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Christian Ben Lakhdar
LEM (UMR 8179 CNRS) and Université Catholique de Lille (FLSEG)

Hervé Leleu
CNRS-LEM (UMR 8179), IESEG School of Management

Nicolas Gérard Vaillant
LEM (UMR 8179 CNRS) and Université Catholique de Lille (FLSEG)

François-Charles Wolff
LEMNA, Université de Nantes

IESEG School of Management
Catholic University of Lille
3, rue de la Digue
F-59000 Lille
www.ieseg.fr
Tel: 33(0)3 20 54 58 92
Fax: 33(0)3 20 57 48 55

Efficiency of purchasing and selling agents in markets with quality uncertainty: The case of illicit drug transactions[#]

Christian Ben Lakhdar[*], Hervé Leleu[**],

Nicolas Gérard Vaillant[***], François-Charles Wolff[****]

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Abstract: Since Akerlof's theory of a market for lemons, economists have viewed quality uncertainty as an informational advantage for sellers. Drawing on frontier techniques, we propose in this paper a simple method to measure inefficiency of both sellers and buyers in markets for goods with different levels of quality. We apply our non-parametric double-frontier framework to the case of illicit substance markets, which suffer from imperfect information about the drug quality for purchasers and to a lesser extent for sellers. We use unique data on cannabis and cocaine transactions collected in France that include information about price, quantity exchanged and purity. We find that transactional inefficiency does not really benefit either dealers or purchasers. Information influences the performance of agents during market transactions, sales in the street being more inefficient than sales made in other places.

Keywords: illicit drug markets, quality uncertainty, efficient transactions

JEL Classification: D12, I18

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[*] LEM (UMR 8179 CNRS) and Université Catholique de Lille (FLSEG), 60 bd Vauban, BP109, 59016 Lille Cedex, France.
E-mail: christian.benlakhdar@icl-lille.fr

[**] CNRS/LEM (UMR 8179 CNRS) and IÉSEG School of Management, 3 rue de la Digue, 59000 Lille, France.
E-mail: h.leleu@ieseg.fr

[***] Corresponding author. LEM (UMR 8179 CNRS) and Université Catholique de Lille (FLSEG), 60 bd Vauban, BP109, 59016 Lille Cedex, France.
E-mail: nicolas.vaillant@icl-lille.fr http://ngvaillant.e-monsite.com/

[****] LEMNA, Université de Nantes, BP52231 Chemin de la Censive du Tertre, 44322 Nantes Cedex and INED, Paris, France.
E-mail: francois.wolff@univ-nantes.fr http://www.sc-eco.univ-nantes.fr/~fcwolff/

1. Introduction

Since the “invisible hand” of Adam Smith, a large part of economic literature has focused on price formation in competitive markets. From a neo-classical viewpoint, prices result from supply and demand interactions in the markets. Prices can be seen as a signalling mechanism that provides incentives for market operators to respond and remedy any imbalances. Examples are numerous and indicate that the price mechanism is a ruthlessly efficient organizer.

Economic theory teaches us that price is unique on a given competitive market. But with the exception of auction markets and a few others satisfiying the conditions for perfect competition, everyday life indicates that markets are not competitive, nor the price unique (Pratt et al., 1979, Walsh and Whelan, 1999). This is especially the case in markets with products of different quality levels. Since Akerlof’s (1970) seminal contribution on the market for lemons, economists have been aware of potential for adverse selection in markets when information is asymmetric between transactors.

In situations where true quality remains undistinguishable by consumers before purchase, there is a probability that sellers set excessive prices for poor quality products and have incentives to offer only low-quality goods. As a consequence, markets should not exist in many situations involving quality uncertainty. Fortunately, there also exist simple strategies for sellers offering high-quality goods to inform their clients, and thus to protect buyers from adverse selection (see for instance Lewis, 2010)[1].

Illicit substances are very good examples of products for which customers face difficulties in assessing the quality of the product purchased at the moment of the transaction. As pointed out by Caulkins and Reuters (1998) and Caulkins (2007), drugs are differentiated by purity and there is large uncertainty on quality. In many cases, only effective consumption of the drug purchased will help to obtain this information. Interestingly, at the retail level, there may also be problems of information for sellers, for instance when dealers obtain secondhand products cut with unknown additives. Illicit drugs are thus sometimes considered as “double experience goods” (Caulkins, 2007). The purpose of our contribution is to develop a general framework to study the performance of buyers and sellers in markets with quality heterogeneity, with an application to illicit drug markets.

A consequence of these informational difficulties is that for a given level of quality, price dispersion is expected to be larger in illicit drugs markets than in any other markets. Considering the price-purity ratio of illicit drugs in the US over the period 1980-2000, Reuter and Caulkins (2004) find a greater variability than that observed in legal goods markets like beer, sugar, coffee or fuel oil. Interestingly, these variations in drug prices (quality and quantity being held constant) are the result of differences in efficiency of buyers and sellers involved in transactions. For instance, sellers with better information than clients may exploit this informational advantage and set excessive prices, as shown

[1] Lewis (2010) shows for instance that for online auctions of used goods sellers disclose their private information through text and photos on the auction webpage. Results from auctions of used cars in the US indicate that online disclosures strongly influence prices.

in the case of housing transactions by Levitt and Syverson (2008).[2] Those agents receiving larger revenues when selling a product of a given quality would behave in a more efficient way.

At the same time, dealers may be interested in setting reasonable prices by offering a discount in order to build up customer loyalty. There may hence be some reasons to believe that despite their informational advantage due to quality uncertainty, it is profitable for sellers in certain circumstances to share a part of their informational with their customers. It is certainly a very bad commercial strategy to be very efficient (by setting high prices for a given quality) with regular consumers as the latter could be tempted to turn to other drug dealers. Conversely, selling drugs to very inexperienced consumers encountered only once can open the door to the temptation of offering drug doses of very poor quality (for a given price) or at very high prices (for a given quality). In any case, information should strongly influence the efficiency of sellers and purchasers in market transactions.

In this paper, we examine the performance of both buyers and sellers in drug markets using unique data on cannabis and cocaine transactions carried out in France in 2005 and 2006. The key feature of these data is that they include information on both quantity purchased and total price as well as on true quality (purity) for each transaction. We see efficient sellers as those who obtain the highest price per gram of drug for a given level of quality and efficient buyers as those who pay the lowest price per gram of drug for a given level of quality. Of course, we account for the negative relationship between quantity purchased and the price paid per gram of drug through possible bulk-buy discounts. To study efficiency of buyers and sellers, we draw on non-parametric frontier techniques and consider a double-frontier framework with price, quality and quantity as variables of interest.

When analyzing the data, we find evidence of large variations in the price paid per gram of drug for a given level of quality. Results from our performance analysis of agents in drug markets indicate that transactional inefficiency does not really benefit either dealers or purchasers. For cannabis resin, the price set by buyers could be 48% higher on average while the price paid by buyers could be 41% lower on average. We also explain efficiency scores using two-stage truncated estimates following Silmar and Wilson (2007). Two results of interest are that total inefficiency per transaction increases with drug quality and inefficiency is greater when the drug is purchased in the street rather than in other places. This shows that information strongly influences the performance of agents involved in transactions in illicit substance markets.

The remainder of our contribution is organized as follows. In Section 2, we briefly review some features characterizing the markets for illicit drugs. We describe our data on cannabis and cocaine transactions concerning a sample of French drug users in Section 3. We present a non-parametric double-frontier framework to study inefficiency of buyers and sellers in a market in Section 4. We discuss the results of our empirical analysis in Section 5, with some evidence of the magnitude

[2] Real estate agents have much more detailed information on housing markets than their clients. They thus have an incentive to convince them to sell their houses too cheaply and too quickly. Using US data, Levitt and Syverson (2008) find that homes owned by real estate agents are sold at higher prices on average than other houses.

of individual inefficiency on markets and on the factors influencing the performance of buyers and sellers. Finally, concluding comments are placed in Section 6.

2. Behavior in illicit drug markets

Empirically, the classic negative effect of price on consumption that is emphasized by standard economic theory is much more difficult to assess when considering illicit drug markets. This occurs because of the difficulty in obtaining good information on consumption and prices, in a context where transactions are illegal (see Horowitz, 2001, Van Ours and Pudney, 2006). However, a review of the scarce empirical literature indicates that for all illicit substances consumption significantly decreases with price.[3] For instance, large values of price elasticity have been reported by Van Ours (1995) for opium (e=-1), by Rhodes et al. (2002) for marijuana (e=-2.8) and by Grossman and Chaloupka (1998) for marijuana once addiction is taken into account (e=-1.3 in the short term and e=-2 in the long term).

