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Volume LX, 2008

Measurement issues in drug policy analysis

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Selected papers from the Third Annual Conference of the International Society for the Study of Drug Policy, held in Vienna on 2 and 3 March 2009

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PREFACE

The *Bulletin on Narcotics* is a United Nations journal that has been in continuous publication since 1949. It is printed in all six official languages of the United Nations—Arabic, Chinese, English, French, Russian and Spanish.

The *Bulletin* provides information on developments in drug control at the local, national, regional and international levels that can be of benefit to the international community.

The present issue of the *Bulletin*, whose guest editor is Martin Bouchard of Simon Fraser University in Canada, is focused on measurement issues in drug policy analysis. It consists of a selection of papers presented at the Third Annual Conference of the International Society for the Study of Drug Policy, held in Vienna on 2 and 3 March 2009.

The United Nations Office on Drugs and Crime wishes to thank Melissa Tullis of the Division for Policy Analysis and Public Affairs and Raggie Johansen of the Studies and Threat Analysis Section for editorial assistance in preparing this issue.

EDITORIAL POLICY AND GUIDELINES FOR PUBLICATION

Individuals and organizations are invited by the Editor to contribute articles to the *Bulletin on Narcotics* dealing with policies, approaches, measures and developments (theoretical and/or practical) relating to various aspects of the drug control effort. Of particular interest are the results of research, studies and practical experience that would provide useful information for policymakers, practitioners and experts, as well as the public at large.

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The following special issues of the *Bulletin* are also available as United Nations publications:

1993

Policy issues relating to drug abuse and the human immunodeficiency virus (HIV) (vol. XLV, No. 1)

Drug testing in the workplace (vol. XLV, No. 2)

1994

The family and drug abuse (vol. XLVI, No. 1)

Special issue on gender and drug abuse (vol. XLVII, Nos. 1 and 2)

1996

Special issue on rapid assessment of drug abuse (vol. XLVIII, Nos. 1 and 2)

1997 and 1998

Double issue on cannabis: recent developments (vol. XLIX, Nos. 1 and 2, and vol. L, Nos. 1 and 2)

1999

Occasional papers (vol. LI, Nos. 1 and 2)

2000

Economic and social costs of substance abuse (vol. LII, Nos. 1 and 2)

2001

Dynamic drug policy: understanding and controlling drug epidemics (vol. LIII, Nos. 1 and 2)

2002

The science of drug abuse epidemiology (vol. LIV, Nos. 1 and 2)

2003

The practice of drug abuse epidemiology (vol. LV, Nos. 1 and 2)

2004

Illicit drug markets (vol. LVI, Nos. 1 and 2)

2005

Science in drug control: the role of laboratory and scientific expertise (vol. LVII, Nos. 1 and 2)

2006

Review of the world cannabis situation (vol. LVIII, Nos. 1 and 2))

2007

A century of international drug control (vol. LIX, Nos. 1 and 2)

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Editorial: measurement issues in drug policy analysis*

Martin Bouchard
Assistant Professor, School of Criminology, Simon Fraser University, Canada

I am pleased to introduce this special issue of the *Bulletin on Narcotics*, which consists of selected papers from the Third Annual Conference of the International Society for the Study of Drug Policy (ISSDP), held in Vienna on 2 and 3 March 2009. The organizers of the ISSDP conferences have always insisted on using this type of publication as a way to disseminate the important work on drug policy that is presented at their meetings, but also to keep stimulating policy research of the highest standards. Selected papers from the first two conferences have been published in *Contemporary Drug Problems* (vol. 35 (2/3), 2008) and the *International Journal of Drug Policy* (vol. 20 (6), 2009).

The publication of these special issues represents a unique opportunity to take the pulse of the field, and this issue of the *Bulletin* is no exception. While the number of research articles selected is relatively small, each one is a prime example of the quality and diversity of research presented at ISSDP conferences. For example, the collection of articles included in this issue contributes to understanding the connections between drugs and crime (Wilkins and Sweetsur), the (dis) organization of drug markets (Costa Storti and De Grauwe), the issue of public expenditures (Vander Laenen, Vandam and De Ruyver) and drug use prevalence in the evaluation of drug policy (Mascioli and Rossi), as well as to the development of drug harm indexes (Attewell and McFadden), an issue that has been the object of a special workshop in Vienna. Although this collection of articles first and foremost illustrates the variety of approaches taken in the analysis of drug policy, all authors share a concern for improving the measures and indicators available to do so. This interest in measurement issues is arguably one of the most important factors for the future of the field.

The special issue opens with Mascioli and Rossi's article ("Capture-recapture methods to estimate prevalence indicators for the evaluation of drug policies") on the measurement of the prevalence of drug users in Italy. The authors make use of capture-recapture methods, which have been shown to provide valid measurements

*The author would like to express his sincere gratitude to Melissa Tullis and Peter Reuter for their generous contributions, and to the reviewers without whom this special issue would not have been possible.

of populations of drug users in a variety of contexts and settings, and innovate over previous studies in a number of ways. First, they use a single data set comprising all individual drug users identified by the Italian police in 2007, avoiding the problem of matching records found in multiple data set capture-recapture studies. Second, they estimate prevalence from three different methods (all with slightly different assumptions), allowing for a proper triangulation of results. Third, they provide separate estimates for males and females and for eight different age groups, including adolescents. They find that the prevalence rates are highest for the 20-24 and 25-29 age groups, but that the capture and recapture rates are highest for adolescent users. In other words, adolescent users are detected and registered at a higher rate than users in other age groups. Because these estimates were derived from police records, these results are of heightened importance for policymakers.

By analysing the concept of public expenditures, the second article, by Vander and others ("Studies on public drug expenditure in Europe: possibilities and limitations"), raises the issue of measurement on the government side, examining how and how much public authorities actually spend on drug policy. The authors first make the important distinction between public (direct expenditures by public authorities), private (expenditures of individuals and private organizations) and external (related to the consequences of drug use) expenditures. Together, the authors argue, these three kinds of expenditure form the total social costs of drugs in society. With a clearer idea of the concepts, the authors then proceed to present the steps that need to be taken in order to estimate public expenditures. Their review of the methodological frameworks used in European studies on public expenditures leads to the identification of five steps: defining the research scope (legal and/or illegal drugs?), identifying the major players responsible for drug policy, collecting the data (top-down or bottom-up approach?), classifying public expenditures (prevention, treatment, law enforcement, etc.) and, finally, calculating the actual expenditures from collected data. The article is essential reading for researchers embarking on public expenditure estimation exercises.

The article by Attewell and McFadden ("Measuring the benefits of drug law enforcement: the development of the Australian Federal Police Drug Harm Index") starts where the previous article left off. The authors document the development of a drug harm index in Australia and examine its utility as a performance measure for the Australian Federal Police. The article raises an important question: are the actions of law enforcement agencies aimed at preventing the importation of illegal drugs effective and, more importantly, what is the appropriate performance measure to answer this question? Assumptions are inevitable in such exercises, and the authors of this paper make an important one: that the drugs seized at the border do not reach drug users and, as such, the costs associated with the use of these drugs could have been avoided. Defined as such, the drug harm index estimates a clear return on investment for each dollar allocated to federal drug law enforcement. The return on investment is especially high for operations involving international partners where the potential for larger seizures is greatest.

One of the greatest harms associated with drug use is the increase in drug-related criminality—the focus of the article by Wilkins and Sweetsur ("The association between the number of days of methamphetamine use and the level of earnings from acquisitive crime among police detainees in New Zealand"). Drawing on the New Zealand version of the Arrestee Drug Abuse Monitoring (ADAM) survey on police detainees, the authors focus on a specific drug (methamphetamine) and its relationship to two money-generating offences (property crime and drug dealing). Several important features make this article worthy of note. First, the main dependent variable (criminal earnings) is a much richer indicator of criminal involvement (and criminal success [1]) than the presence or number of crimes committed, and it is more likely to be directly associated to levels of drug use [2]. Wilkins and Sweetsur find that the number of days over which methamphetamine is used is the strongest predictor of both property crime and drug dealing earnings. Second, the authors control for the effect of other important determinants of earning levels, including the frequency of cannabis and alcohol use. Not only do they find that slightly different predictors are associated with the level of earnings from property crime and from drug dealing, but also that cannabis and alcohol use are significantly related only to the former, not to the latter. The implications for drug policy are straightforward: preventing methamphetamine use—heavy use in particular—has the clear potential to reduce crime.

Although their focus and analysis are completely different, the authors of the closing article of this special issue of the Bulletin ("Modelling disorganized crime: the cannabis market") also deal with the issue of money. Costa Storti and De Grauwe present a fascinating economic analysis of the structure of cannabis markets in industrial countries. They start by emphasizing some of the peculiarities of the cannabis market in comparison to the cocaine or heroin markets, the most important being the decentralization of production leading to a newfound proximity between cannabis producers and users. The objective of the authors is to build a theoretical model that takes these particularities into account. An important assumption of the model is the presence of monopolistic competition, in other words that there are many potential suppliers competing in a market characterized by asymmetric information—a market in which the sellers have a better idea of quality than the buyers. After crafting a model that takes these features into account, the authors use such a model to analyse the effects of two phenomena: a change in remuneration and a change in the number of seizures. Both scenarios have slightly different implications for the market, but both lead to the same overall effect: a decrease in the size of suppliers but a rise in their numbers, which makes for a more competitive market structure. Interestingly, Costa Storti and De Grauwe's model leads to a conclusion that has been offered before in other contexts [3, 4]: past a certain threshold, increases in the intensity of law enforcement may produce diminishing returns by creating a larger number of targets that are increasingly difficult to detect.

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Capture-recapture methods to estimate prevalence indicators for the evaluation of drug policies

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ABSTRACT

In the present paper several capture-recapture procedures in the presence of a single source are compared to estimate the size of the population of drug users that risks being registered for personal drug use under Italian law. It is the first time that this method is used in Italy for this particular subpopulation. Data sets are based on police registration data for the year 2007 and have been provided by the Italian Ministry of the Interior. In order to propose a means of evaluating the impact of demand-reduction policies, particular attention has been devoted to prevalence estimates for the younger age groups (those under 20 years of age), for whom prevalence can be considered as a good proxy for incidence; in fact, incidence indicators are more efficient in assessing the effect of policy intervention but are more difficult to estimate.

Keywords: capture-recapture; truncated Poisson model; heterogeneity; prevalence; incidence; calibration.

Introduction

Historically, capture-recapture procedures have been used to determine the size of an unknown animal population. However, such procedures may be applied more widely, for example to estimate the size of a human population with a certain disease or of a sub-group that is difficult to identify because it is involved in illegal activities.

One such hidden population is that made up of drug users. Estimating the size of this population using the administrative databases available in many countries is important for assessing the effect of anti-drug policies at various

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levels of government. However, new trends in illicit drug markets are challenging for classical methods and definitions, with the main problem being modelling data generation processes in order to estimate the specific subpopulation involved in a given process. In fact, different archives capture different subpopulations of drug users. Data generation processes in each country strongly depend on drug laws and their implementation, and on policy measures. On the basis of the laws and policies implemented, different hidden subpopulations become visible and risk being registered in a database, which means that estimation methods can only be used to measure the size of such subpopulations in relation to the databases available. External information can be used to better specify and estimate the extent of the problem.

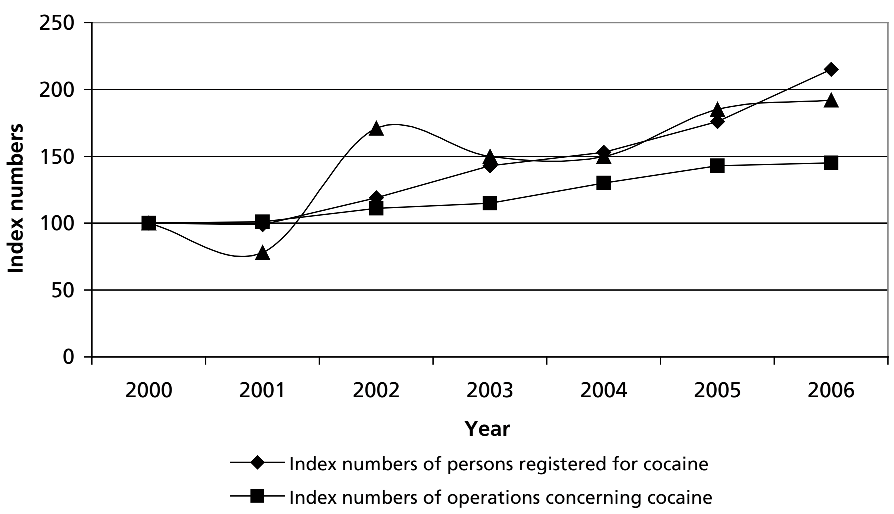
Many capture-recapture contributions in public health use a modelling approach with two or more sources or lists [1-5]. In the field of drug use, these sources are often hospitals, the police, family doctors, etc. If subjects are identified on two or more occasions, estimates of the hidden population are based on the degree of overlap between the resulting data sets.

Another approach involves a single list with repeated entries during the observational period [6-11]. In such an approach, the first step is to count repeated entries of the same user and then to attempt to estimate the frequency of units missed by the sample, using information on the number of people found during the study period in that single list one time, two times, three times and so on. If an appropriate truncated count model can be found and fitted to this type of data, it is possible to estimate the unobserved frequency of zero entries in the list. When the focus is on the population of drug users, police records provide the number of times an individual has been identified; drug users who have never been identified will not appear in the records. Count models differ in the way the count distribution is specified.

In contrast to the multiple-list approach, the one-list approach is less demanding in terms of data requirements, especially as it avoids all the matching problems arising from using different sources. In the literature, this counting approach is commonly classified as a "capture-recapture model". The difference is between studies that examine repeated captures across multiple lists and those that examine repeated captures within a single list. In the field of illicit drug research, the one-list approach has been applied to estimate prevalence of specific subpopulations of drug users, such as opiate users in Rotterdam [12], opiate users in Western Australia [13], injecting drug users in Scotland [14], heroin and methamphetamine users in Bangkok [15], problematic cocaine users in Barcelona [16] and problem drug users in the Netherlands [17].

In this article, a particular application of the multiple captures model within a single data source is presented with the aim of estimating the size of the population of drug users at risk of being registered for personal drug use. This population is "generated" by the current legal framework in Italy, specifically by article 75 of Presidential Decree 309 of October 1990 (D.P.R. 309/90), which prohibits the possession of all drugs.[1] The resulting database makes it possible to follow recent trends in drug markets better than other administrative databases resulting from, for example, data on hospitalizations, arrests for drug-related offences, imprisonments, drug-related deaths and so on, which are commonly employed to estimate the size of the "problem drug user population"[2] or other problematic subpopulations. This is shown clearly in the figure below, where the supply-side indicators are also reported for comparison and show similar behaviour; the example refers to recent trends in the cocaine market. The population studied here is generally younger than that reported in other databases. The main substances used are: cannabis (about 70 per cent), cocaine (about 20 per cent) and synthetic drugs (4 per cent), whereas the problem drug user population in Italy mainly consumes opiates (more than 70 per cent) or cocaine (about 15 per cent). This population is generally not involved in criminal behaviour (either acquisitive crime or drug dealing). The estimates obtained for this specific population lend themselves better to comparison with estimates derived from general population surveys for assessing the implementation and effectiveness of using article 75 of the drug law for the early detection of drug users. The aim of article 75 is dissuasion and secondary prevention for drug users.

Figure I. Supply and demand-related indicators related to cocaine in recent years in Italy (drug users registered for personal use), 2000-2006



[1]Possession of drugs for personal use is punishable by administrative sanctions. A maximum quantity of drugs determines the threshold between personal possession and trafficking. If a person is found in possession of illegal drugs for the first time, administrative sanctions are usually not applied, but the offender receives a warning from the prefect and a formal request to refrain from use.

[2]The term "problem drug use" is defined by the European Monitoring Centre for Drugs and Drug Addiction as "injecting drug use or long duration/regular use of opioids, cocaine and/or amphetamines".

In section II, data sources and the main methodological features are outlined; in section III, the data generation model is presented; in section IV, the results are summarized in tabular and graphical form; and, in section V, conclusions are drawn and further developments are outlined.

Study design

The objective of the study is to apply a capture-recapture method to estimate the prevalence of drug users at risk of being registered for personal possession in Italy during 2007, according to the law presently in force.[3]

The data set has been provided by the Italian Ministry of the Interior and contains various contingency tables with aggregated data on individuals identified by the police in 2007, divided by sex, age and number of times they were registered (once or more than once) during that year. Information on the geographical area (district) in which the registration with the police took place is also available. Individuals can be identified at any time during the period of observation. In our study, individuals were unequivocally identified and recorded.

The procedure involves a single-source capture-recapture analysis in which three different estimators are compared. The three estimators are generated through truncated Poisson modelling. The first is the classical Horvitz-Thompson estimator [18], while the other two, independently, developed by Zelterman [19] and Chao [20, 21], incorporate unobserved heterogeneity, relaxing the assumptions about homogeneity of capture probabilities. The reason for this comparison is that each of the estimators is based on different assumptions and any violation of those assumptions might invalidate the estimates.

To account for observed heterogeneity, stratification by age group, gender or both, is also considered. The geographical covariate will be analysed in a future paper, as the size of the sub-groups obtained including all the observable covariates (age, gender and geographical area) does not permit statistical analysis. Variances and associated confidence intervals have been calculated for the three estimators. The limitations of the methodology applied are also discussed.

Data generation model: the zero-truncated Poisson model

Police records were used to derive count data on how often (once or more than once) each drug user was identified, where repeated identifications can occur at

[3] See www.emcdda.europa.eu/html.cfm/index44943EN.html.

any time during the study period. We do not know the number n_0 of individuals who are identified zero times (individuals who were not identified but had a positive probability of being identified since they belonged to the target population), but can estimate their number from the observed frequencies n_j $(j > 0)$ by assuming that n_j is generated by a Poisson distribution that is truncated below one. Then we were able to estimate the size of the hidden population of target drug users by adding the estimate $\hat{n}_0$ of n_0 to the number of identified drug users, or through calibration.

Let $n_1, n_2, ..., n_k$ be the frequencies of individuals identified 1, 2, ..., *k* times in the time period considered, where *k* denotes the largest count observed, and let $p_1, p_2, ..., p_k$ be the associated probabilities of identifying individuals 1, 2, ..., *k* times. We also denote by n the number of distinct individuals identified, by m the total number of identifications and by N the size of the drug user population at risk of being identified. Then

$$n = \sum_{i=1}^{k} n_i, \quad m = \sum_{i=1}^{k} i n_i, \quad N = n_0 + n_1 + ... + n_k.$$

If p_0 is known, the overall population of drug users can be estimated by means of the Horvitz-Thompson 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 calibration method.

If p_0 is unknown, different approaches lead to different estimates of p_0 and N. We will concentrate on three different estimators suggested in the literature, without providing much detail. These estimators, obtained from data following a Poisson distribution, are subject to the following assumptions:

(a) That the population is closed;

(b) That the individual probabilities of being observed and re-observed are constant during the study period;

(c) That the population of interest is homogeneous.

The first assumption, known as the closure assumption, asserts that the true population size, *N*, is unaffected by migration, birth and death during the period under review. In this particular study, we have chosen a period of one year because we want to estimate the one-year prevalence. Keeping the study period short is one way of addressing the closure assumption. In our case, it is hard to see how the size of the population of drug users could change significantly in a single year.

The second assumption, i.e. constancy of (re)capture probability, does not take into account the possibility of individuals showing a behavioural response to the experience of being registered. Evidently, with respect to the data generating process, this assumption is a restrictive one. Again, one way of dealing with this assumption is to keep the time period under review as short as possible, but not too short, otherwise the number of recaptures is likely to be zero.

Finally, the homogeneity assumption dictates that the probability of being observed and re-observed should not differ too much between different individuals and, in theory, this assumption should not cause too many concerns. The estimators of both Chao and Zelterman considered here are fairly robust, in the sense that both will underestimate the true size of the population in the presence of heterogeneity [21, 22]. So, if heterogeneity is suspected, then it could be assumed that the estimates are in the "lower bounds" of the true population size [23].

It is also possible to stratify the data set and perform a sub-group analysis on groups that are more homogeneous and pool those estimates into a single estimate of N.

All the estimators will produce underestimates of N in the presence of heterogeneity, so we should expect that using regression-type estimators and introducing more covariates will produce a higher estimate of N.

The Horvitz-Thompson estimator under Poisson homogeneity

A traditional approach assumes that the count of each individual is generated by the same Poisson distribution with parameter λ. Then λ can be estimated by maximizing the likelihood for the zero-truncated Poisson distribution. The estimate of $\hat{\lambda}$ of λ leads to the estimate $\hat{p}_0 = e^{-\hat{\lambda}}$ and the Horvitz-Thompson estimator becomes $\hat{N}_{HT} = n/(1-\hat{p}_0)$. The variance of $\hat{N}_{HT}$ can be obtained [8].

To estimate λ, another approach that has been used involves maximizing the likelihood function of the Poisson density via the EM algorithm in the complete data framework [24]. Both approaches applied to our data led to the same estimate for λ, at the chosen level of accuracy. The variance for $\hat{\lambda}$ can be obtained from the log-likelihood function by the standard approach.

Including heterogeneity: the estimators of Zelterman and Chao

The assumption of homogeneity of identification probabilities is rarely met in practice. The simple Poisson model is not flexible enough to capture population heterogeneity and will generally underestimate the size of the population.

Zelterman proposed estimating p_0 using only frequencies n_j, from the zero-truncated count distribution, where j is usually chosen to be 1 or 2. The proposed estimator given by $\hat{N}_Z = \frac{n}{1 - \exp(-2n_2 / n_1)}$ has been shown to be robust against model misspecifications. A relatively simple variance formula can be found for $\hat{N}_Z$ [25, 26].

