Spatial modelling for air pollution epidemiology: hospital admission risk for cardio-respiratory diseases in Torino province

Modelli spaziali per l'epidemiologia ambientale: rischio di ricovero per malattie cardio-respiratorie nella provincia di Torino

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Abstract We analyse the association between atmospheric pollution and hospital admissions for respiratory and cardiovascular causes in the province of Torino in 2004. The proposed model, which is fitted using INLA, includes fixed effects at individual and municipality level and spatially structured random effects for pollutants. Preliminary results suggests a lower risk of cardiovascular hospitalization for younger male and females, while the risk of respiratory hospitalization is significantly higher for both males and females and age classes. Summer days are associated with a lower risk for both cardiovascular and respiratory cases.
Abstract *In questo lavoro si analizza l'associazione tra inquinamento atmosferico e ospedalizzazioni per cause respiratorie e cardiovascolari nella provincia di Torino nel 2004. Il modello proposto, che è stimato usando INLA, include effetti fissi a livello di comune e a livello individuale ed effetti casuali spazialmente strutturati per gli inquinanti. I risultati preliminari suggeriscono un minor rischio di ospedalizzazione per cause cardiovascolari per i maschi le femmine sotto i 15 anni, mentre il rischio di ricovero per cause respiratorie è significativamente più alto per tutte le classi di età e i generi. La stagione estiva è associata con un minor rischio di ospedalizzazione per entrambe le cause di ricovero.*

Key words: INLA, Bayesian modelling

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1 Introduction

Atmospheric pollution is one of the most pressing questions in today's increasingly urbanised world. One of the first studies relating pollution and acute adverse health effects, published in the early 50s by Her Majesty's Public Health Service, reported a rise in mortality rate for respiratory distress and/or cardiovascular events on foggy days characterised by high sulphur dioxide concentrations [9]. Numerous studies followed to assess the short and long-term effects of atmospheric pollution on the incidence of oncologic, respiratory and cardiovascular events, as well as an increase in the overall mortality rate [6, 11, 3]. Nowadays, urban air quality and its impact on health remain a major concern for the international scientific community. Emergency hospital admission rates for respiratory and cardiovascular conditions are taken as good indicators of the acute effects of urban air pollution [13, 15]. Some of the most important recent studies include the American National Morbidity, Mortality and Air Pollution Study (NMMAPS) [5], the European Air Pollution and Health Project (APHEA) [1, 14], the Meta-analysis of the Italian studies on short-term effects of air pollution (MISA) [4] and the Environmental Modular Advanced Compact System project (EMECAS) [2]. These reports confirm the adverse effects pollution has on health and demonstrate a statistically significant increased risk for hospital admission due to cardiovascular and respiratory events, as a result of a rise in particulate matter, sulphur dioxide and/or nitrogen dioxide air pollution levels, especially in the elderly population [8]. Even though urban vehicular traffic is often indicated as the major contributor to air pollution, its contribution is not easily quantified, as many and varied factors may influence the effective exposure rates [10]. Besides, observational data, such as hospital admissions and discharges, are often hampered by limitations due to the investigational modelling tools as a result of the numerous confounding factors of difficult determination.

The main objective of this study is to analyse the association between urban pollution and hospital admissions for respiratory and cardiovascular causes among residents in the province of Torino in 2004 evaluating advantages and disadvantages of different statistical models. In this paper a preliminary model is presented.

2 Data

Data on hospital admissions were obtained from the hospital discharge registers. The analysis was based on a total of 39402 residents in the province of Torino hospitalised for respiratory diseases (ICD 460-519, N=12743) or cardiovascular causes (ICD 390-459, N=26659) in 2004. Patients hospitalised in the same period with a different diagnosis were considered as controls.

