

Spatial analysis of drug-related hospital admissions: an auto-Gaussian model to estimate the hospitalization rates in Italy

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Abstract

Introduction: The aim of this study is to evaluate, even if partially, how much the drug use phenomenon impacts on the Italian National Health System throughout the estimation at local level (Local Health Unit) of the hospitalization rate caused by substance use and abuse such as opiates, barbiturates-sedatives-hypnotics, cocaine and cannabis, and keeping in mind the phenomenon distribution in the space and so the fact that what happens in a specific area depends on what is happening in the neighbourhoods close to it (spatial autocorrelation).

Methods: Data from hospital discharge database were provided by the Ministry of Health and an auto-Gaussian model was fitted. The spatial trend can be a function of other explanatory variables or can simply be modeled as a function of spatial location. Both models were fitted and compared using the number of subjects kept in charge by Drug Addiction Services and the number of beds held by hospitals as covariates.

Results: Concerning opiates use related hospitalizations, results show areas where the phenomenon was less prominent in 2001 (Lombardy, part of Liguria, Umbria, part of Latium, Campania, Apulia and Sicily). In the following years, the hospitalization rates increased in some areas, such as the north of Apulia, part of Campania and Latium. A dependence of the opiates related hospitalization rates on the rate of subjects kept in charge by the Drug Addiction Services is highlighted. Concerning barbiturates-sedatives-hypnotics consumption, the best model is the one without covariates and estimated hospitalization rates are lower than 3 per thousand. The model with only the covariate "rate of subjects kept in charge by Drug Addiction Services" has been used both for cocaine and cannabis. In these two cases, more than a half of the Local Health Units report hospitalization rates lower than 0.5 per thousand.

Conclusions: This study has allowed for the development of an indirect indicator for the phenomenon of drug use and it constitutes an effort in answering specific needs for the planning of health policies related to a field that, given the specificity of the phenomenon, is often difficult to detect and quantify by means of more common data analysis techniques.

Moreover, it is important to highlight that, being this study a first attempt in applying this statistical methodology to data regarding drug addiction, it needs to be further improved.

Key words: hospitalization rate, drug addiction, drug use/abuse, Markov random field, Gaussian auto-model, spatial dependence, GIS

Introduction

Drug consumption constitutes an important public health problem, both for the effects on the drug users healthcare and, on the other hand, for its impact on the hospitals and Drug Addiction Services.

This study is based on the view of the important role of hospitals in the management of the assistance to substance abusers.

The aim of this work is to evaluate, even if partially, how much the drug use phenomenon

impacts on the Italian National Health System throughout the estimation at local level (Local Health Unit) of the hospitalization rate caused by substance use and abuse such as opiates, barbiturates-sedatives-hypnotics, cocaine and cannabis, and keeping in mind the phenomenon distribution in the space and so the fact that what happens in a specific area depends on what is happening in the close neighbourhoods (spatial autocorrelation).

Table 1. ICD9-CM codes related to drug use/abuse.

Disease	ICD9-CM Code
Drug psychoses	292
Drug dependence	304
Nondependent drug abuse	305.2-9
Drug dependence complicating pregnancy, childbirth or the puerperium	648.3
Poisoning by opiates and related narcotics	965.0
Poisoning by sedatives and hypnotics	967
Poisoning by surface (topical) and infiltration anesthetics – cocaine	968.5
Poisoning by psychotropic agents	969
Poisoning by analeptics	970.0
Poisoning by opiate antagonists	970.1

Methods

Data regarding all of the hospitalizations during the years 2001-2003 (excluded the day hospital) of subjects of ages between 15 and 54 years in public and private structures were provided by the Ministry of Health. Raw hospitalization rates were calculated on the basis of the hospital discharges database.