Chao suggested an estimator for the population based on a mixed Poisson model. Chao's estimator is given by $\hat{N}_C = n + n_1^2 / (2n_2)$ and provides a lower bound for the population size, allowing for population heterogeneity.

As before, a variance formula for $\hat{N}_C$ can be derived [25, 26].

In order to use Chao's and Zelterman's estimators, as only n_1 and $n_{>1}$ were available in the data set provided by the Italian Ministry of the Interior,[4] n_2 was obtained by multiple imputation on the basis of $\hat{\lambda}$.

Both estimators are primarily based on the lower frequency classes (n_1 and n_2). People seen rarely (once or twice) are likely to bear a greater resemblance to those never seen than to 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 sub-group compared to persons seen rarely. The influence of persons seen often is weighted down in both estimators; therefore, heterogeneity, if present, is likely to exercise a relatively minor influence. In practice, the underlying conditions that were assumed for the three estimators and previously discussed are unlikely to hold.

The closure assumption is under control if the study period is short. A study period of one year is generally considered satisfactory, but a six-month period might be better and will be used in a future study as soon as adequate data becomes available.

The constant (re)capture probability is hard to control. If a drug user changes his or her behaviour following identification and if, as a result, the probability of him or her being identified decreases or increases, the independence structure of the Poisson distribution is violated. As already mentioned, one way of dealing with this assumption is to keep the study time period as short as possible. However, using the Chao and Zelterman estimates minimizes the problem. A generalized model could also be developed, but proper information must first be acquired by carrying out surveys among drug users.[5]

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[4]Since the Italian Ministry of the Interior did not provide data specifying exactly how many times individuals were registered, the data generation process was adapted to the data set available.

[5]Some surveys will be conducted in Italy in 2010 for this purpose.

A problem in spatial variation may also exist. At the national level, if there are areas where the police are less likely to identify drug users, then the model fitted to data for the entire country may not be valid. In that case, the population should, if possible, be stratified by geographical area.[6]

Indeed, the approach to estimating drug use prevalence by capture-recapture methods generally performs better at the local level than at the national level, as it minimizes heterogeneity problems [27].

Covariate information

One method to account for observed heterogeneity described in the form of covariates is to stratify the population and then pool the estimates into a single estimate of N. This allows individuals with different characteristics to have different Poisson parameters. It is possible that the probability of being identified for males is different to that of females, or that younger drug users are less likely to be identified.

In this study, demographic variables such as age and gender were considered as important covariates. If all relevant covariates are included, estimators are generally less biased and more precise, but if the strata contain too few data, statistical problems can arise and uncertainties in the estimates increase, thus some compromise is necessary.

Confidence intervals

Estimating variances for the three estimators allows a calculation of 95-per-cent confidence intervals for N, according to the usual formula: $\hat{N} \pm 1.96\sqrt{\mathrm{var}(\hat{N})}$.

To improve the confidence interval for the three estimators, the log transformation proposed by Chao [20] was used. A capture-recapture study produces an estimate that is the final stage of a process in which errors can be introduced at different stages. A confidence interval only takes into account sampling variations, not the uncertainty related to possible violations of the underlying assumptions. To calculate the variance for the three estimators, the new approach proposed by van der Heiden et al. [8] and Böhning [26] was used. That approach breaks down the variance into two components: the binomial variance due to sampling *n* units from a population of size N and the variance due to estimation of the model parameters.

[6]Recent analyses at the local level show that the covariate "geographical area" might have a greater influence than the age and gender covariates used in this paper. An estimated size of 558,000 (Horvitz-Thompson point estimate) has been obtained for the target population.

Main results

Available data refer to subjects identified by the police with a quantity of drugs for "personal use only".[7] In the following tables, data and various estimates of λ and N are reported.

Table 1 presents available data, disaggregated by gender and age, as provided by the Ministry of the Interior in its annual report to the national parliament for 2007. There are significant differences between the numbers of individuals identified in each age group, the highest number being observed in the group aged 20-24. Estimates for λ are also presented.

It must be observed that re-capture rates $(n_{>1}/n_1)$ and estimated values for λ are lower for females than for males in each age group, which means that the female population has a smaller chance of being identified than the male population. The same phenomenon appears in another set of data concerning dealers, analysed by Rossi and Ricci [28].

Table 1. Data on registrations by gender and age, and point estimates for λ

	Data			*Estimates*	
	Males				
Age (years)	n_1	$n_{>1}$	n	*Recapture rate (percentage)*	$\hat{\lambda}$
<15	411	16	427	3.89	0.076
15-17	1 918	65	1 983	3.39	0.067
18-19	3 823	135	3 958	3.53	0.069
20-24	6 916	237	7 153	3.43	0.067
25-29	3 894	86	3 980	2.21	0.043
30-34	2 262	52	2 314	2.30	0.045
35-39	1 543	41	1 584	2.66	0.052
>39	1 195	31	1 226	2.59	0.051
Total	**21 962**	**663**	**22 625**	—	—
No age covariate	21 962	663	22 625	3.02	0.059

[7] See www.emcdda.europa.eu/publications/country-overviews/it.

Table 1. Data on registrations by gender and age, and point estimates for λ *(continued)*

	Data			*Estimates*	
	Females				
Age (years)	n_1	$n_{>1}$	n	*Recapture rate (percentage)*	$\hat{\lambda}$
<15	39	1	40	2.56	0.050
15-17	137	3	140	2.19	0.043
18-19	267	5	272	1.87	0.035
20-24	649	10	659	1.54	0.030
25-29	381	6	387	1.57	0.031
30-34	206	3	209	1.46	0.029
35-39	139	3	142	2.16	0.042
>39	107	1	108	0.93	0.018
Total	**1 925**	**32**	**1 957**	—	—
No age covariate	1 925	32	1 957	1.66	0.032

Confidence intervals based on Horvitz-Thompson estimates (see table 2), can be calculated in two ways: either applying the formula $\hat{N} \pm 1.96\sqrt{\text{var}(\hat{N})}$ after a log transformation or by substituting in the formula $\hat{p}_0 = e^{-\hat{\lambda}}$ the lower and the upper 95-per-cent confidence limits for λ. In either case, the intervals are not symmetrical and this reflects the fact that $\hat{N}$ must be non-negative and is likely to be right-skewed.

Table 2. Accuracy of the Horvitz-Thompson estimates

	CI for λ	*Horvitz-Thompson* $\hat{N}_{HT}$	*CI for N*	*CI for N calculated from λ interval*
	Males			
Age (years)	*95 per cent CI*		*95 per cent CI*	*95 per cent CI*
Age <15	(0.071, 0.081)	5 835	(3 685, 9 401)	(5 485, 6 234)
Age 15-17	(0.065, 0.069)	30 600	(24 203, 38 837)	(29 714, 31 542)
Age 18-19	(0.067, 0.071)	59 364	(50 414, 70 038)	(58 138, 60 645)
Age 20-24	(0.066, 0.068)	110 378	(97 530, 125 051)	(108 671, 112 141)
Age 25-29	(0.042, 0.044)	94 562	(76 905, 116 495)	(92 583, 96 630)
Age 30-34	(0.044, 0.046)	52 588	(40 362, 68 742)	(51 156, 54 104)

Age 35-39	(0.050, 0.054)	31 260	(23 246, 42 240)	(30 242, 32 352)
Age >39	(0.049, 0.053)	24 657	(17 557, 34 845)	(23 748, 25 642)
Total	—	**409 244**	—	**(404 753, 412 013)**
No age covariate	(0.058, 0.06)	394 898	(379 028, 440 084)	(391 423, 398 438)
		Females		
Age (years)	*95 per cent CI*		*95 per cent CI*	*95 per cent CI*
<15	(0.039, 0.061)	820	(187, 4 189)	(677, 1 043)
15-17	(0.038, 0.048)	3 326	(1 225, 9 500)	(2 987, 3 756)
18-19	(0.032, 0.038)	7 908	(3 519, 18 223)	(7 308, 8 618)
20-24	(0.028, 0.032)	22 298	(12 337, 40 755)	(21 177, 23 546)
25-29	(0.029, 0.033)	12 678	(5 997, 27 317)	(11 860, 13 621)
30-34	(0.026, 0.032)	7 312	(2 648, 20 894)	(6 684, 8 073)
35-39	(0.037, 0.047)	3 452	(1 270, 9 862)	(3 102, 3 895)
>39	(0.016, 0.02)	6 054	(1 254, 30 950)	(5 350, 6 975)
Total		**63 478**	—	—
No age covariate	(0.031, 0.033)	62 140	(44 317, 87 461)	(60 290, 64 109)

In table 3, estimated capture rates (n/N_{HT}), estimated capture indexes, defined as $\hat{CapI} = \sqrt{n/\hat{N}_{HT}}$, and 95-per-cent confidence intervals for $CapI$ ($\hat{CapI} \pm 1.96\hat{\sigma}(\hat{CapI})$) are presented. Differences regarding estimated capture indexes between males and females are mostly significant, apart from the case of some younger age groups.

Table 3. Inference on capture rate based on Horvitz-Thompson estimates

		Males		
				CapI
Age (years)	$\hat{N}_{HT}$	*Estimated capture*	*Estimated capture index*	*95 per cent CI*
<15	5 835	7.32	0.27	(0.24, 0.31)
15-17	30 600	6.48	0.25	(0.24, 0.27)
18-19	59 364	6.67	0.26	(0.25, 0.27)
20-24	110 378	6.48	0.25	(0.25, 0.26)
25-29	94 562	4.21	0.21	(0.2, 0.21)
30-34	52 588	4.40	0.21	(0.2, 0.22)
35-39	31 260	5.07	0.23	(0.21, 0.24)
>39	24 657	4.97	0.22	(0.21, 0.24)
Total	**409 244**	**5.53**	**0.24**	**(0.23, 0.24)**
No age covariate	394 898	5.73	0.24	(0.23, 0.24)

Table 3. Inference on capture rate based on Horvitz-Thompson estimates *(continued)*

Females				
Age (years)	$\hat{N}_{HT}$	*Estimated capture*	*Estimated capture index*	*95 per cent CI*
<15	820	4.88	0.22	(0.13, 0.32)
15-17	3 326	4.21	0.21	(0.16, 0.25)
18-19	7 908	3.44	0.19	(0.16, 0.22)
20-24	22 298	2.96	0.17	(0.15, 0.19)
25-29	12 678	3.05	0.17	(0.15, 0.2)
30-34	7 312	2.86	0.17	(0.14, 0.2)
35-39	3 452	4.11	0.2	(0.16, 0.25)
>39	6 054	1.78	0.13	(0.1, 0.17)
Total	**63 849**	**3.07**	**0.18**	**(0.16, 0.19)**
No age covariate	62 140	3.15	0.18	(0.17, 0.19)

To better check this gender effect, the odds ratio for gender was calculated for each age group (see table 4). The *p*-values show that the difference between the sexes, for each age group, is highly significant.

Table 4. Inference on odds ratio for males and females

	Ratio males : females			
Age (years)	*Identified*	*Estimated population*	*odds ratio (males : females)*	*p-value*
<15	10.68	7.11	1.58	0
15-17	14.16	9.20	1.57	0
18-19	14.55	7.51	2.00	0
20-24	10.85	4.95	2.27	0
25-29	10.28	7.46	1.40	0
30-34	11.07	7.19	1.56	0
35-39	11.15	9.05	1.24	0
>39	11.35	4.07	2.88	0
Total	**11.56**	**6.35**	**1.86**	**0**

In order to take into account the unobserved heterogeneity, Chao's and Zelterman's population size estimates were calculated and compared (see table 5). As expected, Zelterman's estimates were always greater than Chao's estimates.

Table 5. Chao's and Zelterman's estimates

Males						
Age (years)	*n*	*Imputed* n_2	*Chao*	*95 per cent CI*	*Zelterman*	*95 per cent CI*
<15	427	13	6 924	(4 147, 11 775)	6 966	(4 497, 10 932)
15-17	1 983	58	33 696	(21 249, 43 429)	33 789	(26 867, 42 638)
18-19	3 958	130	60 171	(50 902, 71 270)	60 199	(50 907, 71 334)
20-24	7 153	209	121 581	(106 490, 138 970)	121 962	(108 009,137 845)
25-29	3 980	78	101 180	(81 380, 126 040)	101 350	(82 559, 124 636)
30-34	2 314	47	56 746	(42 918, 75 284)	56 849	(43 792, 74 016)
35-39	1 584	36	34 651	(25 225, 47 835)	34 744	(26 027, 46 569)
>39	1 226	27	27 671	(19 201, 40 133)	27 749	(19 979, 38 736)
Total	**22 625**		**442 620**	—	**443 608**	—
No age covariate	22 625	587	422 566	(390 700, 457 190)	423 431	(393 226, 456 098)

Females						
Age (years)	*n*	*Imputed* n_2	*Chao*	*95 per cent CI*	*Zelterman*	*95 per cent CI*
<15	40	1	820	(190, 4 085)	820	(176, 4 292)
15-17	140	2	4 832	(1 457, 16 854)	4 865	(2 031, 11 951)
18-19	272	3	12 154	(4 362, 34 793)	12 241	(6 109, 24 813)
20-24	659	8	26 984	(13 939, 52 847)	27 062	(15 537, 47 400)
25-29	387	5	14 903	(6 580, 34 413)	14 939	(7 365, 30 736)
30-34	209	3	7 281	(2 632, 20 850)	7 282	(2 606, 21 071)
35-39	142	2	4 972	(1 498, 17 342)	5 006	(2 074, 12 386)
>39	108	1	5 832	(1 209, 29 861)	5 833	(1 155, 31 395)
Total	**1 957**		**77 778**	—	**78 048**	—
No age covariate	1 957	25	70 580	(48 820, 102 450)	70 747	(51 045, 98 335)

Both Chao's and Zelterman's estimates are greater than the Horvitz-Thompson estimates (except for the estimates regarding the sub-groups of females aged 30-34 and >39) (see table 6). Better estimates can be obtained taking into consideration the observed heterogeneity, whereas neglecting heterogeneity (specifically age) produces underestimation.

Table 6. Comparison of the three population estimates

	Point estimates		
	Males		
Age (years)	*Chao*	*Horvitz-Thompson*	*Zelterman*
<15	6 924	5 835	6 966
15-17	33 696	30 600	33 789
18-19	60 171	59 364	60 199
20-24	121 581	110 378	121 962
25-29	101 180	94 562	101 350
30-34	56 746	52 588	56 849
35-39	34 651	31 260	34 744
>39	27 671	24 657	27 749
Total	**442 620**	**409 244**	**443 608**
No age covariate	422 566	394 898	423 431
	Females		
Age (years)	*Chao*	*Horvitz-Thompson*	*Zelterman*
<15	820	820	820
15-17	4 832	3 326	4 865
18-19	12 154	7 908	12 241
20-24	26 984	22 298	27 062
25-29	14 903	12 678	14 939
30-34	7 281	7 312	7 282
35-39	4 972	3 452	5 006
>39	5 832	6 054	5 833
Total	**77 778**	**63 848**	**78 048**
No age covariate	70 580	62 140	70 747

Prevalence estimates per 1,000 inhabitants in the same age groups are presented in table 7. For the first and last age group, the reference populations are those aged 12-14 and 40-54. The highest relative prevalence is observed for males and females aged 18-19. This reflects the peculiarity of the target population, which is quite different from the problem drug user population, which is usually estimated as being much older.

Table 7. Estimates for *N* per 1,000 inhabitants

	Males		
Age (years)	*Chao*	*Horvitz-Thompson*	*Zelterman*
<15	5.98	5.04	6.02
15-17	37.11	33.70	37.22
18-19	99.44	98.11	99.49
20-24	76.77	69.70	77.02
25-29	54.38	50.82	54.47
30-34	24.77	22.95	24.81
35-39	14.30	12.90	14.34
>39	4.33	3.86	4.34
	Females		
Age (years)	*Chao*	*Horvitz-Thompson*	*Zelterman*
<15	0.75	0.75	0.75
15-17	5.63	3.87	5.67
18-19	21.33	13.88	21.48
20-24	17.68	14.61	17.73
25-29	8.21	6.98	8.23
30-34	3.25	3.26	3.25
35-39	2.09	1.45	2.11
>39	0.90	0.94	0.90

The Ministry of the Interior also provides tables of subjects who were identified one or more times in 2007 but who had been identified for the first time in previous years (table 8). As only a few or zero females were registered for each age group, it is possible to calculate $\hat{N}_{HT}$ only for the total female population. Both re-capture rates and estimated capture rates (based on $\hat{N}_{HT}$) are much higher for these individuals than for individuals identified in 2007 for the first time (tables 1 and 3). This shows that what is being observed is a mixture of at least two different subpopulations of drug users: “old” drug users, i.e. those at risk of being identified for the first time before 2007, and “new” drug users, i.e. those at risk of being identified for the first time in 2007.

Table 8. Gender and, for males, age distribution of previously identified subjects who were identified again in 2007

Males						
Age (years)	n_1	$n_{>1}$	n	*Re-capture rate (percentage)*	$\hat{N}_{HT}$	*Estimated capture rate (percentage)*
<15	11	1	12	9.09	77	15.58
15-17	80	6	86	7.50	657	13.08
18-19	464	45	509	9.70	3 086	16.49
20-24	2 095	144	2 239	6.87	18 353	12.20
25-29	1 792	120	1 912	6.70	15 698	12.18
30-34	1 197	86	1 283	7.18	9 835	13.05
35-39	920	61	981	6.63	8 059	12.17
>39	556	28	584	5.04	6 145	9.50
Total	**7 115**	**491**	**7 606**	**6.90**	**61 910**	**12.29**

Females						
	n_1	$n_{>1}$	n	*Re-capture rate (percentage)*	$\hat{N}_{HT}$	*Estimated capture rate (percentage)*
Total	214	14	228	6.54	1 875	12.16

When comparing the age distributions of the two samples and two estimated populations, the non-homogeneity is evident (table 9). The estimate of the female population identified for the first time before 2007 was obtained by distributing $\hat{N}_{HT} = 1875$ proportionally to the observed age distribution.

Table 9. Age distributions of the registered samples and the estimated populations (percentage)

	Registered sample		*Estimated population*	
Age (years)	*First registration in 2007 (sample size=24,582)*	*First registration in the previous years (sample size=7,834)*	*First registration in 2007 (total=473,092)*	*First registration in the previous years (total=63,785)*
<15	1.90	0.15	1.41	0.12
15-17	8.64	1.10	7.17	1.03
18-19	17.21	6.61	14.22	4.95
20-24	31.78	29.28	28.04	29.48
25-29	17.77	25.16	22.67	25.37
30-34	10.26	16.85	12.66	15.90
35-39	7.02	12.96	7.34	13.07
>39	5.43	7.89	6.49	10.07
Total	**100.00**	**100.00**	**100.00**	**100.00**

The remarkably different behaviour of registered subjects in the first three age groups for the two subpopulations indicates that the estimated prevalence in the younger groups (under 20 years of age) can be used as a proxy for incidence rates in the same age classes. It is well known that incidence rates are preferable to prevalence for evaluating drug policies. Unfortunately, these rates are difficult to estimate, especially for recent years and for non-problem drug users [29]. Thus, being able to estimate prevalence for these age groups is very valuable. In fact:

- Available methods only allow estimates of historical trends for the incidence of opiate use.
- Estimating recent trends for stimulants and new drugs is of much greater interest for policymakers.
- New trends cannot be identified using the same approach and data sets as adopted for (historical) opiate users.
- Incidence estimates can be obtained from prevalence estimates by using information about age.
- Conditional distribution of age at first use can be utilized to allocate prevalent cases to the various years and to estimate incidence.

In other words, we need to make a retrospective projection of the prevalent cases to obtain incidence rates.

Conclusion and further developments

Estimates of the population of drug users are essential for calibrating and assessing drug policy, and the task of calculating these estimates is now of growing interest at the European level. Apart from the special case of problem drug users, the population of drug users has not generated many studies adopting capture-recapture methods in Europe.

This study is a first attempt at deriving estimates for this particular subpopulation of drug users who are at risk of being identified in Italy, so some limitations in the results are to be expected. The analyses we performed should be considered a pilot study that presents initial findings.

In order to apply control measures, administer available resources and establish realistic working objectives, it is important to know as accurately as possible the extent to which the size of the drug user population is being underreported.

Both estimators $\hat{N}_Z$ and $\hat{N}_C$ appear to be fairly realistic with respect to underlying assumptions, but we are not sure if the constant recapture assumption is met for each individual over time. How does the violation of this hypothesis affect the results? Analysing patterns over a shorter time interval, for example six months, might produce a better estimate than using data for an entire year. With classical truncated Poisson analyses, the time period is believed to exert a strong effect on the prevalence estimates, but most prevalence estimates across Europe have used a one year period.

The methods that can be utilized to estimate prevalence depend heavily on the nature of the available data. Although there should be flexibility in the choice of methods, there are perhaps some methods that provide more robust estimates than others, so we compared three different methodologies so as to be able to select the best estimate.

Both Chao's and Zelterman's estimators produced about the same estimates of N, for each age group and for the total population. $\hat{N}_Z$ is slightly greater, acting as a sort of "upper bound" estimator, which was expected.

Both Chao's and Zelterman's estimators perform better than the Horvitz-Thompson estimator, which cannot handle heterogeneity. The assumption of heterogeneity in the population will not severely affect $\hat{N}_C$ and $\hat{N}_Z$ robust estimators, but will result in underestimation of the true N by $\hat{N}_{HT}$.

Truncated Poisson estimators are only capable of estimating the size of the group of individuals who have a latent non-zero probability of being identified. Therefore, the results based on these estimators cannot be generalized to the whole population of drug users. On the basis of the last general population survey,[8] the estimated population of drug users in Italy was about 3 million in 2007 (2.5 million of whom were cannabis users), so we can say that at least 80 per cent of the drug user population has a zero probability of being identified.

In Italy, it is difficult to organize data sources with compatible identifiers. Moreover, different data sources in general correspond to different target populations and the database based on article 75 of the relevant law is not homogeneous with the other databases generally available for estimating the problem drug user population.

