi_i^R$ by choosing the quantity x_i, taking the wholesale price w and parameters Θ, s, and q as given:

$\max\limits_{x_i} \left\{ E\Pi_i^R(x_i) = (p-w)x_i - s\left[1-(1-q)^{x_i}\right] \right\}$ with $x = \sum\limits_{s=1}^{n} x_s = \Theta - p$, the total demand.

Consider the following condition:

$$s\left[\ln(1-q)\right]^2 \leq 2. \tag{1}$$

Lemma 1 *If the condition (1) is satisfied, that is, if the law enforcement policy is not too strict, the unique symmetric equilibrium demand of the subgame beginning at* *the second stage is x, where x is the solution of:*

$$\Theta - \frac{(n+1)}{n}x + s(1-q)^{\frac{x}{n}}\ln(1-q) = w.$$

Proof. See appendix A. ■

The condition (1) guarantees that the drug market exists.

We now consider the first stage of the game. The expected profit of the trafficker j is given by: $\Pi_j^T(x_j) = (w-c)\,x_j$. The trafficker's program is:
$\max\left\{\Pi_j^T(x_j) = (w-c)\,x_j\right\}$ with $w = \Theta - \frac{(n+1)}{n}x + s(1-q)^{\frac{x}{n}}\ln(1-q)$.

Consider the following condition:

$$-\ln(1-q)s \leq \Theta - c. \tag{2}$$

Lemma 2 *If the condition (2), which guarantees that the equilibrium demand is positive, is satisfied, there exists a unique symmetric subgame-perfect Nash equilibrium of the game x^*, solution of:*

$$m(\Theta - c) - \frac{(n+1)(m+1)}{n}x^* + s(1-q)^{\frac{x^*}{n}}\ln(1-q)\left[m + \frac{x^*}{n}\ln(1-q)\right] = 0.$$

Proof. See appendix B. ■

The condition (2) eliminates the case where the law enforcement policy is so tough that at the market price the demand does not exist even at a price equal to marginal cost.

Therefore, the equilibrium wholesale price w^* and the equilibrium retail price p^* are given by the following implicit functions:
$w^* = \frac{1}{m+1}\left[\Theta + mc + s\ln(1-q)(1-q)^{\frac{\Theta-p^*}{n}}\left(1 - \frac{\Theta-p^*}{n}\ln(1-q)\right)\right]$ and
$\frac{(n+1)(m+1)}{n}p^* - \frac{n+m+1}{n}\Theta - mc + s(1-q)^{\frac{\Theta-p^*}{n}}\ln(1-q)\left[m + \frac{\Theta-p^*}{n}\ln(1-q)\right] = 0.$

We can compare the profits obtained by each participant. At equilibrium, the trafficker's expected profit $E\Pi_j^{T*}(p^*)$ is higher than the retailer's expected profit $E\Pi_i^{R*}(p^*)$ because of the condition (1) (see appendix C). The retailer's profit is smaller than the trafficker's one. This result is as usual when, in a vertical relationship, the upstream firm chooses the wholesale price.

3.2 Effects of repression tools on the equilibrium prices

We study the effect of a higher probability of arrest at the time of a transaction on the equilibrium wholesale price w^* in the following proposition:

Proposition 3 *There exists a threshold of the probability of arrest* q_1 *such that*

$$\begin{cases} \frac{\partial w^*}{\partial q} \leq 0 \text{ if } q \leq q_1 \\ \frac{\partial w^*}{\partial q} > 0 \text{ if } q > q_1. \end{cases}$$

Proof. See appendix D. ■

Even if the law enforcement policy is aimed at the retailers, traffickers react to a tougher policy. We can call this effect, the "double marginalization" effect. The traffickers, as Stackelberg leaders, internalize the level of retailers' transaction costs when they determine their wholesale price.

If the probability of arrest at the time of a transaction is initially weak ($q < q_1$), the global probability of being arrested is weak as well, and the price is thus low and the number of transactions is high. When the probability of arrest at the time of a transaction increases, the retailers' transaction costs become very high. Thus they want to increase the retail price. The traffickers anticipate this fact and thus they anticipate a decrease of the demand and of their profit. They reduce the effect on the demand of a stricter law enforcement policy by decreasing the wholesale price, because the retailers transfer this cutting-down. It is the usual effect obtained when retailers' costs increase, related to the double marginalization mechanism.

If the probability of arrest is initially high ($q > q_1$), the risk is so high that the retailers fix a high price and thus the demand, i.e. the number of transactions, is low. The traffickers anticipate that the retailers' transaction costs are weak and thus increase the wholesale price if the probability of arrest increases. The traffickers know that the stricter law enforcement policy has little effect on retailers' transaction costs.

The effect of an increase of the probability of arrest at the time of a transaction on the equilibrium retail price is given by the following proposition:

Proposition 4 *There exists two thresholds of the probability of arrest,* q_0 *and* q_2 *with* $q_2 > q_1 > q_0$, *such that*

$$\begin{cases} \frac{\partial p^*}{\partial q} \geq 0 \text{ if } q \leq q_0 \\ \frac{\partial p^*}{\partial q} < 0 \text{ if } q_0 < q < q_2 \\ \frac{\partial p^*}{\partial q} \geq 0 \text{ if } q \geq q_2. \end{cases}$$

Proof. See appendix E. ■

An increase in the probability of arrest has two partial effects on the retail price and the three areas which appear depend on the dominant effect.

The first one is indirect, it is the "double marginalization" effect described in the proposition 3. When the traffickers change the wholesale price following an increase in the probability of arrest of the retailers, the retailers in turn change the retail price.

The second effect is the retailers' reaction and can be called the "transaction costs" effect. If their initial transaction costs are high and increase, when the probability of arrest increases, the retailers want to decrease the number of transactions. They thus decrease the demand by increasing the retail price. If their transaction costs are weak and increase following an increase of the probability of arrest, they prefer to increase the number of consumers in order to increase the deterministic part of their profit.

Depending on the initial level of the probability of arrest, the first or the second effect may dominate, thus implying an increase or a decrease of the retail price.

When the probability of arrest is very weak ($q < q_0$), the initial risk is weak, thus the retail price is very weak and the number of transactions is high. The retailers face very high transaction costs. When the probability of arrest increases, the transaction costs are so high that the retailers lower the quantity, even if the wholesale price decreases. The demand diminishes, but retailers' mark up increases and the transactions costs decrease. The "transaction costs" effect is dominant.

For intermediate values of q ($q_0 < q < q_2$), an increase in this probability lowers the equilibrium retail price. In the whole interval, the retail price decreases with q, but different mechanisms are at work according to the value of q. The implicit threshold q_1 related to the "double marginalization" effect appears.

If the probability of arrest is weak ($q_0 < q < q_1$), the initial risk is weak and thus the transaction costs are high, but less than in the previous case. Even if the transaction costs increase following an increase in probability of arrest, as the traffickers decrease the wholesale price, the retailers transfer this decrease by diminishing the retail price. In this case, the "double marginalization" effect is dominant.

