Epidemiology of Illicit Drug Use and Policy Evaluation: the heroin epidemic example

Carla Rossi *Centre for Statistical and Social Studies and University of Rome "Tor Vergata"*

ce3s CENTRO STUDI STATISTICI E SOCIALI

Centro Studi Statistici e Sociali
Via Fidene 19, Roma
http://www.ce3s.eu/

Drug policy monitoring

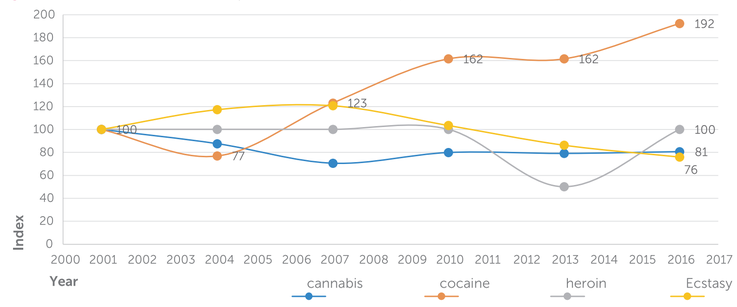
The use of most psychoactive drugs is restricted or considered illicit in most countries so drug consumers and especially drug dealers are forced to conceal their habits; as a consequence, the extent of illicit drug use and the size of the drug market can only be estimated through statistical methods, based on "indirect" measures or indicators.

In order to perform effective analyses on illicit drug supply and use, it is first necessary to have access to reliable data on those different legal, medical and other critical drug-related events that constitutes the visible part of the phenomena (indirect measures). Subsequently, it is necessary to build suitable mathematical models of production processes of such data, linking them to the hidden drug phenomena, in order to investigate these ones. The observational data, available are mostly administrative records (criminal, medical, etc.) deriving from drug laws and policies. They should, indeed, play a role in monitoring national and international drug policies, chiefly on evaluating and forecasting the short or medium term impacts. Some other data are at disposal (drawn from the regular surveys on the general population and on the students) but they are too poor, and so not taken into account, when the aim is to produce estimates and indicators related to the "problematic" use of drugs.

Drug use epidemics and observational data

For over half a century the researchers have recognized the similarities between the spread of drug use and the spread of infectious diseases, the first one being driven by the transmission of knowledge of this 'innovative' social practice (de Alarcón 1969, Hunt and Chambers 1976).
The epidemiological approach makes it possible to model available observational data, relating to the "visible" consequences of drug use, and estimate the hidden part of the phenomenon to carry out the impact assessments of drug policies and short and medium term forecasts (Wiessing et al., 2001).
The main parameters that can be used as indicators are: prevalence, referring to all homogeneous existing cases at a certain time; and incidence, referring to all newly occurring homogeneous cases in a given time span.
Using suitable models it is possible to estimate the prevalence of users and dealers and the incidence of specific consequences as, for instance, deaths or therapy requests or imprisonments. To make forecasts on the progress of the use (or sale) of illegal substances or to carry out scenario analyses, dynamic epidemic models must be used.
The epidemics of infectious diseases and that of drug consumption also share an important qualitative characteristic, the presence of "waves". After an initial eruption a decline and an "endemic" trend follow; then, a new surge appear ("epidemic" wave), in absence of effective control interventions. A disease that spreads by epidemic, if not counteracted with vaccination, indeed recurs with successive waves, at those times when the proportion of "susceptible" subjects increases sufficiently, through births and immigration.
A similar trend, in the absence of effective drug policy interventions, should also be expected from drug use epidemics, particularly with regard to heavier substances, such as heroin.

Figure 1. *Indexed trends of annual prevalence in Australia (time series 2001-2016).*



Source: own elaboration based on data from the National Drug Strategy Household Survey 2016 detailed findings report
https://www.aihw.gov.au/reports/illicit-use-of-drugs/2016-ndshs-detailed/contents/table-of-contents

Focusing on recent prevalence estimates in Australia (**Figure 1**), the comparison of the trends related to the various substances highlights the beginning of the epidemic phase of cocaine use in 2004, while other substances introduced previously are in the endemic trend; but, in 2013, heroin prevalence shows the beginning of a new epidemic wave.