The present study on the prevalence of drug use, which is based on a single source, is more accurate than a study based on repeated identification across multiple sources for our target population. In the presence of observed and unobserved between-subject heterogeneity, estimators derived from mixture-models could be an improvement over Chao's and Zelterman's estimators, and this could indicate a future development for Italian data. Including further covariates (such

[8]See www.governo.it/GovernoInforma/Dossier/relazione_droga_2008/relazione_droga_2008.pdf.

as geographical, behavioural, main substance, polydrug use) could also produce more accurate estimates. Preliminary analyses performed on these data and based on geographical strata show that these covariates might be more important than gender and age.

Presently, work is in progress to separately analyse data from the largest metropolitan areas and small cities and districts in order to incorporate latent information about the lifestyle linked to metropolitan and small areas. Information about the main substance of use will also be considered.

Future work should also concentrate on developing data sources with compatible identifiers so that capture-recapture studies can examine repeated identifications across multiple sources.

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Studies on public drug expenditure in Europe: possibilities and limitations

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ABSTRACT

The number of studies on public expenditure is growing in view of the growing importance of the evaluation of drug policies. Public expenditure is an important indicator of government efforts to tackle the drug problem.

Studying public expenditure and comparing the methodology and the results of existing research is challenging. In the present article, the concepts and methodologies used in studies of public expenditure are reviewed. Public expenditure and social cost models are compared to determine their scope. The possibilities and limitations of studying drug budgets are discussed. A workable methodology for estimating public expenditure on drugs is proposed.

Introduction

Since the 1990s, the evaluation of drug policy and policy programmes has become increasingly important in western societies. An essential step in the evaluation of drug policy is the estimation of public expenditure, since that makes it possible to evaluate the commitments of governments in the field of drug policy.

Canada and the United States of America have a long tradition of studying public expenditure on drugs [1-9]. Since the start of the decade of the 2000s, the importance of this research theme has been increasingly recognized by researchers and policymakers in Europe as well [10, 11]. The European Union action plan on drugs for the period 2000-2004 stated that evaluation was to be an integral part of the European approach to the drug phenomenon and that the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) should be an important contributor to that evaluation. Since 2001, EMCDDA has underlined the importance of studies on public expenditure on drug policy in States members of the European Union. In the most recent European Union action plans on drugs, for the periods 2005-2008 and 2009-2012, the estimation of public expenditure became one of the special points of interest.

The first European studies on public expenditure on drugs were published in Sweden [12] and Luxembourg [13]. Since then, studies have followed in the Netherlands [14], Belgium [15, 16], France [17] and Germany [18]. Parallel to the studies of national public expenditure, some studies have tried to compare public expenditure on drugs in all European Union member States [19, 20]. In 2004, Reuter, Ramstedt and Rigter proposed guidelines for the estimation of public expenditure on drug policy throughout the European Union [21].

Studying public expenditure, in particular comparing the methodology and the results of existing studies conducted in different countries of the European Union, is challenging. The existing studies use differing definitions of public expenditure, and consequently, the object of analysis and the methodology applied differ.

The aim of the present article is to untangle the existing confusion with regard to public expenditure studies in the European Union. To that end, this article reviews the concepts and methodologies used in studies on European public expenditure on drug policy. Such an undertaking might stimulate the development of evidence-based policies in the European Union.

Method

The objective of the present article is to clarify the concept of public expenditure and examine existing methodologies used to calculate public expenditure on drug policy in the European Union. To that end, European studies dealing with the estimation of public expenditure were searched for by consulting search engines and online scientific databases. The databases of the Web of Science, PubMed and Sociological Abstracts were consulted. In addition, the websites of EMCDDA and the World Health Organization were searched. The terms "public expenditure", "public expenditure study", "public expenditure drugs", "public expenditure on drug policy", "budget", "spending", in combination with the terms "drugs" and "substances", were used to screen the databases. Time periods were not determined. The focus was placed on studies estimating public expenditures in European countries.

The search resulted in the identification of 10 studies on public expenditure [12-21]. Table 1 presents an overview of the studies reviewed in this article.

Table 1. Ten studies on public expenditure in Europe

Study	*Countries studied*	*Research scope*	*Methodology (a) Collection of data (b) Classification*	*Results, division of the public expenditures*
Origer (2002)	Luxembourg	Illicit drugs	*(a)* Top-down approach. *(b)* Demand and harm reduction, supply-side reduction, research, European Union drug budget.	Demand and harm reduction: 59%; supply-side reduction: 39%; research: 1%; European Union drug budget: 1%.
Kopp and Fenoglio (2003)	European Union	Illicit drugs	*(a)* Bottom-up approach. *(b)* Health care and law enforcement.	Health care: 25-30%; law enforcement: 70-75%.
Ramstedt (2004)	Sweden	Illicit drugs	*(a)* Top-down approach. *(b)* Prevention, treatment, harm reduction, law enforcement.	Treatment: 24%; enforcement: 75%; prevention: 1%; harm reduction: 0%.
Rigter (2004)	Netherlands	Illicit drugs	*(a)* Top-down approach. *(b)* Prevention, treatment, harm reduction, law enforcement.	Under its drugs policy, the Netherlands spends much more on enforcement than on prevention, treatment and harm reduction combined.
De Ruyver, Casselman and Pele (2004)	Belgium	Illicit drugs	*(a)* Bottom-up and top-down approaches. *(b)* Research/epidemiology, prevention, treatment, law enforcement, policy.	Research/epidemiology: 1%; prevention: 4%; treatment: 38%; law enforcement: 54%, policy: 3%.
Postma (2004)	European Union	Illicit drugs	*(a)* Bottom-up and top-down approaches. *(b)* Prevention and research, treatment, law enforcement, cost of illness.	High-quality information on drug expenditure is urgently needed but is lacking in many countries.

Table 1. Ten studies on public expenditure in Europe *(continued)*

Study	*Countries studied*	*Research scope*	*Methodology (a) Collection of data (b) Classification*	*Results, division of the public expenditures*
Reuter, Ramstedt and Rigter (2004)	European Union	Illicit drugs	*(a)* Top-down approach. *(b)* Prevention, treatment, harm reduction, law enforcement.	The precision of current expenditure estimates is very low. Comparisons of the expenditure estimates of different countries lack credibility.
Kopp and Fenoglio (2006)	France	Illicit drugs, alcohol and tobacco	*(a)* Top-down approach. *(b)* Classification according to different ministries, police forces.	Illicit drugs: 80.24%; alcohol: 15.08%; tobacco 4.69%.
De Ruyver and others (2007)	Belgium	Illicit drugs	*(a)* Bottom-up and top-down approaches. (b) Prevention, treatment, law enforcement, others.	Prevention: 3.82%; treatment: 39.58%; law enforcement: 56.24%; other: 0.36%.
Mostardt and others (2010)	Germany	Illicit drugs	*(a)* Top-down approach. *(b)* Classification of the Functions of Government (COFOG).	Public order and safety: 65-70%; health: 30-35%; general public services: <1%.

Results

On the basis of the review of European public expenditure studies, it is clear that there is no common understanding of the meaning of "public expenditure" in the European Union. Very different concepts are used interchangeably, or the same terminology is used but with definitions and interpretations that can differ widely [20].

Definition of public expenditure in reviewed studies in Europe

The drug phenomenon is multidimensional, consisting of many aspects ranging from health (e.g. epidemiology, prevention and treatment) and legal problems, drug-related crime and security issues (e.g. use of drugs in traffic and drug-related public nuisance) to economic problems (e.g. loss of productivity and absenteeism in the workplace). All these different problems bear costs for the individual and the community [15]. A part of those costs is borne by the public authorities responsible for the different policy areas in the field of drugs. The key element in public expenditure is the financial contribution of public authorities to drug policy [13, 16, 17]. European studies on public expenditure use different concepts and definitions to define the term "public expenditure". In order to compare public expenditure studies throughout Europe, it is important to be clear about the conceptual framework used. It is equally important to define which areas of expenditure lie within and outside the scope of a given public expenditure study. This implies that a public expenditure analysis proceeds from the perspective of the different public authorities that are competent for the respective aspects of the drug policy [16, 20].

Kopp and Fenoglio [17] and Origer [13] refer to expenditure emanating from the public authorities and used for the different policy sectors of the drug policy (law enforcement, treatment, prevention).

Kopp and Fenoglio and De Ruyver and others define the term "drug budget" as being synonymous with public expenditure on drug policy [16, 19, 22]. The drug budget of the public authorities at each different level of competency is analysed. European States are characterized by their various State structures, and those authors stress the importance of taking into account the different levels of competence (national, regional and local) in estimating public expenditure, because in each country the division of areas of competence in the field of drug issues differs and is spread over different policy domains (epidemiology, prevention, treatment, law enforcement). Given the different State structures of France and Germany, for instance, we would not be able to compare the public expenditure of those two countries if we count only expenditure stemming from the national Government.

The key criterion in determining what counts as public expenditure for drug policy is whether the expenditure is directly related to drug policy actions [12, 13, 15, 16, 20]. Such expenditure can be described as investments or budget lines of public authorities for actions expressly and directly aimed at implementing drug policy. Postma states that public expenditures are a part of the “direct costs such as expenditures on prevention, research, treatment, rehabilitation, law enforcement and cost of illness” [20, p. 9]. Ramstedt defines public expenditure as “specific expenditures” or “expenditures directly related to actions targeted at some drug-related consequences or [...] prevention” [12, p. 330]. Origer excludes the indirect costs and the costs of indirect consequences and defines public expenditures as direct costs only [13]. De Ruyver and others refer to “expenditures expressly and directly labelled for drug policy actions” [16, p. 5].

Consequently, expenditures related to the consequences of drug use are excluded in most European public expenditure studies [13, 15, 16, 17]. Those excluded expenditures are referred to as “external expenditures”. Two categories of external expenditure are distinguished: *(a)* external expenditure that is not explicitly aimed at drug policy actions but that indirectly supports the drug policy (e.g. expenditure on drug-related crime such as theft, and spending on drug-related treatment such as treatment of infections contracted through use of contaminated needles); and *(b)* external expenditure arising from loss of productivity and absenteeism in the workplace.

Some authors, however, include a certain degree of external expenditure. Ramstedt and Rigter, both as cited in Reuter, Ramstedt and Rigter (2004), and Postma (2004) include specific consequences of the drug problem [20, 21]. Postma includes the cost of illness for drug-related diseases (such as infections, heart disease, retroviruses and mental disorders) in his analysis. In the studies of Ramstedt (2004) and Rigter (2004), expenditures relating to the consequences ofthe drug problem are limited to drug-related crime such as theft, robbery and traffic offences, and treatment [12, 14]. Ramstedt explicitly states that in addition to the estimation of “specific expenditures”, he also considers “a broader definition of costs where expenditures not specifically defined as drug-related but nevertheless connected to the drug policy are taken into account (e.g. other criminality or morbidity among drug abusers)” [12, p. 330].

Obviously, comparisons between studies including external expenditures and studies not including external expenditures are meaningless if the studies of the former group do not clearly indicate the amount of such expenditure.

The concept of external expenditure is not always presented in studies. Such studies may refer rather implicitly to external expenditure by stating that the various governmental agencies and the drug budget spent by public authorities are the key elements of public expenditure and that consequently, expenditure that goes beyond calculating the drug budget is excluded [12, 14, 19, 21].

In line with the definition of public expenditure, private expenditure is excluded from studies of public expenditure. Private expenditure is the spending of individuals and private organizations, such as the expenditure of drug users and the expenditure of charity funds [14-16].

In studies of public expenditure in Europe, public expenditure is partly defined by distinguishing public expenditure analysis from social cost analysis. Public expenditure is one element of the social cost of the drug problem. The sum of public expenditure, private expenditure and external expenditure constitute the total social cost of drugs in society (see table 2) [13, 15-17, 22, 23].

Table 2. Concept of public expenditure

Public expenditure +	*Private expenditure +*	*External expenditure*	*= Social cost*
Direct expenditure by public authorities on drug policy actions, e.g. street-corner work, prevention work, drug treatment, guidance for drug users, reintegration programmes (employment) for (former) drug users, expenditure for personnel such as police officers working in drug investigation units, customs officers specialized in detecting drug trafficking and magistrates dealing with drug cases, expenditure for drug coordinators, expenditure on research, annual financial contributions to the Pompidou Group of the Council of Europe.	Expenditure of individuals and private organizations, e.g. expenditure of drug users, expenditure by private organizations not subsidized by public authorities and expenditure of charity funds.	Expenditure related to the consequences of drug use, e.g. expenditure on drug-related nuisance, drug-related crime such as theft, robbery, traffic offences committed by drug users, expenditure on the treatment of infections due to contaminated needles, treatment of illness contracted through drug use, such as AIDS and hepatitis, expenditure due to loss of productivity, absenteeism in the workplace.	Total expenditure on the drug problem at the expense of the community.

Methodological frameworks used in the European studies reviewed

The following section describes the various methodological steps taken to estimate public expenditure, drawing on the studies reviewed. As shown, the methodological steps taken and choices made vary from study to study.

Step I. Defining the research scope

In the public expenditure studies reviewed, the scope of research is limited to illicit drugs, with the single exception of the study of Kopp and Fenoglio (2006), which also focuses on alcohol and tobacco [17].

There are good arguments for broadening the scope of research to include licit drugs in public expenditure studies [24]. First, the drug phenomenon is considered a health problem. The distinction between legal and illegal drugs is relevant only from a juridical-criminological point of view. Second, with respect to calculating the total cost of drugs to society, studies show that, for the greater part, costs are related to the alcohol problem, followed by tobacco and, finally, by illicit drugs [23, 25, 26, 27].

Step II. Identifying the major players responsible for drug policy

In a public expenditure study, insight is needed into where the expenditure stems from. To that end, the major players involved in drug policy have to be identified.

Thus, the public authorities competent for aspects of the drug policy are identified. This is important since the specific State and governmental structure in each country differs [15, 16, 19]. The reviewed studies take into account the specific State and governmental structure and analyse expenditure on drug policy by the different public authorities responsible for the policy areas.

In addition to the identification of the public authorities involved in drug policy, the organizations working in the drug field can also be identified. Once those organizations are identified, information can be collected on the financial means of the private (non-governmental) organizations and public organizations and the public authority responsible for their payment. The studies of Kopp and Fenoglio (2003) and De Ruyver and others are the only ones to identify those organizations [15, 16, 19].

Step III. Collection of data: top-down and bottom-up approaches

Once the sources of the expenditure are known, one can start collecting data on budgets. To do so, two methods of analysis are used: a top-down approach and a bottom-up approach. The top-down approach starts with the resources or overall budgets made available by the various public authorities involved in the drug policy. Data on the public authorities' drug budgets are collected, and the budget lines of the public administrations are analysed [15, 16, 20]. The top-down approach has the advantage of not relying on secondary data: the budgets can be retrieved and analysed directly.

The bottom-up approach starts with the activities carried out in the work field and traces the money flow back to the funding from public authorities. Data are examined on the basis of the means of the private (non-governmental) organizations and public organizations and yearly reports, complemented by questionnaires and interviews with those organizations [15, 16]. The bottom-up approach allows for a detailed identification of the existing activities in the work field and the public authority responsible for payment.

The advantage of combining the top-down and bottom-up approaches is that it makes verification possible: the data gathered using the top-down approach can be double-checked and completed with the data retrieved from the project actors in the field.

Most public expenditure studies apply a top-down approach. The only study that is exclusively bottom-up is the study of Kopp and Fenoglio (2003) [19]. The Belgian studies of De Ruyver and others are the only studies that combine both approaches [15, 16].

Step IV. Classification of public expenditure

The classification of expenditure is needed in order to gain insight into the sources and the purpose for which the expenditure is intended [21].

As is the case with the definition of public expenditure, differences were found in the studies reviewed with regard to classification according to drug policy sectors.

In the public expenditure studies of Ramstedt (2004), Rigter (2004) and Reuter, Ramstedt and Rigter (2004), expenditure is classified according to the conventional drug policy areas or sectors: “prevention”, “treatment”, “harm reduction” and “law enforcement” [12, 14, 21]. Postma (2004) makes use of the sectors of prevention, treatment and enforcement but creates an additional sector: the cost of illness [20]. In the study of Kopp and Fenoglio (2003), the only distinction is between expenditure related to health care and that related to law enforcement [19]. The studies of Origer and Mostardt and others do not classify expenditure according to the conventional drug policy areas [13, 18]. Origer classifies public expenditure using the categories of spending for demand reduction and that for harm reduction, expenditure for supply-side reduction, expenditure for research and expenditure for the European Union drug budget [13]. Mostardt and others use the Classification of the Functions of Government (COFOG) classification* and therefore make a distinction between general public services, public order and safety, health and social protection [18].

In the studies of De Ruyver and others, expenditure on harm reduction is not presented as an independent sector but is allocated to the sector of “treatment” [15, 16]. Rigter (as cited in Reuter, Ramstedt and Rigter (2004)) underlines that harm reduction is difficult to define and that some policy actions included in the sectors of prevention and treatment overlap with the harm reduction sector [21]. Moreover, it is not always feasible to separate harm reduction aspects from a treatment programme [28]. This is, for instance, the case for low-threshold methadone

*Classification of the Functions of Government (COFOG) is a detailed classification of functions or socio-economic objectives that general government units aim to achieve through a range of outlays. COFOG is used for making international comparisons within the European Union.

maintenance programmes. A political reason for not studying a harm reduction sector separately may be found in the drug policy aims or intentions of the public authorities. In the drug budget of Sweden, for example, no data on harm reduction as such are available since the goal of a drug-free society is being pursued, and consequently, harm reduction as an outcome is explicitly rejected [29]. Nonetheless, this does not imply that specific harm reduction programmes are non-existent.

Reuter, Ramstedt and Rigter (2004) suggest that it could be useful to split up the conventional sectors into narrower categories, and they point to expenditure on law enforcement, where distinctions can be made between the different levels of the criminal justice system [21]. The two Belgian studies of De Ruyver and others present the results of expenditure on law enforcement according to the different levels of the criminal justice system [15, 16]. All the other studies reviewed contain data collected on expenditure at the different levels of the criminal justice system but do not present the results separately.

Some expenditure cannot be attributed to a conventional policy sector because the purpose of the expenditure does not correspond to any of those sectors [15, 16, 29]. In the Belgian study of De Ruyver and others (2007), the category of "other" is created. This is merely a miscellaneous sector designated for expenditure that cannot be classified under the conventional sectors. Examples are expenditure for drug coordinators and expenditure on non-sector-related research and policy [16].

Studies also differ with respect to the classification of similar expenditures in different policy sectors. Kopp and Fenoglio (2003) point out that treatment of detainees may be classified under treatment in one country and under law enforcement in another [19]. In the study of Rigter (2006), expenditure on treatment programmes for drug users in prison is classified as belonging to the sector of treatment [30]. In the other reviewed studies, it is not explicitly indicated whether prison-based treatment is allocated to the sector of treatment or the sector of law enforcement. Rigter (as cited in Reuter, Ramstedt and Rigter (2004)) refers to expenditure on social cohesion and public safety [21]. This expenditure is intended to protect the community against nuisance caused by drug users and drug dealers. Rigter classified this expenditure under the sector of treatment although he acknowledges that such spending could have been classified as law enforcement. The starting point for deciding to which sector expenditure should be allocated is to determine the intended purpose of that expenditure. Following this line of reasoning, expenditure on the treatment of detainees should be allocated to the sector of treatment.

Step V. Calculating the data

The vast majority of expenditure intended for illicit drugs is embedded in expenditure intended for broader policy domains. Kopp and Fenoglio found that

90 per cent of the drug budget in the European Union reflects spending by bodies not specialized in the drug issue [23].

Some expenditure is exclusively used for initiatives on illegal drugs, e.g. syringe-exchange programmes. To estimate such expenditure, no additional calculation is needed, as the results obtained are drug-specific forms of expenditure.

Because public expenditure on drug policy is often embedded in policy projects with broader objectives, it is important to look beyond the expenditure used exclusively for drug policy and include spending intended for broader policy domains. For example, in the budget of the Ministry of Justice, the expenditure component intended for dealing with drug offences has to be isolated from the total budget spent on the criminal justice system [19, 23]. In this respect, EMCDDA refers to "labelled" and "non-labelled" expenditure [31].

All the reviewed studies attempt to estimate these two types of public expenditure. Nevertheless, all studies emphasize the difficulty in calculating expenditure that is embedded in a broader budgetary structure.

The application of repartition keys is needed to isolate spending embedded into a broader budgetary structure. Kopp and Fenoglio point out that there is no general methodology to determine repartition keys. Determination of the repartition key depends on the case (on the basis of information from registration systems, annual reports, contacts with the work field, etc.) [32]. Use of a repartition key is required, for instance, in the case of health promotion. To isolate public expenditure on illicit drugs in this budget, the number of projects for the prevention of illicit drug use is divided by the total number of prevention projects. This calculation produces a percentage that reflects the proportion of projects designated for illicit drugs. However, when estimating expenditure on all drugs, regardless of their legal status, a repartition key is no longer needed in the case of health promotion. Another example of where the use of a repartition key is needed is in estimating the expenditure on enforcement by police, judicial and customs authorities. The repartition key can be formulated as the fraction of the total number of offences that are offences related to violations of drug laws. For example, in the study of De Ruyver and others (2007), the drug-related expenditure of the local police in the sector of enforcement is calculated as follows [16]:

$$\textit{total budget of local police x} \; \frac{\textit{number of registered "narcotic substance" offences}}{\textit{number of all registered offences}}$$

In this case, the total budget of the local police is multiplied by the repartition key, namely, the fraction of total registered offences that are drug-related registered offences. The result of this formula gives us the public expenditure made by the local police with respect to drug policy. In this method, the proportion of working hours of police staff devoted to criminal cases has to be calculated in order to determine the proportion of working hours spent on violations of drug laws [15, 16, 23]. The repartition key method ensures that all resources deployed—personnel, overhead, equipment and operation—are taken into account [33]. A disadvantage of this method is that it implicitly assumes that the expenditure per unit of activity is the same for all activities (e.g. the expenditure related to a drug user is equal to the expenditure for other clients and the expenditure for a drug case is equal to the expenditure for cases of other types). Differences in the expenditure per unit of activity are ignored [12, 21]. It is therefore essential to study whether the investment in terms of working hours for the treatment of drug users and other clients is comparable [16].