Since drug transactions are by definition illegal, the dynamics of prices on these markets is strongly affected by the level of law enforcement. Prices should be higher when there are more important legal penalties for individuals caught while selling drugs or when there are more police officers in the streets (because of the increased probability of being arrested). These price increases would reflect the risk premium of sellers whose activity becomes more risky. At the retail level, drug dealers facing a sporadic financial shortage due to price increase still have the possibility of cuttting the product they intend to sell to a greater degree, in order to keep their benefits unchanged. Accounting for purity when studying drug transactions is hence a crucial issue as drug quality may be seen as an adjustment variable (Arkes et al., 2004, Caulkins, 1994, Rhodes et al., 1994, Reuter and Caulkins, 2004).

A consequence of the dealers' behavior at the retail level is that purchasers will encounter difficulties in assessing the quality of the drug at the time of the transaction. In fact, many authors have highlighted the fact that consumers may only really know the quality of the product they have bought after the purchase (Reuter and Caulkins, 2004). Caulkins (2007) even goes one step further by qualifying illicit drugs as "double experience goods." While consumers have imperfect information on the quality they purchase, dealers may also be ignorant of the purity of the drugs they sell. This occurs because dealers very often sell secondhand products whose true quality is not always known. The information problem on quality sold is magnified when retailers themselves cut the drug with additives to make more profits. Nevertheless, sellers have much better expectations than purchasers of the purity of the drug they are selling based on personal information (through the source of the product or their relationship with their wholesaler).

[3] Exceptions are DiNardo (1993) for cocaine and Desimone and Farrelly (2003) for marijuana in the US. For a recent survey of price elasticity in drug markets, see Ben Lakhdar et al. (2010).

Because of imperfect information on quality, illicit drugs markets have all the characteristics to become a market for lemons. However, this does not happen. According to Reuter and Caulkins (2004), sellers still have incentives to behave in an honest way especially when there are many illicit drug dealers in competition. By cutting the product they sell, dealers would acquire a bad reputation. Transactions may be seen as repeated games taking place between sellers and purchasers. This precludes the former from offering too low a quality product to their customers. Otherwise, buyers would be abused only once and would turn afterwards to more honest dealers. The quest of drug users is undoubtedly to meet dealers who are able to offer them a drug of high quality at a fair price. Finally, this phenomenon is not very different from that observed in some legal markets like wine (Landon and Smith, 1998).

The few existing studies on the supply side confirm that profits made by sellers at the retail level are close to zero, even if earnings gained from drug dealing in the street are higher than the minimum wage that could be obtained by these workers given their education and qualification levels (Reuter et al., 1990, Berg and Andersen, 1993, Wilkins and Sweetsur, 2006).[4] Using detailed data on the financial activities of a drug-selling street gang in the US, Levitt and Venkatesh (2000) report that street-level drug activities produce limited earnings, from 6$ to 11$ per hour. Nevertheless, the distribution of earnings is highly skewed and gang leaders benefit from large incomes.

All these features are expected to strongly affect the behavior of both sellers and consumers in drug markets. As in any other markets, agents are expected to maximize their own level of satisfaction through the transactions. On the one hand, buyers will try to minimize the price per gram of drug they pay, for a given level of quality. On the other hand, sellers will try to maximize their own profits by setting a high price per gram of drug for a given quality. However, as previously discussed, the true quality (purity) of the drug is likely to be imperfectly known on the demand side and to a lower extent on the supply side.

Inefficient selling or purchase behaviors are thus likely to emerge as a consequence of imperfect information. For instance, consumers anticipating a high quality in the product they are buying could be ready to pay an excessive price with respect to its true quality. Of course, several other factors could contribute to inefficient decisions. On the demand side, addicted users being in an urgent need of an illicit substance will certainly be ready to pay an above-market price for their dose of drug. Irregular users having few interactions with dealers are likely to be less documented on current market prices and are therefore likely to buy products of lower quality at a high price. And more generally, one cannot observe the marginal advantages curve of consumers, nor the true opportunity cost they support.

On the supply side, for a given quality, some dealers may be interested in setting drug prices temporarily below standard market levels to make buyers addicted. The loss of income generated by

[4] On the supply side, Caulkins (1997) presents a model of a drug dealer's decision about how many customers to supply.

such sales in the short run would be more compensated by the expected increased benefits in the long run if dealers decided after a while to offer the same high-quality drug at higher prices. Sellers may also keep their prices at the current level, but decide to manipulate quality. Assuming that quality is positively correlated with price, sellers could make a discount by offering a product of better quality in order to increase consumption of more concentrated drugs. Again, such strategy is expected to generate additional profits in the long run.

As a consequence, there should be large variations in prices on drug markets for a given level of true quality. Since each market transaction involves by definition one purchaser and one seller, it is possible to study the performance of these agents. Are dealers more efficient on average than purchasers when selling their drugs? We investigate this issue using a unique data set on drug transactions combining information on price, quantity and purity.

3. Data and descriptive statistics on drug transactions in France

Our data were collected by the French National Identification System for Drugs and Other Substances (SINTES). SINTES is a scheme whose aim is to gather information on synthetic drugs through both Police and Customs' seizures (Giraudon and Bello, 2007). This system, which is coupled with the TREND network of the French Monitoring Centre for Drugs and Drug Addiction (OFDT), now provides information on all types of illicit drugs in France.[5] TREND is a system structured around local coordination networks that have a common strategy of collecting and analyzing information. In 2008, the network included seven large cities spread over the metropolitan territory (Bordeaux, Lille, Marseille, Metz, Paris, Rennes and Toulouse).

The TREND scheme investigates the behavior of illicit drug users through local observations from places such as reception and harm reduction support centers for drug users, and techno music festivals. Centers have permanent contact with active users and they will mainly concern the more vulnerable consumers. Conversely, places like free parties, rave parties and nightclubs will cover more often well-integrated members of society and they offer opportunities to learn about new forms of drug use. In both cases, it should be kept in mind that the focus is made on specific groups that over-consume illicit substances compared to the rest of the population.

In what follows, we draw on two data sets collected from users of cannabis and cocaine respectively through the SINTES-TREND system. The main purpose of these surveys was to monitor the toxicity of substances found in France, but they also provide detailed information on the context of drug purchase and use. The sample collection procedure draws on local coordinators of the TREND network. These coordinators are social street workers, people involved in techno-music events, students, volunteers in charities dealing with prevention and harm reduction, or nurses and doctors

[5] TREND is the French acronym of "Emerging Trends and New Drugs." See www.ofdt.fr for an overview of the French monitoring system of illicit drugs phenomena.

working in needle-exchange programs (Giraudon and Bello, 2007). Since the survey is by definition about illicit drugs, standard techniques of sampling were not applicable in this context.

As a preliminary step, a fixed number of questionnaires to complete was set for each city of the survey. Within each city, a requirement for collectors was to promote the variability of drug users interviewed. The logic was to carry out data collection in a variety of places and settings, for instance by contacting consumers with different socio-economic backgrounds or users buying drugs in different districts of the city. This was done to avoid collecting drug samples from a very limited number of retailers. For each drug user contacted, the interviewer had to both fill in a questionnaire and purchase a sample of drug from the transaction with a drug dealer or retailer documented by the consumer in the survey. These samples were then sent to a laboratory for chemical analysis.

Each collector received a fixed sum of money after sending a drug sample.[6] The price paid to the collector (and in turn to the consumer) was much above the average market price, meaning that drug users had an incentive to sell a small amount of their product. For cannabis, each interviewer had to collect at least one gram given constraints on toxicological analysis and the fixed payment was set at 25 euros per sample. For cocaine, the sample collected had to exceed 0.1 gram and the lump-sum payment was set at 60 euros. Note that there were no legal repercussions for participants who took part in the survey as collectors were generally known to drug users. At the same time, like any other drug users in France, participants (but not surveyors) could be arrested by the police in case of illicit drug detention.

Each questionnaire provides detailed information about the drug transaction from the drug dealer or retailer corresponding to the sample collected. This includes the total price paid by the user along with the quantity of drug purchased. The data comprise a unique measure of true quality, stemming from a purity analysis through a toxicological analysis. Quality is respectively the THC concentration (percentage of Δ-9-tetrahydrocannabinod) for cannabis and the percentage of pure cocaine for cocaine. There are also a few other characteristics related to the product: origin, location of the deal as well as expected and realized effects from the substance consumption. Finally, the survey includes a brief description of the drug user: gender, age, years of experience in drug consumption, level of education and occupation. However, there is no information on individual income in the questionnaire.

