Monitoring the size and protagonists of the drug market: combining supply and demand data sources and estimates

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Abstract.

The size of the illicit drug market is an important indicator to assess the impact on society of an important part of the illegal economy and to evaluate drug policy and law enforcement interventions. The extent of illicit drug use and of the drug market can essentially only be estimated by indirect methods based on indirect measures and on data from various sources, as administrative data sets and surveys. The combined use of several methodologies and data sets allows to reduce biases and inaccuracies of estimates obtained on the basis of each of them separately.

This approach has been applied to Italian data. The estimation methods applied are capture-recapture methods with latent heterogeneity and multiplier methods. Several data sets have been used, both administrative and survey data sets.

First, the retail dealer prevalence has been estimated on the basis of administrative data, then the user prevalence by multiplier methods. Using information about behaviour of dealers and consumers from survey data, the average amount of a substance used or sold and the average unit cost have been estimated and allow estimating the size of the drug market.

The estimates have been obtained using a supply-side approach and a demand-side approach and have been compared.

These results are in turn used for estimating the interception rate for the different substances in term of the value of the substance seized with respect to the total value of the substance to be sold at retail prices.

1. Introduction.

The majority of approaches to monitoring drug policies and outcomes focus on assessing initiatives to reduce drug use and abuse, which only constitute one aspect of the drug phenomenon[1], perhaps not even the most important one for evaluation. These approaches tend to ignore the economic aspects related to drug market and law enforcement activities, which may be equally or more significant than the phenomenon of "drug consumption" per se. Other aspects are even far more serious, such as organized and petty crime, corruption of the legal economy by drug money laundering [1], enmeshing of criminal and political organizations and collusion between criminal

[1] The five key epidemiological indicators developed by expert groups at EMCDDA are an example of monitoring tools that address the problem exclusively from the demand-side (http://www.emcdda.europa.eu/themes/key-indicators).

organizations and the forces in charge of repressive interventions. Only recently has there been development of supply side indicators[2] to evaluate the size of the market, the induced criminality and the law enforcement policy.

It would be desirable that more extensive and efficient indicators and data collection approaches be developed for national and international analyses to identify best practices, both from the demand and the supply side.

Understanding the nature and extent of the drug market should be one of the first concerns for monitoring and policy evaluation, in order to set up appropriate objectives and evaluate strategies. Since the use of psychoactive drugs is restricted or considered illicit in most countries, drug consumers, traffickers and dealers are forced to conceal their behaviours. As a consequence, the extent of illicit drug use and the size of the drug market can only be estimated by indirect methods based on indirect measures or indicators, on complementary use of mathematical models and on data from various sources, such as administrative data sets and surveys [2], [3], [4], [5], [6], [7], [8]. The combination of several methodologies and data sets and, when possible, the comparison of estimates derived by different methods allows estimation of indicators that would otherwise not be estimable and also the assessment of biases and inaccuracies of estimates obtained on the basis of each data set or method used separately.
In section 2 data and methods are explained, in section 3 results are presented and in section 4 the discussion is reported.

2. Data and Methods for measuring the market.

It is possible to estimate the size of the market both from the demand and from the supply side. Various data sets available in Italy can be used for this purpose.

Administrative data sets

- The data set provided by the Ministry of the Interior of registrations for personal use of illegal substances (art. 75 of the law presently enforced).
- The data set of the subjects registered for dealing drugs (art.73 and/or 74 of the law presently enforced). For the specific analysis of articles 73, 74 and 75 it can be read [9]. There the Italian drug law is completely analysed and compared with other EU drug laws.
- The data set provided by a sample of public health care services of problem drug users in charge for therapeutic interventions (data sets appearing in the yearly report of the Italian Focal Point on the EMCDDA website: http://www.emcdda.europa.eu/publications/country-overviews).

[2] http://www.emcdda.europa.eu/events/supply-indicators;http://www.emcdda.europa.eu/news/2012/fs-10.

