Health impact of air pollution in Italy: two regional studies

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Introduction

- Outdoor air can contain a number of hazardous agents, most of which are combustion products, including carcinogens such as polycylic aromatic hydrocarbons and metals
- On average, an adult inhales about 10,000 L of air per day, thus even hazardous agents present in the air at low concentrations can damage population health

- Numerous epidemiological studies performed in Europe and elsewhere documented harmful effects of air pollution
- Several meta-analyses summarized the published results
- Air pollution can induce acute disease episodes -up to death- chronic conditions and cancers

- In 2013, ambient air pollution and particles have been classified as Group 1 carcinogenics to humans by the International Agency for Research on Cancer
- The message is: immediate action is needed to reduce exposures

Short and long-term effects of air pollution

- Short-term effect: the effect that is observed in the same day or few days after the exposure
- Long-term effect: the effect that is observed many years after the exposure. The exposure can be cumulative

- The short-term effects of air pollution are studied by comparing the daily number of health events (mortality, hospital admissions) with the air pollutants concentrations in the same days or few days before (epidemiological daily time series studies)
- The long-term effects of air pollution are studied in individual cohort studies or by ecological studies that relate exposures to health outcomes observed after years

- Short-term evaluation allows for immediate appraisal of deaths prevented by reduction policies
- Long-term evaluation is more speculative in nature because of latency time and the role of cumulative exposure

Health Impact Assessment

Since 2000, evaluation of the impact of air pollution on people's health in absolute terms has drawn the attention of the general public

Not only relative effects and dose-response functions, but number of deaths and years of life lost due to the exposure to air pollutants such as NO_2, NO_x, PM_{10}, $PM_{2.5}$

small relative risk + widespread exposure= NOT NEGLIGIBLE IMPACTS

Two examples in Italy

ESSIA project: short-term impact of air pollution on mortality and morbidity in the Lombardy region
HIA in terms of attributable deaths for the year 2007

ACAB project (ongoing): impact of smoking, air pollution and occupational exposures on cancer-related deaths and morbidity in Tuscany (2016-2018)
Long-term impact of air pollution on lung cancer (mortality and morbidity)

Lombardy: 10 003 000 inhabitants
Tuscany: 3 730 000 inhabitants

ESSIA project

- Funded by Regione Lombardia
- Partners: Ospedale Maggiore Policlinico, Milan; Università degli Studi di Milano; Università di Firenze

- Impact assessment calculated in terms of Attributable Deaths (AD) at the municipality level (n=1546) in the Lombardy region for the year 2007, considering counterfactual scenarios based on WHO guidelines and EU law limits
- We considered between-municipality school and job commuting
- We accounted for uncertainties (sampling variability and intrinsic variability) via Monte Carlo simulation

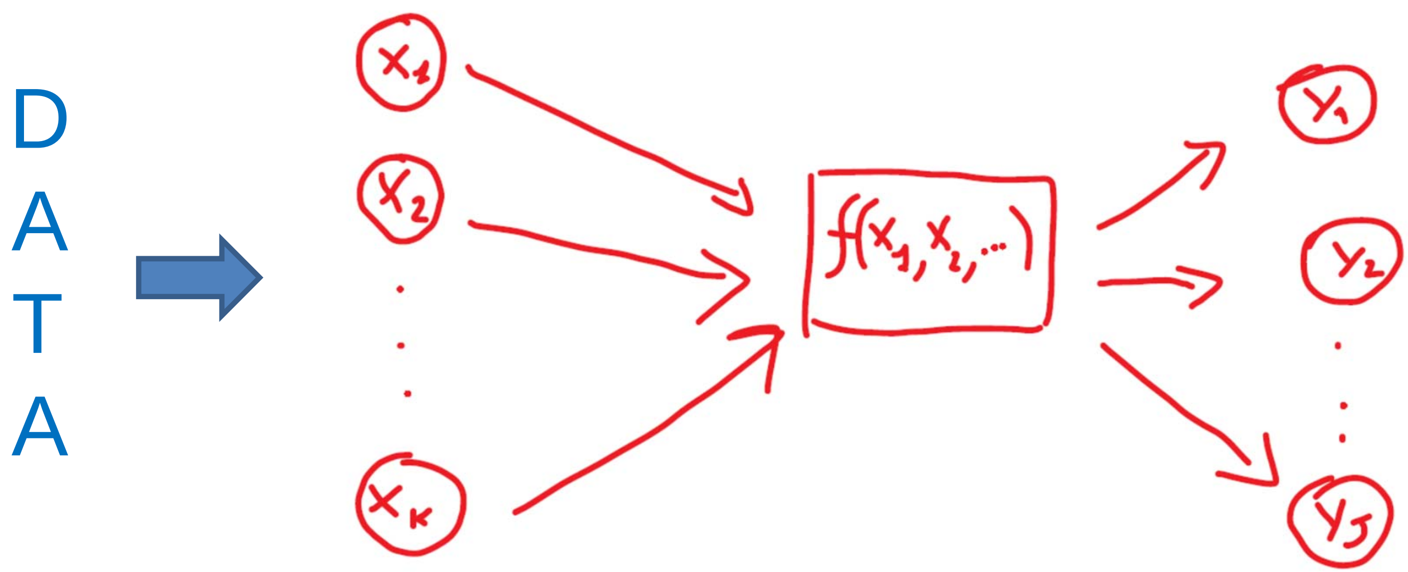
Baccini M, Grisotto L, Catelan D, Consonni D, Bertazzi PA, Biggeri A. 2015. Commuting-adjusted short-term health impact assessment of airborne fine particles with uncertainty quantification via Monte Carlo simulation. Environ Health Perspect 123:27–33

Data

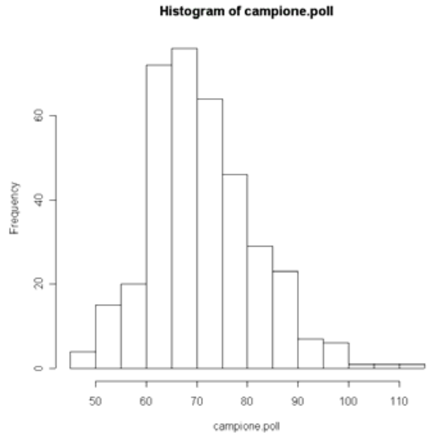
- Resident population (year 2007)
- Average levels of PM10 as predicted by a deterministic model developed by the Lombardy Regional Environmental Protection Agency and as measured by the regional air quality monitoring network (available only for few municipalities) (year 2007)
- Number of deaths and population, by municipality
- Commuting flows from municipality i to municipality j ($i \neq j$, i,j=1,2,…1546) (2001 census)
- Daily mortality time series and PM10 concentrations for the cities with more than 50 000 inhabitants (2003-2006)

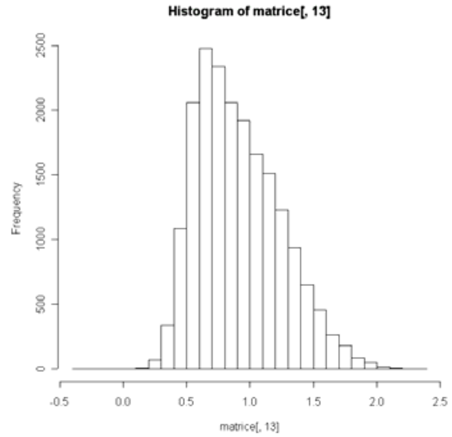
A general scheme

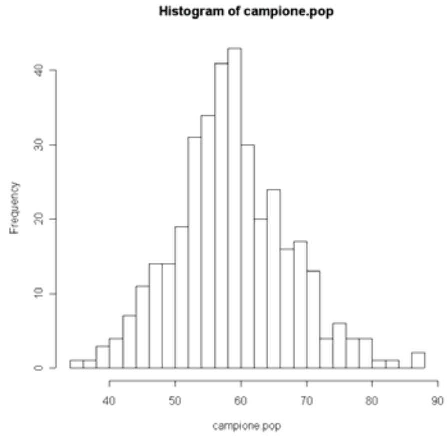
- Data are use to obtain input quantities
- The inputs are used to calculate the impact (outputs)