Let us now describe the two samples. The survey on cannabis users was conducted in 2005 on 391 consumers. We decide to drop respondents producing cannabis by themselves as these users are by definition not involved in drug market transactions (N=111). We also drop two transactions characterized by a very high THC concentration (above 30%) as they are more like outliers.[7] We further delete two transactions with a missing price and one transaction with a price per gram of 15

[6] For further details, see Carpentier et al. (2010).

[7] For these two transactions, the THC concentration is respectively equal to 42.9% and 53%. By comparison, the mean concentration of THC is 9.9% for the rest of the sample and the highest THC concentration is 26.5%.

euros, the maximum price for the other transactions being 10 euros per gram. Our final sample includes 275 cannabis users. Among them, 75 use herbal cannabis and 200 use cannabis resin. The survey on cocaine was conducted in 2006 on 373 consumers. We delete 27 observations with missing values for the price and we also drop from the sample one transaction of one kilogram. Our final sample comprises 345 cocaine users, with 49 crack users and 296 powder users.

While our surveys concern a specific population of regular users, the use of drugs is growing in France. It is currently one of the top-ranking countries in Europe in terms of cannabis consumption (Spilka et al., 2007). Cannabis users smoking at least one joint in the year were estimated at 3.9 million individuals in 2005, while daily smokers of cannabis were estimated at 550,000 individuals among the French population. Cocaine use is also strongly increasing nowadays, especially among young people (Legleye et al., 2009). According to a general population survey, 250,000 individuals experimented with cocaine in 2005 (Beck et al., 2007).

Descriptive statistics of drug transactions for the two samples are presented in Table 1. On average, the price per gram is 5.45 euros for herbal cannabis and 3.85 euros for cannabis resin, with a weight per transaction of 15.03 grams and 31.16 grams respectively. 27.3% of transactions are herbal cannabis, 72.7% are cannabis resin and the concentration in THC is slightly higher for herbal cannabis than for cannabis resin (10.92% instead of 9.47%). Concerning cocaine, the mean price per gram is much higher: respectively 61.86 and 57.53 euros per gram for powder cocaine and crack cocaine. At the same time, the quantity per purchase is much lower, respectively 3.14 grams and 5.38 grams. Finally, the percentage of pure cocaine (chemically measured) is 25.76% in the powder cocaine sample and 33.14% in the crack cocaine sample.[8]

Insert Table 1

For each type of drug, Figure 1 illustrates the relationship between the price paid per gram of illicit substance and the chemical quality given either by THC or percentage of pure cocaine. Interestingly, we only observe a weak positive correlation between price and quality, except for the market of cannabis resin where the slope of the linear regression is higher. On the one hand, the lack of correlation could be interpreted in favor of the hypothesis of Caulkins (2007) that illicit drugs are “double experience goods.” Poor information on the true quality of the product, from the consumer side as well as from the seller side, would lead to large variations in the price corresponding to each level of quality.

Insert Figure 1

On the other hand, Figure 1 does not take into account the correlation between quantity and, respectively, price and quality. Concerning the former, Ben Lakhdar et al. (2010) report substantial bulk-buy discounts for cannabis and cocaine in France. They find a large and significantly negative relationship between the logarithm of the price per gram and the log of drug quantity purchased, with

[8] We note from Table 1 that the minimum value for percentage of pure cocaine is 0 both for powder and crack cocaine, meaning that a few consumers buy an illicit substance without cocaine.

an elasticity of -1.4 for cannabis and -1.5 for cocaine. Concerning the quality–quantity interaction, customers will certainly be interested in buying larger quantities of a drug when having access to illicit products of better quality. In the same vein, dealers will certainly provide higher quality for larger purchases to their more loyal clients, while sales of smaller quantities are more likely to be cut with additives and adjuvant.

So, this description shows that price, quality and quantity have to be jointly taken into account when investigating drug transactions. In what follows, we carry out an efficiency analysis to shed light on deviations from the best choices in selling or purchasing illicit substances.

4. A non-parametric double-frontier framework

We rely on non-parametric frontier techniques to study the efficiency of agents involved in market transactions. In the field of production theory, the most popular non-parametric method is Data Envelopment Analysis (DEA), which assumes that the production set is convex and free disposable (Charnes et al., 1978). In our analysis, we consider the more flexible Free Disposal Hull (FDH) model proposed by Deprins et al. (1984) that assumes only free disposability on the production set. As shown in Park et al. (1999), the limit distribution of the FDH estimator in a multivariate setup is a Weibull distribution.

For the presentation of our methodology, we first set aside the role of quantity and consider a context where each user buys the same fixed quantity of drug. We then exclusively focus on the relationship between quality and the price per gram (or more generally per unit of goods). What is needed at this stage is a definition of efficiency. Keeping in mind that each transaction involves both a purchaser and a seller, we rely on the following hypotheses:[9]

H1. *A buyer paying the lowest price for a given level of quality will be considered as efficient.*

H2. *A seller receiving the highest price for a given level of quality will be considered as efficient*.

Starting from a set of drug transactions, it is then straightforward to identify both efficient sellers and efficient buyers in the two-dimensional price–quality space. From the sellers' perspective, all efficient buyers will be located on the outer envelope of agents obtaining the highest price for any given level of quality. From the consumers' perspective, all efficient users will locate on the outer envelope obtaining the lowest price for any given level of quality. This FDH double-frontier approach is described in Figure 2, each dot corresponding to a specific transaction. The upper frontier indicates efficient sellers, while the lower frontier indicates efficient buyers. All transactions belonging to the closed set delimited by these two frontiers (frontiers being excluded) are inefficient in the sense that some agents perform better than them on the drug market.

Insert Figure 2

[9] For a mathematical definition of the consumption efficiency of multi-attribute products in the price-quality space, see for instance Lee et al. (2005) and the references therein.

Drawing on non-parametric techniques, a few papers have recently investigated such a double-frontier framework. A seminal contribution has been made by Lins et al. (2005), who assess the value range for real-estate units depending on housing features. They analyze the efficiency of buyers and sellers involved in residential units located in Rio de Janeiro. Hadley and Ruggiero (2006) also apply a double-frontier model to final-offer arbitration in major league baseball. Owners perceive a player's value relative to other players performing as well with lower salaries, while players perceive their worth relative to other players who earn more with no better performance. Finally, Mouchart and Vandresse (2010) propose a methodology for evaluating the market imperfection and the bargaining power of agents acting in a given market, with an application to freight transport.

All these studies consider a set of transactions characterized by a price and a vector of observed characteristics related to quality for a given quantity of a good. This setting is unfortunately irrelevant in the context of drug markets where both quantity and price are jointly determined. As for licit goods, purchasers of illegal drugs are likely to obtain significant discounts on price depending on the quantity purchased. Several authors have found that the price per gram was a decreasing function of the quantity of drug purchased, for instance Clements (2006) for marijuana in New Zealand, Caulkins and Padman (1993) and Desimone (2006) for marijuana and various other illegal drugs in the US, and Ben Lakhdar et al. (2010) for cannabis and cocaine in France.

We thus propose a formal framework drawing on FDH techniques to study efficiency of both buyers and sellers on drug markets. Our double-frontier approach is in fact potentially applicable to any other markets where transactions are characterized by a price-quality-quantity triplet. In what follows, we assume that each drug transaction is described by exchanged quantity, drug quality (either THC or purity of cocaine) and price per gram. We denote by $p \in R_+$ the vector of observed unit prices, $q \in R_+$ the vector of exchanged quantities and $k \in R_+$ the quality vector. We define the market *(M)* by the intersection of two sets, namely the Buyer set (*B*) and the Seller set (*S*). They can be represented as follows:

$$B(p,q,k) = \{(p,q,k) : \text{a buyer could buy a quantity } q \text{ at price } p \text{ with quality } k\} \quad (1)$$

$$S(p,q,k) = \{(p,q,k) : \text{a seller could sell a quantity } q \text{ at price } p \text{ with quality } k\} \quad (2)$$

$$M(p,q,k) = B(p,q,k) \cap S(p,q,k) \quad (3)$$

Some axioms are proposed in order to give some structure to these sets. Traditionally, free disposability, additivity, divisibility or convexity are common axioms for structuring these sets. Feasibility of observed transactions is also an accepted and self-evident assumption. We only consider feasibility and free disposability to define *B* and *S*.