In some cases, it is impossible to apply a repartition key as no detailed data on budgets are available. In such cases, a calculation on the basis of unit expenditure is required [16]. This type of calculation is used, for example, in studies to measure public expenditure for the hospitalization of drug users in a non-drug-specific service. The average expenditure for hospitalization per day is multiplied by the average number of days a drug user is hospitalized. However, this method should be used with caution, since the researcher, in order to determine a unit expenditure, has to depend on the institutions/actors involved, leading to a possible contestation of the reliability of the data. Secondly, the determination of unit expenditure is restricted to spending on personnel.

All the studies reviewed make use of repartition keys to estimate expenditure intended for broader policy domains. When no detailed data are available, studies fall back on the use of unit expenditure. Both methods have disadvantages, and therefore the results can be treated only as estimates of public expenditure.

Discussion

Research into public expenditure in Europe is gaining momentum, in view of the growing realization of the importance of the evaluation of drug policy. Public expenditure is an indication of the resources dedicated by government to drug policy and shows whether a Government's priorities for that drug policy are reflected in the corresponding budget. The study of drug budgets does not enable researchers to draw conclusions about the level (or change in the level) of drug consumption in a given region or country. Rather, they inform us of the priorities that a Government has set. A drug budget provides insight into the level of public expenditure in the drug field and into the composition of those expenditures, in other words, the so-called "policy mix" decided on by the public authorities. Consequently, the prevailing balance between the various sectors of illicit drug policy (prevention, treatment and law enforcement) also becomes visible. In the Belgian Federal Drug Policy Note of 2001, for example, prevention is said to be the priority in drug policy, followed by treatment and, as a last resort, law enforcement. In fact, with regard to public expenditure, the opposite became clear from the public expenditure studies: the most substantial expenditures relate to law enforcement, followed by treatment and then prevention [15, 16].

Furthermore, a comparison of the drug expenditures of different countries could be of use to a Government. For example, the performance of a drug policy can be improved if the treatment expenditures per problematic drug user are too high in comparison with the corresponding amount in other countries [28].

The results of public expenditure studies can thus be used to modify or rationalize public expenditure. Research into public expenditure is an important element to meet the requirements of an evidence-based policy, and it is the first step towards cost-effectiveness research. A precise estimate of public expenditures will enable Governments to use their drug budget more effectively to implement strategies [3].

The methodology necessary to study public expenditure on drugs is complex because different policy areas (prevention, treatment and law enforcement) and different levels of government (local, regional and federal) are involved. Ideally, two methods of analysis are combined: a top-down approach analysing the funding sources of the private and public organizations and a bottom-up approach analysing the activities in the work field. To calculate public expenditure, a distinction has to be made between explicitly labelled drug-related expenditure and expenditure not labelled as drug-related.

The study of public expenditure has some important limitations. First, the quality of public expenditure studies is only as good as the quality and timeliness of the available data. For instance, the study of Rigter (2006) calculates the drug policy spending in the Netherlands in 2003 [30]. The estimates of drug expenditures on public prosecution, courts and detention are based partly on old data. The author uses the share of offences under the Opium Act in the total number of cases leading to detention verdicts in courts, although the registration of those Opium Act offences is from the period 1997–2001.

Second, a drug budget is a fragile construction that is liable to variance depending on calculation method. The importance of using a single, clear methodology applied in a uniform manner cannot be stressed enough, particularly when the comparison of different time periods or, especially, of different countries is the aim [3]. A small change in methodology (e.g. a change in the qualification or in a repartition key) might ultimately lead, through a misinterpretation of the change in results, to a decision to increase or decrease public expenditure, even though there was no actual change in the drug budget [34]. For example, between their first study (2004) and the second study (2007), De Ruyver and others changed their methodology for estimating public expenditures for law enforcement [15, 16]. In the 2007 study, expenditures were no longer limited to personnel costs, as costs for investment and functioning were taken into account, making the results more accurate. Consequently, public expenditure for law enforcement appeared to increase by 64 per cent over a period of two years. But the reported increase was owing to the change in methodology, not an actual increase in the public expenditures.

Third, two types of public expenditure exist: spending used exclusively for drug policy and expenditure intended for broader policy domains. To calculate the expenditure on drug policy contained in a general budget (which is where approximately 90 per cent of the total drug budget is contained), it is necessary to apply a repartition key to the obtained amount or make a unit expenditure calculation. Both methods have disadvantages, and therefore the results can be no more than estimates of the public expenditure. In particular, the use of a unit expenditure should be used with caution, since in order to determine unit expenditure, the researcher has to rely on the data provided by institutions/actors involved, leading to a possible contestation of the reliability of the data.

Furthermore, public expenditure studies do not allow for a full policy evaluation. These studies are, in themselves, not a quality measurement of policy. To achieve policy evaluation, an elaborated plan is needed, with clear statements on goals, operational action points, budgets and time frames. Ideally, the policy plan should be evidence-based, that is, based on epidemiological data about new trends in drug use and groups of drug users, including problem drug users, on data about target groups insufficiently reached by prevention, early intervention and treatment efforts and data on evaluation and effectiveness studies.

Finally, studying public expenditure, especially for a delicate subject such as drugs, is potentially hazardous [35]. Public authorities are markedly interested in and concerned about the results of studies of this type. They want the results to be positive, that is, to show that they are investing a substantial amount of government funds in the drug policy priorities that they want to achieve. Conversely, they do not want to invest in policy areas that they do not want the drug policy to be associated with. The latter is clear in the example of Sweden, where harm reduction strategies, although they exist in the country, were not separately reported in the budget's results.

Public expenditure studies are mostly initiated and financed by public authorities; that situation requires researchers to maintain scientific rigour in the execution and presentation of the results of those studies. Therefore, the EMCDDA initiative of developing a uniform methodology for calculating the public expenditures of all European Union member States is laudable.

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Measuring the benefits of drug law enforcement: the development of the Australian Federal Police Drug Harm Index

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ABSTRACT

The present paper describes the historical development of the Australian Federal Police Drug Harm Index and its application in the evaluation of strategic approaches to combating the importation of illicit drugs into Australia. The index encapsulates the potential value to the Australian community of drug seizures made at the border and represents the dollar value of harm that would have ensued had the seized drugs reached the community. The index was developed and refined over almost a decade in response to the expanding body of literature estimating the cost of illicit drug use and the changes in drug types, production, availability and consumption. It is estimated that the Australian community receives approximately $A 5 of benefit for every dollar invested in federal drug law enforcement. Higher rates of return were achieved for drug policy strategies, including partnerships with other agencies and those that focus on serious crime.

Keywords: benefit-cost analysis, evaluation, harm index, illicit drugs, law enforcement, performance

Background

The impetus for the development of an index of policing performance regarding the importation of illicit drugs came initially from government accountability reporting requirements. All Australian federal agencies are required to define and report on the outcomes expected to be achieved through their activities. The Australian Federal Police (AFP) required a measurement of social impact that summarized the potential effect of their drug investigation operations.

AFP provides a federal law enforcement capacity across a large range of national interests. It enforces federal laws covering border crime (such as drug importation and smuggling of persons), economic crime (including fraud, money-laundering, tax offences, identity crime and corruption) and cybercrime (including online child sex exploitation). Other AFP programmes deal with such matters as counterterrorism, aviation security and the protection of high office holders, and an international deployment group provides capacity-building programmes and offshore law enforcement initiatives in the Pacific region and elsewhere. General community policing is the responsibility of separate law enforcement agencies specific to each Australian state and territory. The exception is the Australian Capital Territory, where such services are provided by AFP through a contracted service with the Australian Capital Territory government. Thus, the law enforcement activity referred to in the present paper relates primarily to preventing the importation of large to medium-sized consignments of illicit drugs or their precursors into Australia, and not to domestic production, trafficking or possession of drugs.

This paper provides an overview of a drug-law enforcement performance measurement developed by AFP, the Drug Harm Index (DHI), from its initial, simpler forms [1, 2] to the most recent enhancements. In doing so, it reports for the first time the results of the latest version of the AFP Drug Harm Index, which included a number of methodological changes increasing the accuracy of the index. This version is a significant improvement on previous versions of DHI. It covers a wider range of drugs (e.g. sedatives) through the use of a relative harm rating [3]. It also includes purity adjustments and a separate analysis of the potential damage associated with precursor chemicals. Precursor chemicals are largely ignored in other drug harm indices. This paper also provides an update of previous benefit-cost analyses evaluating drug law enforcement that were based on smaller and less recent seizure and offender data sets and previous versions of DHI [1, 4]. From an operational policing perspective, it is important that the funds being directed to drug law enforcement can be justified.

Drug Harm Index methodology

The original AFP Drug Harm Index was the first index of its type and has been followed by others in the United Kingdom of Great Britain and Northern Ireland [5], the United Nations Office on Drugs and Crime (UNODC) [6] and New Zealand [7]. All are used as summary measurements to compare policy outcomes either internally or externally [8]. However, there are differences in approach and method. The United Kingdom index concentrates on a set of measurable indicators that are related to the social harms caused by drugs. The index for the base year (1988) was set at 100, and subsequent levels of harm were plotted against that point. Thus, it is a relative rather than an absolute measure of harm. The AFP and New Zealand indices share the same methodology, the only difference being that AFP had an independent estimate of the economic cost of drug use in the community [9, 10], whereas the New Zealand study developed its own measurements. Both forms of measurement provide absolute estimates of the level of harm in economic terms, and both are used by their respective law enforcement agencies to report performance. There are differences: the bottom-up approach used in New Zealand resolved the issue of double-counting harm by counting polydrug users in each of the relevant drug categories. The top-down approach used in Australia avoided this problem by segmenting harm at the aggregate level. The issue remains important if harm at the drug-user level is of interest.

The basic notion of the AFP DHI is that the primary benefit from drug seizures at Australian borders is that drugs are prevented from entering the community. Thus, the various costs that would have been associated with the use of these drugs are avoided. The AFP DHI is defined simply as the dollar estimate of harm avoided per kilogram (denoted c) multiplied by the seizure weight in kilograms (denoted w). However, the relative harm differs for various classes of drugs, so this needs to be repeated for each drug type and then summed across the different drug classes. Mathematically, this can be written as:

$$DHI = \sum_i c_i w_i$$

where i = 1,...,n, n is the number of different drug classes and c_i and w_i are the costs and seizure weights for drug class i.

Both the complexity and evolution of DHI are associated with deriving the most valid, accurate and up-to-date estimates of social cost per kilogram, and the choice of the most appropriate and comprehensive groupings of drugs to which these estimates can be applied. The AFP DHI was first derived in 2001 and was revised in 2003. In 2007 an interim adjustment was made, and another major revision was made in 2009 (see table 1).

Table 1. Overview of the development of the Australian Federal Police Drug Harm Index, in the period 2001-2009

DHI version	*Year of primary source data*	*Drug classes*	*Purity adjustment*	*Precursor conversion*	*Primary limitations*
2001	1999	Heroin Cocaine Amphetamines Cannabis	Yes	No	Based on street values, not Australian-based estimates of social costs
2003	1998	Opioids Amphetamines Cannabis	No	No	Based on 1998 source data; amphetamine harm underestimated

Table 1. Overview of the development of the Australian Federal Police Drug Harm Index, in the period 2001-2009 *(continued)*

DHI version	*Year of primary source data*	*Drug classes*	*Purity adjustment*	*Precursor conversion*	*Primary limitations*
2006	1998	Opioids Amphetamines Cannabis Precursors	No	Nominal	Based on 1998 source data; excludes sedatives, only nominal inclusion of precursors
2009	2004	Opioids Amphetamines Cocaine Cannabis Precursors Sedatives	Yes	Yes	Based on 2004 source data; cost estimates extrapolated for certain drugs

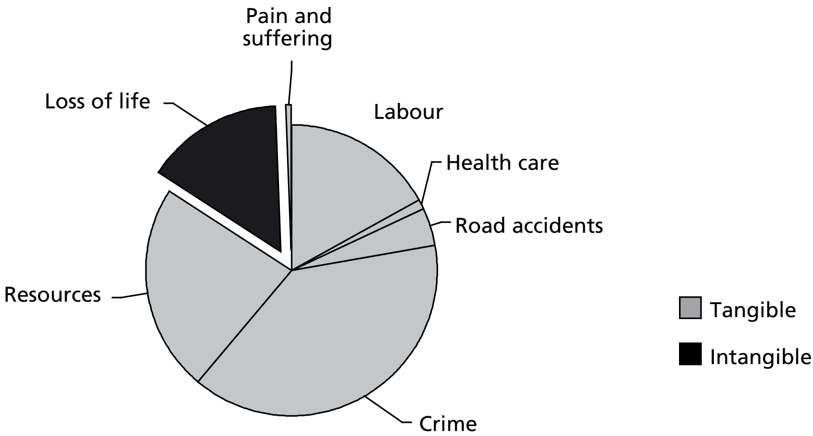
2001 version of the Drug Harm Index

In the absence of a comprehensive estimate of the social cost of drug abuse in Australia, the original index was based on street price converted to cost per kilogram. McFadden et al [1] reasoned that street price could be substituted for economic value, since estimates from separate studies using these different measurements in the United States of America differed by no more than 5 per cent. Regional Australian street prices were then obtained for heroin, cocaine, amphetamines and cannabis and used in the DHI formula after an adjustment for a difference in purity between drugs seized at the border and drugs on the street.

2003 version of the Drug Harm Index

The primary improvement in 2003 was basing the index on Australian social-cost data. Full details are available in McFadden (2006) [2]. The harm value per kilogram for different classes of drugs was estimated by dividing the total annual cost of drug harm derived from Collins and Lapsley (2002) [9] by an estimate of total, annual consumption of drugs from Australian surveys [11, 12]. The Collins and Lapsley study was one of a series of studies commissioned by the Commonwealth Department of Health and Ageing to measure the social costs of drug abuse. Total social costs were obtained by summing separate component estimates of tangible and intangible costs (figure I). Crime was the largest cost component, accounting for 39 per cent of the total. The component costs were disaggregated by drug type (opioids, stimulants and cannabis) by McFadden (2006) [2] in order to obtain a total social cost for each of those three classes of drugs. Dividing by the estimates of consumption gives the per kilogram estimates, approximately $A 1 million for opioids, $A 90,000 for stimulants and $A 25,000 for cannabis (figure II).

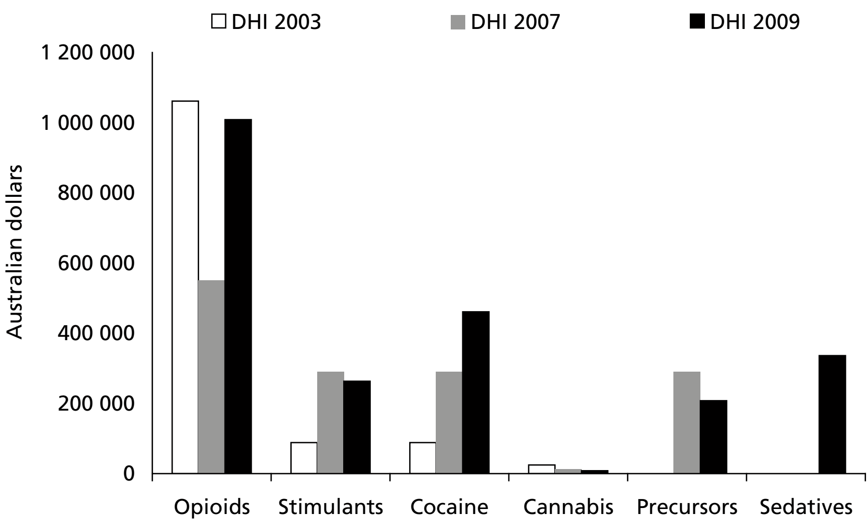
Figure I. Distribution of tangible and intangible costs of social harm attributable to illicit drug use in Australia, 1998-99



Source: David J. Collins and Helen M. Lapsley, *Counting the Cost: Estimates of the Social Costs of Drug Abuse in Australia in 1998-9*, Monograph Series, No. 49 (Canberra, Commonwealth Department of Health and Ageing, 2002).

Note: The resources category includes resources used in abusive consumption.

Figure II. Estimated social cost per kilogram by drug class in successive versions of the Drug Harm Index



Note: Cocaine was included with stimulants until 2009.

2006 version of the Drug Harm Index

An interim update was undertaken in 2006 because a peer review and a review of the literature suggested that the harm associated with heroin was overestimated and the harm associated with amphetamines was underestimated. Hence, the heroin and amphetamine weightings were adjusted using relative weightings later published by Moore (2007) [13] but still keeping the total estimated harm consistent with Collins and Lapsley (2002) [9]. The results are shown in figure II.

2009 version of the Drug Harm Index

The main factors prompting the latest review were the availability of new source data (updated from 1998 to 2004) and the need to evaluate the impact of an additional drug type (sedatives) that had not previously been included, but that had become more prominent in recent seizures by AFP.

Despite an update in the Collins and Lapsley series [10], Moore [13] was used as the basis for the index, since separate specific estimates of social cost for different drug types were provided, and other limitations of Collins and Lapsley were addressed. Although Moore also estimated drug consumption, the estimates were inconsistent with the trends observed in the 2007 National Drug Strategy Household Survey statistics [14], so total consumption of the different drug types was calculated in a manner similar to that used in the previous version of DHI. Estimates of average consumption from the *World Drug Report 2007* [15] were applied to estimates of the total number of illicit drug users in Australia derived from the 2007 National Drug Strategy Household Survey [14] and the population census [16]. Since the *World Drug Report* presents consumption figures in terms of pure drugs, the values were scaled according to the purity of drugs in typical AFP border seizures.

An extension of the previous methodology was the extrapolation of the estimates of social cost per kilogram from the limited set of drugs for which they were available (heroin and amphetamines) to other drugs within the same or a similar class using relative harm ratings derived from Nutt et al [3]. In that work, a panel of experts from medical, scientific and judicial disciplines rated the harm associated with specific drugs using a four-point scale on three dimensions (physical harm, dependence, social harm). The authors of the present article derived an overall rating for each drug by taking the average across the three categories of harm. For the extrapolation, heroin was used as the reference drug for opioids and amphetamine was used for stimulants and sedatives. In a final step, the individual social cost estimates for each drug within a class were averaged into the final proposed DHI classifications weighted by prevalence of use in Australia (see table 2 and figure II).

Table 2. Extrapolation and aggregation, within drug class, of initial social cost per kilogram values (estimate 1) to the final values (estimate 3) used in the 2009 version of the Drug Harm Index

Drug class	*Drugs of interest*	*Social cost per kg: estimate 1[a] (Australian dollars)*	*Relative harm ratio*	*Social cost per kg: estimate 2[b] (Australian dollars)*	*Prevalence of drug use (percentage)*	*Social cost per kg: estimate 3[c] (Australian dollars)*
Opioids	Heroin	1 148 914	2.77/2.77	1 148 914	0.2	1 009 000
	Street methadone		1.94/2.77	802 307	0.05	
	Buprenorphine		1.58/2.77	653 169	0.05	
Stimulants	Amphetamine	333 472	1.66/1.66	333 472	2.3	263 000
	LSD		1.23/1.66	246 421	0.6	
	MDMA ("ecstasy")		1.09/1.66	218 966	3.5	
Cocaine	Cocaine		2.30/1.66	461 369	1.6	461 000
Sedatives	Barbiturates		2.08/1.66	417 844	0.1	336 000
	Ketamine		1.74/1.66	350 212	0.2	
	GHB		1.12/1.66	224 323	0.1	
Cannabis	Cannabis	7 658	1.33/1.33	7 658	9.1	8 000

[a]*Estimate* 1 based on total costs (Tim Moore, *Working Estimates of the Social Costs Per Gram and Per User for Cannabis, Cocaine, Opiates and Amphetamines*, Drug Policy Modelling Program Monograph Series, No. 14 (Sydney, National Drug and Alcohol Research Centre, 2007)) and estimated total consumption (*World Drug Report 2007* (United Nations publication, Sales No. E.07.XI.5) and Australian Institute of Health and Welfare, *2007 National Drug Strategy Household Survey: Fir-st Results*, Drug Statistics Series, No. 20, AIHW catalogue No. PHE 98 (Canberra, 2008)).

[b]*Estimate* 2 = estimate 1 × relative harm ratio (based on average harm scores derived from David Nutt and others, "Development of a rational scale to assess the harm of drugs of potential misuse", *The Lancet*, vol. 369, No. 9566 (2007), pp. 1047-1053).

[c]*Estimate* 3 = weighted average of estimate 2 within drug classes with weighting based on prevalence of recent drug use in Australia (persons aged 14 years or older) (Australian Institute of Health and Welfare, *2007 National Drug Strategy Household Survey: First Results*, Drug Statistics Series, No. 20, AIHW catalogue No. PHE 98 (Canberra, 2008)) (rounded to nearest thousand dollars).

Another enhancement was a more accurate estimation for precursors, which were previously given the same weighting as stimulants. Conversion ratios from precursor to final product [17] were applied to amphetamine costs for the common precursors, ephedrine and pseudoephedrine (0.70), and to costs for MDMA ("ecstasy") precursors (0.10) according to the following formula:

cost per precursor kg = cost per product kg X conversion rate

These two estimates were combined according to a prevalence weighting (as described in table 2) to obtain a final average social cost per kilogram of precursor ($A 208,000).