Posterior distributions of the input quantities



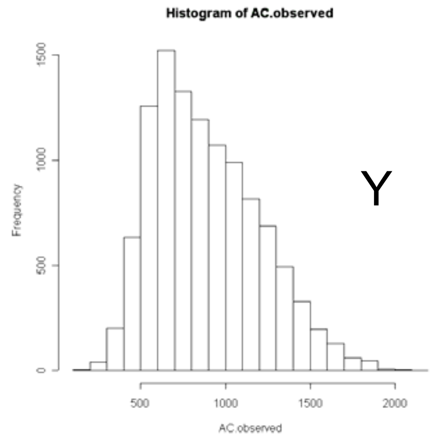




Sampling and output calculation

X_1 X_2 X_3

Bayesian framework



Uncertainty propagation

Y

Posterior distributions of the output

Indicators of health impact

- AD_i: number of deaths among the residents in the *i* municipality attributable to the air pollution in the *i* municipality and in the all other municipalities of the region

- AD_i*: number of deaths among the residents in the *i* municipality and in all the other municipalities of the region attributable to the air pollution measured in the *i* municipality

Assumptions:

- Homogeneous exposure within municipality
- The effect of PM10 is that of the municipality where the individual is exposed
- The mortality rate is that of residence municipality where the individual resides
- On average, commuting people spend 8 hours each day in the other municipality

AD calculation

Threshold corresponding to a specific counterfactual scenario

$$AD = deaths \times AF$$

$$deaths = py \times rate$$

$$AF = 1 - 1/RR = 1 - 1/\exp\left(\beta\left(X - X_0\right)\right)$$

Number of residents and number of commuting people

Crude mortality rate

Effect of PM10

Annual average level of PM10

We considered uncertainty affecting all these components

AD and AD* calculation

$$AD_i = A_i + B_i \qquad AD_i^* = A_i + C_i$$

$$A_i = \left(pop_i - \sum_{j \neq i} \frac{1}{3} exit(i, j) \right) \times r_i \times \left(1 - \frac{1}{\exp\left(\beta_i \times \left(X_i - X_0\right)\right)} \right)$$

$$B_i = \sum_{j \neq i} \frac{1}{3} exit(i, j) \times r_i \times \left(1 - \frac{1}{\exp\left(\beta_j \times \left(X_j - X_0\right)\right)} \right)$$

$$C_i = \sum_{j \neq i} \frac{1}{3} exit(j, i) \times r_j \times \left(1 - \frac{1}{\exp\left(\beta_i \times \left(X_i - X_0\right)\right)} \right)$$

Methods: Monte Carlo procedure

We indipendently sampled 1000 values from the following input distributions:

1- joint posterior predictive distribution of PM10 effect from Bayesian meta-analysis (Baccini et al. 2012);

2- joint posterior distribution of the smoothed crude mortality rate from spatial BYM model;

3- joint posterior distribution of the yearly PM10 level from Bayesian Kriging model;

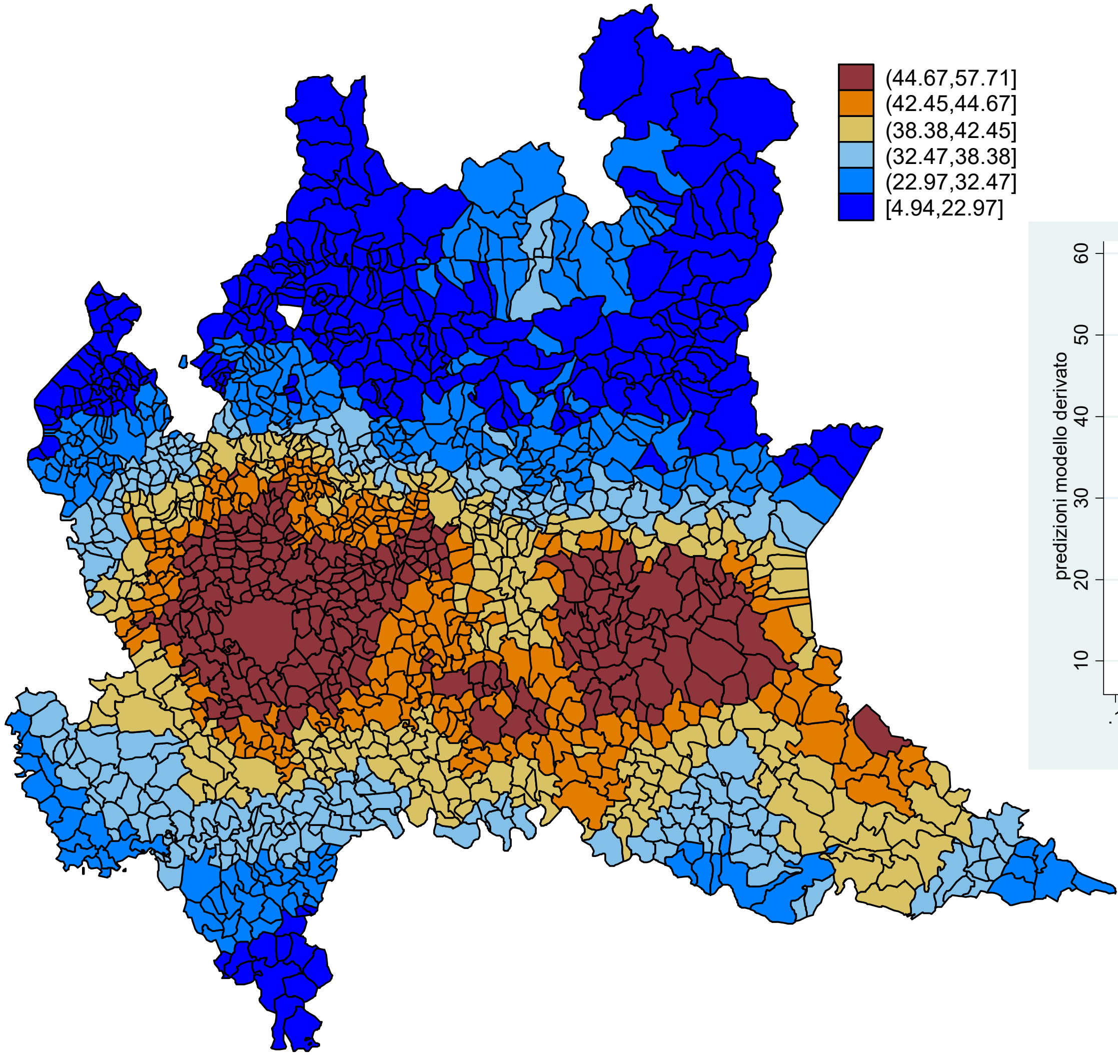
4- posterior distribution of commuting probability from municipality i to municipality j (i=1546, j=1546).