A1. If a transaction (p', q', k') is observed, then it is feasible and

a) $(p',q',k') \in B(p,q,k)$

b) $(p',q',k') \in S(p,q,k)$

c) $(p',q',k') \in M(p,q,k)$

A2. If a transaction $(p',q',k') \in B(p,q,k)$, then for all (p'',q'',k'') with $p'' \geq p'$, $k'' \leq k'$ and $q'' \geq q'$, we have $(p'',q'',k'') \in B(p,q,k)$.

A3. If a transaction $(p',q',k') \in S(p,q,k)$, then for all (p'',q'',k'') with $p'' \leq p'$, $k'' \geq k'$ and $q'' \leq q'$, we have $(p'',q'',k'') \in S(p,q,k)$.

A1 is self-evident and says nothing more than we accept as feasible what we observed in the real world. **A2** and **A3** are a little more subtle. The free disposability says that if a transaction is observed, then any transaction with a higher price, a higher quantity and a lower quality is feasible from the buyer's perspective (**A2**). This means that if we observe a given transaction then the buyer could have paid more for at most the same quality. We consider that we have observed the best situation, but the worst could have been possible for the buyer. The quantity constraint precludes the fact that a higher price could be due to a lower quantity. If unit prices depend on the quantity, then we cannot consider that the unit price of a transaction is higher (all things being equal) than another one if the quantity of the latter is lower. By analogy, any transaction with a lower price, a lower quantity and a higher quality is feasible from the seller's point of view (**A3**).

The Buyer and Seller sets can be estimated from a sample of observed transactions. Suppose that there are $j = 1,\ldots,J$ transactions in the sample. For simplicity, we denote by J either the number of observations or an index set for transactions. The Buyer set is represented by:

$$B = \left\{ (p,q,k) : \sum_{j \in J} \lambda^j p^j \geq p, \sum_{j \in J} \lambda^j q^j \geq q, \sum_{j \in J} \lambda^j k^j \leq k, \sum_{j \in J} \lambda^j = 1, \lambda^j \in \{0;1\} \right\} \tag{4}$$

and the Seller set is represented by:

$$S = \left\{ (p,q,k) : \sum_{j \in J} \lambda^j p^j \leq p, \sum_{j \in J} \lambda^j q^j \leq q, \sum_{j \in J} \lambda^j k^j \geq k, \sum_{j \in J} \lambda^j = 1, \lambda^j \in \{0;1\} \right\} \tag{5}$$

Note that these sets are not convex. By definition, a linear combination of observed transactions is precluded since only one observed transaction can be part of the optimal solution, as shown by the last constraint of each set.

Because we want to measure the extra cost paid by the buyer or the extra gain for the seller, we are interested in finding the frontier (or envelope) of the two sets and measuring the distance to this frontier. Following Shephard (1953, 1970), each frontier can be derived using a distance function. By using a price orientation, transactions interior to the envelope of the set B must contract their price until they are projected onto the set frontier. In the same way, transactions interior to the envelope of the set S must expand their price until they are projected onto the set frontier. The two price distance functions can be written as:

$$\vec{D}_B(p,q,k) = \sup_{\delta_B} \delta_B \in R_+ : (p - \delta_B, q, k) \in B \tag{6}$$

$$\vec{D}_S(p,q,k) = \sup_{\delta_S} \delta_S \in R_+ : (p + \delta_S, q, k) \in S \tag{7}$$

From (6) and (7) and using the representation of the sets given by (4) and (5), the inefficiencies of each transaction $i \in J$ is given by the solutions to the two following linear programs:

P1. Sellers' inefficiency:

$$\vec{D}_s(p^i, q^i, k^i) = \max_{\delta_s, \lambda} \delta_s$$

s.t.

$$\sum_{j \in J} \lambda^j p^j \geq p^i + \delta_s$$

$$\sum_{j \in J} \lambda^j q^j \geq q^i$$

$$\sum_{j \in J} \lambda^j k^j \leq k^i$$

$$\sum_{j \in J} \lambda^j = 1$$

$$\lambda^j \in \{0;1\} \quad \forall j \in J$$

$$\delta \geq 0$$

P2. Buyers' inefficiency:

$$\vec{D}_b(p^i, q^i, k^i) = \max_{\delta_b, \lambda} \delta_b$$

s.t.

$$\sum_{j \in J} \lambda^j p^j \leq p^i - \delta_b$$

$$\sum_{j \in J} \lambda^j q^j \leq q^i$$

$$\sum_{j \in J} \lambda^j k^j \geq k^i$$

$$\sum_{j \in J} \lambda^j = 1$$

$$\lambda^j \in \{0;1\} \quad \forall j \in J$$

$$\delta \geq 0$$

On the supply side (**P1**), we seek to identify sellers who sell drugs at the highest price per gram for a given quality compared to other transactions featured with a lower or equal quality and a higher or equal quantity. This information reveals the upper boundary of prices and defines the potential "over-benefits" from the seller's perspective. Note that the second constraint on quantity in **P1** is very important as it controls the impact of quantity on the unit price through bulk-buy discounts. From **P1**, we get a set of amounts δ_s corresponding to the extra marginal benefit in euros that sellers could have obtained had they been efficient. This value is equal to zero for efficient sellers who by definition sell at the highest price a product of a given quality.

Likewise, the lower boundary provides similar information from the perspective of the consumer. As shown in **P2**, the frontier is built from consumers paying the lowest price for a given quality compared to transactions featured with a higher or equal quality and lower or equal quantity. Again, the constraint on quantities in **P2** allows for taking the discount effect into account. We calculate how much consumers could save in euros per gram of drug purchased (had they been efficient), this value being equal to zero for efficient consumers paying the lowest price.

To summarize, our formal framework uses non-parametric frontier techniques to determine two encapsulating surfaces that enfold all the transactions in a three-dimensional price-quality-quantity space. From the sellers' perspective, the first frontier is the outer envelope of sellers obtaining the highest price for any given level of quality (so an output-oriented FDH model). From the consumers' perspective, the second frontier is the outer envelope of users who obtain the highest quality for a given level of price (so an input-oriented FDH model).

5. Empirical results

5.1. Purchaser and seller inefficiencies in drug markets

We apply this double-frontier FDH framework to our data on drug transactions. By solving the linear programs **P1** and **P2**, we deduce efficient transactions in drug markets and calculate for each transaction how many euros per gram could be saved/gained respectively for buyers and sellers with respect to efficient agents. We treat each product (herbal cannabis, cannabis resin, powder cocaine, crack cocaine) as a separate market.

For the sake of illustration, Figure 3 presents the efficient transactions both for herbal cannabis and cannabis resin. Red dots define the inferior envelope corresponding to efficient consumers. Most of them are located on the lower-front part of the 3D-figure. These users have purchased a low quantity of drug at a low price, with a high quality for transactions located on the right. Conversely, blue dots define the superior envelope indicating efficient sellers. They are more often located in the upper-back part of the box. These agents sell large quantities of drug at a high price, drug quality being low for transactions located on the left.

Insert Figure 3

We describe in Figure 4 the distribution of buyer and seller inefficiencies expressed in euros. According to our data, 35% of buyers of herbal cannabis and 17% of buyers of resin cannabis are efficient, meaning that they have paid the lowest price for the quality level they have obtained. From the sellers' perspective, these proportions are respectively equal to 23% and 18%. When considering the powder cocaine market, a reversed pattern is observed. There are only 7% of efficient buyers, while the proportion of efficient sellers is 13%. There are more efficient agents for crack cocaine, respectively 35% of sellers and 28% of buyers. At the same time, the sample is much smaller, which is also the case for herbal cannabis.[10] This explains the higher number of efficient transactions on both drug markets.

Insert Figure 4

Additional descriptive statistics related to these inefficiencies are presented in Table 2. Our data suggest that buyers of both herbal cannabis and cannabis resin are slightly more efficient than sellers of these products. On average, the price per gram paid by cannabis resin and cannabis resin consumers could be 1.79 euros per gram and 1.56 euros per gram lower respectively, compared to the price paid by efficient buyers. From the sellers' perspective, the price per gram could be 2.20 euros per gram and 1.83 euros per gram higher respectively for herbal cannabis and cannabis resin. When considering crack cocaine transactions, buyers are also more efficient than sellers. The former could save 13.21 euros per gram, while the latter could gain 17.43 additional euros per gram. The situation is more balanced for powder cocaine, the mean inefficiency being around 21-22 euros for both sellers and purchasers.