If the probability of arrest is moderate ($q_1 < q < q_2$), the initial risk and the transaction costs are relatively lower than previously. The transaction costs increase following an increase of the probability of arrest and the traffickers increase the wholesale price, but the retailers prefer to decrease the retail price in order to increase the deterministic part of their profit because of the increase in demand, even if, otherwise, the transaction costs increase. There, the transactions costs effect is dominant.

When the probability of arrest is high ($q > q_2$), the initial risk is high and thus the transaction costs are weak. The "transaction costs" effect can be neglected. As the traffickers increase the wholesale price, the retailers take this augmentation into account by increasing the retail price. The "double marginalization" effect is dominant in this case.

Considering that the objective of a stricter anti-drug policy is to reduce the drug use, thus to increase the retail price, an increase of the probability of arrest is efficient when this probability is initially weak or high. The area where the relation between the retail price and the probability of arrest is negative is all the smallest since the unit sanction is high.[5] Thus the efficiency of an increase of the probability of arrest appears all the more so since the unit sanction is large, because transaction costs are initially high.

The effect of the unitary sanction on the equilibrium wholesale and retail prices is given by the two following propositions:

Proposition 5 *Whatever the repression level, an increase in the unit sanction leads to a decrease of the wholesale price.*

Proof. At equilibrium,
$w^* = \frac{1}{m+1}\left[\Theta + mc + s\ln(1-q)(1-q)^{\frac{\Theta-p^*}{n}}\left(1 - \frac{\Theta-p^*}{n}\ln(1-q)\right)\right]$ and thus
$\frac{\partial w^*}{\partial s} = \frac{\ln(1-q)}{m+1}(1-q)^{\frac{\Theta-p^*}{n}}\left(1 - \frac{\Theta-p^*}{n}\ln(1-q)\right) < 0.$ ■

Due to the double marginalization, the traffickers anticipate the decrease of the demand following the increase of the retail price resulting from the increase of the sanction. Thus, by decreasing the wholesale price, they give incentives the retailers to decrease in their turn the retail price, which increases the demand and therefore they offset the initial fall of the demand. As usual in the analysis of vertical relationships between producers and retailers, if retailers' costs increase, producers diminish the wholesale price in order to partially offset the decrease of demand.

[5] $\frac{dq_0}{ds} > 0$ and $\frac{dq_2}{ds} < 0$.

Proposition 6 *There exists a threshold of the probability of arrest,* $q_3 = 1 - e^{-\frac{(n+1)(m+1)}{\Theta - c}}$, *such that:*

$$\begin{cases} \frac{\partial p^*}{\partial s} > 0 \text{ if } q < q_3 \\ \frac{\partial p^*}{\partial s} \leq 0 \text{ if } q \geq q_3. \end{cases}$$

Proof. See appendix F.

An increase of the unitary sanction has two opposite effects which explain the total effect of a tougher law enforcement policy on the equilibrium retail price.

The first one is the "double marginalization" effect described in the proposition 5. When the traffickers decrease the wholesale price following an increase of the unitary sanction, the retailers partially transfer this decrease. This effect is negative.

The second effect is the positive "transaction costs" effect. As their transaction costs increase, the retailers decrease the demand by increasing the retail price in order to lower the number of transactions.

According to the initial level of the probability of arrest at the time of a transaction, the positive or the negative effect may dominate.

When the probability of arrest is weak ($q < q_3$), the retail price increases, due to the increase of the unitary sanction; the "transaction costs" effect is dominant. The probability of arrest at the time of a transaction is initially weak; the retailers' risk is weak too. Thus the price is initially weak and the demand is high. The retailers face very high transaction costs. An increase of the unitary sanction raises transaction costs. To avoid this effect, the retailers lower the demand and thus the retail price increases. The loss of retailers' profit due to the increase of retail price is partly compensated by the decrease of the wholesale price.

On the opposite, when the probability of arrest and conviction is high ($q \geq q_3$), an increase of the unitary sanction leads to a retail price fall and induces a rise of the number of consumers; the "double marginalization" effect is dominant. The probability of arrest at the time of a transaction is initially high, thus, the retailers' risk is high too. Therefore the price is initially high and the demand is weak. The retailers face low transaction costs. An increase of the unitary sanction has only a weak effect on transaction costs. But, the double marginalization mechanism appears and the traffickers decrease the wholesale price. The retailers lower the retail price following this decrease. They prefer to face higher transactions costs in order to increase the deterministic part of their profit. In this case, the increase of the unitary sanction is not efficient: despite the increase of the sanction, the number of consumers increases.

A first conclusion follows from the previous analysis, by taking into account the effects of a stricter law enforcement policy on the drug retail price and the drug consumption. An increase of the unitary sanction is efficient in terms of a decrease in demand only if the probability of arrest is low. An increase in the probability of arrest at the time of a transaction is more likely to be efficient when the unit sanction is high. This first game where the anti-drug law policy is brought against retailers shows that an increase in repression, whatever the tool used (amount of sanction or probability of arrest), may lead to unexpected results: in some cases, it can result in lower prices, that is, to an expansion of the number of consumers.

4 Trafficker's repression

The distribution network is organized as an oligopoly at each level of the network and the anti-drug law is brought against traffickers.

4.1 Equilibrium prices

In this regime, retailers do not incur repression and thus each of them maximizes his profit $E\Pi_i^R$ by choosing the quantity x_i, taking only the wholesale price w and parameter Θ as given:

$$\max_{x_i} \left\{ E\Pi_i^R(x_i) = (\Theta - \sum_{s=1}^{n} x_s - w)x_i \right\}.$$

Therefore the best reply function of retailer i is easily derived and we can rewrite the first order condition of retailer i, which gives the Cournot-Nash equilibrium quantity as a function of the wholesale price w: $x_i = \frac{\Theta - w}{n+1}$.

The equilibrium between supply and demand on the intermediate market gives the reverse demand function on this market $w(x) = \Theta - \frac{n+1}{n}x$, where x is the unique symmetric equilibrium quantity of the subgame beginning at the second stage.