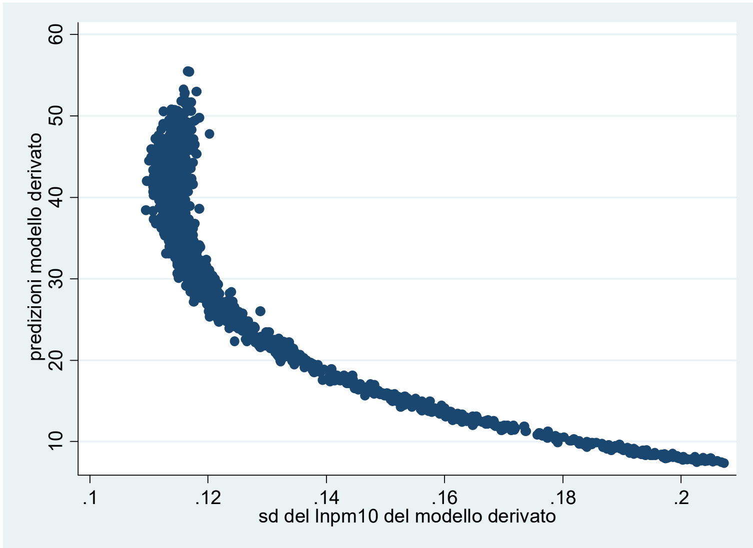
We accounted for intrinsic variability:

- the number of deaths was sampled from a Poisson distribution with mean=smoothed crude mortality rate X population;

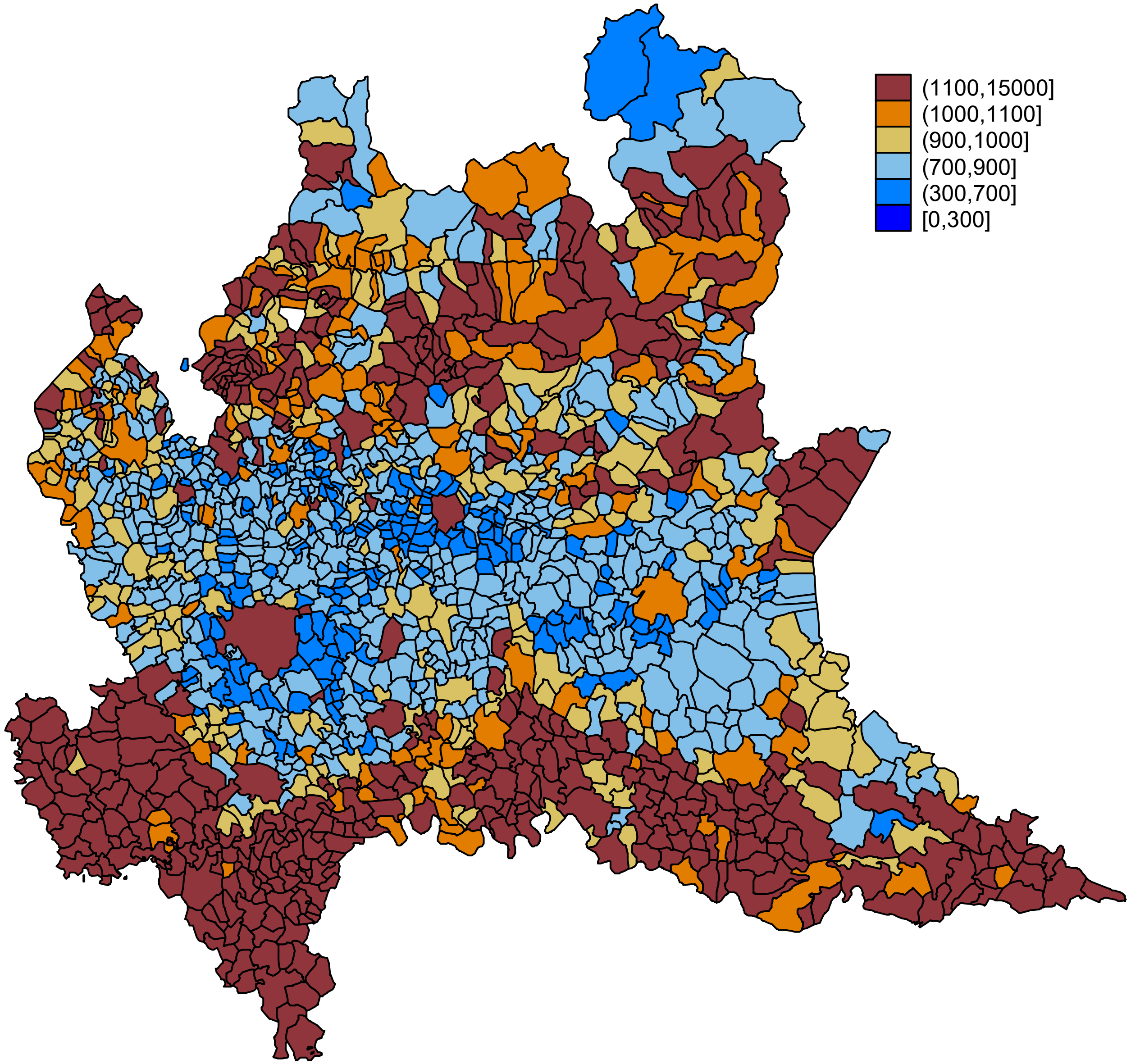
- the number of commuting individuals was sampled from a Binomial distribution with probability equal to the commuting probability and n=population of the municipality i in 2007.