In particular, as the European Monitoring Center for Drugs and Drug Addiction (EMCDDA) suggests [1], only the hospital discharge file cards, having in the principal diagnosis or in one of the five secondary diagnosis, a directly drug use/abuse related ICD9-CM code were considered (Table 1). Therefore, for each of the 195 Italian Local Health Units and for each of the years above mentioned, the raw hospitalization rate for drug related causes was calculated dividing the number of drug related hospitalizations by the number of all of the hospitalizations.

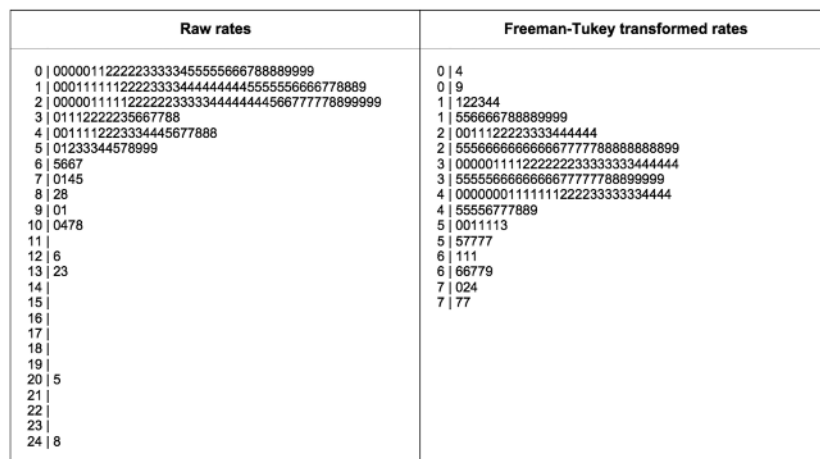
The number of drug related hospitalizations in each Local Health Unit is a count, so the raw hospitalization rates follow a binomial model. In order to apply a Gaussian model, a mean-variance dependence has to be removed, so an appropriate transformation of the raw rates was considered in order to obtain the stability of the variance.

A transformation that shows more stability than the usual transformations was introduced in 1950 by Freeman and Tukey [2] and used by Cressie and Chan in 1989 to analyse Sudden Infant Death Syndrome data [3].

The unequal numbers of total hospitalizations in the Local Health Units make it impossible to assume homoskedasticity.

Figure 1 shows the steam-and-leaf plots of the

Figure 1. Steam-and-leaf plots of raw rates and Freeman-Tukey transformed rates (year 2001, hospitalizations caused by opiates use).



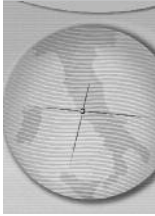
raw rates and the Freeman-Tukey transformed rates (year 2001): the Freeman-Tukey transformed rates are more symmetrically distributed and can be thought of as normally distributed, conditionally to all other observed rates.

The transformed rates can be thought of as realizations of conditional distributions of a spatial process in discrete locations, defined, in this case, by centroids of the Local Health Units.

To estimate the drug-related hospitalization rates eliminating the spatial dependence is equivalent in estimating the means of the joint probability distribution.

The Markov property is assumed, that is, the conditional distribution in a certain location of the spatial process depends only on values observed in a subset of locations, defined as “neighbourhood”. In this article, for each Local Health Unit, its neighbourhood is defined as the set of adjacent Local Health Units.

In 1974, Besag [4] showed how the conditional probability distributions, under certain conditions, determine the form of the joint probability distribution, which is called a Markov random field.



As previously seen, the conditional distributions can be considered Gaussian distributions, therefore the Markov random field is referred to as Gaussian or auto-Gaussian model.

In this case, Besag [4] proved that the conditional distributions are Gaussian distributions with the mean given by the sum of a site-specific mean (large-scale variation) and a term measuring the effect that neighbour sites have on the considered site (small-scale variation). In order to allow the mean of each site to be dependent on site-specific covariates, it is sufficient to express it as a linear function of such covariates.

These conditional distributions determine a multivariate Gaussian joint distribution [4] whose mean vector express the “large-scale” variation and the variance-covariance matrix the “small-scale” variation (i.e. the spatial dependence).