In the first stage, the trafficker j is affected by the repression: he supplies x_{ij} retailers thus x_{ij} transactions take place; since the trafficker carries x_i units at each transaction, the sanction he must pay in the event of arrest is sx_i. He thus obtains the following expected profit:

$E\Pi_j^T(x_j) = [w(x) - c]\, x_j - s x_i \left[1 - (1-q)^{x_{ij}}\right].$
with $x_i = \frac{1}{n} \sum_{k=1}^{m} x_k$ and $w\left(\sum_{k=1}^{m} x_k\right) = \Theta - \frac{n+1}{n} \sum_{k=1}^{m} x_k$.
Let the following condition be satisfied:

$$s \leq \frac{n(\Theta - c)}{m^2\left(1 - (1-q)^{\frac{n}{m}}\right) + n\,(m-1)\ln(1-q)(1-q)^{\frac{n}{m}}}. \tag{3}$$

Lemma 7 *If the condition (3), which guarantees the market existence, is satisfied, there exists a unique symmetric subgame-perfect Nash equilibrium of the game*

$$\overline{x} = \frac{n}{(n+1)\,(m+1)} \left[m\,(\Theta - c) - \frac{s}{n}\left[m + (1-q)^{\frac{n}{m}}\,(m + n\,(m-1)\ln(1-q))\right]\right].$$

Proof. See appendix G. ■

We then obtain the equilibrium wholesale and retail prices
$\overline{w} = \frac{1}{m+1}\left[\Theta + mc + \frac{s}{n}\left[m - (1-q)^{\frac{n}{m}}\,(m + n\,(m-1)\ln(1-q))\right]\right]$
$\overline{p} = \frac{1}{(n+1)(m+1)}\left[(n+m+1)\Theta + mnc + s\left[m - (1-q)^{\frac{n}{m}}\,(m + n\,(m-1)\ln(1-q))\right]\right].$

In this game, it is more difficult to compare the profits obtained by each participant. At equilibrium, for some values of s, m, and n, the trafficker's expected profit $\overline{E\Pi}_j^T(\overline{p})$ is lower than the retailer's expected profit $\overline{E\Pi}_i^R(\overline{p})$.

When $m = 1$, that is, when the upstream level is a monopoly, the trafficker's expected profit $\overline{E\Pi}_j^T(\overline{p})$ is always higher than the retailer's expected profit $\overline{E\Pi}_i^R(\overline{p})$ whatever n and s. When the trafficker is in a monopolist's position, even if he is pursued by the law enforcement authority, he obtains a profit that is higher than the retailers' one. The trafficker transfers a large part of the risk he incurs on the retailers through the wholesale price.

When there are several competing traffickers at the upstream level of the distribution network, they have less power to transfer to retailers the costs of the law enforcement policy.

4.2 Effects of repressive tools on the equilibrium prices

The effect of the probability of arrest at the time of a transaction on the equilibrium wholesale and retail prices, when the law enforcement authority pursues the traffickers, is given by the following proposition:

Proposition 8 *When $m > 1$, there exists a threshold of the probability of arrest, q_4 defined by $q_4 = 1 - e^{-\frac{m^2}{n(m-1)}}$, such that*

$$\begin{cases} \frac{\partial \overline{w}}{\partial q} > 0 \text{ if } q < q_4 \\ \frac{\partial \overline{w}}{\partial q} \leq 0 \text{ if } q \geq q_4 \end{cases} \text{ and } \begin{cases} \frac{\partial \overline{p}}{\partial q} > 0 \text{ if } q < q_4 \\ \frac{\partial \overline{p}}{\partial q} \leq 0 \text{ if } q \geq q_4. \end{cases}$$

Proof. *See appendix H.*

In this case, the traffickers undergo the repression, thus they bear the "transaction costs" effect. But, in this vertical relationship between traffickers and retailers, the balance of power is in the favor of the traffickers because of their Stackelberg leadership. Consequently, when the law enforcement policy is tougher, they can transfer a part of the increase of their costs onto the retailers through the wholesale price.

When the probability of arrest is weak ($q < q_4$), an increase of the resources allocated to the detection increases the equilibrium retail price. The probability of being arrested is initially relatively weak, thus the quantities exchanged between each trafficker and his retailers are high. Therefore the expected amount of the sanctions is high. When the anti-drug law enforcement policy becomes tougher, a trafficker cannot diminish the number of retailers to whom he sells, because the numbers of retailers and traffickers are fixed. But he can change the quantities he sells to each of his retailers by increasing the wholesale price. It is the "transaction costs" effect. As a result of the "double marginalization" effect, each retailer increases in turn the retail price. This lowers the demand and each trafficker carries a lower quantity of drug at each transaction. This leads to lower expected sanctions.

When the probability of arrest at the time of a transaction is high ($q \geq q_4$), an increase of this probability lowers the equilibrium retail price. When the probability of arrest is initially high, traffickers carry lower quantities of drug in order to minimize the sanction they would pay in case of arrest. When they incur a higher risk of arrest, the traffickers prefer to decrease the wholesale price in order to increase the deterministic part of their profit even if their transaction costs increase. Following the decrease in the wholesale price, each retailer decreases the retail price; it is the "double marginalization" effect.

The probability of arrest threshold q_4 is all the more weak since the number of traffickers is weak and the number of retailers is high. Therefore it is all the more difficult to obtain the expected effect of an increase of the probability of arrest, that is, an increase of the price, since few traffickers supply a lot of retailers. The cost related to the enforcement law is borne by few traffickers and they can not transfer this cost to the retailers, because there is a strong competition at the downstream level of the distribution network. Thus the traffickers prefer to act on the deterministic part of their profit by decreasing the price.

When $m = 1$, that is, when the upstream level is a monopoly, $\frac{\partial \overline{w}}{\partial q} > 0$ and $\frac{\partial \overline{p}}{\partial q} > 0$ $\forall q$. An increase of the probability of arrest at the time of the unique transaction rises the transaction costs, because the sanction payed in the case of arrest rises. By rising the wholesale price and thus the retail price, the only trafficker reduces the demand, which decreases the transaction costs. In the upstream monopoly case, when the repression affects the trafficker, any increase in the repression is efficient in terms of consumption decrease, because the trafficker makes higher transaction costs he endures lie on the retailers through the wholesale price.

When the anti-drug policy is brought against the traffickers, the effect of the unitary sanction on the equilibrium prices is given by the following proposition:

Proposition 9 *Whatever the repression level, an increase in the unit sanction implies an increase of the equilibrium wholesale price and the equilibrium retail price.*

Proof. At the equilibrium,
$\overline{w} = \frac{1}{m+1}\left[\Theta + mc + \frac{s}{n}\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right]\right]$ and
$\overline{p} = \frac{1}{(n+1)(m+1)}\left[(n+m+1)\Theta + mnc + s\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right]\right]$,
thus $\frac{\partial \overline{w}}{\partial s} = \frac{1}{n(m+1)}\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right] > 0$ and
$\frac{\partial \overline{p}}{\partial s} = \frac{1}{(n+1)(m+1)}\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right] > 0$. ■

When the sanction increases, the transaction costs become higher thus each trafficker raises the wholesale price and each retailer transfers this increase on the retail price.

When the repression affects the traffickers, an increase in the unit sanction is always efficient, in terms of fall of consumers. But an increase in the resources allocated to the repression is not always effective. The expected effect of an increase in the resources, that is, an increase of the retail price, appears only when these resources are below a certain level.

When the law enforcement policy is brought against traffickers, the effects of a stricter policy are less sensitive to threshold effects. As the traffickers have a great power in the vertical relationship between them and the retailers, they can easily transfer a part of the increase of transaction costs to the retailers through the wholesale price.