INPUT 1: Posterior predicted values of PM10 from a Bayesian Kriging model

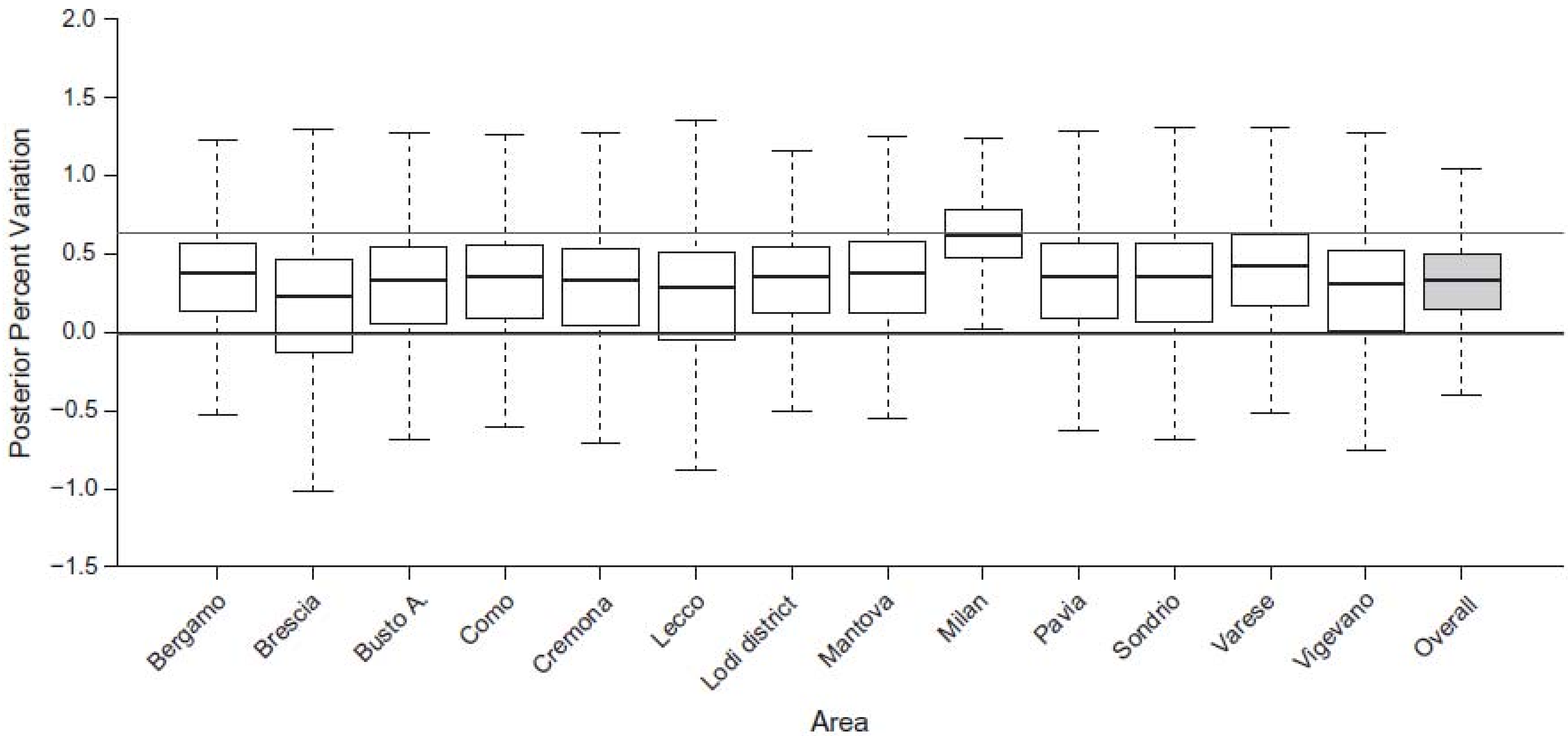




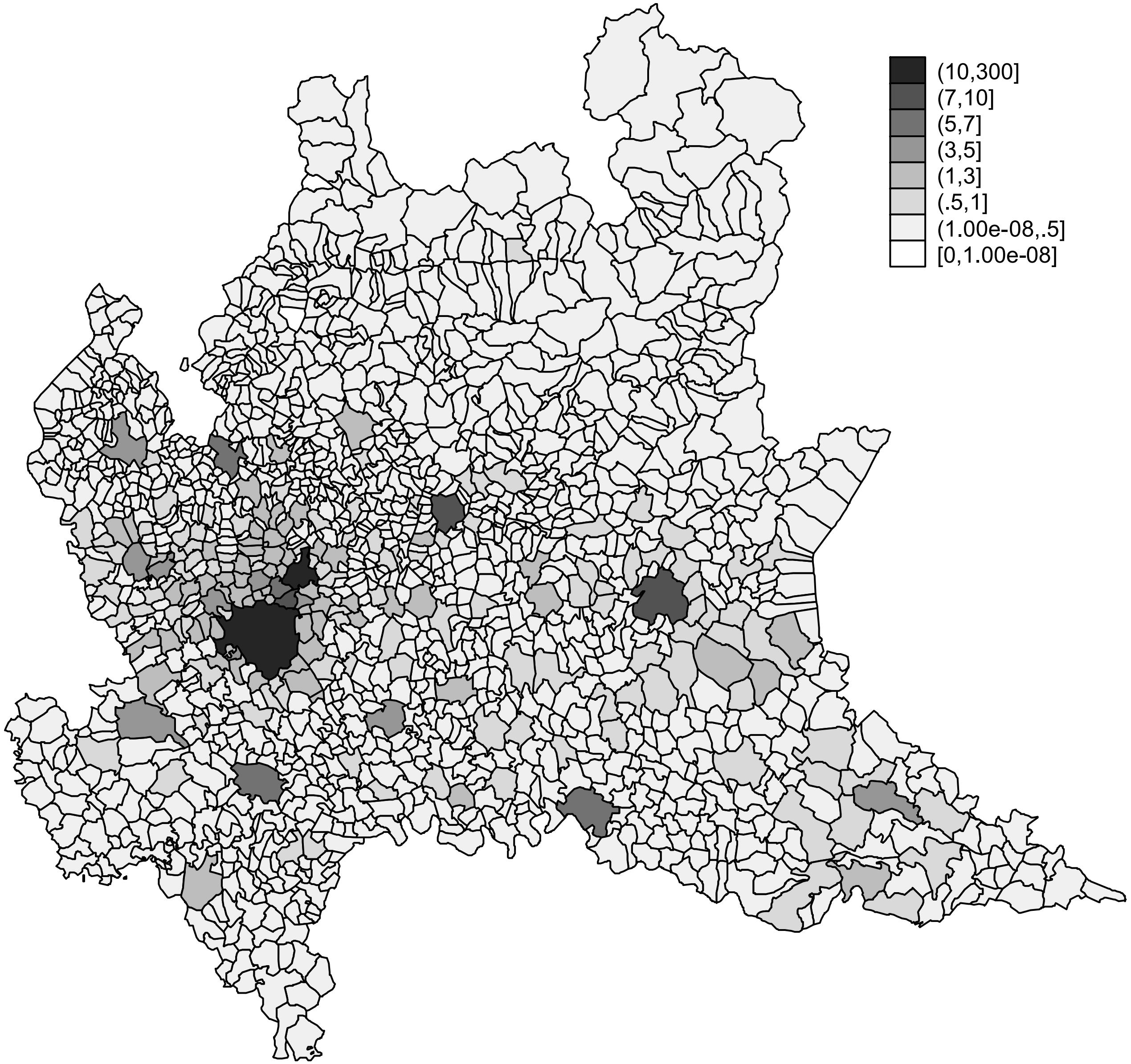
INPUT 2: Smoothed crude mortality rate per 100,000 from BYM model



INPUT 3: Posterior city-specific distributions of the percent variation in mortality associated to a 10 μg/m³ increase of PM10 (from a planned meta-analysis of epidemiological time series studies on the largest cities in the region)



Output: AD by municipality; countefactual PM10>40 µg/m³ (EU limit)



Counterfactual scenarios:

- PM10 annual average < 20 µg/m^3 (WHO Air Quality Guideline)
- PM10 annual average < 40 µg/m^3 (EU limit)
- 20% reduction to reach the annual average of 20 or 40 µg/m^3

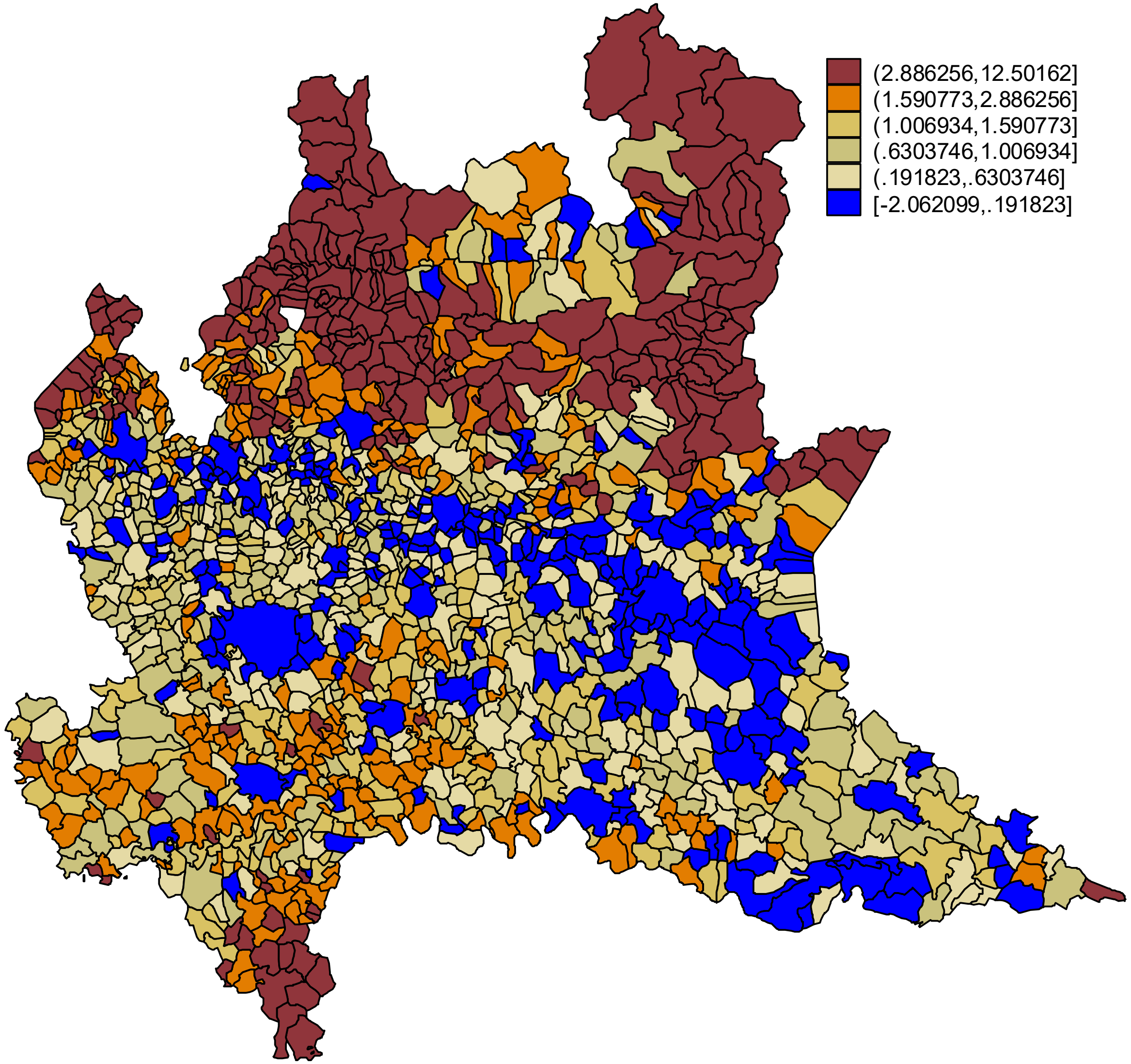
	PM10>20 µg/m^3			**PM10>40 µg/m^3**		
	median	**p10**	**p90**	**median**	**p10**	**p90**
All region	861.8	475.2	1403.1	224.48	111	367.06