For the last 10-15 years, a second wave of trafficking, selling and use of heroin has developed everywhere in Western countries, as reported in a very recent (June 2019) report of the OECD (Organization for Cooperation Economic and Development).

https://www.oecd.org/health/addressing-problematic-opioid-use-in-oecd-countries-a18286f0-en.htm

There is said that in 25 OECD countries, for which data on mortality are available, the average of deaths from opioid overdoses, and in particular from heroin, increased by more than 20% in the period 2011-2016, with the highest increase in the United States, Canada, Sweden, Norway, Ireland and England and Wales.

Mortality from drug use is a typical visible phenomenon from which useful data are taken for monitoring and evaluating anti-drug laws and policies (EMCDDA DRD indicator).

Of course, not all countries show a similar growth of the market and of the use of opioids (heroin in particular) and its consequences, but, in any case, deaths from heroin (and opioids) overdose, the only important data considered by the OECD, increased almost everywhere from 2011 to 2016:

- Average OECD countries + 21%
- Turkey + 225%
- Sweden + 134%
- Norway + 11%
- Czech Republic + 133%
- Slovakia + 41%
- Lithuania + 85%
- Portugal + 25% ...

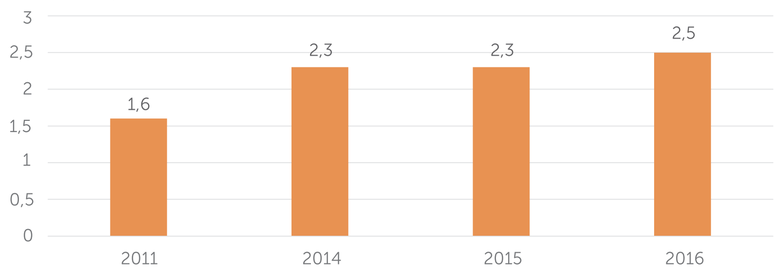
In other countries the data are missing; only in few the overdose deaths are decreasing. In Italy no special increase of overdose deaths is recorded in the period 2011-2016 (OECD data), but a very large increase is observed in 2016-2018 (+24% in 2 years) showing the second epidemic wave of heroin also in Italy.

http://www.emcdda.europa.eu/activities/drd

The second epidemic wave of heroin in Italy begins about 2011

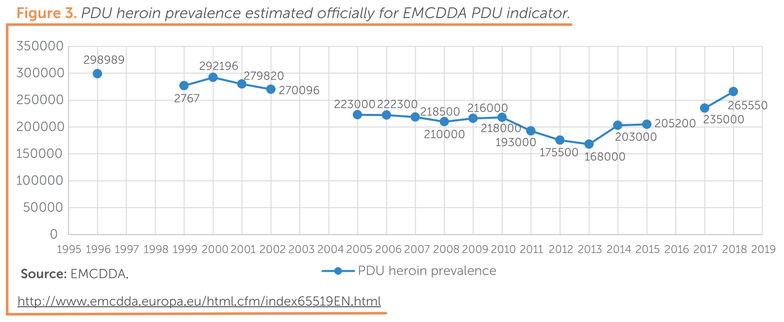
Using further data sources it is clear that in Italy the second heroin epidemic wave started about 2011. In the present context, we show just the market estimate, computed by the Italian National Statistical Institute (Istat), and provided to Eurostat, on the basis of the estimate of prevalence of heroin consumers (**Figure 2**). Other Italian data sets will be described in the oral presentation Application of a preliminary "qualitative" leximetric approach via an example: anti-drug laws, policies and social outcomes in Italy since 2000.
The family expenses increase between 2011 and 2014 (+43.8%), according to the Istat estimate, showing the increase in the heroin market and consequently in the prevalence of heroin users as the retail price of heroin remained constant in the period considered (source: Anti-drug Police Central Services, DCSA). Other heroin market estimates, performed through a different methodology and based on information on seizures and complaints (source: DCSA), also show a growing trend of the heroin market in the period 2011-2014 (+ 40%).
Another important indicator of the prevalence of a "problematic" use is PDU (Problematic Drug Users) which is officially estimated by EU countries and communicated to the European Drug and Drug Addiction Monitoring Centre (EMCDDA). The heroin PDU prevalence estimates (1996-2018) for Italy are reported in **Figure 3**.

Figure 2. *Estimate of the heroin market size regarding family expenses (billions) on the basis of PDU prevalence estimate (retail purchases of heroin).*



Source: National Statistical Institute (Istat).