These kinds of Markov random fields are generally over-parameterized so, in order to decrease the number of parameters and get accurate estimations, the model is simplified.

For this purpose, in this work parameterization of mean vector and variance-covariance matrix of the joint distribution of the model are introduced.

A classical parameterization of mean vector consists of a linear function of site-specific covariates.

Two different site-specific variables are considered as potential covariates:

- number of subjects kept in charge by Drug Addiction Services (rate calculated referring to the total number of residents, of ages between 15 and 54 years in the Local Health Unit area)
- number of beds held by hospitals (rate calculated referring to the total number of residents, of ages between 15 and 54 years in the Local Health Unit area)

The variance-covariance matrix is modeled throughout only one parameter and expressed in function of known quantities, such as the total number of hospitalizations for all the causes in each Local Health Units and a symmetric matrix that describes the neighbourhood structure (adjacency matrix).

In this case, the parameter captures the “power”

of the spatial dependence and it is called “general spatial correlation coefficient”.

Estimations of the parameters introduced in the model have been obtained maximizing the likelihood function (see Cressie [5] for more details) and the 95% confidence intervals have been calculated.

Moreover, it has been possible to choose between two nested models by means of a chi-squared test [6] which compares the models likelihood values.

Therefore, the auto-Gaussian model has been used to statistically forecast the value of the process in a certain point of the space, conditionally to the values of the neighbourhoods. Applying this process to all location of the spatial domain, it calculates a spatial smoothing, is to say, specifically, drug related hospitalization rates adjusted by the spatial dependence of the phenomenon.

Applying the inverse Freeman-Tukey transformation [5] it is possible to go back to the true drug-related hospitalization rates which have then been reported on choropleth maps.

In order to implement this methodology, an algorithm has been written in R language and its functionality has been tested by means of simulations. Results have been visualized as maps in a geographic information system (GIS).

Results

The model described in the previous section has been applied to drug use related hospitalizations (ordinary regime) of people between the ages of 15 and 54 years. Analysis was carried out separately over the years 2001, 2002 and 2003.

Table 2 shows the total number, at national level, of admissions caused by specific drug consumption and the total number of admissions to hospital for all causes.