	20% decrease to reach 20 µg/m^3			**20% decrease to reach 40 µg/m^3**		
	median	**p10**	**p90**	**median**	**p10**	**p90**
All region	312.1	166.8	506.4	189.5	98.2	304.7

log(B_i/C_i): balance between AD “imported” and AD “exported”

Negative values of the log (blue areas) indicate that the AD “exported” are larger than the AD “imported”

NOTE: The balance depends on the municipality’s PM10 level and on the commuting flows



Milan

AD : 265 (145,417)

AD*: 283 (154, 444)

Discussion of the results

- More than 200 deaths could be avoided in 2007 by respecting the realistic EU limit for the annual average concentration of PM10

- Including commuting flows in AD calculation provides useful and interesting information about the critical areas which "export" diseases and mortality

- We don't consider within-municipality flows: we are assuming that the only commuting component is the between-municipality one

- Probably, we are underestimating the impact of commuting because people usually commute along highly polluted road corridors (increased exposure during travelling)

ACAB project

Smoking, air pollution and exposure to occupational carcinogens in Tuscany: impact on oncological diseases and evaluation of preventive policies

- Funded by Regione Toscana: August 2020-August 2023
- Partners:
  - Oncologic Network, Prevention and Research Institute (ISPRO), Florence
  - Università di Firenze
  - Azienda USL Toscana Centro
- External partners:
  - Institute for Maternal and Child Health 'Burlo Garofolo' (Italian GBD Initiative)
  - LAMMA Institute
  - Agenzia Regionale di Sanità della Toscana

ACAB
ATTRIBUTABLE CANCER BURDEN IN TUSCANY

www.acab-toscana.it

ACAB project

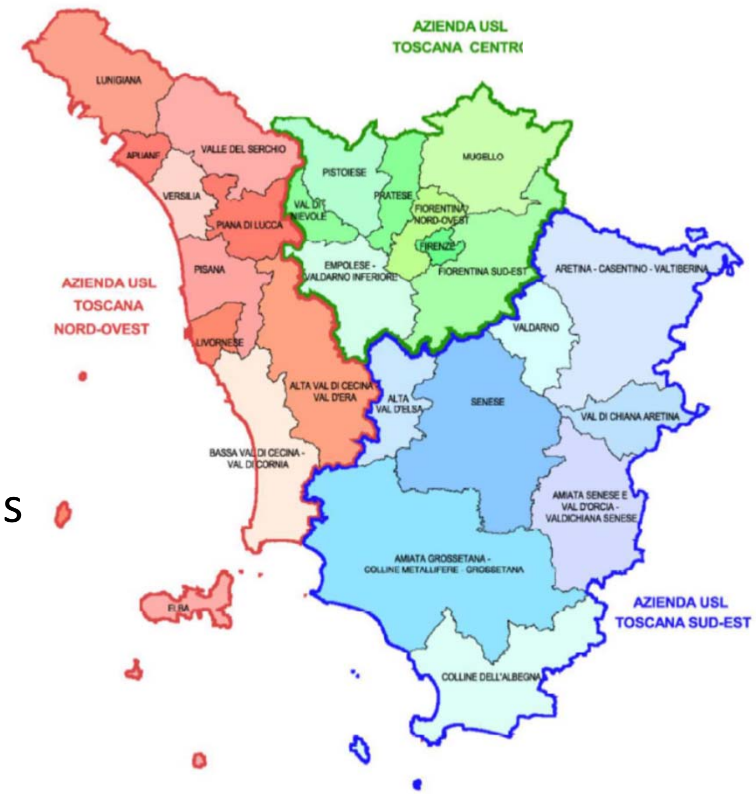
Aims of ACAB:

- Drawing the health profile of the population
- Assessing the burden of disease attributable to smoking, air pollution, occupational exposures

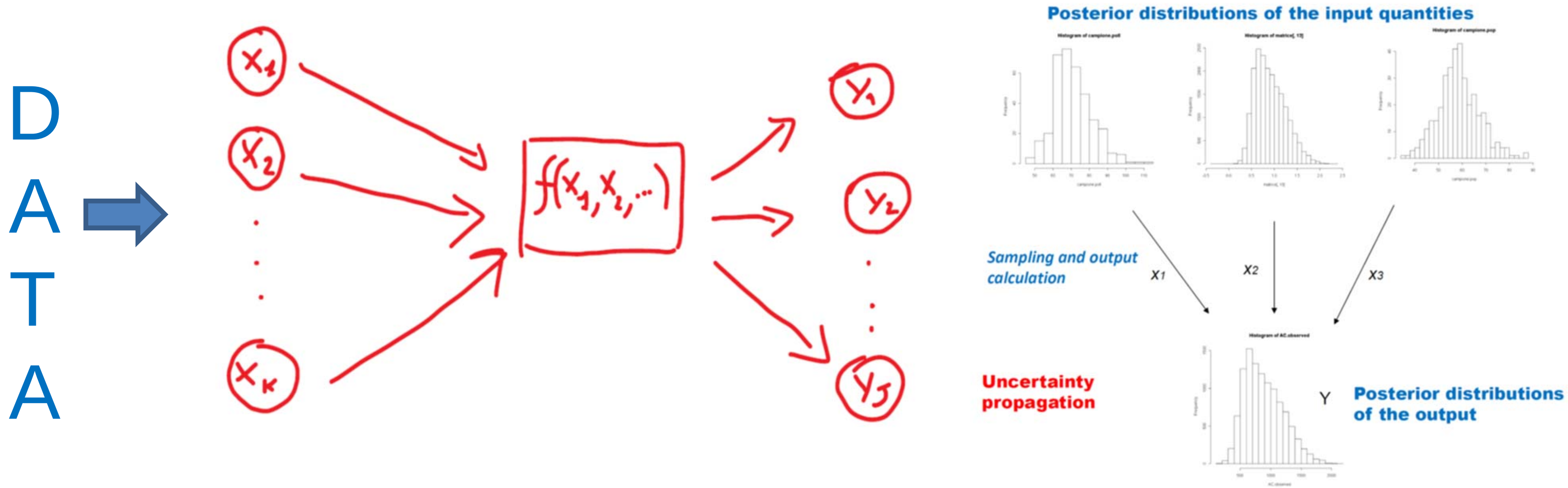
Year 2019

We follow the Global Burden of Disease approach, but we use local data (mortality, disease incidence and prevalence from registries 2016-2018, exposure) at sub-regional level

Focus: long-term effect of air pollution on lung cancer



HIA procedure



- Exposure assessment
- Literature review on the exposure-response curve
- Estimation of the Population Attributable Fraction (PAF)
- Estimation of the impact attributable to the exposure, under counterfactual scenarios

Quantifying the burden of disease

- **Deaths** from lung cancer in the year(s) of interest (for years without mortality data available, deaths are estimated as the product of rates and resident population)
- **Years of Life Lost (YLL)**: Measure of premature mortality that takes into account both the frequency of deaths and the age at which it occurs. For a subject dying at age 70, YLL correspond to the average life expectancy at that age.
- **Years Lived with Disability (YLD)**: Measure of the burden of living with a disease or a disability. YLD calculation accounts for incidence and duration of non-fatal conditions occurring in the population (prevalence) and disability deriving from them (severity weights). Lung cancer may be characterized by one or more stages representing different non-fatal conditions: diagnosis/treatment, controlled phase, metastatic phase, terminal phase.
- **Disability Adjusted Life Years (DALY): YLL+YLD**