5 A comparison between the repression regimes

The effects of a tougher law enforcement policy differ according to the type of seller that is targeted by the policy (i.e. the retailer or trafficker). The "double marginalization" effect and "transaction costs" effect are dominating in the case in which the repression pursues the retailers. When the retailers alone undergo the law enforcement policy, each retailer bears the transactions costs and he is submitted to the power of a trafficker, his supplier, through the wholesale price. When the authority pursues traffickers, the latter bear the transactions costs and they transfer a part of these costs to the retailers through the wholesale price. The balance of power is in favor of the traffickers in the drug market, even if, when the law enforcement agents pursue them, their profit can be lower than the retailers' one. Therefore it is necessary to take into account the vertical market structure in order to determine all effects of a stricter enforcement. Strategic effects which appear in the case of a law enforcement policy brought against traffickers are less complicated than those which appear in the retailers oriented policy.

We can determine the more efficient law enforcement regime in relation to the objective of the law enforcement policy. This allows to identify the seller the authority has to arrest as a priority.

The goals of drug policy can take different forms: "zero-tolerance" policy, supply-side policy (enforcement), demand-side policy (preventive education and treatment), use reduction, harm reduction, decriminalization, legalization. Historically, the United States drug policy has focused on use reduction.[6] Thus we suppose that the objective

[6] In 1988, during the "war on drugs", the Office of National Drug Control Policy was created and was delegated the responsibility of creating policy goals and objectives for the federal government. Its strategy was the reduction of the illicit drugs use: "the highest priority of our drug policy must

of the authority is to minimize the use of drugs.

Proposition 10 *(i) If the drug market is potentially large and profitable and*

(ii) if the unitary sanction is not too high,

then the retail price under the retailers oriented policy, p^*, is lower than the retail price under the traffickers oriented policy, $\overline{p}$.

Proof. See appendix I. ■

If the drug market is potentially large and profitable and if the unitary sanction not too tough, the number of drug consumers is lower when the law enforcement policy is aimed at the traffickers. Thus, under some conditions, the policy which enforces the use reduction objective is the traffickers oriented regime.

This can be explained by the vertical relationship between traffickers and retailers. When the traffickers are pursued by the law enforcement agents and face a higher sanction, they transfer their supplementary transaction costs to the wholesale price. Facing a higher wholesale price, the retailers raise the retail price. In the opposite situation, that is, when the law enforcement agents pursue the retailers and when the latter risk a higher sanction, the traffickers decrease the wholesale price because of the double marginalization mechanism. The retailers face higher transaction costs but also a lower wholesale price. Thus they can diminish the retail price or increase it but, in this last case, the rise is limited because of the decrease of the wholesale price.

In this way, the vertical relationship between traffickers and retailers, as a characteristic of the drug market, partially explain the importance of the choice of the seller to arrest as a priority in the drug law enforcement policy.

6 Conclusion

In this model, the drug trade is not only considered as a crime but also as a market. We have pointed out that the transaction costs and the vertical relationship are the specific characteristics of the drug market. These characteristics lead to strategic effects which are generally ignored by the drug law enforcement policy. The drug policy

be a stubborn determination further to reduce the overall level of drug use nationwide-experimental first use, 'casual' use, regular use and addiction alike." [Reuter and Caulkins, 1995].

analysts usually consider only the direct effect of a tougher law enforcement policy, that is, a decrease of the supply. But retailers and traffickers react strategically to a tougher law enforcement policy by taking into account the transaction costs related to the risk. As a result, an anti-drug policy can thus have unexpected effects.

The results can be explained by the fact that we model the transaction costs in a non-linear way. Chiu, Mansley and Morgan (1998) model the costs related to the anti-drug law enforcement policy as linear production costs and obtain more clear-cut results. Their model simply considers the repression as an additional cost for sellers and therefore neglects the transaction costs effects which are predominant in the drug market. In our model, the member of the vertically organized market who has to be arrested as a priority is an important question if, besides the vertical structure of the market, we integrate into the model non-linear transaction costs related to the risk of arrest.

We have shown that an increase of the repression may have paradoxical effects. For example, when the authority pursues the retailers and when the probability of arrest at the time of a transaction is relatively high, an increase of the unitary sanction leads to a retail price fall and thus induces a rise of the number of consumers, which is opposite to the objective of anti-drug authorities. More generally, when the drug law enforcement authority raises the repression, either by increasing the sanction or by increasing the resources allocated to the detection, the number of consumers can grow on the market, even though the initial objective of this policy is to reduce the quantity of drug on the market or the number of consumers.

The strategic effects that appear in this model could explain the failure of the "war on drugs". Between 1985 and 1989, the number of arrests for cocaine and heroin trafficking and the average length of prison sentences didn't stop increasing. During this period, the percentage of high school seniors answering "fairly easy" or "very easy" to the question "How difficult do you think it would be for you to get each of the following types of drugs, if you wanted some?" did not change for marijuana. But, for cocaine and heroin, this percentage grew from 49% to 59% for the former and from 21% to 31% for the latter. Moreover unexpectedly cocaine and heroin import prices were falling. In summary, increasing toughness has not reached its immediate objectives of raising price and reducing availability.

This paradoxical result of a tougher anti-drug policy can be explain by this model. Generally, it is easier for the law enforcement agents to capture street dealers, that is, the retailers, which are numerous and easy to spot, than traffickers. According to our results, traffickers would rather reduce the wholesale price in order to increase the demand and thus the deterministic part of their profit, when they notice that the retailers face a stricter law enforcement policy. The retailers can diminish the retail price in turn even if their transaction costs raise, which finally leads to an increase of drug consumption.

Therefore the failure of the "war on drugs" could be at least partially explained by the strategic effects related to the vertical structure of the drug market and the analysis of the risk in terms of non-linear transaction costs.

7 References

Becker G. S. and Murphy K. M., (1988) : "A Theory of rational Addiction", *Journal of Political Economy*, 96 (4), pp. 675-700.

Becker G. S., Grossman M. and Murphy K. M. (1991) : "Rational Addiction and the Effect of Price on Consumption", *The American Economic Review*, 81 (2), pp.237-241.

Caulkins J. P. (1995): "Dealing With the Country's Drug Problem", *OR/MS Today*, February, pp. 32-40.

Chiu S., Mansley E. C. and Morgan J. (1998): "Choosing the right battlefield for the war on drugs: an irrelevance result", *Economics Letters*, 59, pp. 107-111.

Choiseul-Praslin C.-H. (1991) : "La drogue, une économie dynamisée par la répression", Presses du CNRS, Paris.

Eatherly B. J. (1974): "Drug-Law Enforcement: Should We Arrest Pushers or Users?", *Journal of Political Economy*, 82 (1), pp. 210-214.

Grossman M. (2000): *The Economics of Substance Use and Abuse: The Role of Price,* for the Conference on Recent Economic Analysis of Individual Behavior Regarding Drugs, Université de Paris 1 - Panthéon-Sorbonne.

Kopp P. (1997): "L'économie de la drogue", Ed. la Découverte, coll. Repères.