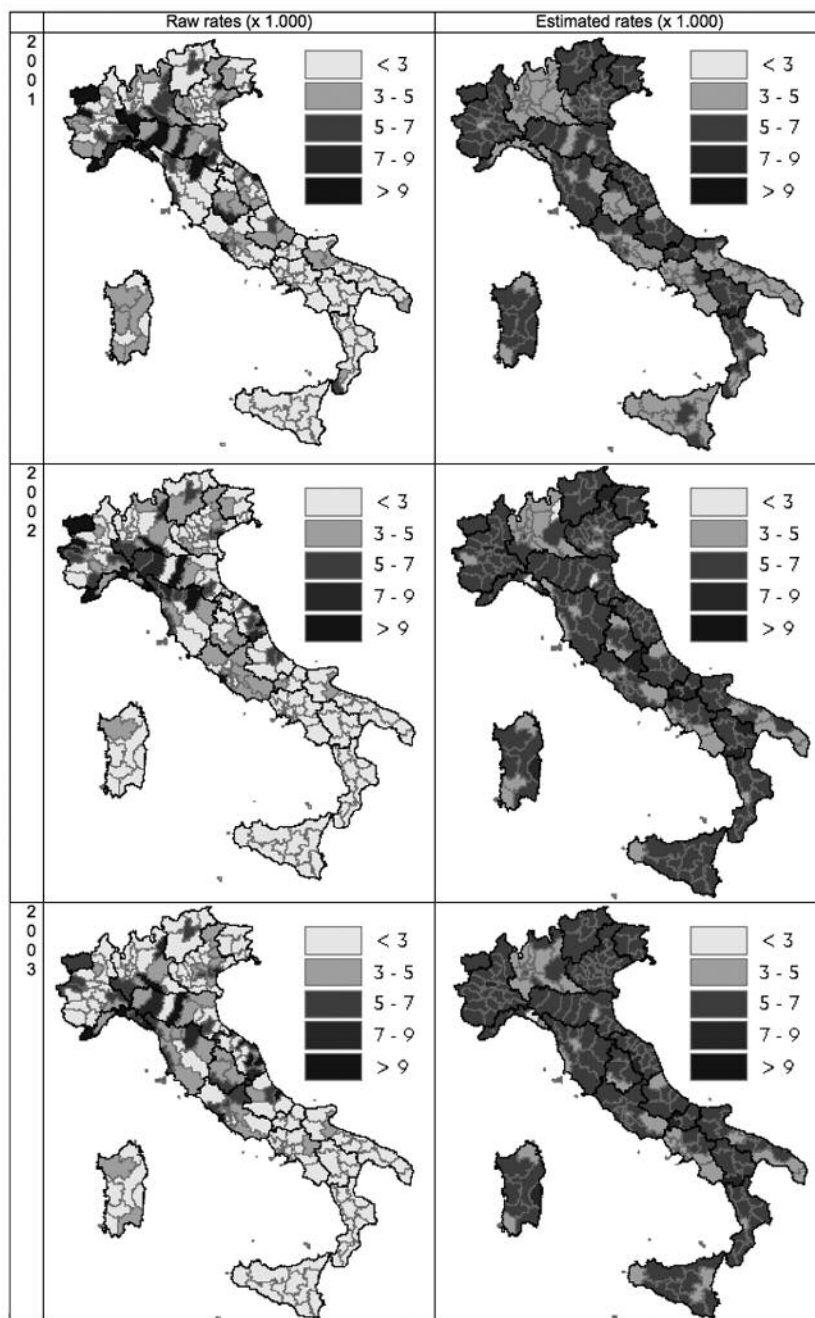
Hospitalizations related to drug consumption are around the 0.6% of admissions for all causes: substances associated were in 60% of cases opiates, in 30% barbiturates-sedatives-hypnotics, in 5% cocaine and in 5% cannabis.

Figure 2 reports the comparison between raw

Table 2. Hospital admissions (all causes and drug use related causes) in Italy (year 2001-2003).

Year	Admission for all causes	Admission for drug use related causes	Opiates	Barbiturates sedatives hypnotics	Cocaine	Cannabis
2001	3.576.490	21.155 (0,6%)	13.299 (63%)	5.711 (27%)	1.147 (5%)	998 (5%)
2002	3.404.941	20.638 (0,6%)	11.252 (55%)	6.657 (32%)	1.540 (7%)	1.189 (6%)
2003	3.185.630	19.727 (0,6%)	10.568 (54%)	6.005 (30%)	1.881 (10%)	1.273 (6%)

Figure 2. Choropleth maps of raw and estimated hospitalization rates (opiates use, years 2001-2003).



and estimated rates referring to hospitalizations caused by opiates; they have been calculated using the model containing both considered covariates. This model was considered the best after various comparisons with other models. As it can be seen, the model has reduced the variability of hospitalization rates caused by the use of opiates (for the majority of the Local Health Units between 3 and 9 hospitalizations per thousand).

The model has, moreover, reduced the difference between rates observed in the southern and northern Italian Local Health Units

(in the latter case lower than 3x1.000 almost everywhere).

The choropleth map for 2001 for estimated rates, points out areas where the phenomenon is less prominent (rates between 3 and 5 per thousand) such as Lombardy, Liguria (with the exception of the Local Health Unit of Imperia where are estimated between 5 and 7 hospitalizations per thousand referring to opiates consumption), Umbria, part of Latium, Campania, Apulia and Sicily.