- The data set of police operations and seizures (data sets appearing in the yearly available English reports on the website of Police: http://www.poliziadistato.it/articolo/view/23045/).

- The data set of persons in prison for breaching the drug law (art.73 and/or art. 74 of the law presently enforced) and of drug users in prison for any cause [10].

Data sets from surveys

- The School Population Surveys SPS 2010 and SPS 2011, conducted by the University of Rome "Tor Vergata" for the Anti-Drug Department of the Presidency of the Council of Ministers (some interesting results in [5] and the Italian report at: http://www.politicheantidroga.it/pubblicazioni/in-ordine-alfabetico/report-sps-dpa-2011-(1)/presentazione.aspx).

- The Survey in the Therapeutic Communities and in the Low Threshold Services 2010, conducted by the University of Rome "Tor Vergata" for the Anti-Drug Department of the Presidency of the Council of Ministers (some important results reported in [5] and [11]).

- The Survey in the Italian Therapeutic Communities and in the Low Threshold Services 2012, conducted by the University of Rome "Tor Vergata" in the framework of the EU project *New methodological tool for policy and programme evaluation* [11].

- The online survey among occasional and regular users and the face to face interviews in the Therapeutic Communities and in the Low Threshold Services conducted by the University of Rome "Tor Vergata" in 2012 within the framework of the project *Study on the further analysis of the EU illicit drugs market and responses to it – responding to future challenges* [12].

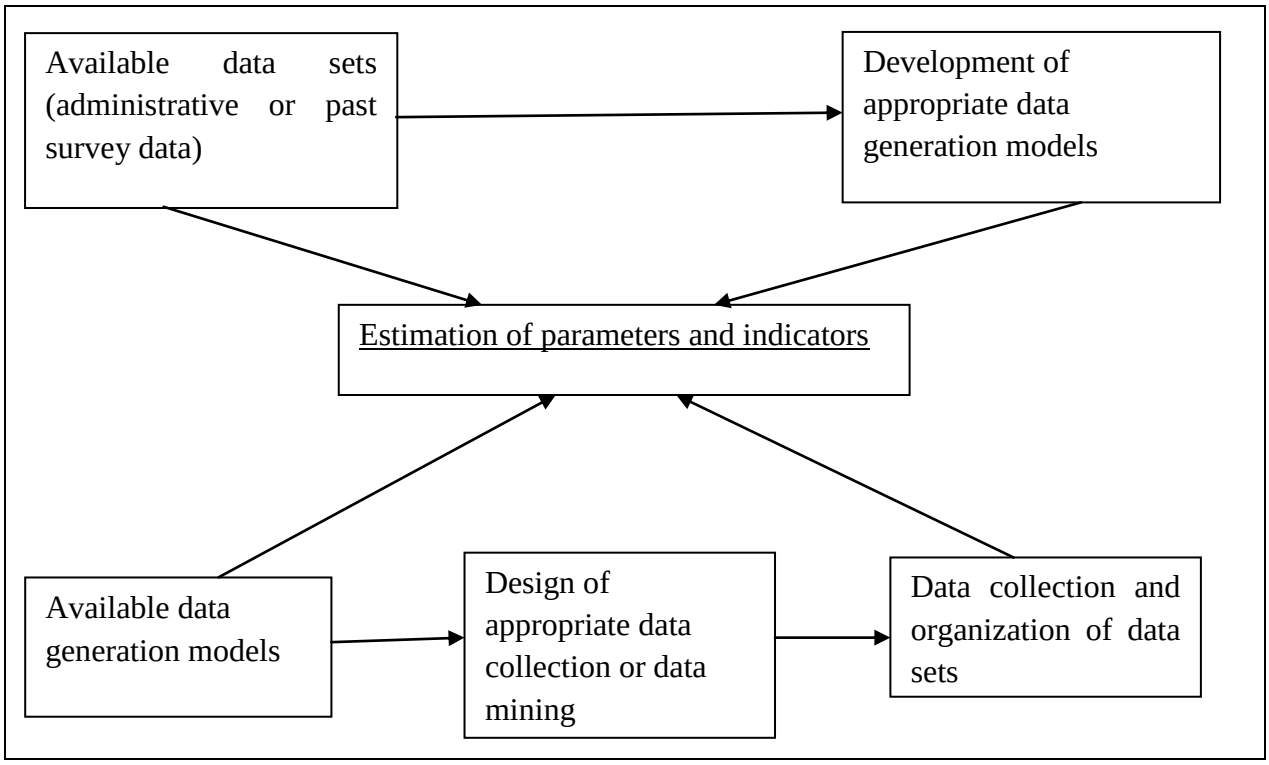
How available data and methods influence each other