Table 3 shows that the mean inefficiency for cannabis ranges from 33 to 48% of the price per gram, while the mean inefficiency for cocaine ranges between 23 and 37%. At an aggregate level, this could significantly affect consumers' expenditure or sellers' income. Consider for instance the cannabis resin market. The 200 purchasers in the survey spent 17,154 euros to obtain 6,231 grams of

[10] In France, the number of crack consumers is estimated at less than 9,000.

cannabis. Consumers would have paid 10,064 euros to obtain the same quantity had they all been efficient, so a decrease of 41.3%. Similarly, sellers would have obtained 23,314 euros from their drug had they all been efficient, which corresponds to a 35.9% increase. For powder cannabis, similar calculations show that consumers spent 51,850 euros for 928.6 grams. Users would have paid 33,812.5 euros had they all been efficient (a 34.8% decrease) and sellers would have received 66,835 euros had they all been efficient (a 28.9% increase).

Insert Table 3

So, a first conclusion stemming from this inefficiency analysis is that illicit drug markets do not seem to be markets for lemons. Indeed, the average inefficiency of purchasers is lower than the average inefficiency of dealers (except for powder cocaine) even though no quality certification on products exists for this kind of illicit market. A simple explanation could be that we focus on a sample of more or less regular drug users who are likely to have frequent interactions with dealers. Users would hence be experienced in drug purchase and could benefit from discounts offered by sellers. Experienced users are also expected to have a better knowledge of the illicit products and it would be much more difficult for dealers to sell them drug samples of bad quality.

Interestingly, we find a reverse pattern for transactions involving powder cocaine. For that substance, the average inefficiency of purchasers is slightly higher than that of sellers. Two interpretations may come to mind. On the one hand, this substance is much more addictive than cannabis. So, if users are in need of the drug, then they could be ready to pay a higher price to buy a sample of cocaine. Similarly, dealers would be expected to charge higher prices to their customers in order to take advantage of their stronger addiction.[11] On the other hand, powder cocaine is a drug that can be more easily cut than cannabis. This would offer opportunities for sellers to propose samples of bad quality at an excessive price.

5.2. The determinants of inefficiency in drug transactions

We now further investigate inefficiency in transactions by explaining the performance of drug sellers and purchasers through an econometric analysis. To examine efficiency, almost all studies have so far relied on a two-stage approach where efficiency was first estimated through a non-parametric analysis, and then the estimated inefficiencies were regressed on a set of covariates representing environmental variables. Censored models were considered for the second stage as all efficient units had the same efficiency score.

As recently highlighted by Simar and Wilson (2007), the difficulty with the classic two-stage procedure is that the serial correlation of the efficiency estimates is not taken into account. In the

[11] Our data suggest that this interpretation is certainly relevant. We compute the mean of the inefficiency scores as a function in relation to the intensity of cocaine consumption during the previous month. We find that the mean efficiency of sellers is 21.88 euros when cocaine is sold to daily users, but 19.30 euros when sold to regular users. Conversely, the inefficiency from the buyers' perspective is 2.4 euros lower for regular users compared to daily users (21.19 instead of 23.62). We further investigate this issue through an econometric analysis in the next subsection.

second stage, the dependent variable under consideration is itself the result of an estimation since the efficiency scores stem from the non-parametric estimation of an unobserved true frontier. These efficiency scores are serially correlated in an unknown way and the error term in the second-stage equation is furthermore correlated with the explanatory variables. The problem is even more severe in finite samples, which is usually the case in envelopment analyses.

As a consequence, standard inference methods are not consistent in the second-stage regression. We therefore implement the bootstrap procedure for the two-stage estimation problem recently proposed by Silmar and Wilson (2007). The model we seek to estimate is $\hat{\delta}_j = Z_j\beta + \varepsilon_j$, with $\hat{\delta}_j$ the estimated efficiency (either for sellers or buyers), Z_j a set of buyers' characteristics, β the associated vector of coefficients, and ε_j a residual. Considering the $M < J$ observations that are characterized by $\hat{\delta}_j > 0$ (they correspond to inefficient agents), we estimate a truncated regression to obtain an estimate $\hat{\beta}$ of β and an estimate $\hat{\sigma}_\varepsilon$ of σ_ε.

To obtain a set of bootstrap estimates $(\hat{\beta}^*, \hat{\sigma}^*)$, we replicate N times the following procedure.[12] First, we draw a set of M residuals ε_m with $m = 1,\ldots,M$ from the $N(0;\hat{\sigma}_\varepsilon^2)$ distribution with left-truncation at $(1 - Z_m\hat{\beta})$. Then, we compute for each m the new efficiency score $\delta_m^* = Z_m\hat{\beta} + \varepsilon_m$ and estimate by maximum likelihood a new truncated regression explaining δ_m^* as a function of Z_m. In so doing, we obtain a set of coefficients $(\hat{\beta}^*; \hat{\sigma}_\varepsilon^*)$. This parametric bootstrap of a nonlinear regression model provides inference about β.

In what follows, we estimate regressions on efficiency scores only for cannabis resin and powder cocaine.[13] By construction, the survey only includes characteristics of users but provides no information on the characteristics of the sellers. We consider the following variables to explain inefficiency: gender, age, education, occupation, years of experience in cannabis or cocaine, daily use of the drug and the place where users have bought their product. We provide a brief description of these variables in Table 3.

Insert Table 3

In both markets, there are many more men than women consuming drugs (77-78%). The mean age of cocaine users is slightly higher than that of cannabis users (28.8 instead of 26.7 years old). However, age at first use of cannabis resin is lower than that of powder cocaine (17 instead of 20), so that years of experience in cannabis use is longer. Both samples comprise low- and high-educated users in somewhat similar proportions, but there are many more students among cannabis users (29%) than among cocaine users (9%). This may be partly explained by the difference in price between the

[12] When exploiting the data, we choose 1,000 bootstrap replications.
[13] We choose to estimate no regression for herbal cannabis and crack because of smaller sample size.

products. Finally, 69% of cannabis users and 28% of cocaine users are daily consumers and the product was often bought at the dealer's home (54% for cannabis and 39% for cocaine).

We first study the inefficiency of purchasers and sellers respectively. We present the results of the two-stage bootstrap procedure in Table 4. Both for cannabis resin and powder cocaine, we find that gender and education have no significant effect on inefficiency. Students purchasing drugs are more inefficient than the other users. Those buying cannabis could save 0.8 euro per gram had they been efficient, while the price paid in excess is 6.6 euros per gram for those buying cocaine. Students may have less experience in bargaining when buying the illicit substance, but they could be also ready to pay a higher price if they have less frequent access to purchasing opportunities. Cocaine users having a paid job also appear to be more inefficient (at the 10% level).[14] An explanation could be that these users have less time to find a dealer selling drugs at a low price. At the same time, the paid job category could also produce income-related effects..

Insert Table 4

Experienced buyers of cannabis resin are more efficient on average. The survey only provides information on the last transaction, but one could imagine that experienced purchasers are more accustomed to buying illicit substances. They may have more information on the product they are buying and would therefore be less often swindled. They may also have frequent interactions with the same sellers and benefit from products of better quality at the same price.[15] Very similar results are observed for regular users of cannabis, defined as those consuming cannabis at least five days per week. Regular users are less inefficient when purchasing drugs, but we also note that transactions are more efficient for sellers when purchasers are regular consumers. The repetition of transactions between both agents may be the explanation of the increased efficiency (Reuter and Caulkins, 2004).

At first sight, it is more surprising that experience or regular consumption play no role in efficiency where powder cocaine is concerned. A difference with cannabis is that cocaine may be more easily cut with a range of products such as phenacetin, caffeine, paracetamol, lidocaine or diltiazem. It would hence be much more difficult for purchasers to have relevant information on the quality of the drug quantity they purchase. Results from toxicological analysis show that there are often two or three additives in the cocaine samples. Our data thus suggest that what matters for cocaine is not really who is transacting, the context of the transaction being apparently much more important.

We further study this point by estimating an equation where we explain the total inefficiency per transaction (defined as the sum of the purchaser's and seller's inefficiencies) as a function of various characteristics of the transaction.[16] As shown in Table 5, total inefficiency decreases with

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[14] The reference category is made up of people who are unemployed or without a professional occupation.

[15] The marginal effect of experience remains low as purchasers save only 0.06 euro per gram per year of experience.

[16] We turn to an OLS regression to explain total inefficiency as there are almost no censored values. There are for instance only four total inefficiency scores equal to 0 euro for herbal cannabis (and zero for powder cocaine). Concerning inference, we again rely on a bootstrap procedure where we draw some residuals in the normal distribution with the variance

quantity. Clearly, there are greater interests at stake for both sellers and purchasers when transactions involve large quantities of a drug. Agents are expected to behave with more professionalism and longer negotiations are likely to increase the efficiency of transaction for all participants. Conversely, inefficiency is positively correlated with drug quality. Recalling that participants involved in the transaction (especially users) have only imperfect information about the drug quality, there may be more room for bargaining in such transactions and this would lead to more variability in price.