After 2001, hospitalization rates caused by opiates use increased in areas such as the north of Apulia, part of Campania and Latium, with rates between 5 and 7 per thousand. Only in some areas, amongst which are Belluno (Veneto) and Rieti (Latium), the rate exceeds 7 per thousand.

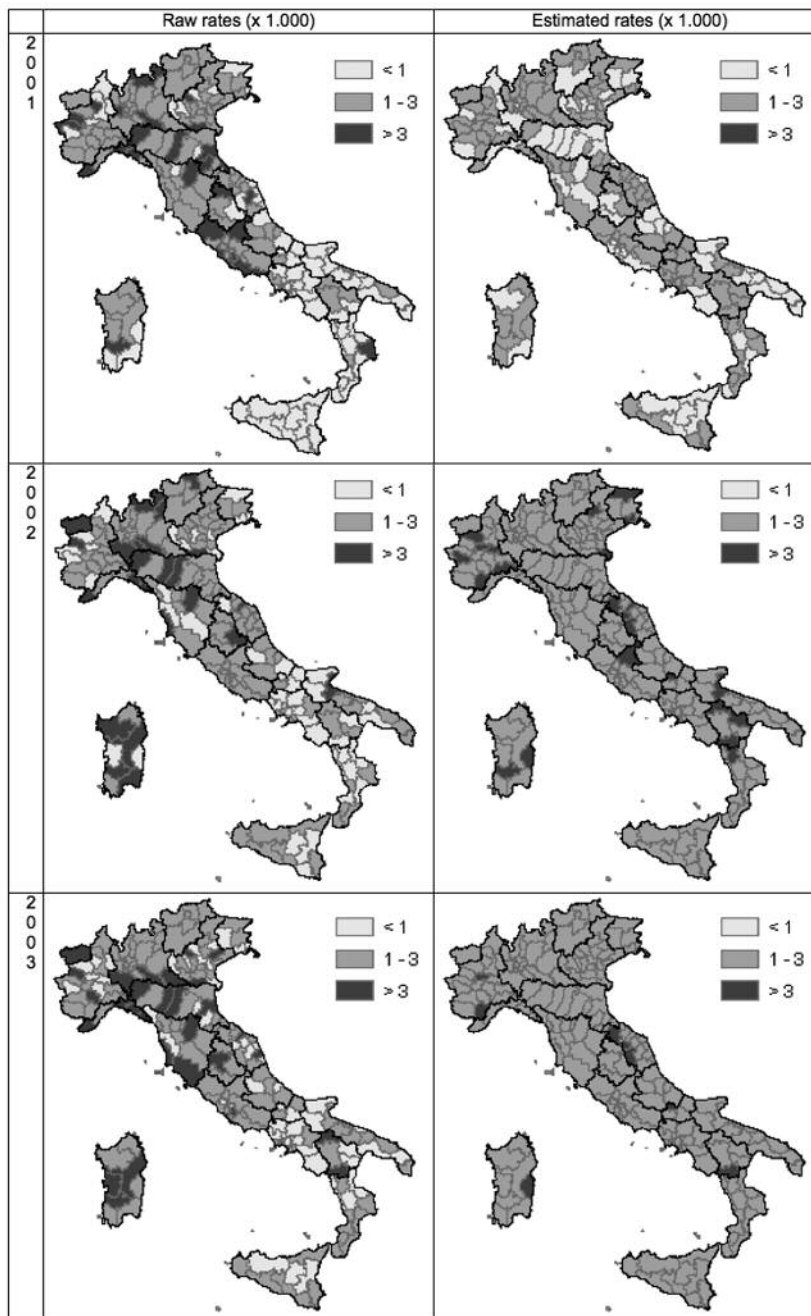
For the entire period of 2001-2003 the hospitalization rates caused by opiates consumption are statistically correlated to the number of subjects kept in charge by Drug Addiction Services (the rate has been calculated referring to the total number of residents of ages between 15 and 54 years in the Local Health Unit area). The negative value of the covariate parameter indicates that higher hospitalizations rates have been observed whereas the rates of subjects kept in charge by Drug Addiction Services are lower.