Methods developed to estimate hidden populations require good quality data. It is possible to develop estimation models that mirror the data generation processes or to adapt data sets to available estimation models. The two approaches are complementary and both are necessary in the analysis of drug related issues to get reliable knowledge about various aspects of the drug phenomenon and interactions between them.
Most estimation methods used in drug use epidemiology have been developed, historically, in the field of ecology and classical epidemiology and then adapted to available administrative data sets for the estimation of the population of drug consumers (demand side analysis). Relatively few methods have, however, been "imported" for supply side analyses in order to estimate, for example, the population of drug dealers, allowing to fill some important gaps in the global analysis of drug markets [13] and [8].
There are limitations in estimating the various populations involved in the drug market from demand and supply side using only administrative data and indirect estimation methods. For example, several methods are available to estimate prevalence of the various populations of interest[3] but, for incidence estimation, say, further information that may be available from surveys or detailed personal data, is necessary to apply suitable methods, such as back calculation methods,

[3] http://www.emcdda.europa.eu/html.cfm/index65519EN.html.

that need e.g. latency time distributions [14]. Also multiplier methods based on prevalence usually need other estimates such as, for example, the age at first use distribution [11]. These distributions can only be estimated from survey data.
The interactions between data, methods and estimates are represented in Figure 1.

Figure 1. Relationships between models, data and estimates.



In the following, an example of combined use of several data sets and methods to estimate the size of the drug market is illustrated and discussed to better outline the potentialities and the problematic aspects of this approach, which might be called the "***fusionist estimation approach***".
For example, if the data set of the subjects registered for dealing drugs is considered and properly assumptions are taken into account, then the development of data generation model can provide truncated Poisson model. Then the data set and the modeling allow to estimate the parameters, such as prevalence and possible differences of capture rate between males and females etc. If it is of interest to estimate the cannabis onset distribution and the passage to either higher drugs, then properly survey among drug users are needed and the analysis of data collected allows to estimate interesting parameters. If the two approaches are taken into account, then a more comprehensive understanding of the process can be obtained.
Now the methodology used for estimating the size of the market is described.

Drug dealer estimation method

To estimate the prevalence of drug dealers at risk of being captured in Italy, according to the law presently enforced and, in particular, those related to art. 73[4] are considered. This provides the exact

[4] http://www.emcdda.europa.eu/html.cfm/index44943EN.htm.

case definition of a dealer in the present framework: *a subject who is at risk of being identified by the police and charged of drug offenses in relation to art. 73 of the drug law presently in action in Italy*. Although this population might not correspond exactly to the common concept of the street dealer population, its estimate can be taken as a good proxy for the prevalence of the street dealer population, its dynamics and trends.
Police records of the data set concerned art.73 were used to derive count data on how often (once, twice...) each drug dealer is identified, where repeated identifications can occur at any time during the study period (one year). The number n_0 of individuals who are identified zero times (individuals who were not identified but had a positive probability of being identified as belonging to the target population) is unknown, but can be estimated from the observed frequencies $n_{j\ (j>0)}$ by assuming that n_j is generated by a Poisson distribution which is truncated below one. Then the size of the hidden population of target drug dealers can be estimated by adding the estimate $\hat{n}_0$ of n_0 to the number of identified drug dealers, or through multiplier method.