Impact of Drug Harm Index development

Figure II illustrates the change in relative weights for each primary drug class across the historical development of DHI. In all versions of the index, heroin has the largest weighting and cannabis the lowest. The high relative weighting for cocaine in the latest version of the index is consistent with its high ranking on all three dimensions of harm in Nutt et al [3]. McFadden (2006) [2] made detailed comparisons of the impact of applying the 2001 version and the 2003 version to AFP seizures in the period from 1987 to 2003. It was concluded that the results were comparable (a difference of only 3 per cent) and trends in annual values were similar. The impact is greater in the most recent review, but this is largely due to large *gamma*-hydroxybutyrate (GHB) seizures in 2008. The total savings to the community from AFP drug seizures during the period from July 1999 to December 2008 were estimated to be $A 7.8 billion using AFP DHI 2007, but increases by 30 per cent, to $A 10.1 billion, using AFP DHI 2009. A breakdown of costs indicates that, of that 30 per cent increase, 15 per cent is based on the inclusion of sedatives, 2 per cent is due to increases in the consumer price index and 13 per cent is due to changes in the cost estimates.

Return on investment methodology

Benefit-cost analysis provides a way of quantifying the economic performance of a programme. Firstly, benefits and costs are estimated in dollar terms, and then they are compared by calculating either a ratio (of benefit to cost) or a difference (benefit minus cost). The ratio is termed the "return on investment" and is interpreted as the return achieved for each dollar spent. The difference is termed the "net present value", the net return after costs are taken into account.

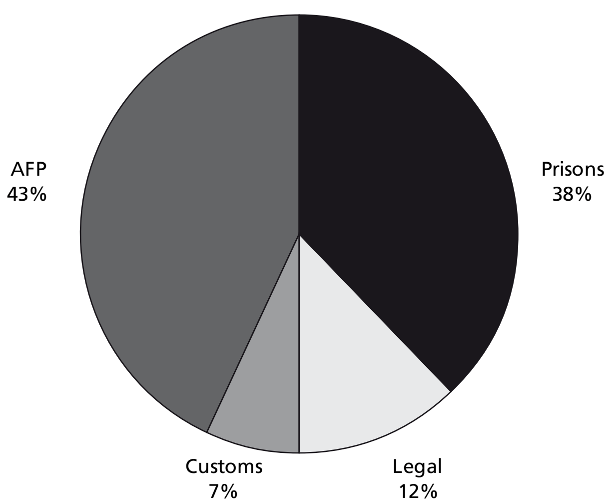
This type of analysis was used in evaluating AFP drug law enforcement for the 1999/00 to 2000/01 period [1] and the 2000/01 to 2004/05 period [4] and was repeated here with a more comprehensive data set including all drug investigations in the period from July 2000 to the end of 2008 (see table 3 and figures II and III). Given the volatility of drug markets and the accountability requirements under which law enforcement agencies operate, it would be preferable to have an ongoing estimate of the return on investment of drug-law enforcement programmes. However, given the complexity of the data collection and estimation required, it is more practical to attempt such reviews at regular intervals.

On the benefits side of the equation, successive versions of DHI were used to estimate the direct impact of the investigations based on the seizures that were made. DHI 2009 was used for the first time in the current study. An additional deterrence benefit of 10 per cent of the direct impact was included by McFadden (2009) [4] to reflect the positive deterrence value of successful prosecutions for drug importations. In cases where fines were imposed by courts, they were also included in the current analysis, but this amounted to less than 1 percent of the total benefits. On the costs side of the equation, the original analysis included only estimates of policing and border-control costs incurred by AFP and the Australian Customs and Border Protection Service. This was expanded to include legal costs (Director of Public Prosecutions costs and court costs) and prison costs (based on Productivity Commission estimates of costs per prisoner per day) [4]. The policing and prison costs were the major component costs (see figure III).

Table 3. Estimates of costs, benefits, net present value and return on investment in drug law enforcement associated with 4,579 drug investigations carried out by the Australian Federal Police, 2000-2008

	Cases	*Costs* (Millions of Australian dollars)	*Benefits* (Millions of Australian dollars)	*Net present value* (Millions of Australian dollars)	*Return on investment* (Australian dollars)
All AFP cases	4 579	647.5	3 423.8	2776.3	5.30
Subset involving:					
Domestic partner	3 039	357.8	1 940.0	1 582.3	5.40
International partner	140	24.5	277.2	252.7	11.30
High to very high impact	1 257	356.4	2 911.5	2 555.1	8.20
Low to medium impact	3 314	231.7	512.3	280.6	2.20

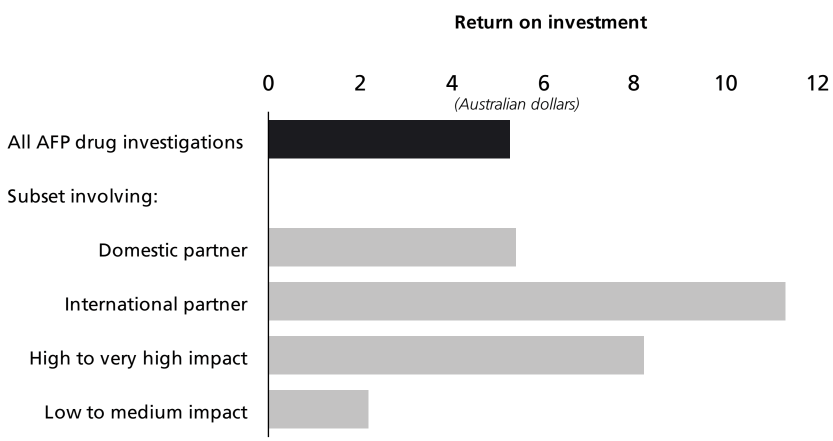
Figure III. Component cost distribution of drug investigations carried out by the Australian Federal Police, 2000-2008



Return on investment results

An overall return on investment value of $A 5.30 was achieved, which was consistent with the earlier related studies ($A 5.20 in McFadden et al, 2002 [1] and $A 5.80 in McFadden, 2009 [4]). Specific policing strategies relevant to this period were able to be evaluated by recalculating the return on investment after restricting the analysis to those cases affected by the policy, such as those involving domestic or international partners, or those concentrating on serious, high-impact crime (see table 3 and figure IV). For example, 3,039 of the 4,579 cases were referred to AFP by the Customs and Border Protection Service. These cases resulted in a return on investment estimate of $A 5.40, as compared with the overall estimate of $A 5.30. Each policy-related estimate corresponded to a larger return than the overall estimate and thus provides an evidence base for recommending further implementation of the policies.

Figure IV. Estimates of return on investment in drug law enforcement associated with 4,579 drug investigations carried out by the Australian Federal Police in the period 2000-2008



Discussion

The simplicity of the AFP DHI as an aggregation of social cost by seizure weight across different drug types belies the difficulty of producing a valid and accurate index. The estimation of the social cost of illicit drugs is truly applicable only in the time frame and region in which source data are collected. However, the expense of conducting such studies makes it unlikely they would ever be conducted annually. The same limitation applies to estimating consumption. In addition, consumption estimates are notoriously difficult, and non-response and underestimation will always be a problem when posing questions about illegal activity. Further limitations of the methodology include the assumption that harm is constant by weight and over time. Adjustments for dependent users and market supply may address these issues. Some consideration should also be given to environmental costs, such as those associated with the production of synthetic drugs, as presented in a recent report on the economic cost of methamphetamine use [18] and the estimation of statistical precision, or lack thereof, in the estimation process.

A range of issues relating to difficulties in the construction, use and interpretation of drug harm indices has been canvassed by Roberts, Bewley-Taylor and Trace [19], Reuter and Stevens [20] and Ritter [8, 21], including some outside the scope of the present paper. The most frequent criticism of the AFP DHI has been that it assumes that a kilogram of illicit drug seized is equivalent to a kilogram not consumed, and therefore also to the health and social benefits associated with this reduction in consumption. It is argued that illicit drugs are readily replaced on the streets and that a short-term shortage is probably the best expected outcome of a large seizure. The first point to make about this concern is the definition. DHI has been defined as the harm *that would have ensued* had the seized drugs reached the community. As such, DHI is a measurement of the potential harm saved through the seizure of drugs and does not purport to be a direct measurement of reduction in consumption. In fact, drug seizures that occur in conditions of oversupply, as critics note, may have very little real impact, whereas drug seizures that occur in periods of reduced supply may have an impact well in excess of that predicted by DHI. It should be noted that most high-level estimates of harm, e.g. aetiological fractions, are an average over time and across locations, which will always limit their applicability to specific instances of harm. DHI is certainly within this class of measurements. The second point concerns the availability of drugs and their production. At the level of individual drugs, there are plainly peaks and troughs in supply, and some of these are sustained over periods of time; e.g., the heroin drought in Australia has persisted since 2000. Empirically, there is no published evidence that drugs can be placed on the streets at will, and certainly DHI assumes that law enforcement activities have an impact on the availability of illicit drugs. The published evidence supports this assumption. Smithson et al [22], in the only large-scale time series analysis of its type, reported that the number and size of heroin seizures at the border was negatively correlated in the long term with the availability of heroin in the local community. It should be noted that the position of Australia as an island with relatively few entry points and as a terminal point rather than transit point for drugs may restrict the extent to which these findings can be applied to other countries.

Conclusion

Despite the limitations resulting from the paucity of social-cost data and the complexity required to keep pace with the changing illicit drug landscape, DHI has proved to be of great utility as a performance measurement within AFP. Although originally designed as a reporting and accountability tool, it is also an essential component of the ability of AFP to monitor and refine specific operational strategies in drug law enforcement through its use in benefit-cost analyses. It also has potential applicability beyond law enforcement, for example, in the evaluation of drug-treatment programmes, where benefit is related to reduction in consumption.

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The association between the number of days of methamphetamine use and the level of earnings from acquisitive crime among police detainees in New Zealand

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ABSTRACT

Methamphetamine is a problem in a number of countries around the world. This paper examines the statistical association between methamphetamine use and acquisitive crime among police detainees in New Zealand. Cannabis and methamphetamine use were both associated with involvement in acquisitive offending. A number of demographic variables related to social and economic disadvantage could predict involvement in property offending. Being under 25 years old and having been imprisoned could predict involvement in drug dealing. A consistent and strong positive association between the number of days of methamphetamine use and the level of dollar earnings from property crime and drug dealing was found. These findings suggest that frequent methamphetamine use may contribute to higher levels of acquisitive offending among criminally active individuals. Reductions in acquisitive crime may be possible by offering such offenders drug treatment. Further research into the causal nature of these associations is required to more clearly inform policy options.

Keywords: Methamphetamine; cannabis; property crime; drug dealing; police detainees; New Zealand

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Introduction

Methamphetamine is currently a drug of concern in a number of countries, including Mexico and the United States of America, and regions, including South-East Asia, East Asia and Oceania [1-7]. Studies of frequent methamphetamine users in Australia, New Zealand and the United States have found high proportions of users reporting recent involvement in property offending and drug dealing [2, 8-10]. The police of New Zealand have attributed increases in burglaries, robberies and car thefts in the early 2000s to the rise in methamphetamine use in New Zealand and the need by some users to obtain money to pay for the drug [11]. The financial cost of methamphetamine in New Zealand [10] and the potential of methamphetamine to create dependency among some users [12,13] means that frequent methamphetamine use could plausibly be a driver of acquisitive offending among criminally active users. However, the statistical association between methamphetamine use and acquisitive offending among criminally active individuals is yet to be explored in any detail.

Research on the link between drug use and acquisitive crime has traditionally focused on heroin and, more recently, on cocaine [14-19]. A number of studies have found that daily or near-daily users of heroin and cocaine have significantly higher levels of acquisitive offending than less frequent users of these drug types or non-drug users [14, 17, 19-21]. For example, Johnson and others [21] found that daily users of heroin committed approximately twice as many acquisitive crimes per year as irregular users of heroin (i.e. those who use heroin no more than on two days per week). Several studies have used drug users' self-reported dollar earnings from acquisitive crime to illustrate the impact of acquisitive offending and to explore the relationship between drug use and acquisitive crime [20-22]. Collins and others [20] found that daily users of heroin had earned US$ 8,426 more illegal income in the previous year than non-users of heroin, and that daily users of cocaine had earned US$ 7,206 more in illegal income in the previous year than non-users of cocaine.

While researchers have long found statistical associations between drug use and crime, the extent to which the two behaviours are causally related remains unclear [see 14, 19, 36 and 41-43]. Four main theoretical models are commonly used to explain the statistical association between drug use and acquisitive offending. According to the first model, known as the "drug-crime model", drug use causes acquisitive offending because drug users resort to acquisitive crime to pay for expensive drug use. According to the second model, known as the "crime-drug model", the criminal lifestyle provides the money, peer group and leisure time that encourages serious drug use. The third model is the "common cause model", which proposes that both drug use and acquisitive crime are related by common psychological or socio-economic factors, such as low educational achievement, unemployment or poor housing. The fourth model, known as the "coincidence model" or the "spuriousness model", argues that drug use and crime are not causally connected at all but rather exist within a nexus of problematic behaviours.

New Zealand's geographical isolation, small population and effective border control has resulted in a fairly unusual drug-using culture compared to that in many other developed Western countries [23]. A principal point of difference is that the supply of heroin and cocaine has been poor in New Zealand for many decades and consequently the use of these drug types has been low [23-25]. In contrast, the use of cannabis is fairly prevalent in New Zealand, as the climate and environment suits the cultivation of cannabis, which has been grown illegally on a large commercial scale since the mid-1980s [24, 26]. In more recent years, there has been an emergence of methamphetamine use in New Zealand [5, 25]. The availability of methamphetamine has been enhanced by the fact that it can be manufactured domestically in small "kitchen" laboratories using locally sourced ingredients [27]. Studies of frequent methamphetamine users in New Zealand have found that these drug users also use high levels of cannabis and alcohol [10]. New Zealand police have identified alcohol and cannabis to be factors in the offending behaviour of criminally active individuals in New Zealand [28, 29].

The aim of the present study is to examine the statistical association between methamphetamine use and acquisitive crime among a sample of police detainees in New Zealand. Following the associations found in the existing literature on drugs and crime between daily use of heroin and cocaine and higher earnings from acquisitive crime, we aimed to investigate the associations between daily methamphetamine use and the level of earnings from acquisitive crime. To obtain a clearer picture of the association between methamphetamine use and acquisitive crime, we sought to control for other variables that might be associated with acquisitive crime in New Zealand, including high cannabis and alcohol use.

Our research questions were the following: *(a)* are police detainees who use methamphetamine more likely than detainees who do not use methamphetamine to be involved in property crime and drug dealing?; and *(b)* to what extent can the number of days of methamphetamine use predict the level of earnings from property crime and drug dealing?

Method

The analysis was conducted using data from the New Zealand Arrestee Drug Abuse Monitoring (NZ-ADAM) research programme [30, 31], which was developed on the basis of the Arrestee Drug Abuse Monitoring programme conducted in the United States [see 32-34]. In the framework of NZ-ADAM, individuals who are detained at police stations for less than 48 hours are interviewed about their drug use and related activities [30, 31]. The NZ-ADAM programme is carried out at four police stations located in different regions of New Zealand (Whangarei, Henderson, Hamilton and Dunedin).

Potential participants in the NZ-ADAM study include all persons detained at selected police watch houses for less than 48 hours at a time when interviewers are present. Interviewing is conducted every week over an entire 12-month period at each site. Interviewers complete four three-hour shifts per week on a rotating basis. The national project manager schedules the shift times to ensure completeness of coverage for every day of the week over each quarter of the year. Summaries of the days and times of shifts completed at each site are included in the appendix of the annual NZ-ADAM report [see 30]. Certain types of police detainees are deemed ineligible to participate in the study for ethical, practical or safety reasons, including persons under the age of 17; persons who are intoxicated from alcohol, drugs or medications; persons suffering from mental health issues; persons unable to complete the interview due to poor English language skills; persons exhibiting violent behaviour; and persons held in custody for more than 48 hours. The interviewers identify themselves as civilian researchers and explain the purpose of the study to eligible detainees and the confidentiality protections employed. In addition, they provide detainees with an informational sheet about the study before inviting them to be interviewed. The interviews are conducted in a private room in the police watch house, away from police officers. The ethical procedures used in the study have been approved by the New Zealand Multi-region Ethics Committee.

The present analysis draws on interviews completed during the national pilot phase of NZ-ADAM, which lasted from April 2005 to September 2007. A total of 2,681 detainees met the eligibility criteria to participate in the study during this period, of whom 2,164 agreed to be interviewed. Only 38 of the detainees interviewed during that time had used heroin, morphine or methadone on more than two days during the previous 30 days. The small number of frequent opioid users among the detainee sample was not sufficient to carry out any meaningful analysis of the association between opioid use and acquisitive crime and so they were removed from the sample for the purposes of the present analysis.

Measures

Drug use

Respondents were asked on how many days they had used a range of drug types during the previous 30 days.

Sources of income

Respondents were asked about all their sources of income during the previous 30 days and were read a list of 14 possible legal and illegal sources of income.

Detainees were then asked to estimate the amount of New Zealand dollars they had earned from a given source in the previous 30 days.

Demographic variables

A range of demographic information was collected from respondents, including with regard to age, gender, ethnicity, current marital status, educational history, current employment status, current housing status and prison history.

Analysis

Regression models

The primary interest was the association between methamphetamine use and acquisitive crime, but as methamphetamine users also had high levels of cannabis and alcohol use, [10, 35] it was necessary to control for any influence those substances might have had on acquisitive crime and for demographic variables that might be associated with acquisitive crime, such as low educational achievement and unemployment. A rigorous checking process was undertaken to ensure only variables related to acquisitive criminality were modelled and that no highly correlated predictor variables were fitted into any one model.

Two types of regression models were developed. The first type sought to predict involvement in property crime and drug dealing in the previous 30 days based on the use of alcohol, cannabis and methamphetamine in the previous 30 days and demographic variables. The second type of regression model (a "factorial ANOVA model") aimed to predict the level of dollar earnings from property crime and drug dealing in the previous 30 days based on the number of days of alcohol, cannabis and methamphetamine use in the previous 30 days and demographic variables. Only those detainees who had earned money from property crime or drug dealing during the previous 30 days were included in these models.

The drug use variables included in the models were the number of days of methamphetamine, cannabis and alcohol use in the previous 30 days. The number of days of methamphetamine, cannabis and alcohol use were classified into four categories for inclusion in the later models: no use (0 days); low use (1-2 days); medium use (3-19 days) and high use (20-30 days). The definitions of the four categories were informed by the existing literature on drugs and crime, which found that persons using heroin and cocaine on a daily or almost daily basis (i.e. 20-30 days in the past month) had higher levels of acquisitive offending [14, 17, 19-20]. At the other end of the scale, a low-use category that captured only occasional or infrequent use (i.e. 1-2 days in the past month) was needed. The distribution of the number of days of methamphetamine, cannabis and alcohol use among the detainees was examined and logical cut-off points sought.

Two categories of acquisitive crime were created for the analysis: property crime and drug dealing. The property crime category included dollar earnings from "shoplifting", "burglary", "car theft", "theft" and "robbery" in the previous 30 days. The drug dealing category included earnings from "drug dealing" in the previous 30 days. Four categories of earnings from acquisitive crime were created for inclusion in the later models: no earnings ($NZ 0); low earnings ($NZ 1-100); medium earnings ($NZ 101-1,000); and high earnings ($NZ 1,001 and above). The criminal earnings categories were created with a broad understanding of average incomes in New Zealand in mind, by examining the distribution of the dollar earnings from property crime and drug dealing among the detainees, and looking for logical cut-off points. The high earnings category represented a substantial income from acquisitive crime (i.e. over $NZ 250 per week), while the low earnings category represented a fairly small income source from acquisitive crime (i.e. less than $NZ 25 per week).

The demographic variables included in the models were the following: gender, age, ethnicity (i.e. Maori,[1] European, Pacific islander or other), marital status, level of educational achievement, unemployment status/recipient of sickness benefits, kind of accommodation and whether he or she was imprisoned during the previous 12 months.

The categories of drug use and the demographic variables were first fitted to predict the level of dollar earnings from property crime and drug dealing in the previous 30 days. The initial test was whether drug use in the previous 30 days and the demographic variables had any statistically significant influence on the level of dollar earnings from acquisitive crime in the previous 30 days. A test was then run for differences in the dollar earnings from acquisitive crime in the previous 30 days between each combination of the number of days of drug use in the previous 30 days using Tukey's multiple comparison procedure. Since the dollar earnings from acquisitive crime were highly skewed, the data was log-transformed for the purposes of analysis. Geometric means were produced by back-transforming the log means. Tukey-Kramer adjustments were used to control for multiple comparisons among the drug use categories. All dollar amounts are reported in New Zealand dollars. All analysis was conducted using SAS.

Results

Demographics

The police detainee sample was overwhelmingly male (87 per cent), the mean age of the sample was 27 years (the median age was 24 years, the range being 17-74 years) and a high proportion were of Maori ethnicity (50 per cent) (table 1). A large portion of the sample of detainees was unemployed or received sickness

[1]The Maori are the indigenous people of New Zealand.

benefits (42 per cent); many detainees had not completed compulsory high school (46 per cent) and lived in temporary housing (59 per cent). Some had been imprisoned in the past 12 months (18 per cent).

Table 1. Proportion of the police detainee sample (*n*=2,126), by selected demographic variables

Demographic variable	
Age (mean)	27 years
Gender	
Male	87%
Female	13%
Ethnicity	
European	37%
Maori	50%
Pacific islander	5%
Other	8%
Marital status	
Single (never married)	60%
Married/de facto relationship	32%
Separated/divorced/widowed	8%
Level of educational achievement	
Did not go to school	5%
Did not complete compulsory high school	41%
Completed compulsory high school	34%
Received tertiary education	20%
Employment status	
Is unemployed or receives sickness benefits	42%
Is employed full time	33%
Is employed part time	12%
Is a student	8%
Is a full-time parent or retired	5%
Kind of accommodation	
Lives in his or her own house	40%
Lives in someone else's house	53%
Lives in a caravan or boarding house	3%
Lives in the street	2%
Lives in prison	1%

Patterns of drug use

Alcohol, cannabis and methamphetamine were by far the drug types most commonly used by the police detainees in the previous month (table 2): 81 per cent of the detainees had drunk alcohol, 69 per cent had used cannabis and 20 per cent had used methamphetamine during that time. Only 8 per cent of the sample had used a drug other than alcohol, cannabis or methamphetamine in the previous 30 days. Very few of the detainees had used cocaine (<1 per cent) or heroin (<1 per cent) in the previous 30 days.

