European Commission


# EVALUATING THE ROBUSTNESS OF THE SHERPA AIR QUALITY MODEL THROUGH THE APPLICATION OF GLOBAL SENSITIVITY ANALYSIS TECHNIQUES

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*Joint Research Centre*

# Outline

1. Introduction of challenges and tools
2. How to apply the sensitivity analysis to an integrated assessment tool, SHERPA case
3. Results
4. Conclusions

# Background

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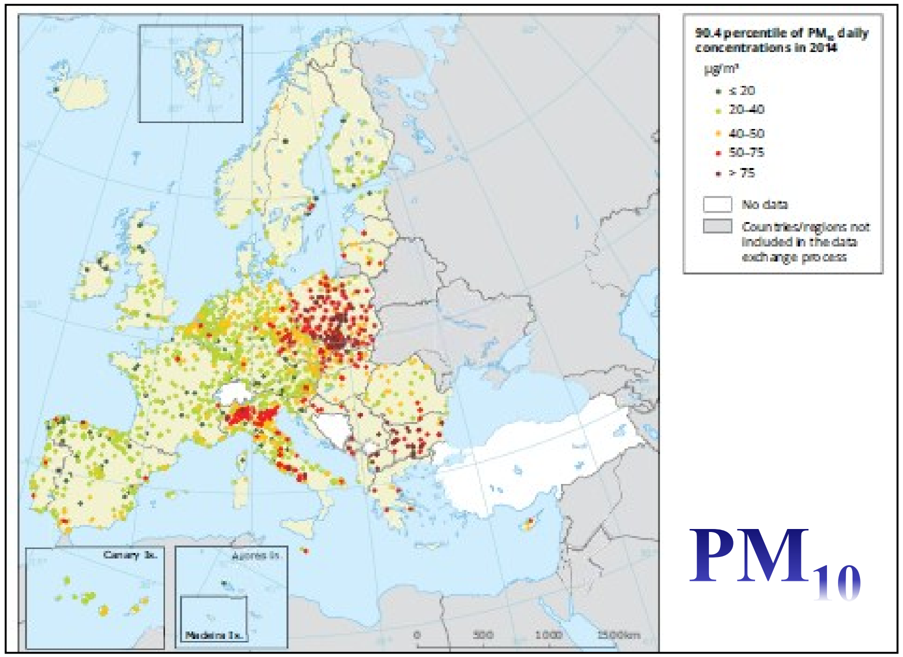
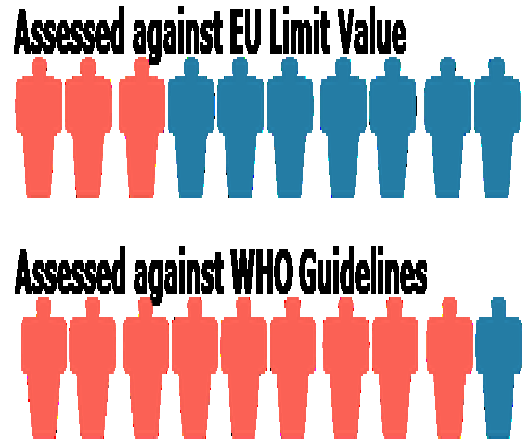
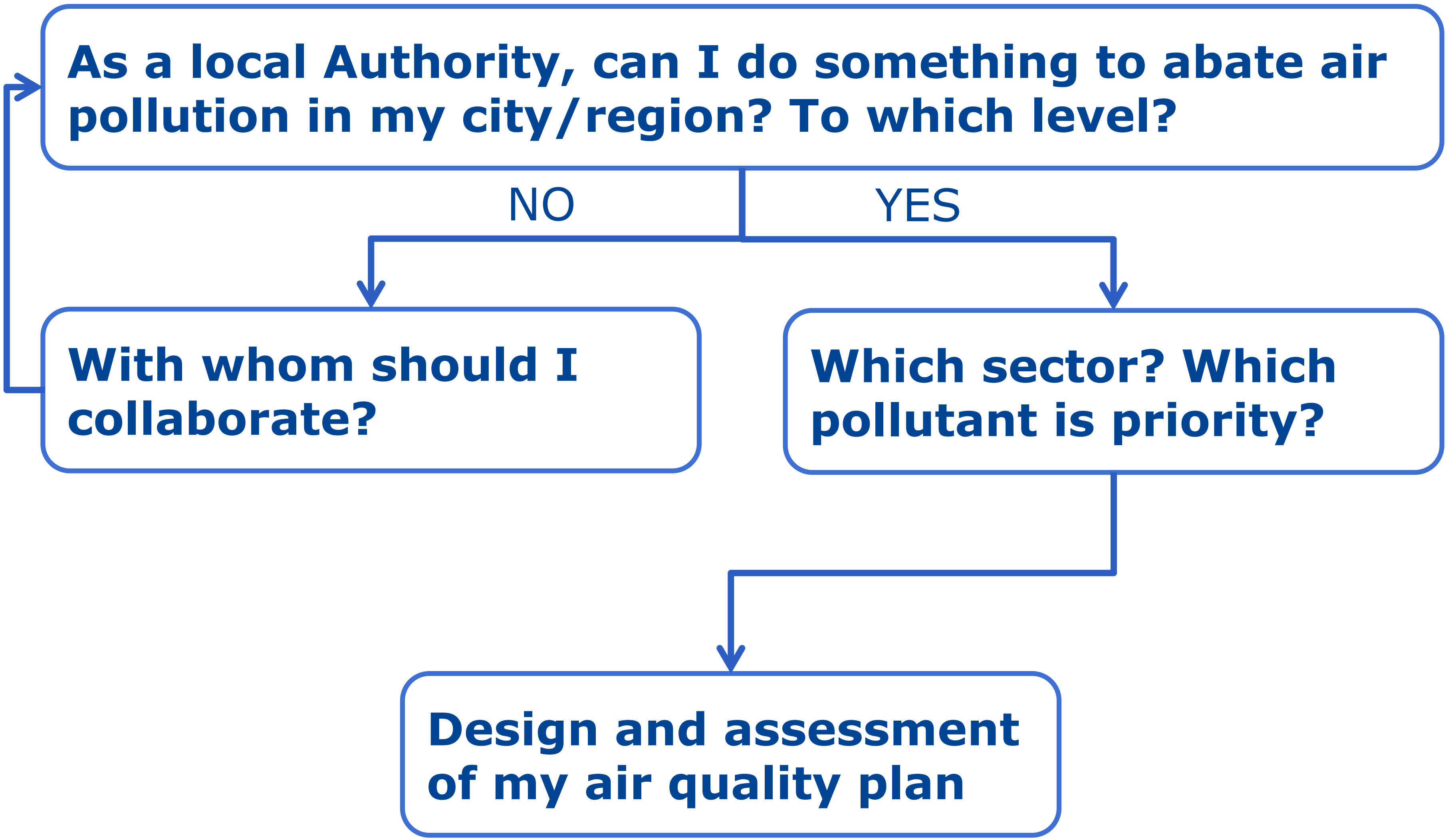
Europe’s air quality is slowly improving, but fine particulate matter nitrogen oxides and ground-level ozone in particular continue to cause serious impacts on health, especially in urban environments