If p_0 is known, the overall population of drug dealers can be estimated by means of well known maximum likelihood estimator:

$$\hat{N} = n/(1-p_0)$$

which represents the number of observed cases identified by the police, adjusted for the probability of being included in the database. This estimation method may be viewed as a multiplier method.

If p_0 is unknown, different approaches lead to different estimates of p_0 and N. Further technical details about the assumptions and limitations of the truncated Poisson model are reported in [7]. In the following section the estimator proposed by Zelterman is applied.

The estimator of Zelterman.

The assumption of the homogeneity of identification probabilities is rarely met in practice.

The simple Poisson model is not flexible enough to capture population heterogeneity and, generally, the maximum likelihood estimator underestimates the population size.

Zelterman [15] proposed estimating p_0 using only frequencies n_i, from the zero-truncated count distribution, where i is usually chosen to be 1 or 2. The proposed estimator is thus given by:

$$\hat{N}_Z = \frac{n}{1-\exp(-2n_2/n_1)}$$

and has been shown to be robust against model misspecifications and latent heterogeneity of the population.

A relatively simple variance formula can be found for $\hat{N}_Z$ [16] and [17].

The estimator is primarily based on the lowest frequency classes (n_1 and n_2): this emphasis on these classes makes sense. People rarely seen (only once or twice) are likely to bear a greater resemblance

to those never seen than those seen very often. In addition, the emphasis on the lower frequency classes makes the estimators robust in the presence of 'heterogeneity', e.g. persons seen very often may form a different subgroup as compared to persons rarely seen. The influence of the persons often seen is weighted down in the estimator and, therefore, heterogeneity, if present, is likely to exercises a relatively minor influence.

Confidence intervals

Estimating variances for the estimator, allows for the calculation of 95% confidence intervals for N by the usual formula:

$$\hat{N} \pm 1.96\sqrt{\text{var}(\hat{N})}$$

To improve the confidence interval estimation for the estimator a log-transformation was proposed [18] and is used in the present application. A capture-recapture study produces an estimate which is the final point of a process in which errors can be introduced at different stages. A confidence interval takes into account only sampling variations and does not take into account the uncertainty related to possible violations of the underlying assumptions. To calculate the variance for the estimator, the new approach proposed by Böhning [16] and [17] has been used, which breaks down the variance into two components: the first component is the binomial variance due to sampling n units from a population of size N , the second one is the variance due to estimation of the model parameters. Thus, this variance takes into account the uncertainty related to various aspect of the estimation procedure.

3. Results.

The various results have been obtained by applying truncated Poisson methods (Zelterman's estimator) and multiplier methods for the various different situations.

Supply side estimation of the market

The first step for estimating the size of the market has been the estimation of the size of the street dealer population, as defined above, using capture-recapture methods with a single data source: the data set of the subjects registered for dealing drugs (art.73). In particular, Zelterman's estimator has been applied [15].

In Table 1 the estimates obtained, together with the data set of the subjects registered for dealing drugs for the period 2005-2009, are reported.

The number of dealers, defined as above, has been estimated also from the data set of imprisoned dealers (art.73) for the years 2007 and 2008. The Zelterman's estimates were respectively 388,959 (2007) and 386,460 (2008), of the same order of magnitude as the estimates from the first data set [10]. It has to be underlined that the estimates are not simply proportional to the number of registered subjects: the estimated number of dealers for 2009 is higher than for 2008, whereas the number of registered subjects is higher in 2008. This is simply due to the recording delay of

administrative data sets. This is one important reason to prefer the dealer population estimate over the observed number of registered dealers as drug supply indicator for evaluation purposes; the former makes use of more information in the data than the latter which may be biased.

Table 1. Zelterman estimates of the population of street dealers and 95% confidence intervals (95%CI), obtained using the data set of individuals registered for dealing drugs for the period 2005-2009.