Lee L. W. (1993): "Would Harassing Drug Users Work?", *Journal of Political Economy*, 101 (5), pp. 939-959.

Reuter P., MacCoun R. and Murphy P. (1990): "Money from Crime: A Study of the Economics of Drug Dealing in Washington, D.C." Santa Monica, California: Rand Corporation, Drug Policy Resources Center.

Reuter P. and MacCoun R. (1995): "Lessons from the absence of harm reduction in American drug policy", *Tobacco Control: An International Journal*, 4 (2), pp. S28-S32.

Reuter P. and Caulkins J. P. (1995): "Redefining the Goals of National Drug Policy: Recommendations from a Working Group", *American Journal of Public Health*, 85 (8), pp. 1059-1063.

Reuter P. (1997): "Why Can't We Make Prohibition Work Better?", *Proceedings of the American Philosophical Society*, 141 (3), pp. 262-275.

Rottenberg S. (1968): "The Clandestine Distribution of Heroin, Its Discovery and Suppression", *Journal of Political Economy*, 76 (1), pp. 78-90.

Salinger M. A. (1988): "Vertical Mergers and Market Foreclosure", *Quarterly Journal of Economics*, 103 (2), pp. 345-356.

A Proof of lemma 1

The profit function of retailer i can be written
$E\Pi_i^R(x_i) = (\Theta - \sum_{s=1}^{n} x_s - w)x_i - s\left[1-(1-q)^{x_i}\right].$

Therefore the best response function of retailer i is the solution of:

$$2x_i - s(1-q)^{x_i}\ln(1-q) = \Theta - \sum_{s\neq i} x_s - w \tag{4}$$

Let $\Psi(x_i) = 2x_i - s(1-q)^{x_i}\ln(1-q)$ with $x_i \in [0,\Theta]$, $\Psi'(x_i) = 2 - s(1-q)^{x_i}\left[\ln(1-q)\right]^2$ and $\Psi''(x_i) = -s(1-q)^{x_i}\left[\ln(1-q)\right]^3 > 0$.

Thus, if $s\left[\ln(1-q)\right]^2 < 2$, $\Psi'(x_i) > 0\ \forall x_i$, that is, $\Psi(x_i)$ is positive and increasing in x_i. Thus, the equation (4) has an unique solution whatever i.

Then, if $s\left[\ln(1-q)\right]^2 < 2$ (condition 1), we obtain the unique symmetric equilibrium of the subgame beginning at the second stage x, solution of:

$$\Theta - \frac{(n+1)}{n}x + s(1-q)^{\frac{x}{n}}\ln(1-q) = w.$$

The second order condition $\frac{d^2 E\Pi_i^R(x_i)}{dx_i^2} = -2 + s\left[\ln(1-q)\right]^2(1-q)^{x_i}$ is automatically verified because of the condition (1).

B Proof of lemma 2

The trafficker's program is:
$\max\limits_{x_j}\left\{\Pi_j^T(x_j) = (w-c)\,x_j\right\}$ with $w = \Theta - \frac{(n+1)}{n}x + s(1-q)^{\frac{x}{n}}\ln(1-q)$.
But $x = \sum\limits_{t=1}^{m} x_t$, thus the trafficker's program can be rewritten:

$$\max_{x_j}\left\{\Pi_j^T(x_j) = \left(\Theta - \frac{(n+1)}{n}\sum_{t=1}^{m} x_t + s(1-q)^{\frac{\sum_{t=1}^{m} x_t}{n}}\ln(1-q) - c\right)x_j\right\}.$$

The maximization of the expected profit of the trafficker j gives the following result:

$$\Theta - c - \frac{n+1}{n}\sum_{t=1}^{m} x_t + s(1-q)^{\frac{\sum_{t=1}^{m} x_t}{n}}\ln(1-q) = \frac{x_j}{n}\left[(n+1) + s(1-q)^{\frac{\sum_{t=1}^{m} x_t}{n}}\left[\ln(1-q)\right]^2\right].$$

This equation has an unique solution in x_j, we can thus sum over j these first order conditions, which leads to:

$$m(\Theta - c) - \frac{(n+1)(m+1)}{n}x^* + s(1-q)^{\frac{x^*}{n}}\ln(1-q)\left[m + \frac{x^*}{n}\ln(1-q)\right] = 0$$

where x^* is the equilibrium demand.
The second order condition is verified because of the condition (1).

Let $g(x) = m(\Theta - c) - \frac{(n+1)(m+1)}{n}x + s(1-q)^{\frac{x}{n}} \ln(1-q) \left[m + \frac{x}{n}\ln((1-q)\right]$, we must verify that the equation $g(x^*) = 0$ have only one solution, which defines the unique equilibrium demand x^* with $x^* \in [0, \Theta]$: $g(0) = m[\Theta - c + s\ln(1-q)]$ and $g(\Theta) = -\frac{n+m+1}{n}\Theta - mc + s(1-q)^{\frac{\Theta}{n}} \ln(1-q) \left[m + \frac{\Theta}{n}\ln((1-q)\right]$.
$g'(x) < 0$ because of the condition (1), thus if $g(\Theta) < 0$ and $g(0) > 0$, then $\exists!\, x^*$ such as $g(x^*) = 0$.

- $g(\Theta)$:

  $g(\Theta) = -\frac{n+m+1}{n}\Theta - mc + s(1-q)^{\frac{\Theta}{n}} \ln(1-q) \left[m + \frac{\Theta}{n}\ln((1-q)\right] \Longleftrightarrow$
  $g(\Theta) = ms(1-q)^{\frac{\Theta}{n}} \ln(1-q) - mc + \frac{\Theta}{n}\left[-(n+m+1) + s[\ln(1-q)]^2 (1-q)^{\frac{\Theta}{n}}\right]$.
  But $s(1-q)^{\Theta}\ln(1-q) - c < 0$ and $-(n+m+1) + s[\ln(1-q)]^2(1-q)^{\Theta} < 0$ by the condition (1).
  Therefore this proves that $g(\Theta) < 0$.

- $g(0)$:

  The equilibrium demand is positive if and only if
  $m(\Theta - c) + s(1-q)^{\frac{x^*}{n}} \ln(1-q) \left[m + \frac{x^*}{n}\ln((1-q)\right] > 0$.
  The following condition
  $$-\ln(1-q)s \leq \Theta - c \tag{2}$$
  i.e. $g(0) < 0$, assures this inequality. This condition (2) guarantees that the equilibrium demand is positive.

If $g(0) > 0$, that is, if the condition (2) is satisfied, since $g(\Theta) < 0$ and $g'(x) < 0$, $\exists!\, x^*$ as follows $g(x^*) = 0$.