Particulate matters (PM_{10}) measured in $\mu g/m^3$ was considered as predictor of urban pollution along with NO_2 and CO. Given the strong correlation between pollution levels and season, daily air temperature (in Kelvin degrees), week-day and season of admission to hospital (classified as summer/winter [1]) were considered as predictors for the seasonal control. As suggested by the literature [4], lags 0-3 were considered in the analysis. As the hospital discharge data only include the town of residence of the patient (and not his/her address), exposure has been assessed at the municipality level. For this reason, it can be viewed as the exposure of an "average" person living in a specific municipality. Daily exposure to airborne pollutants of the population of the Torino province has been estimated using two data sources: daily-average pollutant concentrations (measured by the national monitoring networks of the EU member states) and population density at 1 km spatial resolution.

In order to map the daily pollutant concentration at the same spatial resolution of the population density, the multivariate space-time model introduced in [7] has been implemented. Daily exposure for each municipality has been assessed by weighting the estimated pollutant concentration with respect to the population density.

3 Spatial model for hospital admission

We implement a spatial model using the observed hospitalization (for a given cause) $y_i(s_j,t)$ of an individual $= 1,\dots,127441$ in a given municipality $j = 1,\dots,315$ in a specific day $t = 1,\dots,366$ as response variable, assuming:

$$y_i(s_j,t) \sim \mathrm{Bin}(\pi_i, 1)$$

and including in the latent field for environmental contaminants a spatially structured random effect, unstructured components and fixed effects at individual and municipality level. By estimating the relative risk of hospitalization, we are able to detect high risk areas. The linear predictor is specified on the logistic scale:

$$\begin{aligned}\mathrm{logit}(\pi_i) = {} & \boldsymbol{x}(s_j)\boldsymbol{\beta}^{\mathrm{Mun}} + \boldsymbol{x}_i\boldsymbol{\beta}^{\mathrm{Ind}} + x_{PM_{10}}(s_j)\beta_{PM_{10}}(s_j) + x_{CO}(s_j)\beta_{CO}(s_j) \\ & + x_{NO_2}(s_j)\beta_{NO2}(s_j) + v(s_j) + u(s_j)\end{aligned}$$

where $\boldsymbol{x}(s_j) = \{\mathrm{T\_low}, \mathrm{T\_high}\}$ represents temperature on the hospitalization day with

$$\mathrm{T\_low} = \begin{cases} T_t & \text{if } T_t < 275.33 \\ 0 & \text{otherwise} \end{cases} \qquad \mathrm{T\_high} = \begin{cases} T_t & \text{if } T_t \geq 296.26 \\ 0 & \text{otherwise} \end{cases}$$

The individual predictors are: $\boldsymbol{x}_i = \{\mathrm{Age} < 15, \mathrm{Age} > 64, \text{ holiday}, \text{summer}\}$. Inclusion of PM_{10}, CO and NO_2 concentration allows to assess the potential impact of environmental contaminants on human health. The terms $u(s_j)$ and $v(s_j)$ represent the Besag-York-Mollie (BYM) specification with $u(s_j)$ being a spatially structured residual, modelled using an intrinsic conditional autoregressive structure (iCAR), and $v(s_j)$ representing the unstructured residual, modelled using an exchangeable prior.

4 Preliminary results

The model introduced in Section 3 was fitted separately for male/female respiratory and cardiovascular hospitalizations using INLA [12]. Computing times were 1.43 h and 1.00 h (respiratory) and 1.78 h and 1.18 h (cardiovascular) for female and male, respectively. Tables 1 and 2 summarize the posterior distribution of fixed effects. Figure 1 shows ORs per 1 $\mu g/m^3$ increase in PM_{10} and CO concentration.

Table 1 Fixed effect posterior summaries (exp scale) - respiratory

	Female					Male				
	mean	sd	$q_{0.025}$	$q_{0.5}$	$q_{0.975}$	mean	sd	$q_{0.025}$	$q_{0.5}$	$q_{0.975}$
age<15	12.1574	0.5677	11.0797	12.1419	13.3102	3.8918	0.1489	3.6071	3.8885	4.1920
age>64	4.6441	0.1744	4.3120	4.6397	4.9974	1.9685	0.0598	1.8537	1.9673	2.0887
holiday	1.1227	0.1238	0.8942	1.1171	1.3806	1.2204	0.1137	1.0089	1.2158	1.4555
summer	0.7364	0.0355	0.6694	0.7353	0.8086	0.7345	0.0311	0.6754	0.7336	0.7975
T_low	0.9996	0.0002	0.9992	0.9996	1.0000	0.9994	0.0002	0.9991	0.9994	0.9998
T_high	1.0004	0.0002	1.0000	1.0004	1.0007	1.0004	0.0001	1.0001	1.0004	1.0006