Figure 3. *PDU heroin prevalence estimated officially for EMCDDA PDU indicator.*



Source: EMCDDA.

http://www.emcdda.europa.eu/html.cfm/index65519EN.html

As can be seen, a phase of decrease or stability lasts until 2013, then a phase of sharp increase begins (second heroin epidemic wave ongoing.Given that this prevalence refers to problematic use, it can be assumed that the second epidemic wave of selling and buying heroin is at least 2 years earlier (about 2010-2011) .

The new heroin epidemic, which could be scientifically forecast and, with adequate policies, limited a lot, shows in general the inadequacy of anti-drug policies in western countries and, in particular, in Italy. Indeed in all the legal contexts in force in Italy since 1990, the political approach has always been analogous of a prohibitive and repressive and even ascientific type (Eranid-IDPSO for Italy).

A country where the second epidemic wave of heroin is not in progress is Switzerland. It is therefore interesting to examine the link between the epidemiological trend of the sale and use of heroin and a specific intervention of the anti-drug policy in Switzerland: the therapeutic treatment of serious heroin addicts with the controlled administration of heroin.

http://www.emcdda.europa.eu/publications/methods/pdu-overview_fr

https://www.eranid.eu/projects/idpso/.

Endemic phase of heroin use in Switzerland

In Switzerland, the heroin endemic phase which follows the "first heroin wave" is still ongoing, as shown in **Figure 4**.
As can be seen, the trend shows, after the first "steep" descent (1995-1999), a period, on average less decreasing and with some small short increases (only 2 years) in the period 2000-2010, then an average constant trend, characteristic of the endemic periods of diffusion of any infectious disease, since 2011.
The second heroin epidemic wave on data relating to opioid overdoses is not observed in Switzerland.
The trend of deaths due to overdoses of young people in Switzerland also suggests that the entry of new subjects, especially young people, into the use of heroin is negligible, given that the users, who suffer a death, are aging (**Figure 5**).
The use of a suitable dynamic epidemic model of the spread of heroin use will allow us to mathematically evaluate the therapy with controlled administration of heroin applied in Switzerland (HAT).

Figure 4. *Trend of deaths due to opioid overdoses in Switzerland.*

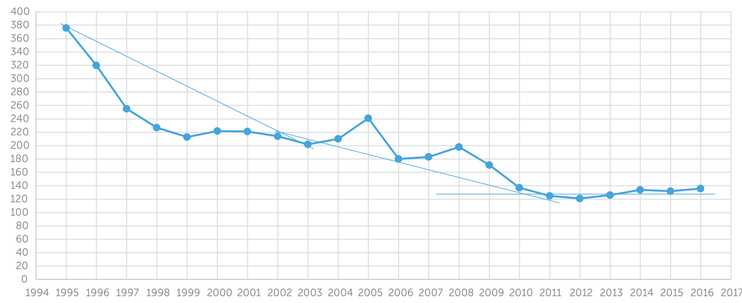
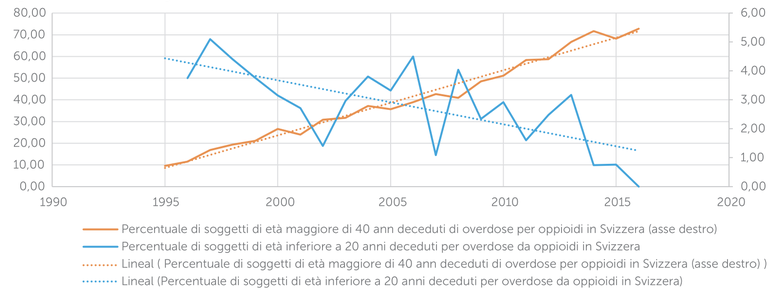


Figure 5. *Trend in the percentage of subjects who died of opioid overdoses in Switzerland under the age of 20 (right axis) and over 40 years.*



Evaluating drug policy by epidemic dynamic models

The methodological tools that allow to evaluate "a priori" and forecast the consequences of situations linked to the drug policy are dynamic mathematical models of the epidemiological phenomenon of drug use.

Such models enable prevalence and incidence to be estimated, scenario analyses to be carried out and trends to be predicted, on the basis of indirect indicators such as therapy presentations, imprisonments, deaths and so forth.