Source : Wiki Commons

Population Attributable Fraction

- The population Attributable Fraction (PAF) is the proportion of disease burden that is due to the fact that the actual levels of exposure exceed the counterfactual one
- In other words, it measures the proportion of disease burden that could be saved by reducing the actual levels of exposure to the conterfactual one

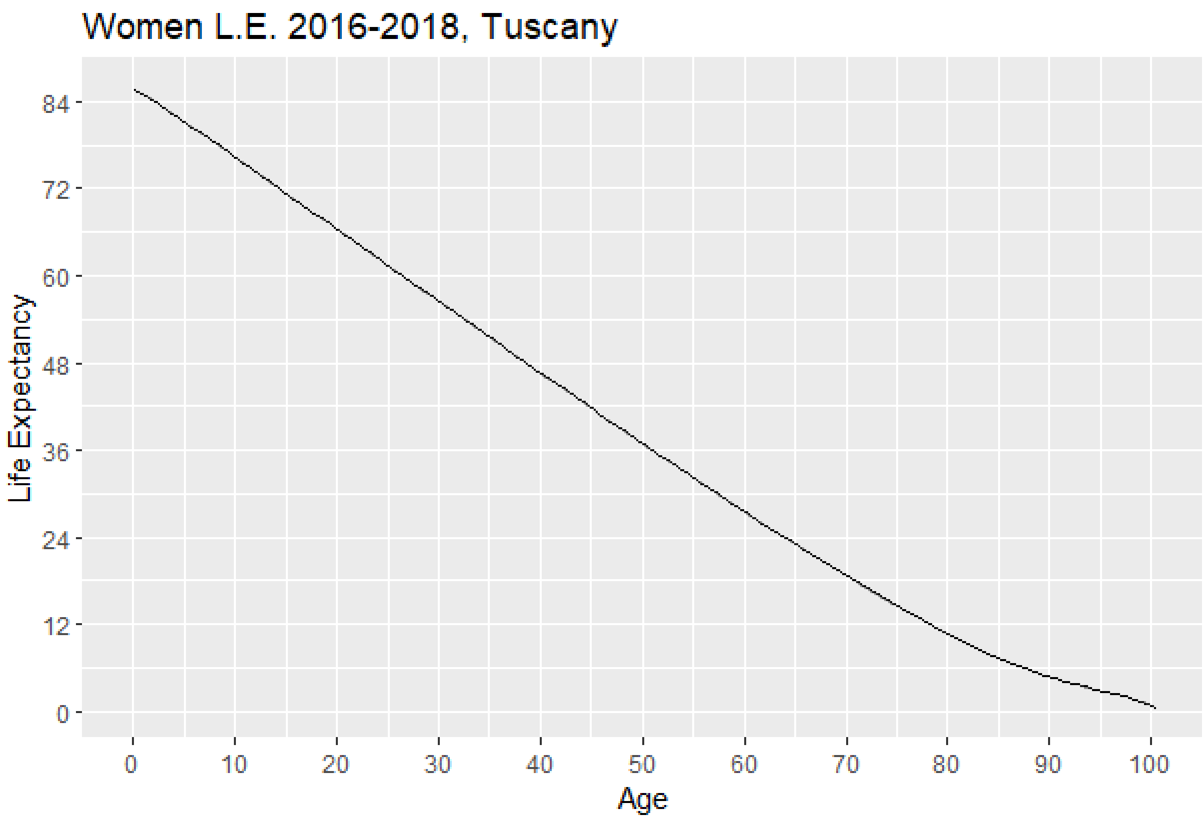
$$PAF = \frac{\sum p_x RR_x - \sum p_x^C RR_x}{\sum p_x RR_x}$$

Attributable burden of disease

$$attributable\ DALY = PAF \times DALY$$

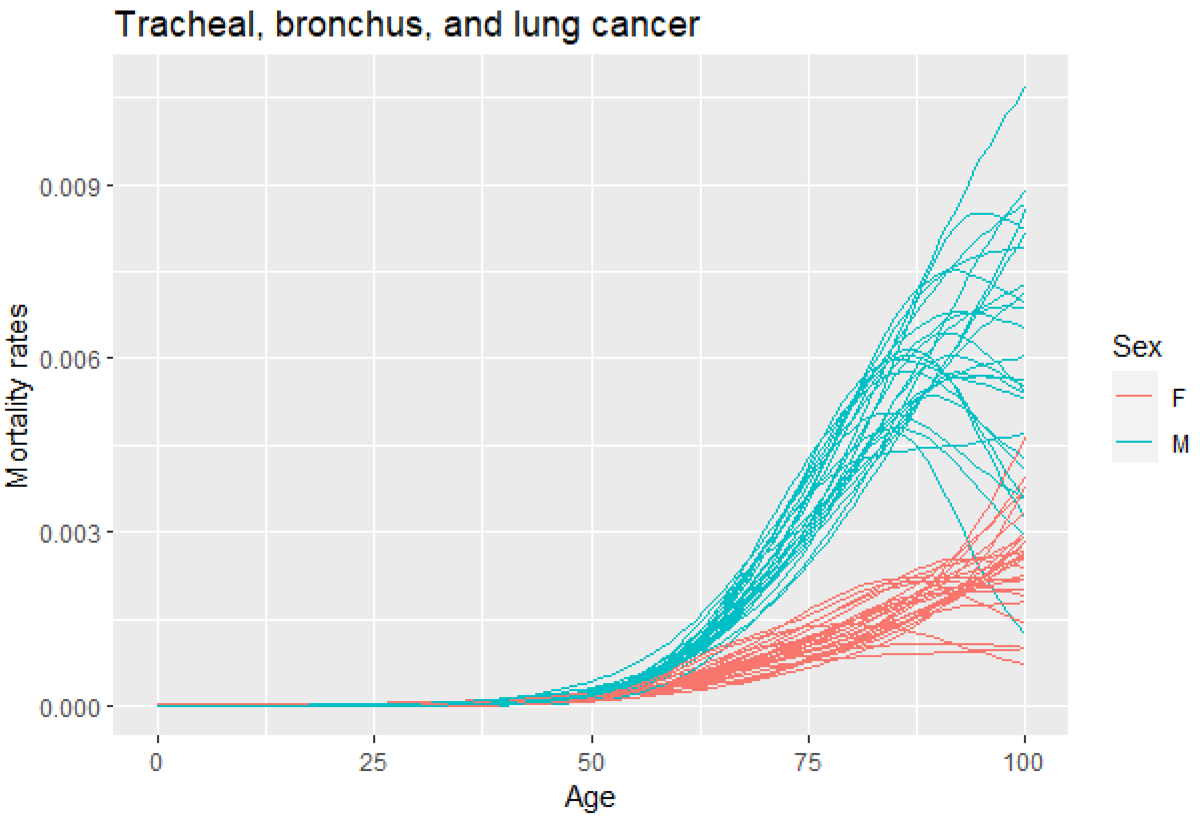
1 attributable DALY= 1 year in good health lost due to the risk factor

Input 1: Life expectancy



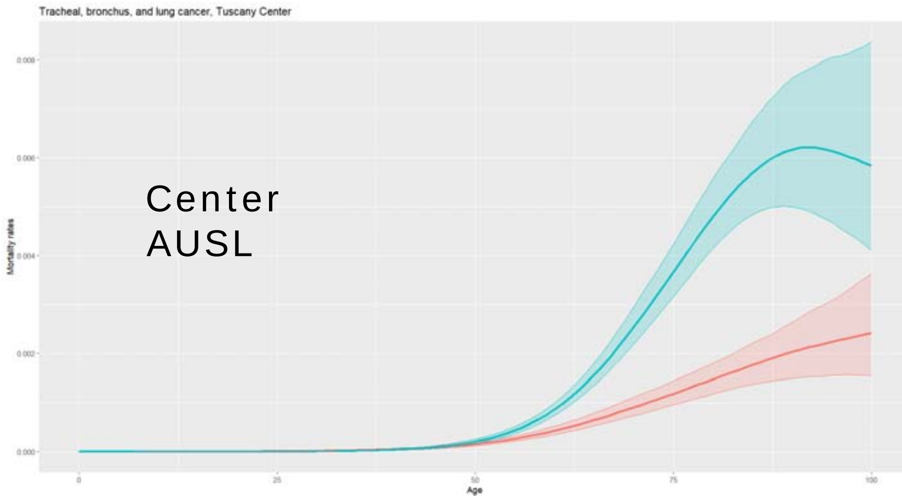
Life expectancy derived from 2016-2018 mortality data (Bayesian approach)