Insert Table 5

Finally, the place where the drug has been purchased plays a role in the explanation of total inefficiency. Both for cannabis and cocaine transactions, we find that drug sales in the street are much more inefficient than sales made in other places. A similar result is observed for cannabis transactions made in a bar, while cocaine exchanges in a scheduled meeting are more efficient on average. Although the survey provides no information on the identity of the sellers, it seems clear that transactions made in a street are more likely to involve agents who do not know each other. Our results hence suggest that the closeness between sellers and customers is an influential factor when explaining transaction efficiency. Information definitely affects the performance of agents involved in illicit substance markets.

6. Concluding comments

In this paper, we have investigated the efficiency of both purchasers and sellers in illicit drug markets that are characterized by imperfect information on quality, especially from the purchasers' perspective and to a lesser extent from the sellers' perspective. For that purpose, we have used unique data collected in France in 2005 and 2006 with detailed information about quantity, price and quality for a sample of cannabis and cocaine transactions.

Drawing on frontier techniques, our contribution proposes a simple method to measure the performance of buyers and sellers in a market. For given levels of quality and quantity, a seller is defined as efficient when the price paid by the consumer is maximal. In a similar way, a buyer is efficient when the price paid to the dealer is minimal. Our measures of efficiency thus indicate how many euros sellers could have gained in addition per gram of drug had they been efficient and how many euros buyers could have saved per gram of drug had they been efficient. As usual in efficiency analysis, our definition of performance is a relative one since each agent is efficient only as a result of a comparison to the other agents involved in the drug transactions.

Our main empirical results are twofold. On the one hand, we find that buyers of illicit substances (except for powder cocaine) are slightly more efficient than sellers of these products. The mean inefficiency for cannabis ranges from 33 to 48% of the price per gram, while the same

obtained from the OLS regression and calculate simulated values of total inefficiency for each transaction by adding the calculated total inefficiency to the residual drawn from the normal distribution. We replicate the procedure 1,000 times to obtain a set of bootstrapped estimates of total inefficiency.

percentage ranges between 23 and 37% for cocaine. The difference observed between powder cocaine and cannabis is interesting. As the former product may be easily cut, this offers opportunities for sellers to charge excessive prices (for a fixed level of quality) and thus improve their efficiency. On the other hand, two-stage truncated estimates of the efficiency scores show that regular users of cannabis are more efficient on average. Experience thus plays an important role in efficient transactions. Furthermore, total inefficiency per transaction is increasing with drug quality and is greater when a drug is purchased in the street.

When interpreting our results, the composition of our sample has to be kept in mind. It is neither representative of the French population, nor of French cannabis and cocaine users. The focus on regular consumers living in large cities could be an explanation of the relative efficiency of purchasers and sellers that we observe in our data. Infrequent consumers of illicit substances, with little experience in drug use, would certainly be less efficient when buying drugs for at least two reasons. Firstly, they are expected to be much more affected by quality uncertainty since time is needed to acquire a reasonable knowledge of the type of product bought and its purity. Secondly, as in any commercial relationship, informational problems will be lessened with the repetition of transactions between a purchaser and a seller.

While quality uncertainty plays a role in the understanding of price setting in illicit drug markets, the role of drug addiction has also to be taken into account. Our results show that when the drug can be more easily cut (which is evidently the case of cocaine), the mean efficiency of consumers is lower on average. An interpretation is that inefficiency is greater when purchasers have poor information on the product they are buying, but the result could alternatively be explained by drug addiction. Indeed, several authors have shown that cocaine dependence was much stronger than cannabis addiction (Wagner and Anthony, 2002).[17] According to the theory of rational addiction (Becker and Murphy, 1988, Becker et al., 1991), the reinforcement of drug use would blur the ability to be efficient in drug transactions. At the same time, dealers do not take great advantage of the cocaine users' inefficiency.

While imperfect information is likely to affect the price-quality ratio in drug markets, we also note that the double quality uncertainty (respectively for purchasers and to a lesser extent for sellers) does not cause the market to disappear because of a "bad drives out the good" phenomenon. Our data show that efficiency on transactions depends not only on individual characteristics of sellers and purchasers, but also on the context of the transaction. Additional factors such as the proximity between sellers and purchasers or the intensity of competition in the market naturally solve the phenomenon of "lemons" without the need of certification institutions suggested by Akerlof (1970).

It would hence be worthwhile to have more detailed data on drug transactions to further disentangle the role of imperfect information from the effect of alternative mechanisms like local

[17] In the US, Wagner and Anthony find that about 5-6% of cocaine users become cocaine dependent in the first year of use, while there is no significant dependence within the first year of use for cannabis.

competition between sellers or repeated interactions between buyers and sellers. Firstly, it would be appropriate to have characteristics of both the sellers and the purchasers involved in the different transactions. Secondly, panel data on drug transactions would be helpful to look for unobserved heterogeneity at the individual level and to better understand the purchase behavior of drug users. Among regular consumers, some of them may buy very frequently small quantities of drug from regular dealers while other users may purchase infrequently large quantities from different sellers. Thirdly, exhaustive data on drug sales at the local level would be useful to understand the setting of prices among dealers and to study the effect of competition (or collusion) on drug prices.

Unfortunately, the data at hand do not allow us to study the dynamics of purchase and sales on illicit substance markets. At the same time, the detailed information on price, quantity and true quality (purity) for each transaction makes our empirical analysis unique. In many contributions that have investigated the sensitivity of drug consumption to price, prices are very often identified only at the state or regional level. Clearly, our data show that there are large variations in price per gram of drug for a given level of quality. The law of unique price does not hold in the illicit drug markets, which opens the door to an analysis of performance of buyers and sellers in these markets.

As a final comment, we would like to point out that our methodology can be applied in the context of any markets where quality is a choice variable. In such markets, it is straightforward to study the efficiency of agents involved in transactions through the non-parametric double-frontier framework that we have described in our paper. Automobile, housing and restaurant markets to quote but a few examples are potential candidates as they involve goods of different quality levels. For each of these markets, the availability of data on transactions with detailed characteristics of the goods sold would enable the computing of the distribution of inefficiency between buyers and sellers and a better study of the factors influencing the performance of agents in each market.

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Table 1. Description of drug transactions

Characteristics	Herbal cannabis	Cannabis resin	Powder cocaine	Crack cocaine
Price per gram				
Mean	5.45	3.85	61.86	57.53
Standard deviation	1.90	1.65	13.21	14.37
Minimum	2.00	0.80	25.00	33.33
Maximum	10.00	10.00	100.00	90.00
Quality				
Mean	10.92	9.47	25.76	33.14
Standard deviation	5.59	3.88	20.65	22.77
Minimum	1.20	0.80	0.00	0.00
Maximum	22.30	25.30	88.00	86.00
Quantity				
Mean	15.03	31.16	3.14	5.38
Standard deviation	27.91	57.35	4.13	8.68
Minimum	1.00	1.00	0.30	0.50
Maximum	200.00	500.00	35.00	50.00
Number of transactions	75	200	296	49

Source: OFDT, authors' calculations.
Note: quality is given by THC for herbal cannabis/cannabis resin and by percentage of pure cocaine for powder cocaine/crack cocaine.