Table 2. Patterns of drug use among the sample of police detainees (*n*=2,126) in the previous 30 days

Drug type	*Used in the previous 30 days (%)*	*Used on 20 or more days in the previous 30 days (%)*	*Mean number of days of use in the previous 30 days*[a]
Alcohol	81	11	8
Cannabis	69	33	17
Methamphetamine	20	4	10
Hallucinogens	7	<1	3
Amphetamine	5	1	6
"Ecstasy" (MDMA)	5	0	2
Tranquillisers	2	<1	6
Cocaine	<1	0	4
Heroin	<1	0	2
Methadone	<1	0	1

[a] Mean number of days of use among persons who reported any use in the previous 30 days.

There was some variation in the number of days of use of the different drug types. Those detainees who had used methamphetamine had used it on a mean of 10 days in the previous 30 days (median=5 days; standard deviation=10 days). Four per cent of the detainee sample had used methamphetamine on 20 or more days in the previous 30 days (i.e. on a daily or near daily basis) (table 2). Those detainees who had used cannabis had done so on a mean of 17 days in the previous 30 days (median=15 days; standard deviation=12 days). Thirty-three per cent of the detainee sample had used cannabis on 20 or more days in the previous 30 days. Those detainees who had drunk alcohol had done so on a mean of 8 days in the previous 30 days (median=4 days; standard deviation=8 days). Eleven per cent of the detainee sample had drunk alcohol on 20 or more days in the previous 30 days. Only approximately 1 per cent of the detainees had used hallucinogens, amphetamines or tranquillisers on 20 of the previous 30 days. None of the detainees had used "ecstasy", cocaine, heroin or methadone on 20 of the previous 30 days.

Illegal income from acquisitive crime

In the previous 30 days, 11 per cent of the police detainees participating in the study had earned money from drug dealing in the previous 30 days, and 10 per cent had earned money from property crime and 3 per cent had earned money from both property crime and drug dealing. There was considerable variation in the dollar earnings from acquisitive crime committed during the previous 30 days: those detainees who had earned money from property crime had earned a mean of $NZ 2,338 (median=$NZ 500; S.D.=$NZ 5,408), 4 per cent of whom had earned more than $NZ 1,000; those detainees who had earned money from drug dealing had earned a mean of $NZ 4,665 (median=$NZ 500; S.D.=$NZ 19,384), of whom 3 per cent had earned more than $1,000.

Table 3 presents the proportion of the detainee sample that had earned money from property crime and drug dealing in the previous 30 days by involvement in drug use in the past 30 days and other demographic variables. A higher proportion of those who had used cannabis in the previous 30 days than those who had not used cannabis in the previous 30 days had earned money from property crime (14 per cent compared with 3 per cent, $p<0.0001$). A higher proportion of those who had used methamphetamine in the previous 30 days than those who had not used methamphetamine in the previous 30 days had also earned money from property crime (23 per cent compared with 8 per cent, $p<0.0001$). Those who had drunk alcohol in the previous 30 days were also more likely to have earned money from property crime than those who had not drunk alcohol in the previous 30 days (12 per cent compared with 8 per cent), although that difference was only just statistically significant ($p=0.0445$). A range of demographic variables were also associated with a higher prevalence of having earned money from property crime, including being under 25 years old, being Maori, being unemployed or the recipient of sickness benefits, having a low level of educational achievement, being single and having been imprisoned in the previous 12 months.

A higher proportion of those who had used cannabis in the previous 30 days than those who had not used cannabis in the past 30 days had earned money from drug dealing in the previous month (14 per cent compared with 3 per cent, $p<0.0001$). A higher proportion of those who had used methamphetamine in the previous 30 days than those who had not used methamphetamine in the previous 30 days had also earned money from drug dealing (25 per cent compared with 7 per cent, $p<0.0001$). Being under 25 years old, unemployed or the recipient of sickness benefits, having a low level of educational achievement and having been in prison in the previous 12 months were also associated with a higher prevalence of involvement in drug dealing in the previous 30 days.

Table 3. Involvement in property crime and drug dealing in the past 30 days among the sample of police detainees (*n*=2,126), by drug use in the previous 30 days and demographic variables

	Involved in property crime in the previous 30 days		*Involved in drug dealing in the previous 30 days*	
	%	*p-value*	%	*p-value*
Drug use in the previous 30 days				
Used alcohol	12	0.0445	11	0.1797
Did not use alcohol	8		9	
Used cannabis	14	<0.0001	14	<0.0001
Did not use cannabis	3		3	
Used methamphetamine	23	<0.0001	25	<0.0001
Did not use methamphetamine	8		7	
Demographic variables				
Male	11	0.3167	10	0.8064
Female	13		11	
Under 25 years old	14	<0.0001	13	0.0001
Over 25 years old	7		8	
Maori	14	<0.0001	12	0.0817
Not Maori	8		9	
Unemployed or receiving sickness benefits	15	<0.0001	12	0.0312
Not unemployed or receiving sickness benefits	8		9	
Has a low level of educational achievement	14	<0.0001	12	0.0275
Does not have a low level of educational achievement	8		9	
Lives in temporary housing	14	<0.0001	11	0.1846
Does not live in temporary housing	6		9	
Single	12	0.0225	11	0.0578
Not single	9		9	
Imprisoned in the previous 12 months	19	<0.0001	17	<0.0001
Not imprisoned in the previous 12 months	9		9	

Involvement in acquisitive crime

Those detainees who had used methamphetamine and cannabis in the previous 30 days were three times more likely to have been involved in property crime during that same period (table 4). Being Maori, living in temporary housing, being unemployed or the recipient of sickness benefits, having low levels of educational achievement and having been in prison in the previous 12 months were also associated with a higher likelihood of involvement in property crime in the previous 30 days.

Those detainees who had used methamphetamine in the previous 30 days were four times more likely to have been involved in drug dealing during that period. Being under 25 years old and having been in prison in the previous 12 months were also associated with a higher likelihood of involvement in drug dealing in the previous 30 days.

Table 4. Odds ratios of the likelihood that the police detainees (*n*=2,126) were involved in property crime and drug dealing in the previous 30 days

	Property crime		*Drug dealing*	
	Odds ratio	*p-value*	*Odds ratio*	*p-value*
Drug use in the previous 30 days				
Alcohol	1.44	0.0852	1.32	0.1912
Cannabis	3.00	<0.0001	2.93	<0.0001
Methamphetamine	3.24	<0.0001	4.19	<0.0001
Demographic variables				
Male	0.72	0.1435	0.94	0.7983
Under 25 years old	2.17	<0.0001	1.89	0.0002
Maori	1.59	0.0030	1.19	0.2582
Unemployed or receiving sickness benefits	1.54	0.0048	1.08	0.6128
Has low level of educational achievement	1.45	0.0152	1.13	0.4189
Lives in temporary housing	1.85	0.0006	0.86	0.3636
Single	0.91	0.6047	1.05	0.7466
Has been in prison in the previous 12 months	1.61	0.0051	1.51	0.0174

Dollar earnings from acquisitive crime

The number of days of cannabis use in the previous 30 days, the number of days of methamphetamine use in the previous 30 days and being Maori were all associated with the level of dollar earnings from property offending in the previous 30 days (table 5). The number of days of alcohol use was also associated with the level of earnings from property offending but was just under the 0.05 per cent cut-off point. The number of days of methamphetamine use in the previous 30 days and having been in prison in the previous 12 months were associated with the level of dollar earnings from drug dealing in the previous 30 days. Being under 25 years old was close to being statistically significantly in terms of the level of dollar earnings from drug dealing in the previous month.

Table 5. Statistical association between the number of days of drug use in the previous 30 days and the level of dollar earnings from property crime and drug dealing among those detainees who had earned money from those activities in the previous 30 days

Explanatory variable	*Level of dollar earnings from property crime in previous 30 days (n=227)*	*Level of dollar earnings from drug dealing in previous 30 days (n=213)*
Days of alcohol use in previous 30 days	p=0.0423	p=0.5619
Days of cannabis use in previous 30 days	p=0.0055	p=0.7566
Days of methamphetamine use in previous 30 days	p<0.0001	p<0.0001
Male	p=0.0942	p=0.5145
Under 25 years old	p=0.4743	p=0.0669
Maori	p=0.0056	p=0.1827
Unemployed or receiving sickness benefits	p=0.5689	p=0.6964
Has low level of educational achievement	p=0.5738	p=0.7746
Lives in temporary housing	p=0.7136	p=0.3116
Single	p=0.1646	p=0.9856
Has been in prison in the previous 12 months	p=0.7573	p=0.0331
R^2	27.3%	31.9%

Table 6 presents the (geometric) mean dollars earned from property crime and drug dealing in the previous 30 days, by drug use and demographic categories. As outlined, we tested for differences in acquisitive criminal earnings between all the combinations of the drug use categories for each drug type. Detainees who drank alcohol on a high number of days (on 20-30 days of the previous 30 days) reported higher dollar earnings from property crime compared to those who drank alcohol on a medium number of days (on 3-19 days of the previous

30 days) ($NZ 1,142 compared with $NZ 464, p=0.0287). There was no statistically significant difference in dollar earnings from property crime between those who drank alcohol on a medium number of days and those who drank alcohol on a low number of days (on 1-2 days of the previous 30 days) ($NZ 464 compared with $NZ 542, p=0.9499). There was also no statistically significant difference in earnings from property crime between those who drank alcohol on a medium number of days and those who had drunk no alcohol in the previous 30 days ($NZ 464 compared with $NZ 444, p=0.9994). Those detainees who used cannabis on a high number of days reported higher mean dollar earnings from property crime than those who used cannabis on a medium number of days ($NZ 1,006 compared with $NZ 362, p=0.003). There was no statistically significant difference in dollar earnings from property crime for those who had used cannabis on a high number of days and those who had used cannabis on a low number of days ($NZ 1,006 compared with $NZ 552, p=0.4809) or no cannabis at all ($NZ 635, p=0.6468). Detainees who had used methamphetamine on a high number of days reported higher dollar earnings from property crime than those who had used no methamphetamine ($NZ 1,841 compared with $NZ 265, p<0.0001). Detainees who had used methamphetamine on a medium number of days also reported higher dollar earnings from property crime than those who had used no methamphetamine ($NZ 646 compared with $NZ 265, p=0.0293). There was no statistically significant difference in the dollar earnings from property crime between those who had used methamphetamine on a low number of days and those who had used no methamphetamine ($NZ 405 compared with. $NZ 265, p=0.5709). Maori detainees reported higher mean dollar earnings from property crime than non-Maori detainees ($NZ 826 compared with $NZ 432, p=0.0056).

Table 6. The (geometric) mean dollars earned from property crime and drug dealing in the previous 30 days among detainees who earned money from those activities and who used drugs on a low (1-2 days), medium (3-19 days) or high (20-30 days) number of days, or on no days (0), in the previous 30 days and demographic variables

	Property crime		*Drug dealing*	
	Geometric mean dollars earned in previous 30 days ($NZ)(n=227)	*95% confidence interval*	*Geometric mean dollars earned in previous 30 days ($NZ)(n=213)*	*95% confidence interval*
Level of use in the previous 30 days, by drug type, where: no=0 days; low=1-2 days; medium=3-19 days; and high=20-30 days				
Alcohol				
No	444	(228, 864)	1 076	(539, 2 149)
Low	542	(302, 974)	859	(452, 1 632)
Medium	464	(274, 785)	813	(449, 1 471)
High	1 142	(595, 2 191)	1 333	(620, 2 862)

Table 6. *(continued)*

	Property crime		*Drug dealing*	
	Geometric mean dollars earned in previous 30 days ($NZ)(n=227)	*95% confidence interval*	*Geometric mean dollars earned in previous 30 days ($NZ)(n=213)*	*95% confidence interval*
Cannabis				
No	635	(297, 1 359)	988	(455, 2 144)
Low	552	(245, 1 240)	861	(286, 2 585)
Medium	362	(197, 662)	949	(519, 1 735)
High	1 006	(652, 1 551)	1 240	(763, 2 015)
Methamphetamine				
No	265	(167, 419)	345	(199, 597)
Low	405	(207, 792)	501	(223, 1 123)
Medium	646	(337, 1 236)	1 134	(599, 2 148)
High	1 841	(865, 3 919)	5 111	(2 491, 10 487)
Demographic variables				
Gender				
Male	795	(507, 1 245)	886	(576, 1 361)
female	450	(242, 834)	1 130	(546, 2 339)
Age				
Under 25 years old	544	(341, 868)	778	(464, 1 302)
25 years and older	657	(388, 1 111)	1 287	(730, 2 270)
Ethnicity				
Maori	826	(528, 1 293)	1 188	(722, 1 953)
European/Pacific islander/Other	432	(258, 723)	843	(447, 1 487)
Employment status				
Unemployed or receiving sickness benefits	560	(356, 882)	954	(569, 1 598)
Employed	638	(385, 1 057)	1 050	(611, 1 805)
Level of educational achievement				
Low	638	(395, 1 031)	1 037	(602, 1 787)
High	560	(345, 909)	965	(574, 1 623)
Kind of accommodation				
Temporary housing	568	(365, 882)	874	(526, 1 454)
Renting or in own private house	629	(358, 1 106)	1 145	(650, 2 017)

	Property crime		*Drug dealing*	
	Geometric mean dollars earned in previous 30 days ($NZ)(n=227)	*95% confidence interval*	*Geometric mean dollars earned in previous 30 days ($NZ)(n=213)*	*95% confidence interval*
Marital status				
Single	503	(312, 809)	1 003	(604, 1 665)
Married/in a de facto (common-law) marriage/divorced/ separated/ widowed	711	(429, 1 176)	998	(564, 1 767)
Recent prison history				
Imprisoned in the previous 12 months	622	(360, 1 075)	1 345	(733, 2 467)
Not imprisoned in the previous 12 months	574	(371, 889)	744	(465, 1 192)

Detainees who had used methamphetamine on a high number of days reported higher mean dollar earnings from drug dealing than those who had used no methamphetamine ($NZ 5,111 compared with $NZ 345, p<0.0001). Detainees who had used methamphetamine on a medium number of days also reported higher mean dollar earnings from drug dealing than those who had used no methamphetamine ($NZ 1,134 compared with $NZ 345, p=0.0012). There was no statistically significant difference in the dollar earnings from drug dealing between those who had used methamphetamine on a low number of days and those who had used no methamphetamine ($NZ 501 compared with. $NZ 345, p=0.7822). Detainees who had been in prison in the previous year reported higher dollar earnings from drug dealing than those who had not been in prison in the previous year ($NZ 1,345 compared with $NZ 744, p=0.0331).

Discussion

Our analysis provides the first detailed look at the statistical association between methamphetamine use and acquisitive offending among a sample of police detainees in New Zealand. In this analysis, we have focused on the impact that frequent methamphetamine use has on the level of acquisitive offending of a criminally active population. We examined the statistical association between the number of days of methamphetamine use in the previous 30 days and the level of dollar earnings from acquisitive crime in the previous 30 days, while controlling for the number of days of alcohol and cannabis use in the previous 30 days and other demographic variables associated with acquisitive offending in New Zealand.

We found that cannabis and methamphetamine use in the previous month were both associated with involvement in acquisitive offending in the previous month. A number of variables linked to social and economic disadvantage in New Zealand were also associated with involvement in property crime, including being Maori, being unemployed, having a low level of educational achievement, living in temporary housing and having been in prison in the previous 12 months. A high level of alcohol, cannabis and methamphetamine use (in other words, the use of those substances on between 20 and 30 of the previous 30 days) were all associated with higher dollar earnings from property crime in the previous 30 days. The association between the number of days of methamphetamine use and the dollar earnings from property crime was the strongest and most consistently positive association.

The number of days of methamphetamine use in the previous 30 days and having been in prison in the previous 12 months were associated with higher dollar earnings from drug dealing in the previous 30 days. The number of days of methamphetamine use was again the factor with the strongest and most consistently positive association with the level of dollar earnings from drug dealing. These findings suggest that frequent methamphetamine use is associated with higher levels of acquisitive offending among criminally active individuals. Our findings are broadly consistent with previous studies that have found strong associations between the daily use of heroin and cocaine and higher levels of acquisitive offending [14, 17, 19-21].

We acknowledge a number of limitations in our analysis. Firstly, our police detainee sample is not representative of drug users in the wider New Zealand population. The detainee sample includes a high proportion of criminally active individuals who tend to come from disadvantaged backgrounds.

Secondly, our police detainee sample may not be representative of the police detainee population in New Zealand. It was not practical or ethical to interview police detainees who were intoxicated, acting violently or suffering from mental health issues. These ineligible detainees may differ from the eligible detainees who were interviewed. Surveys of police detainees will tend to exclude detainees who are heavily intoxicated from alcohol and drug use, suffering from mental health issues or acting aggressively and this appears be an inherent limitation of this type of methodology. Detainees excluded on the basis of these criteria may well have higher levels of drug use than those interviewed.

Thirdly, all the data used in the analysis is based on information reported by the individuals in the sample. Studies that have compared the validity of self-reported information on drug use with results from drug tests through urinalysis and hair samples have found that while there is a tendency for people to under-report their drug use, overall the self-reported measures are fairly good [36-38]. A number of procedures were followed in the NZ-ADAM study to encourage detainees to provide truthful and accurate information. At the beginning of the interview the interviewer identified himself or herself as a civilian researcher and explained the confidentiality and privacy protections of the study. Detainees were given an information sheet signed by the Commissioner of the New Zealand Police and the Research Director guaranteeing that the information provided during the interview would be confidential and would not be used in any legal proceedings. The interviewer explained that the findings would be reported as an aggregate and that no individual would be identified. The ability of the detainees to correctly recall details about their drug use and offending behaviour was maximized by restricting the period of interest to the previous 30 days.

Fourthly, the cross-sectional design of the NZ-ADAM survey means we can only make limited inferences about the causal nature of the statistical associations found. Longitudinal research designs that examine the age at which drug use and criminal careers started and intensified can provide a fuller understanding of the temporal progression between drug use and crime [see 14, 36]. In summaries of the research on drugs and crime, the conclusion is that no single causal pathway can explain the statistical association between drug use and crime, and that different causal links can exist for different subpopulations of drug users [14, 19, 36]. Among criminally active individuals who have few alternative legal means of income, intensifying acquisitive offending may be viewed as the most convenient way to pay for expensive drug use.

The policy implications of our study are that reductions in acquisitive offending may be possible by encouraging acquisitive offenders who are daily alcohol, cannabis and methamphetamine users to enter drug treatment programmes. The criminal justice system is potentially an important means by which problematic drug-using offenders can access drug treatment with strong institutional incentives to enter and stay in programmes (i.e. to avoid more punitive options such as incarceration) [39, 7]. Studies of the effectiveness of drug treatment and methadone maintenance for heroin users have found that while individuals with high levels of criminal offending prior to drug use may continue to offend at some level following drug treatment, those with low levels of criminality prior to their drug use can report dramatic reductions in acquisitive offending following drug treatment [36, 39, 40].

Our analysis is a first attempt at looking in detail at the association between methamphetamine use and acquisitive crime. We recognize that much more research is required, including of frequent methamphetamine users outside of the criminal justice system, to understand this relationship. Longitudinal research designs could be utilized to provide a clearer picture of the temporal causal relationship between methamphetamine use and acquisitive crime. Better measures of youth delinquency than are used here could also enhance the understanding of the role that developmental problems among youth play in drug use and criminal offending.

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Modelling disorganized crime: the cannabis market

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ABSTRACT

*The cannabis market can be characterized by two opposing forces. The first one, based on technological developments, leads to more producers (competition). The second one, arising from asymmetric information of sellers and buyers and risk minimization, leads to a monopolistic structure. This combination of competitive and monopolistic forces leads us to use a model of monopolistic competition of the cannabis markets. The present article analyses how this market is affected by the use of payments in kind and by the probability of seizures, and it is found that both factors cause an increase in the number of sellers and a reduction of the size of drug syndicates.**

Keywords: illicit drugs, cannabis, drug policies, monopolistic competition

Introduction

Retail prices in the major illicit drug markets (cannabis, cocaine and heroin) have declined significantly in the last two decades. We show the evidence in figure I for cocaine and heroin. The evidence for cannabis relates to a shorter period (see figure II), but this main trend is confirmed from other sources [1].

Despite this similarity, the underlying mechanisms at work in these different markets have been very different. A first difference relates to their production characteristics. The cocaine and heroin markets are characterized by a strong regional concentration of the production of the raw material (coca bush and opium poppy). As a result of the forces of globalization, this concentration has intensified in the past few decades [2]. The opposite has occurred in the cannabis market. Owing to the indoor cannabis technology revolution, cannabis

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crops are increasingly produced indoors under tightly controlled conditions [3]. This has led to increased productivity and has deconcentrated production so that cannabis now can be produced in virtually every country. Consequently, distances between producers and consumers have been reduced, lowering risks.