Concerning barbiturates-sedatives-hypnotics consumption, the best model is the one without covariates; Figure 3 shows the choropleth maps for the predicted values.

In 2001 estimated hospitalization rates caused by barbiturates-sedatives-hypnotics consumption were lower than 3 per thousand (and in many areas also lower than 1). In the following years, rates were all around 1 and 3 per thousand, this last value is exceeded only in a few areas: however no specific spatial trends were demonstrated.

The model that only has the covariate "rate of subjects kept in charge by Drug Addiction

Figure 3. Choropleth maps of raw and estimated hospitalization rates (barbiturates-sedatives-hypnotics use, years 2001-2003).



Services” was used for both cocaine and cannabis. The results are shown in Figures 4 and 5.

Relating to cocaine, more than a half of the Local Health Units report hospitalization rates lower than 0.5 per thousand. This rate increases to 1.5 in Aosta Valley and Piedmont (with the exception of Turin Local Health Unit where a higher rate has been estimated), South Tyrol and part of Veneto, Marches, Basilicata and part of Sardinia. This behaviour has remained constant over the period 2001-2003.

Concerning hospitalizations caused by

cannabis, if in 2001 rates are all lower than 0.5 per thousand (with the exception of a Local Health Unit in Molise), in 2002-2003 rates increase to 2 per thousand in many Local Health Units (Piedmont, Aosta Valley and in general in the boundary Local Health Units, Marches, part of Umbria and Latium, Molise, part of Basilicata, Calabria and Sardinia).

Discussion

This work's methodology has allowed to estimate trend over space of hospitalization rates caused by drugs consumption; the phenomenon has been analysed eliminating existing dependence between observations made in contiguous Local Health Units and confounding caused by site-specific characteristics.

In studies carried out until now [7-12] such rates have been computed without keeping in mind the phenomenon distribution in the space and so the fact that what happens in a specific area depends on what is happening in the close neighbourhoods (spatial autocorrelation).

In particular, this study allowed for the development of an indirect indicator for the drug use phenomenon and it constitutes an effort to answer to specific needs in the planning of sanitary policies related to a field that, given the specificity of the phenomenon,