Year	Observed just once	Observed just twice	Observed more than twice	Total observed	Estimated population size	95%CI
2005	**44,112**	**2,605**	**349**	**43,066**	353,877	337,119-371,895
2006	**42,057**	**2,886**	**394**	**45,337**	359,199	338,906-373,433
2007	**44,663**	**3,075**	**430**	**48,168**	374,891	358,586-392,328
2008	**46,827**	**3,279**	**414**	**50,520**	387,940	371,152-405,932
2009	**44,162**	**2,885**	**314**	**47,361**	389,956	371,694-409,654

It must be noted that the size of uncertainty (explicitly reported in [8]) can be obtained in the last column where 95%CI is reported.

The size of the market can be estimated on the basis of the information about the quantity sold by each dealer per year [11], once the total population of dealers has been disaggregated with respect to the substance dealt.

Unfortunately, the information about the substance sold is not available in the data sets used to estimate the population of dealers, but it is possible to estimate the number of dealers of the various substances of interest using information from the literature [13] and information from the data base of police operations and seizures already used for estimating the parameters of the dynamic model of drug using [6].

Using such information, estimates of the size of the market for the traditional substances are obtained (Table 2).

The possible part time involvement in the drug market and the specific risk for cannabis dealers, as reported in [13], have been included in the calculation. This takes into account the possibility of imprisonment and of being replaced by others in specific periods such as in the paper by Bouchard and Tremblay. The information about the mean and median quantities sold per week of activity, as well as the data on median and mean prices of the various substances, have been obtained from the data of the Survey in the Therapeutic Communities and in the Low Threshold Services 2012.

In particular from the 720 persons of the Italian survey, several gave information on the number of doses sold per week, sample sizes: 91 for cannabis, 164 for cocaine and 156 for opiates. The

persons who dealt higher number of doses have been excluded. In other word it has been decided that those who dealt more than 200 doses per week for cannabis and analogous threshold for the other drogues were not street dealers, according to the suggestion given by the police. Similarly for the price per dose, sample sizes: 351 gave information for cannabis, 387 for cocaine and 504 for opiates. It is interesting that the mean price obtained from this survey is very close to the mean price available from the report of the police.

Having all this data, the total amount of the market has been obtained by multiplying the number of active dealers by 52, by the median number of doses sold per week and by the mean price. The use of the median takes into account the skewness of the distribution of the number of doses sold per week.

Table 2. Market estimation (supply side).

Substance	Estimated active dealers	Median number of doses sold per week of activity	Sample size dose	Mean price per dose	Sample size price	Total amount (billion euro)
Cannabis	125,184	110	91	10	351	7.16
Cocaine	43,991	70	164	75	387	12.01
Opiates	34,206	55	156	35	504	3.42
Total	203,381					22.59

It is important to consider that a user is sometimes also a dealer as it is shown by the results of the survey in the various countries analysed [14]. It must also take into account that utilizing the adaptation model proposed by Bouchard and Tremblay [13] allows to include in a general model the contact between users and dealers (imprisoned or outside).

It is also important to observe that some information in the above table has been compared with similar information from other countries participating in the survey and reported in the book of the survey [19].

It is important to observe the fact that user population has been obtained from dealer population does not imply that there is a necessary dependence as, for example, the number of doses used per month are independent of the sold doses by a dealer.

Of course it might be possible to make sensitivity analysis for the various estimates, but it is not the main interest now.

Demand side estimation of the market

The size of the drug market can be estimated on the basis of demand data using estimates of the various consumer populations and the information about the average number of doses consumed per

month (or per week) provided by general population surveys (or other kinds of surveys) and the prices of the substances given by surveys or by police data.

However, general population surveys in Italy suffer from very low response rates (lower than 25% in recent years) and all the consumer populations are highly underestimated using this data source.

It must thus preferred to estimate active consumers on the basis of the estimates of active dealers and information from the literature about the ratio consumers/dealers for the various substances [13], [8] and [6].

In Table 3 the results of this estimation procedure, using the two ratios provided in the literature and reported in [13], are presented.