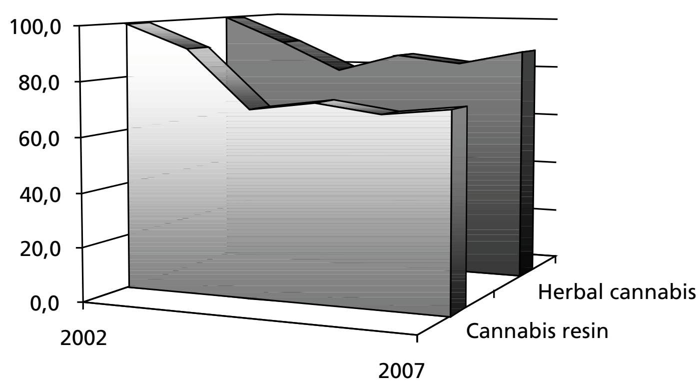
A second major difference between the cocaine and heroin markets, on the one hand, and the cannabis market, on the other, relates to public policies. More than the cocaine and heroin markets, the cannabis market has profited from less severe penalties for personal use during the past few decades.[1] That difference in severity of penalties may be related to the fact that there is less social reluctance to acceptance of marijuana use, compared with that of cocaine and heroin.

The present article develops a theoretical model that tries to capture the essential characteristics of the cannabis market in order to permit a better understanding of the workings of that market and shed some light on the empirical phenomena observed.

The second section of this article sets out the main assumptions that underlie the theoretical model. The third section presents the model and the main result derived. The fourth section examines how law enforcement policies affect the structure of the cannabis market. The conclusions are contained in the final section.

Figure I. Retail prices of cannabis, cocaine and heroin

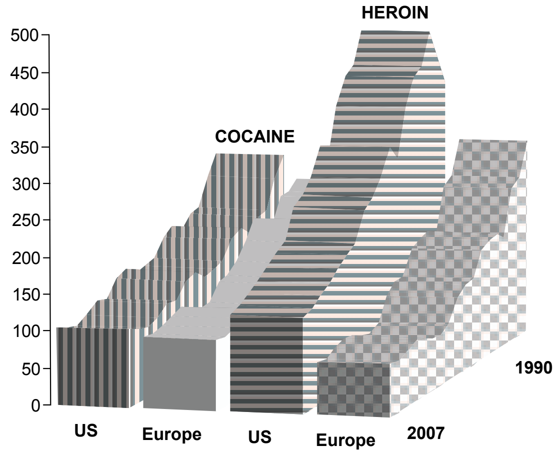
(a) **Retail price of cannabis (inflation adjusted, index 2002=100, Eur, 2002-2007)**



Source: EMCDDA Statistical Bulletin (2009)

[1] Room and others [4] make a very comprehensive description of a considerable number of cannabis prohibition systems around the world. The authors conclude that despite the fact that while a number of countries have implemented reforms aimed at softening cannabis-use control, few have addressed the issue of supply.

(b) **Retail price of cocaine and heroin (inflation adjusted 2007, US$/gram, 1990-2007)**



Source: UNODC *World Drug Report 2009*, pp215, 200

Main assumptions

Our main working assumption is that the cannabis retail market is characterized by monopolistic competition. For a similar analysis, see Costa Storti and De Grauwe [2]. The emergence of monopolistic competitive structures originates with two different forces. The first force introduces a dynamic leading to more competition; the second enhances a monopolistic structure.

The competition-enhancing force stems from two different factors. The first factor is linked to technological developments that allow the cultivation of cannabis at low cost and risk inside consuming countries.[2] The second force derives from the impact of law enforcement activities, which give incentives to drug dealing organizations to become small because large organizations are more vulnerable to detection and penalties [10-12]. As a result, these factors have tended to produce a market structure with many sellers, which in turn leads to more competition.

[2]See the European Monitoring Centre for Drugs and Drug Addiction 2008 annual report for an attempt to draw a European picture of the cannabis in-house production [5]. Wouters describes phenomena in cannabis production in the Netherlands, a country which has recently passed from being a significant hashish importer to a major marijuana producer [6]. Decorte describes the Belgium situation [7]. Potter estimates that about 60 per cent of the cannabis consumed in the United Kingdom of Great Britain and Northern Ireland is produced domestically [8]. Hough and others analyse the situation in England and Wales and conclude that despite the difficulty of obtaining precise figures on home cultivation, it is clear that this phenomena is growing, competing with imported cannabis [9].

The monopoly-enhancing force arises from asymmetric information between the buyer and the seller of drugs, that is, the seller knows the quality (potency) of the drug better than the buyer does, even if neither of them has perfect information. This asymmetry of information leads to a market failure: the high-quality drug tends to disappear, leaving only the low-quality drug.[3] This market failure, however, can be partially overcome when buyers and sellers establish a relationship based on trust, which can be achieved by repeated transactions between the same sellers and buyers. Trust is also necessary to minimize the risk of getting caught by the police.

Trust in turn creates a network structure in the retail market which allows the information about the quality of the drug and the reliability of the seller/buyer to be shared. Once trust is achieved, the seller can charge a quality premium. As a result, the price exceeds marginal costs, and the market comes closer to a monopolistic structure.

The relations based on trust in a network environment in the cannabis market have been described by economists and many criminologists [10, 11, 14, 16-23]. As stressed by Caulkins and Pacula, based on United States household population surveys, 82 per cent of cannabis drug users acquired their drugs from a friend and 11 per cent from a relative [19]. Only 7 per cent bought their drugs from a stranger. The percentages of users acquiring drugs from a friend or relative are highest among those who received marijuana for free (93 per cent) but is also high for those who most recently obtained marijuana by purchase (83 per cent) or trade for other goods (86 per cent). This relationship of trust is thoroughly described and well documented in the literature. Box 1 contains a brief survey of recently published literature.

Concerning the risk associated with trafficking, Pearson and Hobbs also observed that dealers perceive the cannabis markets as being less risky than the cocaine or heroin markets [18]. This seems to be due to less severe judicial sentences associated with cannabis-dealing. Therefore, cannabis traffickers do not like to be multi-commodity dealers, who typically receive more severe penalties when caught.

As stressed by Caulkins and Pacula, cannabis street markets differ from street markets of cocaine and heroin in that cannabis sellers are more likely to operate independently, rather than as part of an organized operation. They also tend to sell indoors and are involved in referral networks [19].

[3]The classic analysis of the "lemon problem" was first made by Akerlof [13]. Several recent studies have analysed this issue (Caulkins and Reuter [14], Pacula and others [15], Stevenson [16]).

Box 1. The distribution of marijuana: a selective survey of the evidence

Based on the 2007 United States National Survey on Drug Use and Health, the United States Office of National Drug Control Policy estimated the percentage of past-year users obtaining marijuana by the following methods: 53 per cent obtained it for free or shared it; 43 per cent bought it; and 1 per cent grew it [22].

Using a United States household survey, Caulkins and Pacula found that a large share of the users (57.8 per cent) obtained cannabis for free. They also reported that the large share of drug users who had received marijuana for free in the past 12 months were responsible for only a small share of self-reported days of past-year marijuana use (13.5 per cent) [19].

One should keep in mind that household surveys may bias results, because they exclude problematic drug users, incarcerated and transient homeless people and others.

Werse performed a school survey and a study on recreational drug use among adults in the Frankfurt area and concluded that a significant part of the drug distribution takes place in a non-monetary manner, mainly by sharing joints.* Friends and acquaintances account for most of the actual sale of hashish and marijuana, while street dealers play a minor role among regular drug users. Frequent users often cover their own supply by selling small amounts to friends. Intensive users are able to finance their own supply by selling drugs [23].

Coomber and Turnbull describe the social supply of cannabis among the adolescent population in England [24]. Potter stresses the significance of bias in answers given in the United Kingdom towards disregarding the user's own dealing or tending to consider dealers as friends, owing to difficulties accepting the underlying illicit activity. Furthermore, even when a monetary profit is made, respondents tend to dislike the labelling of individuals as drug dealers [8].

Toufik, Legleye and Gandilhon analysed the French market and stressed the importance of not being perceived as a cannabis drug dealer in order to be accepted among cannabis users. Their study analyses the methods of obtaining cannabis in France and the frequency of drug use. Once again, most of the population (60 per cent) obtained it for free, while 33 per cent bought it, and the remaining grew it themselves. However, these shares change considerably when the typology of drug user is taken into account. Among regular drug users, only 25 per cent received cannabis for free, while 62.2 per cent had to buy it, and 12 per cent grew it. Among daily users, the percentages of users in the above categories are 20.5 per cent, 62.8 per cent and 16.7 per cent, respectively [20].

The research contained in that study may provide a more in-depth analysis of the volume of so-called "free" cannabis in the market as a whole. Even if the number of drug users who consume free cannabis is significant, the volume of cannabis effectively consumed for free is not as significant, since intensive users of cannabis generally have to pay for it. Thus, the volume of effectively bought cannabis becomes much more significant than suggested by the statistics concerning indiscriminate prevalence.

In the Netherlands, the National School Survey asks young cannabis users where they acquire cannabis. The most frequent response is that it comes from friends and relatives (67 per cent), followed by coffee shops (35 per cent) and dealers (12 per cent). Detainees and dropouts, however, report that they are most likely to acquire it in coffee shops.

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*This conclusion should be treated with caution. In our view, sharing joints is not the equivalent of free cannabis. Such practice should be considered as group purchases, where, most likely, there are quantity discounts but, nevertheless, the cannabis is paid. Group purchases are commonly rotative, that is, different users will be in charge of buying the cannabis at different times. Consequently, the cost of the purchased cannabis is shared among the group of cannabis users.

The model

The local market power of the supplier is represented in our model by the assumption that each "upper-level trafficker" or supplier encounters a downward-sloping demand curve for the cannabis he sells. We assume that there are *n* suppliers of cannabis in the retail market. The number of suppliers is endogenously determined in the long run by imposing a long-term no-profit condition.

We assume that the upper-level traffickers hire lower-level traffickers. The latter can be remunerated in two ways: first, through a standard wage per working hour; second, by giving the lower-level trafficker a remuneration in kind (i.e. a quantity of cannabis). This assumption is based on empirical evidence suggesting that part of the drugs used is received free and that drug users finance their use by selling cannabis (see box 1).

Thus, we assume two types of remuneration, and we will analyse how different combinations of these two types of remuneration affect the cannabis market.

The profit of supplier i (π_i) is defined as follows:

$$\pi_i = p_i x_i - \left[(1-\gamma)w + \gamma u_i\right] l_i - \left[\theta_i p_m + (1-\theta_i) p_d\right] x_i \tag{1}$$

where x_i is the quantity of the cannabis sold by *i*; p_i is the price charged; l_i is the number of lower-level traffickers employed by supplier *i*; *w* is the identical wage paid to all "lower-level dealers". This wage includes a risk premium to compensate for the risk of violence, the risk of incarceration and the penalties associated with this. (For an analysis of the factors that affect this risk premium see the study of Kugler, Verdier and Zenou and the study of Mansour, Marceau and Mongrain (2006) [25, 26].) We will consider this risk premium to be exogenous. The second component in the remuneration, u_i, is the compensation paid in kind (cannabis). In contrast to the wage, this compensation is specific to supplier *i*. The last term in (1) is the cost of "raw" cannabis. The upper-level trafficker can buy cannabis either in the import market (at the unit cost p_m) or in the domestic market (at the unit cost p_d). The share of imported cannabis in dealer *i*'s operations is represented by θ_i. We assume that this share is specific to dealer *i*. We assume it to be exogenous.[4] In the section on conclusions, below, however, we ask the question of how it can be affected by law enforcement.

We specify the in-kind remuneration u_i as follows:

$$u_i = \frac{\mu_i x_i}{l_i} \tag{2}$$

[4]As mentioned in the introduction, technological developments have made it possible to produce cannabis crop indoors under tightly controlled conditions. As a result, θ_i has tended to decline everywhere, making cannabis production increasingly domestic in nature. See Clements and Zhao [1, chap. 3].

where μ_i is the fraction of total cannabis output reserved for remuneration to lower-level traffickers. Thus u_i is the amount of cannabis paid by supplier *i* to a lower-level trafficker.

We assume a very simple linear technology guiding the demand of lower-level drug dealers or employees by firm *i* (the "upper-level drug dealer *i*"):

$$l_i = \alpha + \beta x_i \tag{3}$$

α is the fixed amount of labour needed to set up the distribution process. Such a fixed cost arises because the upper-level trafficker, like a commercial entrepreneur, commands a number of employees to control the hierarchical structure of the organization and its internal discipline (see the study of Levitt and Venkatesh for a description of how a Chicago drug gang is organized [27]). The β_i is the number of dealers needed to sell one unit of drugs (the marginal labour input coefficient). That is, $\frac{1}{\beta}$ is the marginal productivity of a lower-level dealer in selling drugs.

Efficiency improvements can lead to an increase in the marginal productivity of dealing. Conversely, stricter law enforcement can have the effect of lowering the marginal productivity of dealing in drugs. That is, when the number of arrests increases, more dealers will have to be employed to traffic the same amount of drugs.

Before turning to an analysis of the profit-maximizing supply of cannabis, it is useful to show the implicit cost structures introduced by the two different remuneration schemes. We do this by setting different values for γ and distinguish three cases:

(a) γ = *0*, i.e. the remuneration consists of wages only

In this case the average cost, AC, and marginal cost, MC, can be written as

$$AC = \beta w + \frac{\alpha w}{x_i} + p_C \qquad MC = \beta w + p_C \qquad \text{where} \quad p_C = \theta p_m + (1-\theta) p_d$$

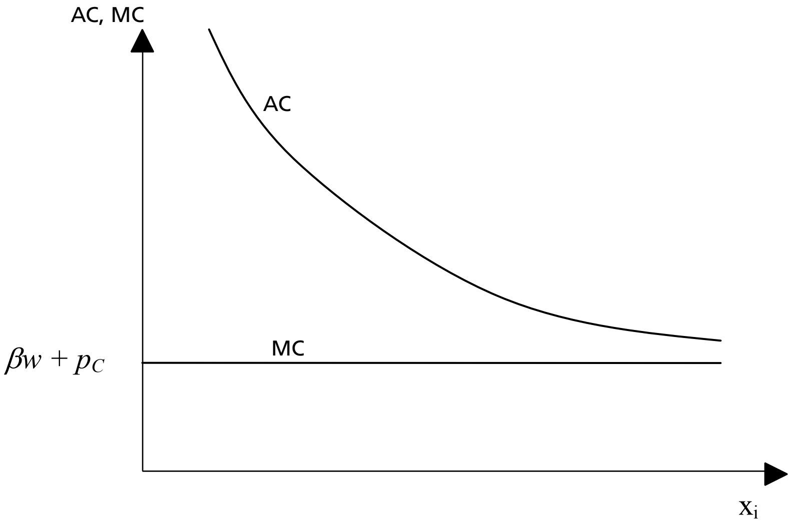
Figure II *(a)* shows average cost (AC) and marginal cost (MC). Under the normal wage-based remuneration, AC has a downward slope and converges asymptotically with the marginal cost.

(b) γ = *1*, i.e. the remuneration is only in kind

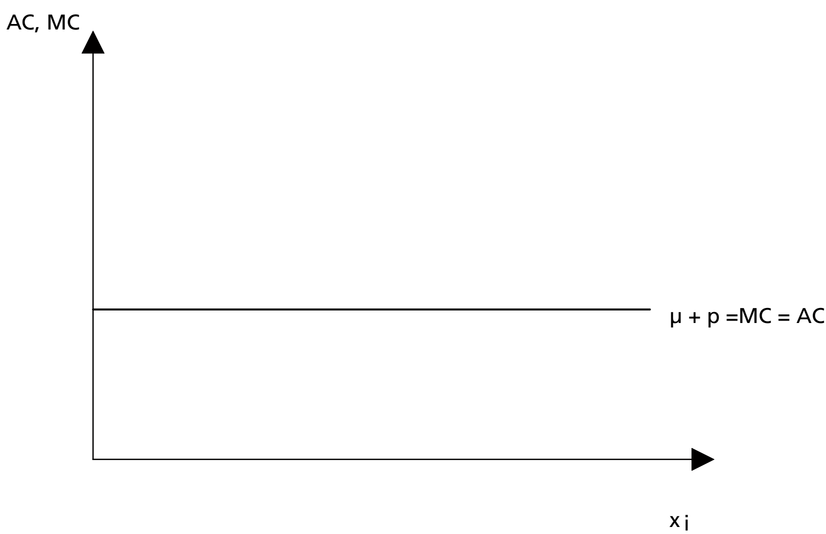
In this case, AC and MC can be written as AC = MC = $\mu_i + p_C$. Figure II *(b)* shows this case.

Figure II. Average and marginal costs

(a) **Only remuneration in cash**



(b) **Only remuneration in kind**



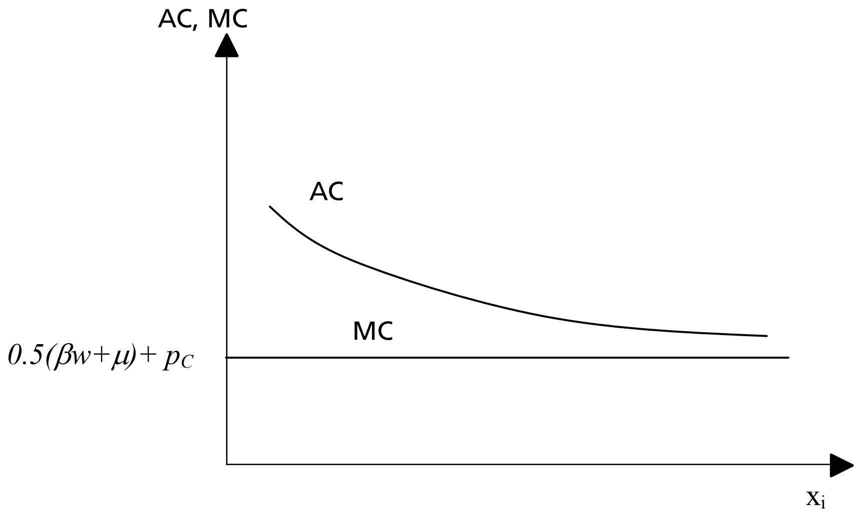
Finally, figure III shows the mixed remuneration system where γ = *0.5*.

In that case, the average and marginal costs can be written as:

$$AC = 0.5\left(\beta w + \frac{\alpha w}{x_i}\right) + 0.5\mu + p_C \qquad MC = 0.5(\beta w + \mu) + p_C$$

In the mixed system, the average cost curve is located closer to the marginal cost curve. When γ increases, the AC curve moves closer to the MC curve and it coincides with it when $\gamma = 1$.

Figure III. Average and marginal costs with mixed remuneration



We now turn to an analysis of the optimal supply of cannabis. In order to do so, we first substitute (2) and (3) into (1). This yields

$$\pi_i = p_i x_i - (1-\gamma) w(\alpha + \beta x_i) - \gamma \mu_i x_i - p_C x_i \tag{4}$$

The first order condition for a profit maximum is given by the following expression:

$$p_i = \frac{\eta}{\eta - 1}\left[(1-\gamma)\beta w + \gamma \mu_i + p_C\right] \tag{5}$$

where η is the price elasticity of the demand for drugs of supplier *i* (in absolute value).

It is important to stress here that the price elasticity, η, measures the reaction of a representative drug user to a change in price asked by supplier *i*, assuming that other suppliers do not change their price. Thus, this price elasticity is different from the price elasticity of the total demand for cannabis. Let us call the latter the market elasticity and represent it by ε. The market elasticity, ε, measures the extent to which drug users change their demand for drugs when the price of this drug, as applied by all drug suppliers, changes. The empirical evidence suggests that this market elasticity is between 0 and 1 in absolute value (see box 2 containing a survey of the empirical evidence). The price elasticity η used here, is larger than the market elasticity ε, because it also reflects the possibility that the consumer substitutes from one dealer to another. The larger the number of dealers, the greater the substitution elasticity, η, relative to the market elasticity ε because the existence of more dealers increases the possibilities of substitution. We will assume that the number of dealers is large enough so that $\eta > 1$ (in absolute value). It can been shown that in order for the model of monopolistic competition to have an equilibrium, $\varepsilon < \eta$, which is easily satisfied [28].

Box 2. The price elasticity of demand for cannabis

The poor quality of estimates of drug consumption has restricted the number of available studies of cannabis price elasticity. Most studies available focus on the "elasticity of participation". That is, they estimate how the prevalence rate changes when drug prices vary, leaving the analysis of changes in the volume of drug effectively used for further analysis. Thus, the existing estimates measure the percentage change in the number of drug users when the price of cannabis changes by 1 per cent. Additionally, these estimates do not correct the price by adjusting for differences in cannabis potency.

Nisbet and Vakil estimated the price elasticity of marijuana based on the student population of the University of California, Los Angeles. They arrived at values varying between 0.7 and -1.0 per cent [29].

Saffer and Chaloupka used national household surveys on drug abuse of the United States (which exclude individuals in college dormitories and prisons and the homeless) for 1998, 1990 and 1991. The excluded groups represent only 2 per cent of the whole population, but as stated by the author, that 2 per cent of the population contains most regular drug users. Using the effect of marijuana decriminalization as a proxy for marijuana price decline, they conclude that decriminalization of marijuana increases past-month participation by about 8.4 per cent and past-year participation by 7.6 per cent [30].

In that connection, Pacula estimated the elasticity of the previous year's participation of high school seniors. After controlling for effects due to specific conditions in states (some states of the United States are more permissive towards cannabis use than are others), past-year participation elasticity is -0.33, when time effects are omitted, but only -0.69 when time is entered quadratically [31].

Desimone and Farrelly found that the impact of changes of marijuana prices on drug use differs when analysing the adult or juvenile marijuana demand in the United States (national household surveys on drug abuse from the period 1990-1997). The adult behaviour was very reactive to marijuana price levels, suggesting that the income effect of marijuana consumption may be predominant. Concerning juvenile marijuana drug demand, the authors explained this behaviour by noting two different factors. First, some juveniles might use their parents' money to buy drugs, keeping their level of drug use relatively unchanged. Second, sellers find it profitable to give away some drugs to young initiators in order to "hook" them and charge them higher prices at a later stage. All in all, these authors found that cannabis demand decreases with family income [32].