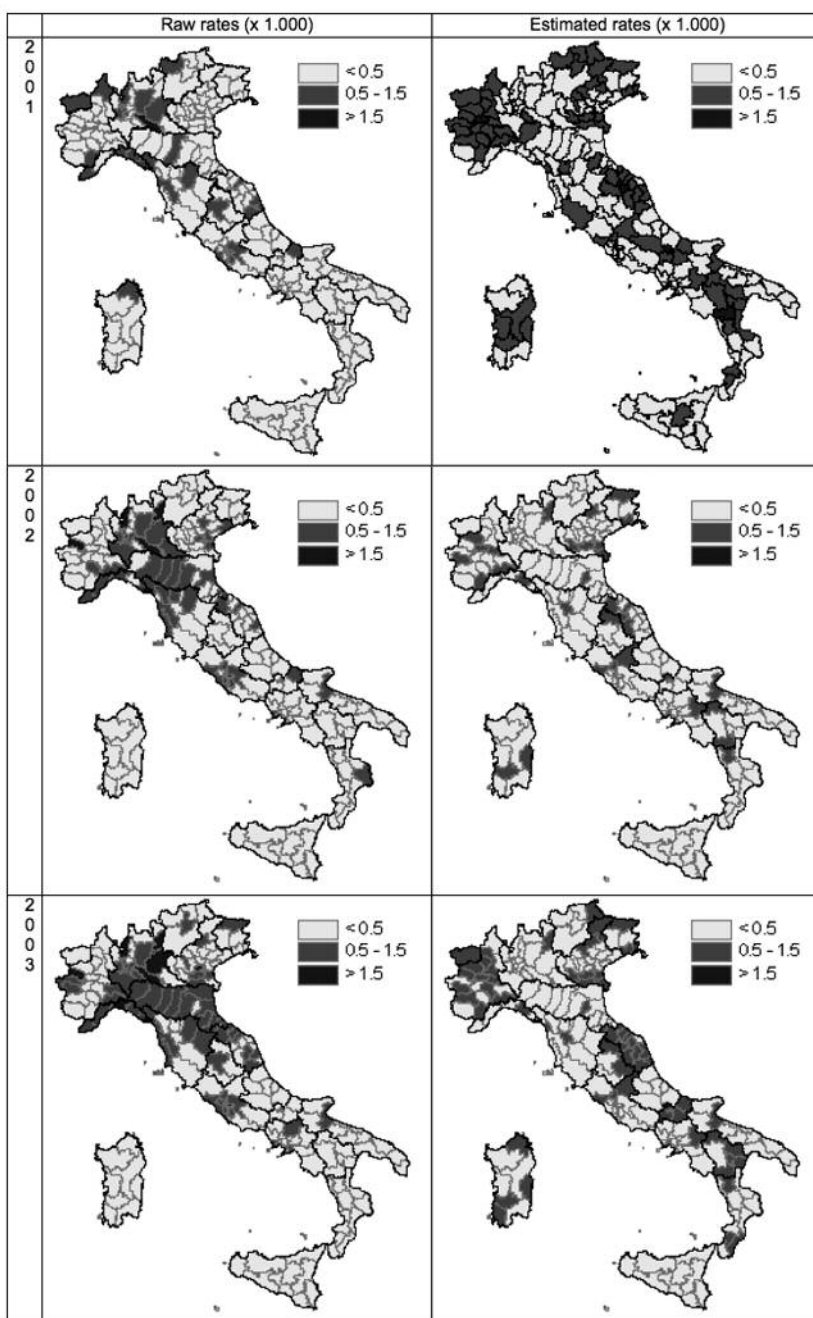
is often difficult to detect and quantify by means of more common data analysis techniques.

It has to be highlighted the dependence of spatial trend of hospitalization rates related to opiates use from the proportion of subjects kept in charge by Drug Addiction Services and also from the rate of number of beds held by hospitals.

In particular, relating to drug users in charge in Drug Addiction Services, hospitalization rates are lower in areas where drugs consumption phenomenon is sharper.

This situation can be better understood taking

Figure 4. Choropleth maps of raw and estimated hospitalization rates (cocaine use, years 2001-2003).



into account media prevention campaigns aimed, in a specific way, to damages caused by heavy drugs consumption such as opiates. Areas with higher rates of drug users treated by Drug Addiction Services are at the same time areas where the prevention interventions have more effect (giving sequence to a higher number of treatments intakes); this is the reason why in these areas there is a decrease of the probability that a drug addict goes to a hospital for problems caused by his condition.

Those same variables don't affect the spatial

trend of hospitalization rates caused by barbiturates-sedatives-hypnotics, while drug addict's rate treated by Drug Addiction Services is the only variable influencing spatial trend of hospitalization rates caused by cocaine and cannabinoids consumption, giving origin to higher hospitalization rates in areas with higher rates of drug addicts treated by Drug Addiction Services.

Low values (around zero) observed at the Local Health Units level, explains the low number of cocaine and cannabis related hospitalizations observed at the national level (Table 2). Spatial dependence estimation could be improved by using statistical models taking into account the presence of many zero counts in observed rates (Zero-Inflated Models).

However, in the evaluation of these results it is needed to be kept in mind some of the limits of the study related to the representativeness of the information supplied by the hospital discharge databases. This is probably affected by poor data filling, by insufficient attention given to addiction conditions or by the scarce propensity to point out habits not socially accepted. So it might be possible that the number of drug related hospitalizations are underestimated.

In order to partially contain this problem, this study considered the hospital discharge file cards based on principal diagnosis or on one of the five secondary diagnosis directly related to drug use/abuse using ICD9-CM code.