C Equilibrium profits

The expected profit of retailer R_i is:
$E\Pi_i^{R*}(p^*) = \left(\frac{\Theta - p^*}{n}\right)^2 - s\left[1 - (1-q)^{\frac{\Theta - p^*}{n}}\left(1 - \frac{\Theta - p^*}{n}\ln(1-q)\right)\right] > 0$ because of the condition (1).
The expected profit of trafficker T_j is:
$E\Pi_j^{T*}(p^*) = \frac{1}{n}\left(\frac{\Theta - p^*}{m}\right)^2\left[n + 1 - s[\ln(1-q)]^2(1-q)^{\frac{\Theta - p^*}{n}}\right] > 0$ because of the condition (1).

$E\Pi_j^{T*}(p^*) - E\Pi_i^{R*}(p^*) = \left[\frac{n^2+n-m^2}{n^2m^2}\right](\Theta - p^*)^2 +$
$s\left[1-(1-q)^{\frac{\Theta-p^*}{n}}\left(1-\frac{1}{n}(\Theta-p^*)\ln(1-q)+\frac{1}{nm^2}(\Theta-p^*)^2[\ln(1-q)]^2\right)\right] > 0$ because of the condition (1).

D Proof of proposition 3

At the equilibrium, $w^* = \frac{1}{m+1}\left[\Theta + mc + s\ln(1-q)(1-q)^{\frac{\Theta-p^*}{n}}\left(1-\frac{\Theta-p^*}{n}\ln(1-q)\right)\right]$.
Thus, $\frac{\partial w^*}{\partial q} = \frac{s}{m+1}(1-q)^{\frac{\Theta-p^*}{n}-1}\left[\left(\frac{\Theta-p^*}{n}\ln(1-q)\right)^2 + \frac{\Theta-p^*}{n}\ln(1-q)+1\right]$.
$P\left(\frac{\Theta-p^*}{n}\ln(1-q)\right) = \left(\frac{\Theta-p^*}{n}\ln(1-q)\right)^2 + \frac{\Theta-p^*}{n}\ln(1-q)+1$ is a second degree polynomial with an unique negative root $\frac{\Theta-p^*}{n}\ln(1-q) = \frac{-1-\sqrt{5}}{2}$.

Let q_1 defined by $\frac{1+\sqrt{5}}{2} + \frac{\Theta-p^*}{n}\ln(1-q_1) = 0$, thus $p^* = \Theta + \frac{n\left(1+\sqrt{5}\right)}{2\ln(1-q_1)}$.
$g(p^*) = \frac{(n+1)(m+1)}{n}p^* - \frac{n+m+1}{n}\Theta - mc + s\ln(1-q_1)(1-q_1)^{\frac{\Theta-p^*}{n}}\left[m+\frac{\Theta-p^*}{n}\ln(1-q_1)\right] = 0$.
Thus, $g\left(\Theta + \frac{n\left(1+\sqrt{5}\right)}{2\ln(1-q_1)}\right) = m(\Theta - c) + \frac{(n+1)(m+1)\left(1+\sqrt{5}\right)}{2\ln(1-q_1)} + s\ln(1-q_1)e^{\frac{-1-\sqrt{5}}{2}}\left[m-\frac{1+\sqrt{5}}{2}\right] = 0$.
$\ln(1-q_1)$ with $q_1 = 1-\exp\left[\frac{-(\Theta-c)+\sqrt{(\Theta-c)^2 - s\frac{(n+1)(m+1)}{m}\left(\frac{2m-(1+\sqrt{5})}{m}\right)\exp\left[-\frac{1+\sqrt{5}}{2}\right]}}{s\exp\left[-\frac{1+\sqrt{5}}{2}\right]\left(\frac{2m-(1+\sqrt{5})}{m}\right)}\right]$ is the unique negative solution of the following second degree polynomial:
$se^{-\frac{1+\sqrt{5}}{2}}\left(\frac{2m-(1+\sqrt{5})}{2m}\right)[\ln(1-q_1)]^2 + (\Theta-c)\ln(1-q_1) + \frac{(n+1)(m+1)\left(1+\sqrt{5}\right)}{2m} = 0$.
If $q \leq q_1$, $P\left(\frac{\Theta-p^*}{n}\ln(1-q)\right) \leq 0$, thus $\frac{\partial w^*}{\partial q} \leq 0$ and if $q > q_1$, $P\left(\frac{\Theta-p^*}{n}\ln(1-q)\right) > 0$, thus $\frac{\partial w^*}{\partial q} > 0$.

E Proof of proposition 4

$$\frac{\partial p^*}{\partial q} = \frac{s(1-q)^{\frac{\Theta-p^*}{n}-1}\left[\left(\frac{\Theta-p^*}{n}\ln(1-q)\right)^2 + (m+2)\left(\frac{\Theta-p^*}{n}\ln(1-q)\right)+m\right]}{\frac{(n+1)(m+1)}{n} - \frac{s}{n}[\ln(1-q)]^2(1-q)^{\frac{\Theta-p^*}{n}}\left[m+1+\frac{\Theta-p^*}{n}\ln(1-q)\right]}.$$

$\left(\frac{\Theta-p^*}{n}\ln(1-q)\right)^2 + (m+2)\left(\frac{\Theta-p^*}{n}.\ln(1-q)\right) + m$ is second degree polynomial with the two roots $(\frac{\Theta-p^*}{n})\ln(1-q_0) = \frac{-m-2+\sqrt{m^2+4}}{2}$ and $(\frac{\Theta-p^*}{n})\ln(1-q_2) = -\frac{2+m+\sqrt{m^2+4}}{2}$.

As q_0 defined by $(\frac{\Theta-p^*}{n})\ln(1-q_0) = \frac{-m-2+\sqrt{m^2+4}}{2}$, $p^* = \Theta + \frac{n}{2}\frac{2+m-\sqrt{m^2+4}}{\ln(1-q_0)}$.
$g(p^*) = \frac{(n+1)(m+1)}{nm}p^* - \frac{n+m+1}{nm}\Theta - c + s(1-q)^{\frac{\Theta-p^*}{n}}\ln(1-q)\left[1+\frac{\Theta-p^*}{nm}\ln((1-q)\right] = 0$

have an unique solution if the condition (2) is satisfied.
Thus, $g(\Theta+\frac{n}{2}\frac{2+m-\sqrt{m^2+4}}{\ln(1-q_0)})=0$ and $\ln(1-q_0)$ with
$q_0=1-\exp\left[\frac{-(\Theta-c)+\sqrt{(\Theta-c)^2-s\exp\left[\frac{-m-2+\sqrt{m^2+4}}{2}\right]\frac{(n+1)(m+1)\left(m^2-\left(\sqrt{m^2+4}-2\right)^2\right)}{m^2}}}{s\exp\left[\frac{-m-2+\sqrt{m^2+4}}{2}\right]\frac{m-2+\sqrt{m^2+4}}{m}}\right]$ is the unique negative solution of the following second degree polynomial which satisfies the condition (2):
$se^{\frac{-m-2+\sqrt{m^2+4}}{2}}\frac{m-2+\sqrt{m^2+4}}{2m}[\ln(1-q_0)]^2+(\Theta-c)\ln(1-q_0)+\frac{(n+1)(m+1)\left(2+m-\sqrt{m^2+4}\right)}{2m}=0.$