Table 2 Fixed effect posterior summaries (exp scale) - cardiovascular

	Female					Male				
	mean	sd	$q_{0.025}$	$q_{0.5}$	$q_{0.975}$	mean	sd	$q_{0.025}$	$q_{0.5}$	$q_{0.975}$
age<15	0.1643	0.0240	0.1203	0.1631	0.2147	0.0326	0.0041	0.0250	0.0324	0.0411
age>64	9.4667	0.2478	8.9900	9.4622	9.9636	2.0409	0.0423	1.9590	2.0403	2.1252
holiday	1.0453	0.0921	0.8740	1.0416	1.2360	0.9621	0.0764	0.8194	0.9592	1.1197
summer	0.7821	0.0279	0.7286	0.7815	0.8384	0.6577	0.0211	0.6175	0.6572	0.7009
T_low	0.9998	0.0001	0.9995	0.9998	1.0001	0.9995	0.0001	0.9993	0.9995	0.9998
T_high	1.0001	0.0001	0.9998	1.0001	1.0003	1.0001	0.0001	0.9998	1.0001	1.0003

5 Discussion and further research

The model presented in this paper considers the effect of air pollution, upscaled at municipality level in a previous step, on cardiovascular and respiratory events. Municipality specific risk estimates for 1 $\mu g/m^3$ increase in PM_{10} adjusted for NO_2 and CO are largely comparable with estimates reported in literature, with a posterior mean ranging from 0.996 to 1.003. It seems that for younger males and females there is a lower risk of hospitalization for cardiovascular diseases. Moreover, both age categories are associated with a greater risk of respiratory hospitalization. Finally, risk appears to be significantly lower during the summer time.

Data from patients attending the emergency department may be available in the near future so that a more complete analysis can be carried out. Also, note that

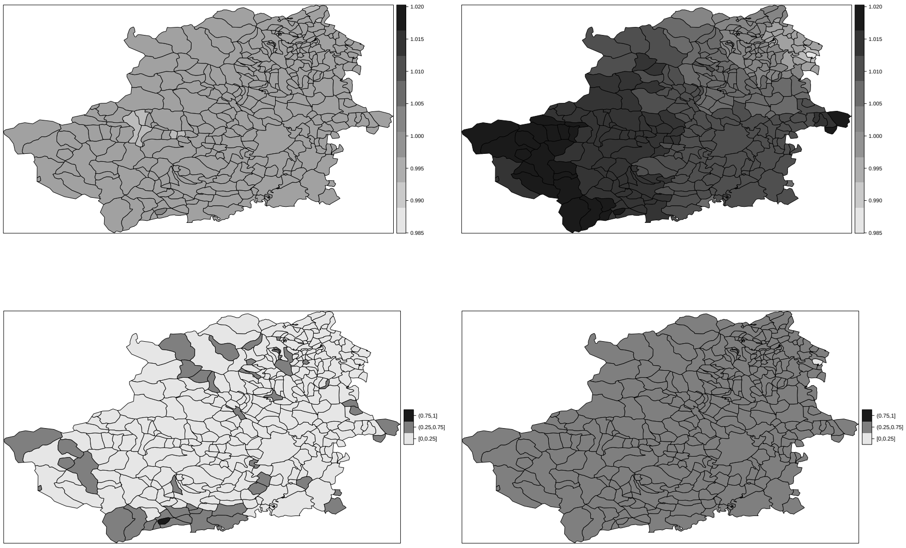

Fig. 1 First row: male (cardiovascular) posterior mean of $\exp\beta(s_j)$ for PM_{10} (left), CO (right). Second row: associated probability of $OR > 1$ for PM_{10} (left), CO (right)

information on personal exposure and life style is not available so that we cannot estimate the effect of pollutants on individual level but directly at municipality level.

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