Grossman concluded that trends in marijuana participation point to an increase in the number of youth who use cannabis as its real price falls. He estimates that wide swings in the real price of marijuana explain 70 per cent of the reduction in participation from 1975 to 1992, 60 per cent of the subsequent growth until 1997, and almost 60 per cent of the decline since 1997 in the United States. He also estimates price elasticity based on rates for hospital emergency room admissions and arrestees. On the basis of those rates, he concludes that cannabis participation reacts negatively to prices [33].

Bretteville-Jensen and Biorn made use of a sample of 2,500 interviews close to a needle exchange service centre in Oslo, testing how those data behaved with respect to four different models: switching regression mechanism treating dealing/non-dealing; spline functions examining "kinks" in the price responses; dynamic addiction models; pseudo-panel data focusing on unobserved heterogeneity [34]. Despite the fact that the paper is concerned only with heroin and amphetamines demand injectors' elasticity, there are results that should be kept in mind for the cannabis analysis. First, the models gave quite different estimates for dealers and non-dealers, suggesting that dealers are much less reactive to prices than non-dealers, as could be expected. Although this result has not been tested in the cannabis market, it is likely to be easily transposed for two reasons. First, price rises increase the dealer's income. Second, dealers are most likely confronted with less volatile prices than final users, especially in the case of home-grown cannabis.

A second result is how addicts react to income changes. Bretteville-Jensen and Biorn conclude that even heroin addicts (where withdrawal pain is significant) were responsive to income changes. Thus, in the case of addicts, for whom drug consumption represents an important share of their expenses, changes in drug prices may have a larger than expected response due to the income effect.

Clements estimated the price elasticity of marijuana consumption, taking into account alcoholic substitute beverages and their cross-price elasticity in Australia. He concluded that marijuana price elasticity varies between -0.8 and -0.77, depending on the value of the own-price elasticity of demand for alcohol and marijuana as a group, since they are strongly negatively correlated. The author also estimates that the income elasticity of cannabis is close to 1.2 [35].

Chaloupka also concluded that rising cannabis prices reduce cannabis use [36]. Van Ours and Williams analysed how cannabis use reacts to prices at different stages of the "drug career", namely, the initiation and the quitting phases. They concluded that in Australia, based on a population aged from 12 to 52, over a sample period from 1985 to 2001, the initiation into cannabis use was price responsive; with the estimated price elasticity in the range of -0.47 to -0.55. However, they also obtained robust results showing that lower cannabis prices are associated with early initiation phases. Additionally, their results suggest that the price is unlikely to play a significant role in the quitting behaviour [37].

All in all these empirical studies suggest that the market elasticity (e in our notation) may be substantial and may be located in a range between 0 and 1 (in absolute value).

We recognize in equation (5) the typical markup condition of price over marginal cost. The marginal cost is $(1-\gamma)\beta w + \gamma\mu_i + p_C$ and consists of three components, the wage cost, the in-kind remuneration cost and the cost of cannabis. $\frac{\eta}{\eta-1} > 1$ is the markup.

Equation (5) allows us to gauge the impact of exogenous changes to the retail price of cannabis. An increase in the wage rate (owing, for example, to an increase in the risk premium) and an increase in the in-kind remuneration cost have an amplified effect on the price of the drug produced by the markup, i.e.

$$\frac{\partial p_i}{\partial w} = \frac{\eta}{\eta - 1}(1-\gamma)\beta \qquad \text{and} \qquad \frac{\partial p_i}{\partial \mu_i} = \frac{\eta}{\eta - 1}\gamma \tag{6}$$

It should be stressed that these effects apply to the short term. In the long run, the profits of the drug suppliers are lost through competition through the entry of new drug suppliers. Long-run equilibrium is obtained by imposing a zero profit condition $\pi_i = 0$. We will also impose the condition that the equilibrium is symmetric, i.e. that prices and quantities are identical across drug suppliers. This allows us to concentrate on the representative drug supplier without subscript, i.e. to focus on a representative upper-level drug dealer.

Setting $\pi_i = 0$ in (4) and dropping the subscript *i*, the long-run equilibrium condition is

$$p\ x\ - (1-\gamma)w(\alpha + \beta x\ ) - \gamma\mu\ x\ - p_C x = 0 \tag{7}$$

Rearranging leads to $$p\ = \frac{(1-\gamma)w(\alpha + \beta x\ )}{x} + \gamma\mu\ + p_C \tag{8}$$

or

$$p\ = \frac{(1-\gamma)w\alpha}{x} + (1-\gamma)w\beta + \gamma\mu\ + p_C \tag{9}$$

It can be seen that this amounts to setting price equal to average cost.

We can derive the long-run effect of a change in the wage rate or in the in-kind remuneration. We have

$$\frac{\partial p}{\partial w} = (1-\gamma)\left[\frac{\alpha}{x} + \beta\right] \text{ and } \frac{\partial p}{\partial \mu} = \gamma \tag{10}$$

We observe an important difference between the effects of the two remuneration schemes. In the wage remuneration scheme, the effect of an increase in the wage cost on the price declines with the size of the drug sales, while in the in-kind remuneration scheme, the effect of a higher in-kind remuneration on the price remains constant and is independent from the scale of the supply. This implies that in the wage remuneration scheme, there is an incentive for the supplier to go for economies of scale, i.e. to increase supply so as to profit from a declining average cost. This incentive to increase supply is absent in the in-kind remuneration.

Finally, in order to close the model, we introduce the condition that the demand for cannabis is equal to the supply. Total demand is equal to the consumption (c) of the representative consumer multiplied by the size of the population L (the prevalence), i.e. cL. In equilibrium $cL = x$. We substitute this expression in (8)

$$p = \frac{(1-\gamma)w\alpha}{cL} + (1-\gamma)w\beta + \gamma\mu + p_C \qquad (11)$$

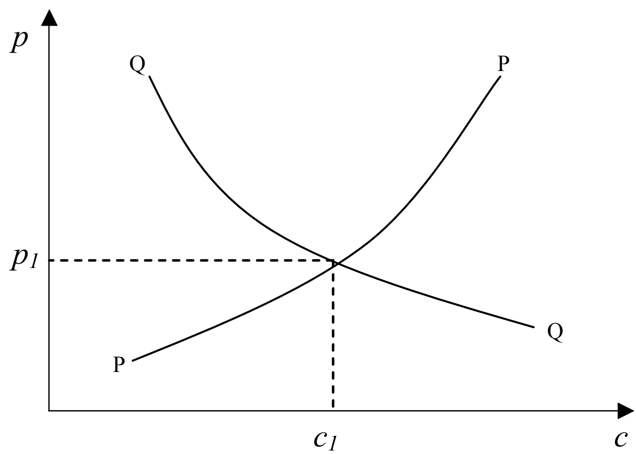
The equilibrium of the model is fully described by equations (5) and (11). These two equations determine the equilibrium value of the retail price (p) and the consumption of drugs (c), in the short and long term, respectively.

We represent the short-term and long-term equilibria expressed in equations (5) and (11) graphically in figure IV. The PP line is the graphical expression of the short term shown in equation (5). We assume here that the retail demand curves are linear. As a result, the elasticity η is declining for increasing values of c, i.e., the higher the drug use the less sensitive drug demand is to price changes. This feature of the demand curve is consistent with the evidence suggesting that high-use drug users become addicted (dependent) so that their demand becomes less price sensitive (see box 2). This produces an upward sloping PP line. The upward slope reflects the fact that with a higher level of drug consumption, the market power of the drug supplier is increased, allowing him to apply a higher markup. This leads to a higher retail price.

The QQ line is the graphical representation of the long-run equilibrium condition (11). The negative slope (which is readily seen from equation (11)) expresses the fact that QQ is derived from the average cost curve. Thus as consumption increases, drug suppliers are able to “slide down” their average cost curves. In the long run, this leads to a declining retail price.

The equilibrium values of the price and the consumption of the representative drug user are given by the intersection point of the PP and QQ lines. At this intersection point, short-term and long-term equilibria are satisfied simultaneously. While the short-term equilibrium can be considered to be satisfied at each point in time, this is not the case with the long-term equilibrium. In the following sections, we will analyse how changes in exogenous variables affect this intersection point, i.e. how these shocks affect both the short- and long-run equilibrium. We do not go into a dynamic analysis of how the long-run equilibrium is reached.

Figure IV. Equilibrium of the retail market



The remuneration scheme and market structure

This model is then used to analyse how a changing composition of in-kind and wage remuneration affects the equilibrium. Figure V shows how an increase in γ (i.e. the relative importance of in-kind remuneration as compared to a remuneration in wages) affects the short- and long-run equilibria. The effect of an increase in γ is to make the long-run QQ line (the average cost curve) flatter and to shift it down (Q'Q'). This can be seen from equation (11). As a result, the equilibrium levels of consumption (of the representative consumer) for the drug supplied by an individual supplier declines and so does the price. This does not mean that the representative consumer will reduce his drug use. It means that he will now have the choice between more suppliers of cannabis, each of which becomes smaller in size. Put differently, in the new equilibrium point there will be more suppliers of cannabis, which all have a smaller size. In order to show the latter, we use equations (5) and (11) describing the short- and long-run equilibria. We can then solve for x (remembering the $x = cL$). This yields an expression for the optimal size of the representative producer:

$$x = \frac{(1-\gamma)(\eta-1)w\alpha}{(1-\gamma)w\beta + \gamma\mu + p_C} \qquad (12)$$

We can now see that as $\gamma \to 1, x \to 0$. The counterpart of this result is that the number of firms goes to infinity. We can show the latter as follows. The total population of workers can be divided into those who work in the cannabis industry and those who do not.

$$L = LC + LL \qquad (13)$$

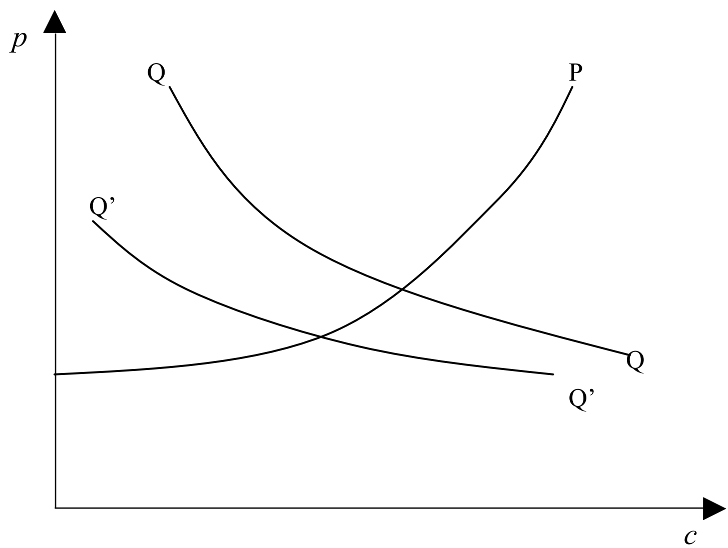
Where L is the total population, LC the population working in the cannabis industry and LL the population working in the legal sector.

$$L = \sum_{i=1}^{N} l_i + LL = \sum_{i=1}^{N} (\alpha + \beta x_i) + LL = N(\alpha + \beta x) + LL \qquad (14)$$

It follows that $N = \dfrac{L - LL}{\alpha + \beta x}$ (15)

We can conclude from (15) that a decline in *x* coincides with an increase in the number of cannabis suppliers, *N*. In addition, since in an in-kind remuneration system (i.e. γ = *1*) the fixed cost component α drops out, we conclude that as $\gamma \to 1, N \to \infty$. Thus, an exclusively in-kind remuneration system leads to a market structure of perfect competition.

Figure V. Effect of increasing in-kind remuneration



We can use this model to analyse important policy questions. The first question we analyse is how drug seizures affect the retail market.

Impact of seizures

The way we model seizures is as follows. We introduce in equation (1) the probability that a certain percentage of drugs sold in the retail market is seized. This leads to a new definition of the profits of supplier *i*:

$$\pi_i = p_i x_i (1 - s) - [(1 - \gamma)w + \gamma u_i] l_i - p_C x_i \qquad (16)$$

where s is the probability that the drug supplied by i will be seized. Thus we assume that the drugs distributed to the lower-level traffickers are not seized because these do not reach the retail market but are consumed by the traffickers. Note that π_i now has to be interpreted as expected profits.

The first order condition for profit maximization is now given by

$$p_i = \frac{\eta}{\eta - 1}\left(\frac{1}{1-s}\right)\left[(1-\gamma)\beta w + \gamma\mu_i + p_C\right] \tag{17}$$

This equation has the same interpretation as (5), that is, it describes the short-term equilibrium. We observe from (17) that when the probability of seizures increases, the upper-level traffickers raise the retail price. Because of the existence of a markup ($\frac{\eta}{\eta-1}$), the price increase will be a multiple of the increase in the probability of seizures. But this price increase will be smaller when consumers are more responsive to price rises (when η increases, that is, when the level of addiction is smaller). Note also that the markup ($\frac{\eta}{\eta-1}$) can be interpreted as reflecting higher expected costs that are due to the increases in the probability of seizures.

The zero profit condition $\pi_i = 0$ is imposed to obtain long-run equilibrium. It yields

$$p = \left(\frac{1}{1-s}\right)\left[\frac{(1-\gamma)w\alpha}{x} + (1-\gamma)w\beta + \gamma\mu + p_C\right] \tag{18}$$

Since in equilibrium $x(1-s) = cN$, (17) becomes

$$p = \left(\frac{1}{1-s}\right)\left[(1-\gamma)w\beta + \gamma\mu + p_C\right] + (1-\gamma)\frac{w\alpha}{cN} \tag{19}$$

We can now analyse the effect of changes in the probability of seizures brought about by stricter law enforcement. We do this in figure VI using the same graphical procedure as in figure V. An increase in s has the effect of shifting both the PP curve and the QQ curve upwards. However, it can be shown that the upward shift of the PP curve is higher than that of the QQ curve. This can be seen by taking the partial derivative of p with respect to s in equations (17) and (19). We obtain

From equation (17): $$\frac{\partial p}{\partial s} = \frac{\eta}{\eta - 1}\left(\frac{1}{(1-s)^2}\right)\left((1-\gamma)w\beta + \gamma\mu + p_C\right) \tag{20}$$

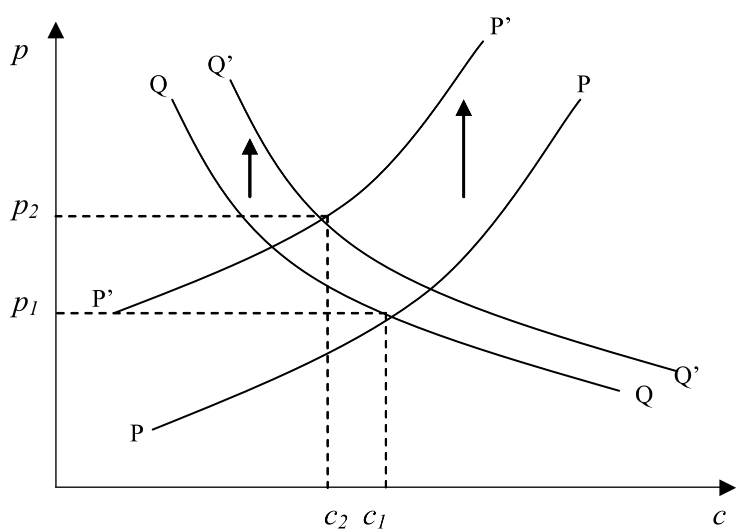
From equation (19): $$\frac{\partial p}{\partial s}=\left(\frac{1}{(1-s)^2}\right)\left((1-\gamma)w\beta+\gamma\mu+p_C\right) \tag{21}$$

It can be seen that (20) > (21), showing that the upward shift of the PP curve is higher than that of the QQ curve (see figure VI).

We conclude that an increase in the probability of seizures raises the retail price of drugs and reduces the amount of drug use (c declines). The latter effect follows from the fact that drug users are sensitive to a price increase. Note also that as the price increases and drug use declines, the price elasticity, η, increases.

Seizures have an interesting effect on the structure of the market in the long run. The model predicts that increases in seizures reduce c. This implies by (15) that N also increases (given that $x = cL$). Thus, increases in seizures raise the number of higher-level traffickers who all have a smaller size. In this sense, law enforcement (seizures) has the effect of changing the market structure, that is, it leads to more but smaller drug dealing organizations. As a result, the drug dealing business becomes less monopolistic and more competitive.

Figure VI. Effect of increases in the probability of seizures



The risk of importing cannabis

In many countries, import of cannabis is subject to more stringent law enforcement than is domestic production. Empirical research has shown that home-growing of cannabis plant is a way to reduce or avoid the risk of getting caught, because imports are more easily detected than domestic production, which is often small-scale and indoor [7]. Importation requires lengthy transportation, imaginative concealing methods and evading border controls. Furthermore, the penal status of cannabis cultivation remains ambiguous[5*] or non-existent, and, consequently, some European law enforcement entities still disregard the importance of detecting home-grown production. The latter is sometimes perceived to be a small-scale problem, where the cost of detecting small units of cannabis cultivation is too high for the volume of cannabis seized.

We model this feature in the following way. We defined the price of cannabis as a weighted average of the price of the imported cannabis and the price of domestically produced cannabis:

$$p_C = \theta p_m + (1-\theta) p_d$$

We now assume that the import price p_m carries a risk premium, ρ, which is a function of the tightness of border controls:

$$p_m = p'_m + \rho$$

We substitute this expression into the short-term and long-term equilibrium conditions (5) and (11):

$$p = \frac{\eta}{\eta - 1}\left[(1-\gamma)\beta w + \gamma\mu_i + \theta(p'_m + \rho) + (1-\theta)p_d\right] \tag{22}$$

$$p = \frac{(1-\gamma)w\alpha}{cL} + (1-\gamma)w\beta + \gamma\mu + \theta(p'_m + \rho) + (1-\theta)p_d \tag{23}$$

Taking the derivative of p with respect to ρ yields the following two expressions:

$$\frac{dp}{d\rho} = \frac{\eta}{\eta - 1}\theta \qquad \text{and} \qquad \frac{dp}{d\rho} = \theta$$

We obtain the same qualitative result as in the previous section, i.e. both the short-term PP line and the long-term QQ line shift upwards, but the shift in the PP line is stronger than the shift in the QQ line. As a result, the retail price increases, and the consumption of the representative user declines. The market structure effects are also qualitatively the same.

It should be stressed that the previous analysis should be completed by analysing how the risk premium affects the import share, θ. We have kept θ constant but it is clear that the risk premium is likely to lead to a shift towards

[5] See Gamella and Rodrigo (2004) for the Spanish situation [38].

the use of domestic cannabis, thereby reducing θ. We leave this problem for further research. Note also that a shift in the preferences of European consumers and traffickers towards indoor production has been observed.[6]

All in all, the empirical evidence and the existing studies suggest that there is an exogenous dynamic that tends to reduce θ, thereby favouring the future development of home-grown production in replacement of imported cannabis.

Conclusions

In this paper, we have modelled the cannabis market, starting from the idea that this market can be characterized by two opposing forces. The first force leads to more competition. Technological developments have made it possible to increase the number of producers dramatically. In addition, production can now be done in virtually all countries. All this has led to more competition. The second force arises from the asymmetric information between sellers and buyers and leads to monopolistic structures. Asymmetric information leads to the need to develop a network based on trust. Trust, in turn, allows the seller to charge a premium above marginal costs.

This combination of competitive and monopolistic forces led us to use a model of monopolistic competition. We used this model to analyse the workings of the cannabis market. One of the questions that we studied was how the use of in-kind payments, which are widely observed in the cannabis market, affect the market structure. We concluded that in-kind payments tend to increase the number of sellers and reduce their size.

We also analysed how the probability of having cannabis seized affects the market structure. The model shows that a higher probability of having cannabis seized has the effect of changing the market structure, i.e. it leads to more but smaller drug dealing organizations. As a result, the drug dealing business becomes less monopolistic and more competitive.

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[6]Criminological and ethnographic studies report a set of factors that justify this change in preferences [7, 8]. First, technological developments have allowed for the introduction of increasingly sophisticated growing equipment, requiring know-how which is widely available, for instance on the Internet or in specialized magazines. Second, there is a wide availability of tried-and-tested premium strains of cannabis. Third, the seeds and the equipment needed to produce cannabis plant are cheap. Both are available either in the Internet shops or, as with some of the material, in legal horticulture shops. Fourth, production does not require much space, if well organized in-house. Fifth, consumers seem to prefer domestic cannabis production because of its better quality (considering it to be healthy and organic) and because of its more controlled potency. On the demand side, cannabis users also prefer cannabis herb to cannabis resin which is the product most commonly imported. Finally, drug users and dealers prefer producing their own cannabis plant. As a result, they become less dependent on external market fluctuations and less involved in the illegal circuit. Furthermore, local production reduces the number of intermediaries involved in the cannabis trafficking compared with overseas production. This leads to an increase of domestic traffickers' profit margins. All these factors have enhanced the domestic production of cannabis plant.

Empirical surveys have shown the growing importance of domestic cannabis production, compared with imports. It appears that the recent production structure has probably reduced the interest of penal and law enforcement authorities in detecting these small-scale producing "factories" but has simultaneously made the law enforcement goal of defeating cannabis trafficking less effective. Further research will be necessary to substantiate that conclusion.

The combination of these factors has allowed for a market structure dominated by monopolistic competition, where competition is becoming more intense owing to several factors. One is the structure of payments in kind to lower-level traffickers/dealers; the other is the recent tendency to move from imported cannabis to domestic production of cannabis in important consumption areas, such the United States and Europe. Both factors favour the development of small production and distribution structures. As a result, law enforcement action becomes more difficult.

The model presented in this paper is very simple, abstracting from some special features of the cannabis market. Further research will be necessary to make the model more realistic. Our ambition is to develop models that, while being more sophisticated, maintain sufficient simplicity. Without such simplicity, models quickly lose their usefulness.

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