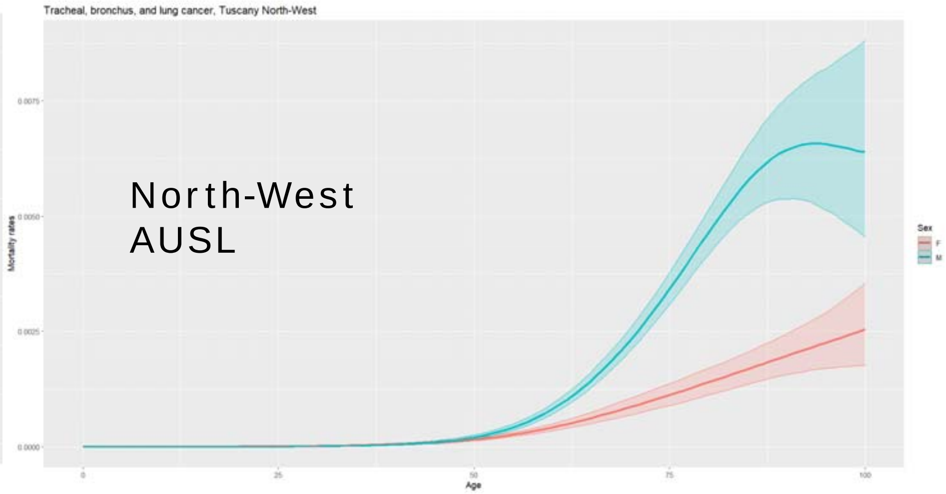
Input 2: Mortality rate from lung cancer by district 2016-2018

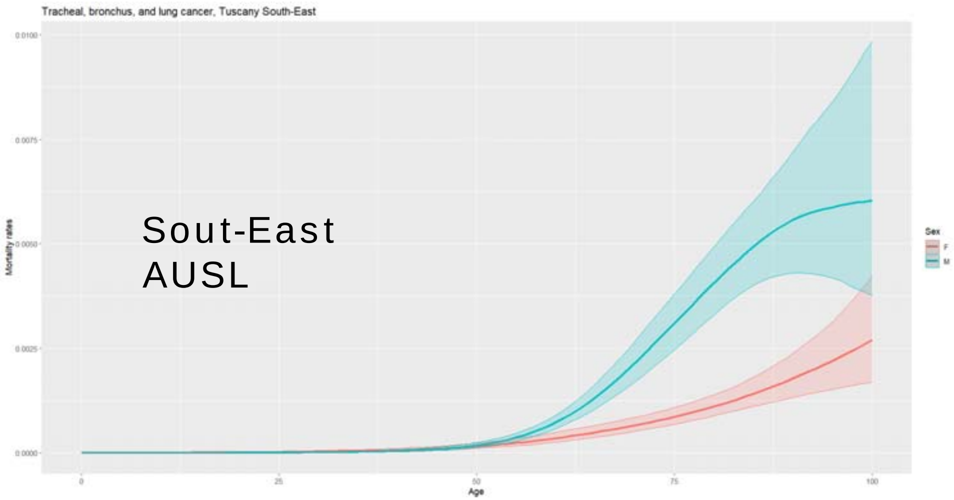


Bayesian penalized splines to avoid problems of rates equal to 0 in the younger classes of age