Table 3. Active consumer populations estimated on the basis of the active dealer populations.

Substance	Estimated active dealers	Ratio (Reuter)	Ratio (Bouchard & Tremblay)	Estimated active consumers (Reuter)	Estimated active consumers (Bouchard & Tremblay)	Average
Cannabis	125,184	40	32	5,007,360	4,005,888	4,506,624
Cocaine	43,991	25	28	1,099,776	1,231,749	1,165,763
Opiates	34,206	15	16	513,090	547,296	530,193
Total	203,381	These estimates are affected by double counting for poly-use and poly-dealing				

On the basis of the estimated consumer populations and the information about the average number of doses consumed per month and about the mean price per dose of the various substances, provided by the surveys, the size of the market can be estimated (Table 4). It is sufficient to multiply the number of consumers by 12, by the average doses consumed per month and by mean price per dose.

The market value estimates from demand and supply side are quite similar. These results provide a tool to evaluate law enforcement interventions estimating the interception rate, both in term of value of the market and in term of seized substances, as reported below.

The demand side estimate for the cannabis market can furthermore be compared with an estimate of the same market obtained using a different data set and a different methodology. The data set comes from the online survey among cannabis users conducted in 2012 within the framework of the project *Study on the further analysis of the EU illicit drugs market and responses to it – responding to future challenges* [12]. The segmentation of the cannabis user population in three groups (occasional, regular and intensive users) is discussed in [6]. In particular, active cannabis consumers are estimated to be subdivided into 53% occasional, 24% regular and 23% intensive users. This

information, combined with the information on the average dose for the three typologies of users from the online survey, allows to estimate the average amount of cannabis consumed in a year per user. The estimated average consumption per year is 7.8 grams for the occasional users, 106.9 grams for regular users and 372.3 for intensive users [12].

Table 4. Market estimation (demand side).

Substance	Estimated active consumers	Average number of doses per month per person	Mean price per dose	Total amount (billion euro)
Cannabis	4,506,624	13	10	7.03
Cocaine	1,165,763	12	75	12.59
Opiates	530,193	15	35	3.34
Total	6,202,580			22.96

The resulting market estimates are reported in Table 5, together with the estimates of the market obtained using the other two approaches.

Table 5. Estimates of the cannabis market in Italy, obtained using different data sets and methodologies.

Substance	Methodology	Average quantities used for estimation	Total amount per year	Total amount (billion euro)
Cannabis	Supply side estimation	110 doses sold per dealer per week	716,052,480 (doses)	7.16
Cannabis	Demand side estimation	13 doses consumed per user per month	703,033,334 (doses)	7.03
Cannabis	Online survey estimation	115.42 grams consumed per user per year	520,150,035 (grams)	6.03

All the estimates are likely to be conservative. The Zelterman's estimate provides lower bound estimates of the populations of interest. For the supply side market estimate, the median number of doses sold per week has been used instead of the mean because of the right-skewness of the

distribution and, in the web survey, the most intensive consumers are likely underrepresented and the estimated average annual consumption of intensive users is underestimated.

Interception rate estimation

Interception rate is an indicator for evaluating law enforcement interventions. Estimates of interception rates are provided by UNODC at the global level in terms of amount of seized substance in proportion to the estimated production of that substance in the world. Information is also provided for specific areas. In the present contribution, a different approach is proposed. The interception rate is defined in terms of value of the seized substance divided by the value of the retail market for that substance. The value of the seized substance (numerator) is calculated on the basis of the unit value of that substance at the stage just before the retail stage, provided by the police. The global value of the market (denominator) is calculated at retail stage. The rationale of this choice is based on the consideration that the "damage", in term of money lost by traffickers and dealers, can be reasonably evaluated as the money spent to buy the substance to deal. In Table 6 seizure data and estimates of the value of the seized substances are reported together with the interception rates.

Table 6. Seizure data and estimates of the total value of substances seized with respect to the value of the market.