As q_2 defined by $(\frac{\Theta-p^*}{n})\ln(1-q_2)=-\frac{2+m+\sqrt{m^2+4}}{2}$, $p^*=\Theta+\frac{n}{2}\frac{2+m+\sqrt{m^2+4}}{\ln(1-q_2)}$. $g(p^*)=0$, thus $g(\Theta+\frac{n}{2}\frac{2+m+\sqrt{m^2+4}}{\ln(1-q_2)})=0$ and $\ln(1-q_2)$ with
$q_2=1-\exp\left[\frac{-(\Theta-c)+\sqrt{(\Theta-c)^2-s\exp\left[-\frac{m+2+\sqrt{m^2+4}}{2}\right]\frac{(n+1)(m+1)\left(m^2-\left(\sqrt{m^2+4}+2\right)^2\right)}{m^2}}}{s\exp\left[-\frac{m2+\sqrt{m^2+4}}{2}\right]\frac{m-2-\sqrt{m^2+4}}{m}}\right]$ is the unique negative solution of the following second degree polynomial:
$se^{-\frac{m+2+\sqrt{m^2+4}}{2}}\frac{m-2-\sqrt{m^2+4}}{2m}[\ln(1-q_2)]^2+(\Theta-c)\ln(1-q_2)+\frac{(n+1)(m+1)\left(2+m+\sqrt{m^2+4}\right)}{2m}=0.$

$$\text{Thus}\left\{\begin{array}{l}\frac{\partial p^*}{\partial q}\geq 0 \text{ if } \ q\leq q_0\\ \frac{\partial p^*}{\partial q}<0 \text{ if } \ \ q_0<q<q_2\\ \frac{\partial p^*}{\partial q}\geq 0 \text{ if } \ \ q\geq q_2\end{array}\right. .$$

And, as $(\frac{\Theta-p^*}{n})\ln(1-q_0)=\frac{-m-2+\sqrt{m^2+4}}{2}$, $\frac{\Theta-p^*}{n}\ln(1-q_1)=\frac{-1-\sqrt{5}}{2}$,and $(\frac{\Theta-p^*}{n})\ln(1-q_2)=-\frac{2+m+\sqrt{m^2+4}}{2}$, we obtain $q_0<q_1<q_2$.

F Proof of proposition 6

At equilibrium,
$p^*=\frac{n}{(n+1)(m+1)}\left[\frac{n+m+1}{n}\Theta+mc-s(1-q)^{\frac{\Theta-p^*}{n}}\ln(1-q)\left[m+\frac{\Theta-p^*}{n}\ln(1-q)\right]\right]$, thus
$\frac{\partial p^*}{\partial s}=\frac{-(1-q)^{\frac{\Theta-p^*}{n}}\ln(1-q)\left[m+\frac{\Theta-p^*}{n}\ln(1-q)\right]}{\frac{(n+1)(m+1)}{n}-\frac{s}{n}[\ln(1-q)]^2(1-q)^{\frac{\Theta-p^*}{n}}\left[m+1+\frac{\Theta-p^*}{n}\ln(1-q)\right]}$.
$\frac{\partial p^*}{\partial s}>0$ if $m+\frac{\Theta-p^*}{n}\ln(1-q)>0$.
Let q_3 defined by $m+\frac{\Theta-p^*}{n}\ln(1-q_3)=0$, thus $p^*=\Theta+\frac{nm}{\ln(1-q_3)}$.
$g(p^*)=\frac{(n+1)(m+1)}{n}p^*-\frac{n+m+1}{n}\Theta-mc+s\ln(1-q)(1-q)^{\frac{\Theta-p^*}{n}}\left[m+\frac{\Theta-p^*}{n}\ln((1-q)\right]=0.$
$g(\Theta+\frac{nm}{\ln(1-q_3)})=0\Rightarrow q_3=1-e^{-\frac{(n+1)(m+1)}{\Theta-c}}$.

If $m > 1$, $q_1 < q_3 < q_2$ and if $m = 1$, $q_0 < q_3 < q_1$.

G Proof of lemma 7

The trafficker's program is:

$$\max_{x_j} \left\{ E\Pi_j^T(x_j) = \left[\Theta - \tfrac{n+1}{n} \sum_{t=1}^{m} x_t - c\right] x_j - \tfrac{s}{n} \left[1 - (1-q)^{\frac{\frac{nx_j}{m}}{\sum_{t=1}^{m} x_t}}\right] \sum_{t=1}^{m} x_t \right\}.$$

The first order condition is:

$$\Theta - \frac{n+1}{n}\left(\sum_{k=1}^{m} x_k + x_j\right) - c - \frac{s}{n}\left[1 - (1-q)^{\frac{\frac{nx_j}{m}}{\sum_{k=1}^{m} x_k}} \left(1 + \frac{n\left(\sum_{k=1}^{m} x_k - x_j\right)}{\sum_{k=1}^{m} x_k} \ln(1-q)\right)\right] = 0 \tag{5}$$

This equation is equivalent to $\Phi(x_j) = \frac{n+1}{n} \sum_{k \neq j} x_k - \Theta + c + \frac{s}{n}$

with $\Phi(x_j) = -2\frac{n+1}{n} x_j + \frac{s}{n}\left[(1-q)^{\frac{\frac{nx_j}{m}}{\sum_{k=1}^{m} x_k}} \left(1 + \frac{n\left(\sum_{k=1}^{m} x_k - x_j\right)}{\sum_{k=1}^{m} x_k} \ln(1-q)\right)\right]$.

If $\Phi'(x_j) = -2\frac{n+1}{n} + ns\left[\ln(1-q)\right]^2 (1-q)^{\frac{\frac{nx_j}{m}}{\sum_{k=1}^{m} x_k}} \frac{\left(\sum_{k=1}^{m} x_k - x_j\right)^2}{\left(\sum_{k=1}^{m} x_k\right)^3} < 0$, the equation (5) has an unique one solution in x_j, and we obtain the equilibrium demand $\overline{x}$ of the game:

$$\overline{x} = \frac{n}{(n+1)(m+1)} \left[m(\Theta - c) - \frac{s}{n}\left[m + (1-q)^{\frac{n}{m}} \left(m + n(m-1)\ln(1-q)\right)\right]\right].$$

The condition $\Phi'(x_j) < 0$ can be rewritten to obtain a constraint on the unitary sanction s:

$$s \leq \frac{2m^3(\Theta - c)}{\frac{2m^3}{n}\left(1 - (1-q)^{\frac{n}{m}}\right) - (m-1)\ln(1-q)(1-q)^{\frac{n}{m}}\left[2m^2 - n(m^2-1)\ln(1-q)\right]}. \tag{6}$$

With this condition, the second order condition is satisfied at the equilibrium.[7]
The following condition guarantees that the equilibrium demand is positive:

$$s \leq \frac{nm(\Theta - c)}{m - (1-q)^{\frac{n}{m}}\left(m + n(m-1)\ln(1-q)\right)}. \tag{7}$$

[7] When $n = 1$ and $m = 1$, the second order condition is automatically satisfied.