Input 2: Mortality rate from lung cancer by AUSL

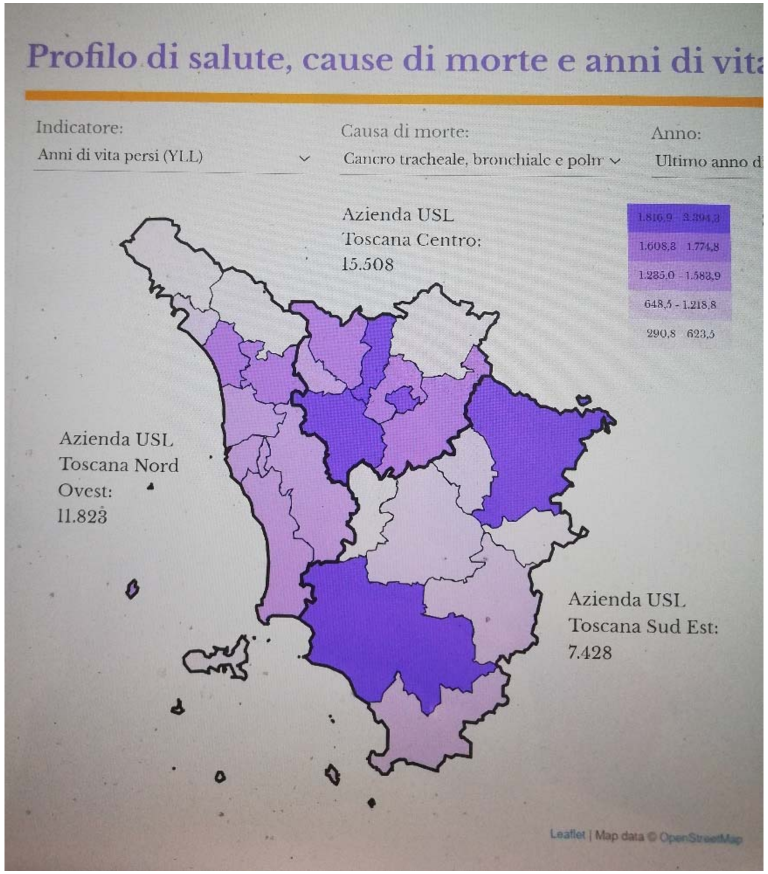


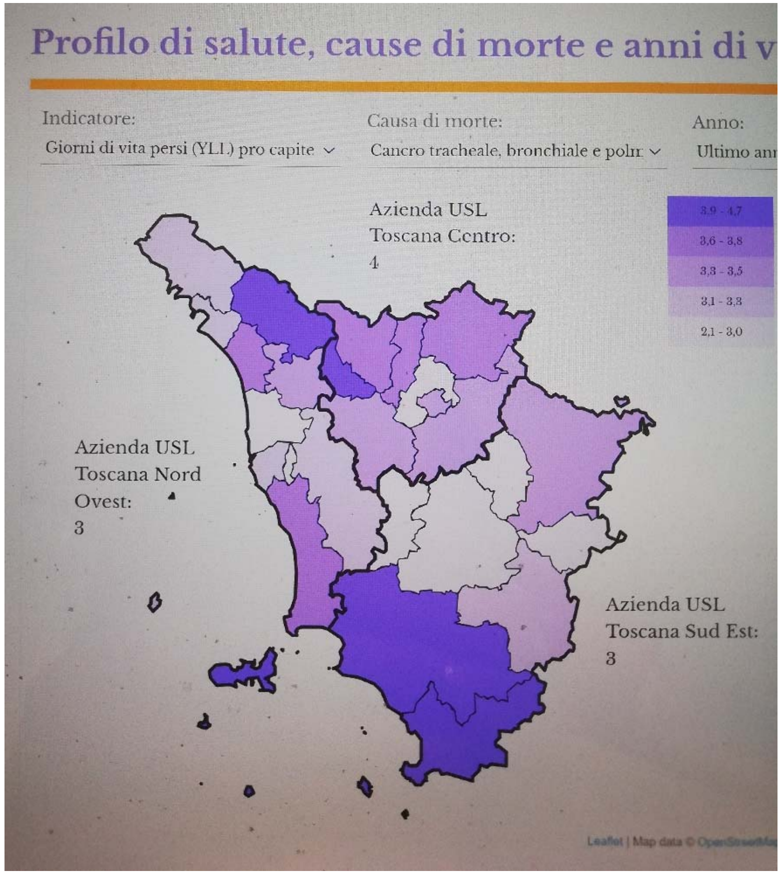




Combined mortality rates from a Bayesian meta-analysis of curves

Preview of the YLL for 2018

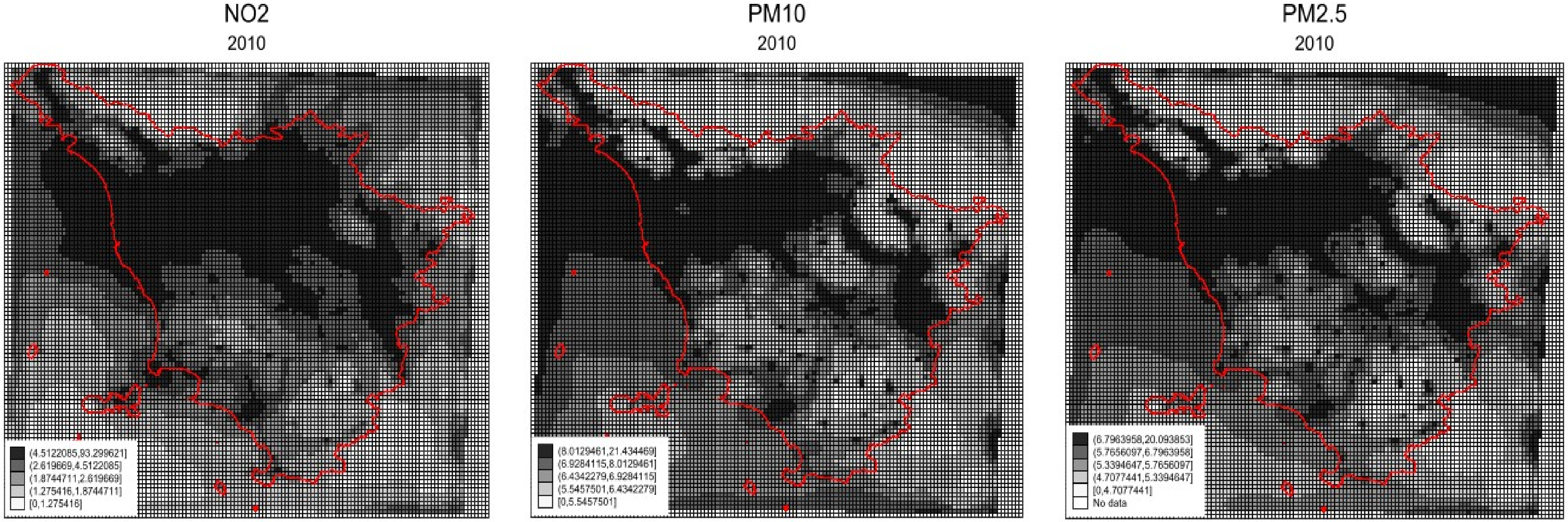




We are producing the expected YLL for 2019

We are still working on YLD

Input 3: Exposure maps



- Data from deterministic dispersion models developed by the LAMMA consortium + data from the stations belonging to the regional air quality monitoring network (years: 2010, 2014, 2015)
- Multivariate Bayesian Kriging model to obtain the predictive posterior distribution of the average levels of the air pollutants by municipality/district
- Exposures in 2010, 2014, 2015 related to outcomes in 2019 (latency time of 3-8 years)

Input 4: Effects estimates

- The Innovation

Review

Cohort studies of long-term exposure to outdoor particulate matter and risks of cancer: A systematic review and meta-analysis

Pei Yu,[1] Suying Guo,[2] Rongbin Xu,[1] Tingting Ye,[1] Shanshan Li,[1] Malcolm R. Sim,[1] Michael J. Abramson,[1] and Yuming Guo[1,*]

This recent meta-analysis (2021)

- updates evidence for the association between PM and lung cancer risk
- summarizes evidence on associations between PM and cancer risks from 13 sites

Linearity assumption

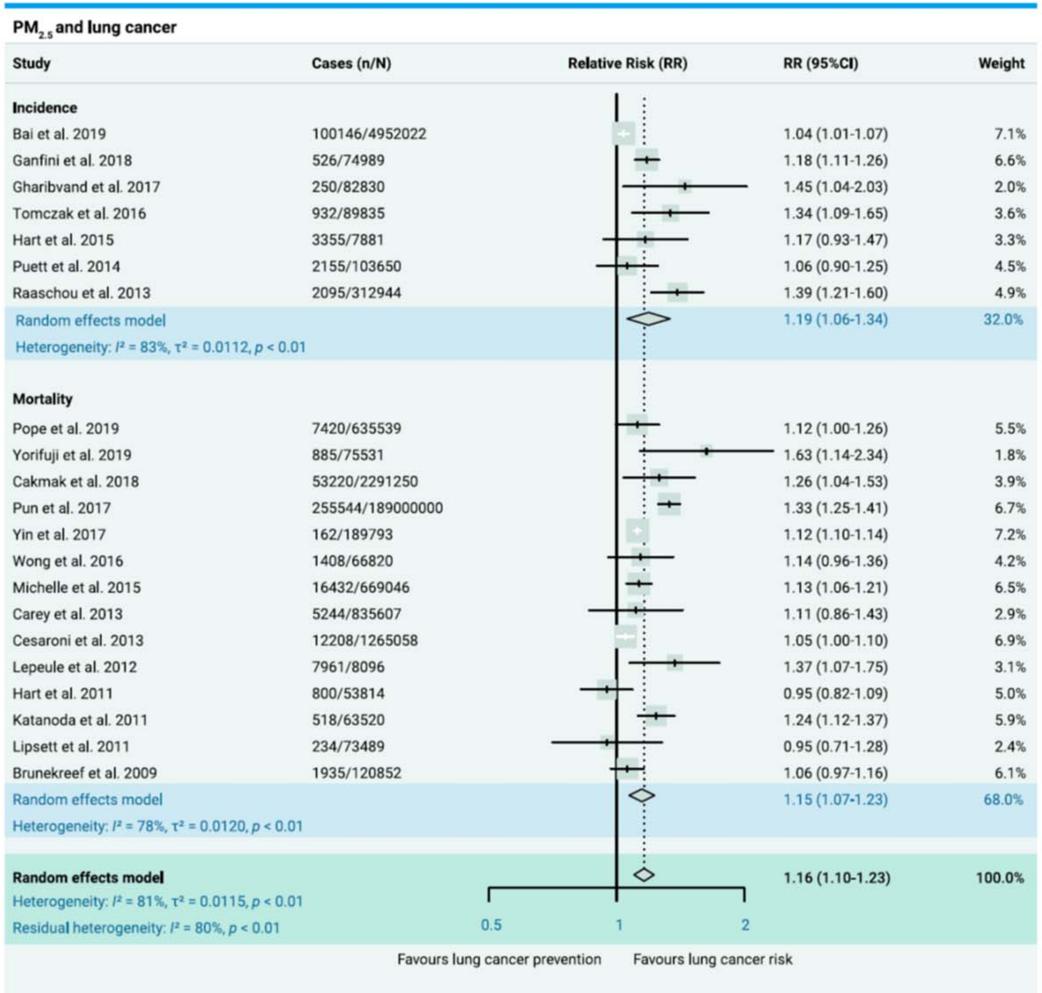


Figure 2. Estimates of lung cancer risk associated with a 10-μg/m³ change in exposure to $PM_{2.5}$ overall and by outcome

Expected results

- Map of the attributable burden for the year 2019 under different conterfactual scenarios

- Projections for the most recent years

- Communication of the project results to the general public

- Extension to other cancer sites

- Uncertainty evaluation through Global Sensitivity Analysis methods based on variance decomposition

General conclusions

- HIA is a powerful, even if complex, tool
- Local assessments are important
  - to define priorities of intervention in public health (comparative assessment)
  - to quantify economic costs related to the exposure to risk factors
  - to enhance community and stakeholders awareness
- Communicating uncertainty is an exciting challenge!