Moreover, it is important to highlight that, as this is a first attempt in applying this type of statistical methodology to data regarding drug addiction, it requires further improvement.

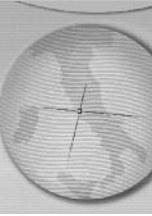
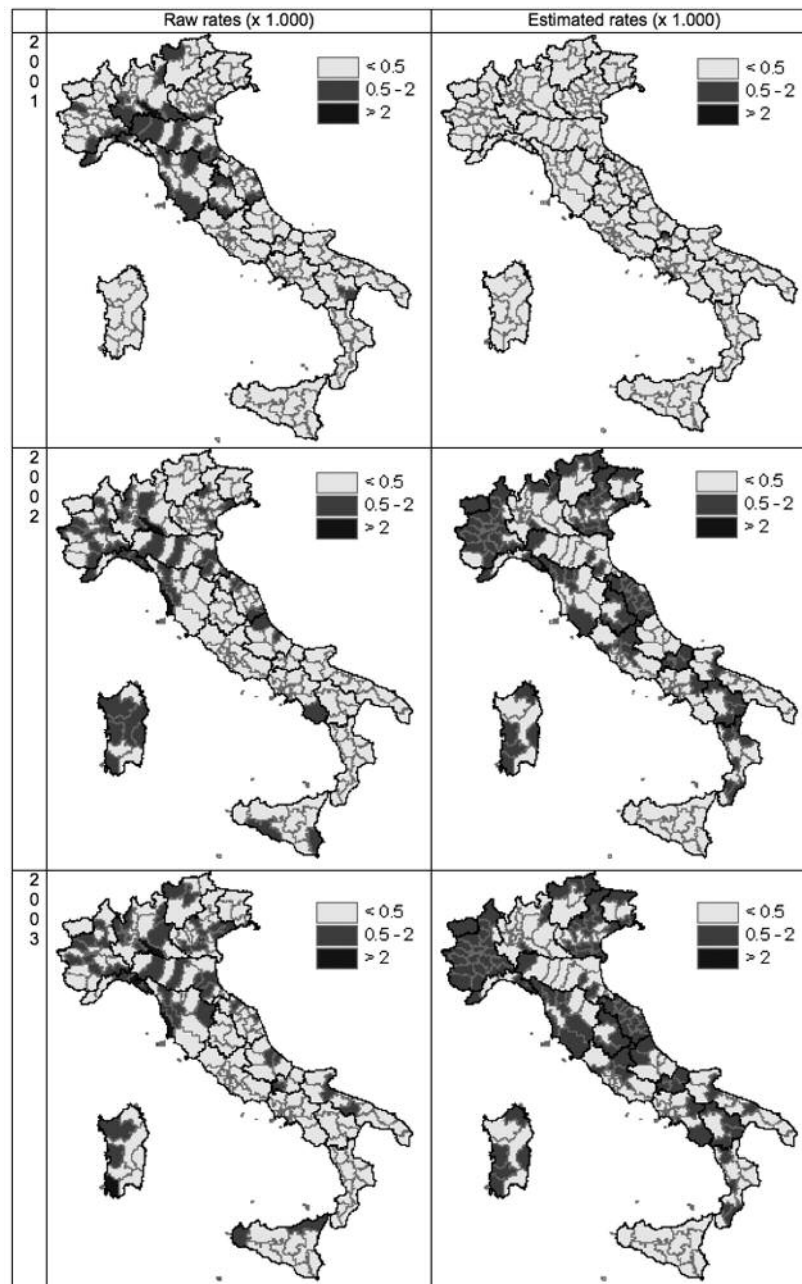


Figure 5. Choropleth maps of raw and estimated hospitalization rates (cannabis use, years 2001-2003).

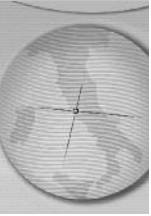


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