	Seizures 2011				
Substance seized	**Amount (kgs)**	**Unit price on the market (last level before retail)**	**Total value of the substance seized (euros)**	**Retail value of the market (euros)[5]**	**Ratio**
Cocaine	6,346.3	39,000	247,505,700	12,590,000,000	0.020
Heroin	810	24,700	20,007,000	3,340,000,000	0.006
Marijuana	10,907.88	1,360	14,834,717		
Hashish	20,257.57	2,200	44,566,654		
Plants	100,822.8[6]	1,360	13,711,901		
Total cannabis	131,988.25			7,030,000,000	0.010
Total			340,625,972	22,960,000,000	0.017

It is possible to go more in depth for cannabis, evaluating the interception rate also in terms of substance seized over the total of the substance on the market (Table 7) including also the marijuana

[5] Demand side estimates.
[6] It is supposed that a plant provides 100 grams of substance.

represented by whole plants (estimated as 100 gr per plant according to police files), the interception rate is around 20%.

Table 7. Interception rate for cannabis.

Cannabis 2011(included plants)		
Substance seized (Kgs)	Substance on the market (Kgs)	Interception rate
131,988.25	652,138.285	0.202

If plants are not included, then the interception rate is much lower (about 6%). It must be underlined that, as the market estimate is a lower bound, the interception rate estimate is an upper bound.

The same analysis could be conducted for the other substances, but, for this purpose, it would be necessary to include information about purity of the seized substances and purity of the substances at retail level. This analysis for cocaine appears elsewhere [20].

It is important to observe that, once the interception rate has been estimated, if it is possible to assume that it would not change very much for some period, then the amount of substances on the market can be estimated using a simple multiplier method with the estimated interception rate as multiplier, this can be applied to big countries, such as Italy or Germany or others, whereas in small countries the interception rate may easily change.

4. Discussion

Recently, interest in drug supply issues has increased considerably. In Europe, research in these fields is relatively new and systematic information to describe illicit drug markets and trafficking is still limited. The last annual report by EMCDDA [21] on drug related research in Europe shows that studies on supply and markets make up only 5% of all studies.

Drug supply is a key drug policy area that receives a large amount of public funding; however, there is a huge gap in the existing knowledge about the efficacy of interventions and unintended consequences.

Sound supply indicators are needed to provide evidence for understanding drug markets and assessing policies, planning interventions and identifying best practices as underlined in the European Conferences on drug supply indicators [22]. Such indicators should primarily measure, at the European level, the extent of the drug market in all its aspects.

The present contribution illustrates a comprehensive approach to estimating the size of the drug market based on the application of various estimation models and methods to several data sets of various nature. The application to Italian data shows the potentialities of the approach and allows to propose a supply side indicator for evaluating law enforcement interventions.

The starting point is the estimation of the population of active dealers on the basis of administrative data [8]. This hidden population is very important to study as it reacts immediately to modifications of the policy makers' and traffickers' strategies and provides a useful tool for estimating the size of consumer population and the amount of the substances in the market at retail level, once information about dealer behaviour is acquired by means of proper surveys.

The results show that the combined use of several data sets and estimation approaches can be fruitfully used to estimate the size of the drug market and its trends.

The size of the market is one of the proposed indicators for evaluating supply side policies proposed by the second Conference on drug supply indicators [22] and is also the denominator of the interception rate for assessing the outcomes of law enforcement interventions.

The application to the Italian situation also shows how the general population surveys are presently inadequate to estimate the consumer population and to study its behaviours. For instance, the underestimation in recent years reaches 95% under conservative assumptions [8]. On the other hand, it also shows that surveys addressed to specific populations allow to better understand the market from both demand and supply side. Such surveys are also less costly and could be conducted with a shorter periodicity.

Survey data from specific populations are also important per se as they allow to study behaviours, risk factors and concomitant factors that can suggest best practices from demand and supply side interventions and policies aimed at reducing harmful use and risks. Some preliminary analyses aimed at the individuation of best practices are reported in the contributions by Elena Ventura collected in [9].

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