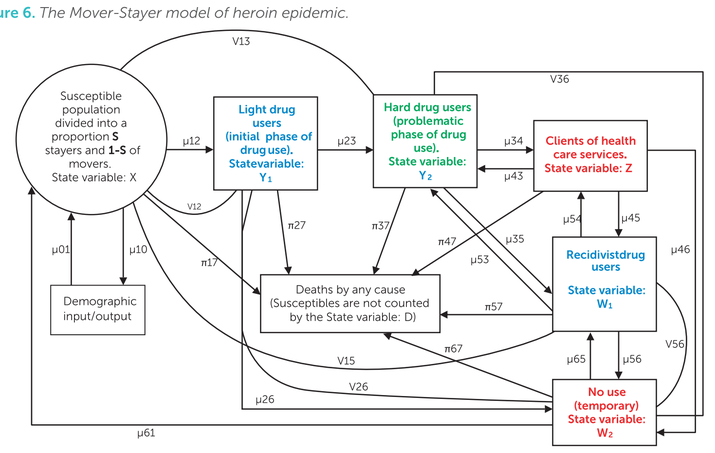
A specific operational model, with an open population (Rossi, 2001, 2004), can be used to explain the trend of the second epidemic wave concerning the supply and use of heroin in western countries. The model can also be used to assess how the specific aspect of Swiss policy, regarding therapeutic assistance HAT to heroin addicts with specific characteristics, has modified there the behaviour of heroin use and supply preventing the development of the second epidemic wave (Rossi, 2019).

Mover-Stayer models with open populations

In models with open populations it is important to subdivide subjects, that are not yet users (susceptibles), into two categories: those that are not likely to be induced into use (such as subjects vaccinated for infectious diseases) and those that risk being induced to use. In formal words the former can be referred to as "stayers" and as "movers" the latter.
A Mover-Stayer model with open populations is used to understand why in Switzerland, where the Heroin Assisted Treatment "HAT" (Uchtenhagen, 2017) is used in general since 1997 as therapeutic intervention for specific heroin addicts (experimentally since 1991), the second heroin epidemic wave is not in progress.
The general scheme of the model is in **Figure 6**.
The population of interest is subdivided into compartments (which group the subjects considered homogeneous by some aspect of interest) indentified by specific variables that enter into the equations of the model. Since the "contagion" between subjects is the critical factor of spread, in the blue compartments the consumer subjects are included who "lure" others on an average modest measure and in the green compartment those that, being problematic consumers, have a strong propensity to involvement of others in consumption for financial reasons. The red compartments contain subjects that are not users; the black compartments regard the population of susceptibles and the subjects entering and leaving any compartment.

A modeller must know how to neglect less relevant aspects to represent the truly relevant aspects in a simpler and more effective way. A good model must limit the number of compartments as much as possible and in this model we neglect, for example, the sex and age of the subjects studied, which influence the phenomenon, but in a negligible way compared to other characteristics, such as use of heroin (problematic yes / no), therapy (yes / no) and, for the population of non-users, being willing (yes / no) to use heroin, i.e

Figure 6. *The Mover-Stayer model of heroin epidemic.*



Mover or Stayer. Another simplification considers non-users the subjects in therapy, who actually partially continue to use drugs.

Variables and parameters

- The variables (X, Y, Z, W) are the measure of the number of subjects with the indicated characteristic, i.e. "prevalence"; the variable D counts the deaths (final exits) from any compartment;
- Considering the population of susceptibles, the variable S measures the share of subjects immune to the use of heroin, the so-called Stayers; the non-immune subjects, the so-called Movers, naturally represent a 1-S quota;
- The arrows indicate the possible status changes of the subjects (passages between compartments due to interactions) and the corresponding mathematical symbols (μ with subscripts) indicate the frequency of passage in a year and constitute crucial "parameters" of the model;
- The curved lines represent the intensities of the compartment passages, by interaction between subjects placed in two different compartments, in particular between users and non-users that are "lured"; the corresponding mathematical symbols (ν, with subscripts) represent the intensity of the interaction (priming for drugs or passage of infection for infectious diseases) and are also parameters of the model;
- The mathematical symbols π, with subscripts, represent the parameters that measure the intensity of death, very different from the different states; for example we know from the VedeTTE study that π_{47} is much smaller than π_{37}.