The condition (7) is more restrictive than the condition (6).

As $\Theta - \overline{p} = \overline{x}$, the equilibrium retail price thus is:

$$\overline{p} = \frac{nm}{(n+1)(m+1)} \left[\frac{n+m+1}{nm}\Theta + c + \frac{s}{n} - \frac{s}{n}(1-q)^{\frac{n}{m}} \left(1 + n\frac{m-1}{m}\ln(1-q)\right)\right].$$

The expected profit of retailer R_i is:
$\overline{E\Pi}_i^R(\overline{p}) = \left(\frac{\Theta-\overline{p}}{n}\right)^2 > 0$

The expected profit of trafficker T_j is:
$\overline{E\Pi}_j^T(\overline{p}) = \frac{n+1}{n}\left(\frac{\Theta-\overline{p}}{m}\right)^2 - s\frac{\Theta-\overline{p}}{n}\left[1 - \frac{1}{m} - (1-q)^{\frac{n}{m}} + \frac{1}{m}(1-q)^{\frac{n}{m}}\left(1 + \frac{n(m-1)}{m}\ln(1-q)\right)\right]$
$\overline{E\Pi}_j^T(\overline{p}) \geq 0$ if and only if

$$s \leq \frac{n(\Theta - c)}{m^2\left[1-(1-q)^{\frac{n}{m}}\right] + n(m-1)\ln(1-q)(1-q)^{\frac{n}{m}}}. \tag{3}$$

The condition (3) is more restrictive than the condition (7), thus, the condition (3) is the valid condition. Thus, the unique symmetric equilibrium exists if the condition (3) is satisfied.

The difference between the profits is
$\overline{E\Pi}_j^T(\overline{p}) - \overline{E\Pi}_i^R(\overline{p}) = \frac{\Theta-\overline{p}}{nm}\left[\frac{n^2-m^2+n}{nm}(\Theta-\overline{p}) - s(m-1)\left[1-(1-q)^{\frac{n}{m}} + \frac{n}{m}\ln(1-q)(1-q)^{\frac{n}{m}}\right]\right].$
With the condition (3), we obtain that $\overline{E\Pi}_j^T(\overline{p}) - \overline{E\Pi}_i^R(\overline{p}) \geq -\left(\frac{\Theta-\overline{p}}{n}\right)^2$. Thus, for some values of s, m, and n, we can obtain $\overline{E\Pi}_j^T(\overline{p}) \leq \overline{E\Pi}_i^R(\overline{p})$, but for $m = 1$, $\overline{E\Pi}_j^T(\overline{p}) > \overline{E\Pi}_i^R(\overline{p})$.

H Proof of the proposition 8

At equilibrium,
$\overline{w} = \frac{1}{m+1}\left[\Theta + mc + \frac{s}{n}\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right]\right]$ and
$\overline{p} = \frac{1}{(n+1)(m+1)}\left[(n+m+1)\Theta + mnc + s\left[m - (1-q)^{\frac{n}{m}}\left(m + n\left(m-1\right)\ln(1-q)\right)\right]\right],$
thus $\frac{\partial\overline{w}}{\partial q} = \frac{1}{(m+1)}s(1-q)^{\frac{n}{m}-1}\left[m + n\frac{m-1}{m}\ln(1-q)\right]$ and
$\frac{\partial\overline{p}}{\partial q} = \frac{n}{(n+1)(m+1)}s(1-q)^{\frac{n}{m}-1}\left[m + n\frac{m-1}{m}\ln(1-q)\right].$
We obtain $\left[m + n\frac{m-1}{m}\ln(1-q_4)\right] = 0$ with $q_4 = 1 - e^{-\frac{m^2}{n.(m-1)}}$.
If $q < q_4$, $\left[m + n\frac{m-1}{m}\ln(1-q)\right] > 0$ and if $q \geq q_4$, $\left[m + n\frac{m-1}{m}\ln(1-q)\right] \leq 0$.

I Proof of proposition 10

p^* is such that $h(p^*) = 0$ with
$h(p) = \frac{(n+1)(m+1)}{n}p - \frac{n+m+1}{n}\Theta - mc + s(1-q)^{\frac{\Theta-p}{n}}\ln(1-q)\left[m + \frac{\Theta-p}{n}\ln(1-q)\right]$
and $\overline{p} = \frac{1}{(n+1)(m+1)}\left[(n+m+1)\,\Theta + nmc + s\left(m - (1-q)^{\frac{n}{m}}\left(m + n\,(m-1)\ln(1-q)\right)\right)\right]$.
$h(\overline{p}) = s\Big[\frac{m}{n}(1-(1-q)^{\frac{n}{m}}) - (m-1)\ln(1-q)(1-q)^{\frac{n}{m}} + (1-q)^{\frac{\Theta-\overline{p}}{n}}\ln(1-q)\,\Big[m + \frac{\Theta-\overline{p}}{n}\ln(1-q$
It exists a value of $\overline{p}$, $\overline{p}_0$, such that if $\overline{p} \leq \overline{p}_0$, $h(\overline{p}) \geq 0$ and if $\overline{p} \geq \overline{p}_0$, $h(\overline{p}) \leq 0$.
$h(\Theta - \frac{n^2}{m}) = s\left[\frac{m}{n}(1-(1-q)^{\frac{n}{m}}) + \ln(1-q)(1-q)^{\frac{n}{m}} + \frac{n}{m}(1-q)^{\frac{n}{m}}\left[\ln(1-q)\right]^2\right] > 0$, thus $\Theta - \frac{n^2}{m} \leq \overline{p}_0$.
Thus, if $\overline{p} \leq \Theta - \frac{n^2}{m}$, that is $\frac{\Theta-\overline{p}}{n} \geq \frac{n}{m}$, $h(\overline{p}) \geq 0$ and $\overline{p} \geq p^*$ because $h'(p) > 0$ (condition (1)).
$\overline{p} \leq \Theta - \frac{n^2}{m} \Leftrightarrow s\left(m - (1-q)^{\frac{n}{m}}\left(m + n\,(m-1)\ln(1-q)\right)\right) \leq mn(\Theta - c) - \frac{(n+1)(m+1)n^2}{m}$.
Thus, if $(\Theta - c) > \frac{(n+1)(m+1)n}{m^2}$, that is, if the difference between the number of potential consumers and the cost of production is high, and if $s \leq \frac{mn(\Theta-c) - \frac{(n+1)(m+1)n^2}{m}}{m-(1-q)^{\frac{n}{m}}(m+n(m-1)\ln(1-q))}$, that is, if the unitary sanction is not too high, $\overline{p} \geq p^*$.

The fact that the difference between the number of potential consumers and the cost of production is high means that the drug market is potentially large (Θ high) and profitable (c low).