Table 2. Buyers' and sellers' inefficiency (in euros per gram)

Inefficiency	Herbal cannabis	Cannabis resin	Powder cocaine	Crack cocaine
Buyer				
Mean	1.79	1.56	22.62	13.21
In % of price	33%	41%	37%	23%
Standard deviation	1.75	1.29	12.52	13.63
Minimum	0.00	0.00	0.00	0.00
Maximum	7.00	8.00	60.00	50.00
Seller				
Mean	2.20	1.83	21.27	17.43
In % of price	40%	48%	34%	30%
Standard deviation	1.75	1.46	13.61	16.76
Minimum	0.00	0.00	0.00	0.00
Maximum	7.00	8.00	60.00	50.00
Number of transactions	75	200	296	49

Source: OFDT, authors' calculations

Table 3. Descriptive statistics of the consumers

Drug	Cannabis resin	Powder cocaine
Male	0.78	0.77
Age	26.68	28.67
Experience	9.50	8.08
Education		
Less than high school	0.31	0.37
High school	0.29	0.25
More than high school	0.41	0.38
Occupation		
Paid job	0.46	0.51
Student	0.29	0.09
Other	0.25	0.40
Site		
Bordeaux	-	0.06
Dijon	-	0.06
Lille	-	0.12
Lyon	0.18	-
Marseille	0.15	0.08
Metz	0.14	0.18
Paris	0.25	0.22
Rennes	0.14	0.10
Toulouse	0.15	0.18
Place where the product was purchased		
Café/bar	0.09	-
Nightclub/concert	0.12	-
Dealer home	0.54	0.39
School	0.15	-
Street	0.04	0.16
Workplace	0.07	-
Other scheduled meeting	-	0.24
Other	-	0.22
Regular/daily consumer	0.69	0.28
Number of observations	200	296

Source: OFDT, authors' calculations

Table 4. Two-stage estimates of buyers' and sellers' inefficiency

Variables	Cannabis resin		Powder cocaine	
	Sellers	Buyers	Sellers	Buyers
Constant	1.098*	0.711	25.257***	12.191***
	(1.80)	(1.30)	(6.02)	(2.80)
Male	-0.029	0.101	-1.287	-0.711
	(-0.15)	(0.53)	(-0.76)	(-0.42)
Age	0.057**	0.048*	0.138	0.269
	(2.01)	(1.89)	(0.86)	(1.58)
Experience	-0.038	-0.062**	-0.130	0.093
	(-1.17)	(-2.15)	(-0.70)	(0.49)
Education (ref: Less than high school)				
High school	-0.015	0.145	0.806	-1.685
	(-0.07)	(0.74)	(0.45)	(-0.90)
More than high school	-0.062	0.024	-0.690	0.434
	(-0.28)	(0.13)	(-0.37)	(0.22)
Occupation (ref: Other)				
Paid job	0.107	0.290	-0.715	3.021*
	(0.47)	(1.53)	(-0.45)	(1.85)
Student	0.278	0.815***	-3.578	6.572**
	(1.04)	(3.45)	(-1.22)	(2.22)
Regular consumer	-0.530***	-0.614***	-0.593	-1.196
	(-2.78)	(-3.62)	(-0.37)	(-0.72)
σ^2	1.435***	1.420***	11.023***	11.255
	(22.21)	(23.87)	(21.69)	(21.35)
Number of observations	200	200	296	296

Source: OFDT, authors' calculations

Note : Truncated regression estimates of buyers' and sellers' inefficiency (in euros), with bootstrapped standard errors (1,000 replications). Significance levels are respectively 1% (***), 5% (**) and 10% (*). Each regression also includes specific-city dummies corresponding to the place of purchase.

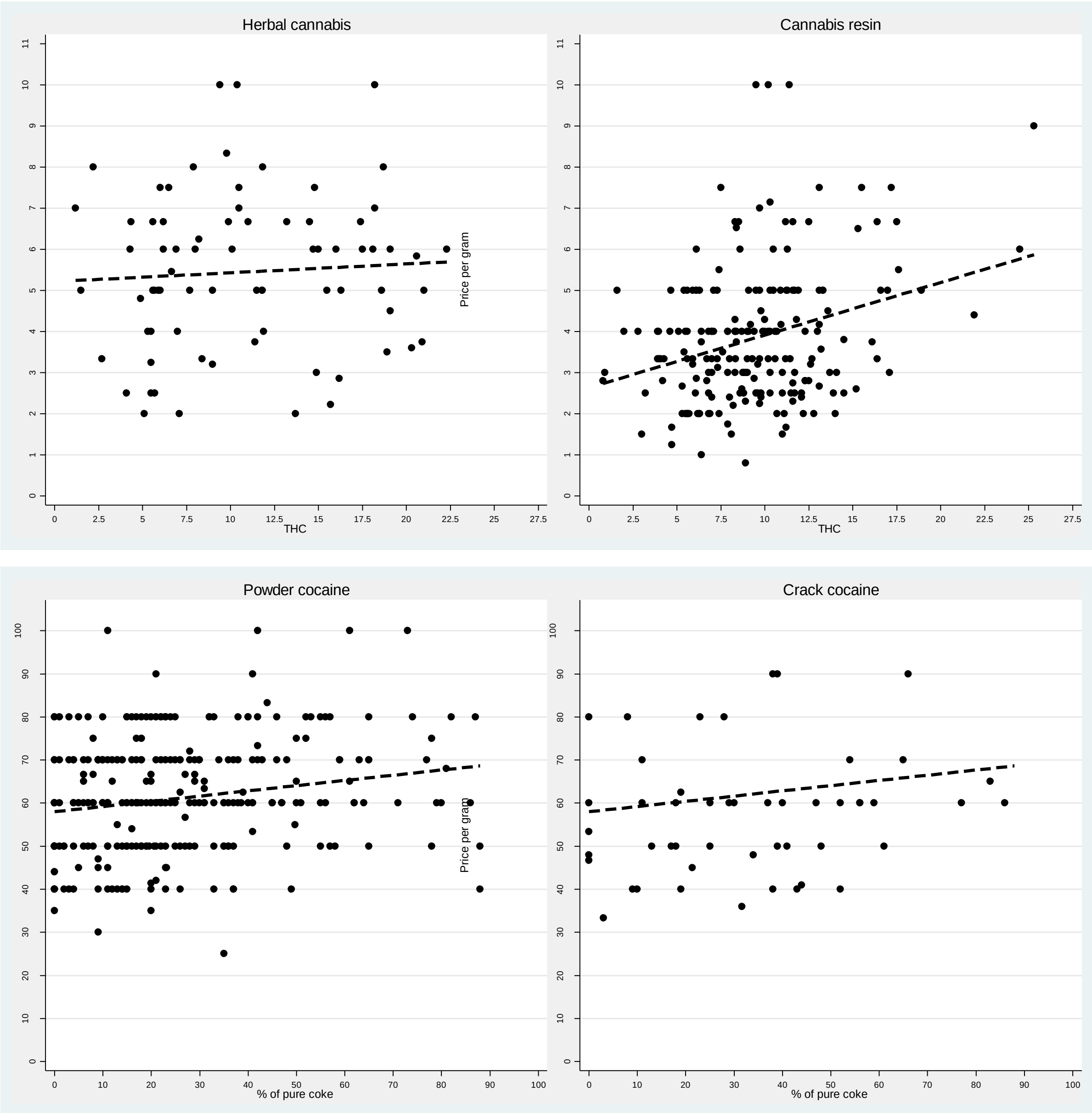
Table 5. OLS estimates of total inefficiency

Drug	Cannabis resin	Powder cocaine
Constant	2.909***	40.449***
	(8.29)	(33.62)
Total quantity	-0.012***	-1.409***
	(-7.74)	(-14.62)
Quality (%THC or % of pure coke)	0.050**	0.321***
	(2.01)	(16.79)
Place where product was purchased (ref : Dealer's home)		
Café/bar	0.575*	-
	(1.65)	
Nightclub /concert	-0.102	-
	(-0.35)	
School	-0.165	-
	(-0.67)	
Street	0.946**	1.933*
	(2.08)	(1.79)
Workplace	0.391	-
	(1.02)	
Scheduled meeting (no home dealer)	-	-1.669*
		(-1.77)
Other	-	1.286
		1.34
Number of observations	200	296
Adjusted R²	0.313	0.700

Source: OFDT, authors' calculations

Note : OLS estimates of total inefficiency (sum of buyer and seller inefficiency in euros), with bootstrapped standard errors (1,000 replications). Significance levels are respectively 1% (***), 5% (**) and 10% (*). The regression also includes specific-city dummies corresponding to the place of purchase.

Figure 1. The price-quality relationship in drug markets



Source: OFDT, authors' calculations
Note: each dot corresponds to a drug transaction.