On the basis of the graph of Figure 6 it is possible to write the equations of the model (a "universal language") and then study them or simulate the trend in correspondence with different values of the parameters, due to hypothetical control interventions. These are the scenario analyses that allow the "a priori" evaluation of anti-drug policy interventions with assumptions about the modification of the parameters.

https://www.studio-vedette.it/Presentazioni.htm.
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1360-0443.2007.02025.x

Drug policy influence on parameter values

Political interventions modify the values of the parameters and, therefore, the trend of the phenomenon envisaged by the model. For example, an intervention such as the Fini-Giovanardi law (2006-2014) decreases the value of μ_{34}, a mathematical translation of the fact that there are more subjects in the compartment of problematic users due to obstacles to entering therapy (art. 75 of the law); and this leads to an increase in the number of subjects with death parameter π_{37}, or overdose deaths (well verified on available data) and, above all, more subjects interested to induce to use non-users higher values of Y_1 and Y_2.

Effectiveness of HAT

To evaluate the anti-drug policy applied in Switzerland, it is necessary to briefly describe the HAT therapy.
Assisted prescription of heroin (HAT) is a therapy aimed at patients with a severe type of heroin addiction and involves, in addition to drug administration, an interdisciplinary treatment approach provided in licensed outpatient or residential facilities.
Patients who can access HAT are heroin-dependent patients, who have tried other methods of treatment that have however proved to be ineffective or patients for whom the health condition does not allow other types of treatment; in order for patients to benefit from the therapy they must be at least 18 years old, have a serious addiction for more than two years, have made at least two attempts at treatment that have proved to be not effective, have psychological and physical problems attributable to the use of the substance.

The impact of HAT is very positive, even in controlling the spread of heroin use. The scientific evidences derive from several specific studies, in particular various "randomized clinical trials", available in the literature and, recently, summarized in RAND (2018) where also epidemiological studies, analysing the influence of HAT on the incidence of heroin use, and then prevalence, are reported. The number of references is there 162.

The very concise summary is that if the HAT is available for the serious heroin addicted subjects, who have not responded to standard therapies, then:

- when such users enter therapy they stay there longer and stop using illicit heroin;
- the subjects in treatment improve their health and the social aspects of their life (quality of life);
- the heroin use incidence decreases, thus the general public health increases;
- other crimes committed to earn money to buy heroin in the illegal market diminish;
- the public expenses for law enforcing, courts and prisons decreases much more than the public expenditure necessary to ensure public and free HAT treatment;
- the profits of the criminal organizations diminish and therefore also investments for recycling.

Taking into account these specific results it is possible to conclude that HAT increases the value of μ_{34} and μ_{54} and decreases that of μ_{45} and these outcomes decrease deaths, Y_1, Y_2 and W_1.
Using the Mover-Stayer model we can obtain the proof of the effectiveness of HAT in blocking the development of the second epidemic wave of heroin.
Working on the model equations, a special indicator, denoted ρ(t), can be obtained from the main variables; it influences the epidemic/endemic trend (Rossi, 2019).
In particular, if ρ(t) is greater than or equal to zero the epidemic does not develop, while if it is less than zero it develops. The expression of ρ(t) depends on the parameters μ_{12} and ν, with any subscript, and on the variables Y_1, Y_2 and W_1. It is greater if parameters and variables are smaller and this happens if HAT is applied, therefore HAT hinders the development of the epidemic trend prolonging instead the endemic trend.

There are also other results, secondary but very positive, from the application of HAT that do not enter directly into the Mover-Stayer model. In particular, the reduction of criminal behavior of addicts subjected to HAT and therefore the reduction of public spending necessary in the field of justice: police, trials and prison and also the reduction of gains of criminal organizations (administrative data support these results) as reported in (Killias and Aebi, 2000) where some observational data are shown. In particular, it has been estimated that the 10% heaviest users of heroin in Switzerland (who fall into the HAT target group) consumed around 50% of all the illicit heroin imported. As a result, the reduction in consumption of illicit heroin by those entering a HAT programme (and the absence of any increase in new users) could substantially reduce the scale of the illicit heroin market, depriving organised criminals of resources.

Conclusions

In the last 20 years, many studies have been published on the efficacy of HAT as a therapy (primary objective), also reporting in various ways sometimes even partially secondary objectives, such as improving public health, criminological consequences, saving public spending and so on.
From all these scientific studies it is possible to derive that in Switzerland ρ(t) values are greater than, or equal to, 0 (endemic phase) whereas in Italy it is always less than 0, as in most other western countries (second epidemic wave). This is why Denmark recently introduced HAT as standard therapy for the serious heroin addicted subjects, who have not responded to standard methadone therapy, following the Swiss protocol.
This is why it is ethical that other countries adopt the same decision introducing HAT as standard therapy for specific heroin addicts.

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We declare no conflict of interest in the present work.