Figure 2. Buyer/Seller sets and efficient frontiers

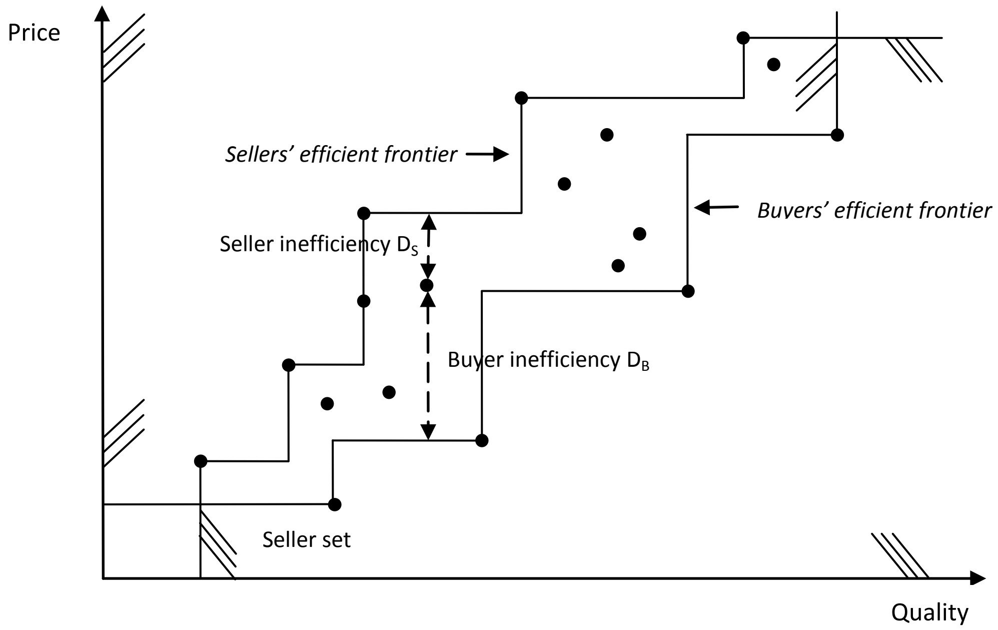
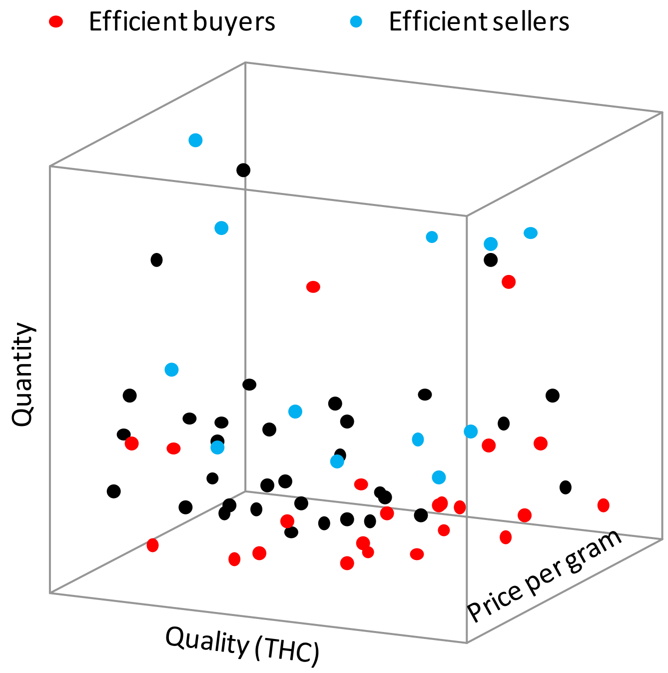
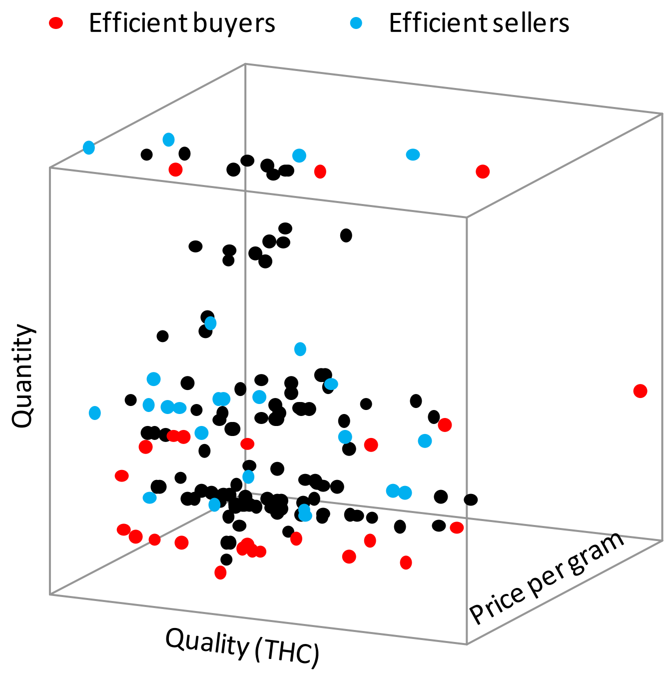


Figure 3. Efficient sellers and buyers in the price-quality-quantity space

Herbal cannabis

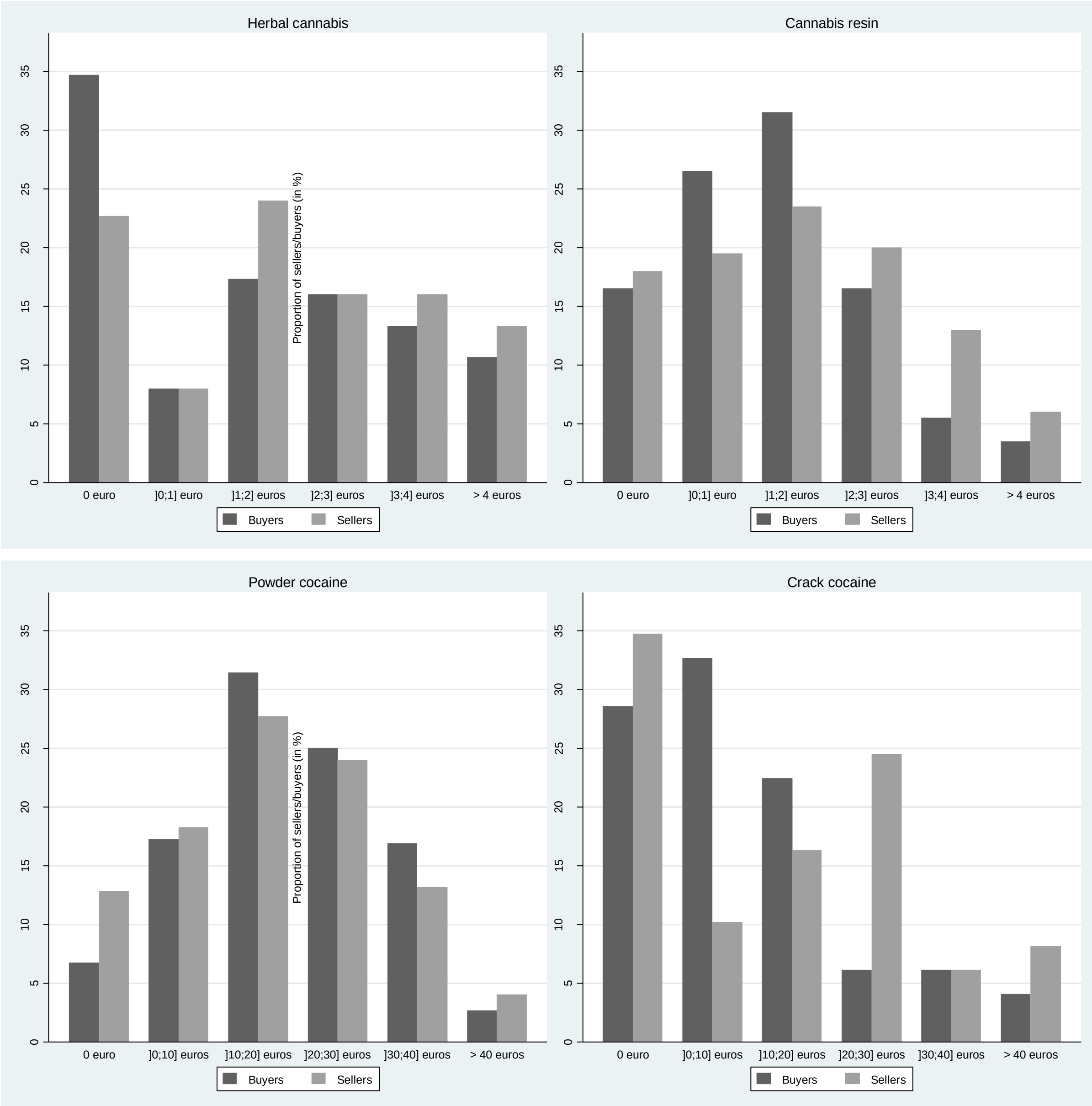


Cannabis resin



Source: OFDT, authors' calculations
Note: drug transactions above 25 grams are not represented. Both price, quantity and quality are normalized to cover the same interval of values.

Figure 4. Distribution of buyer and seller inefficiency



Source: OFDT, authors' calculations
Note: inefficiencies correspond to the amount in euros that could be saved or gained.