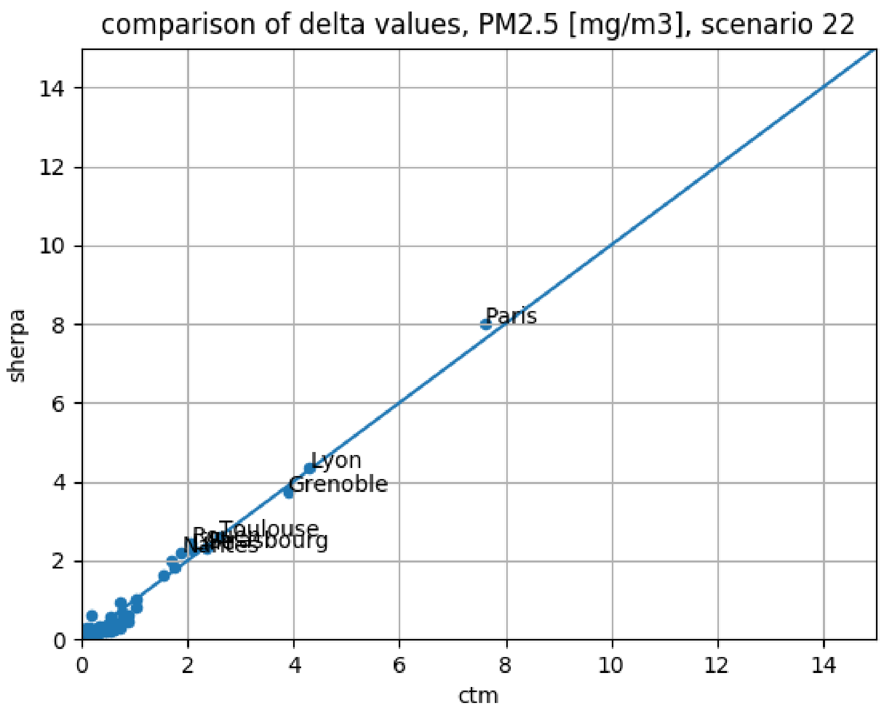

- 400.000 premature deaths in the EU28 (PM2.5)
- Most country (cities) fail to fulfill the EU limit values
- Compliance is an Air Quality Directive obligation → air quality plans

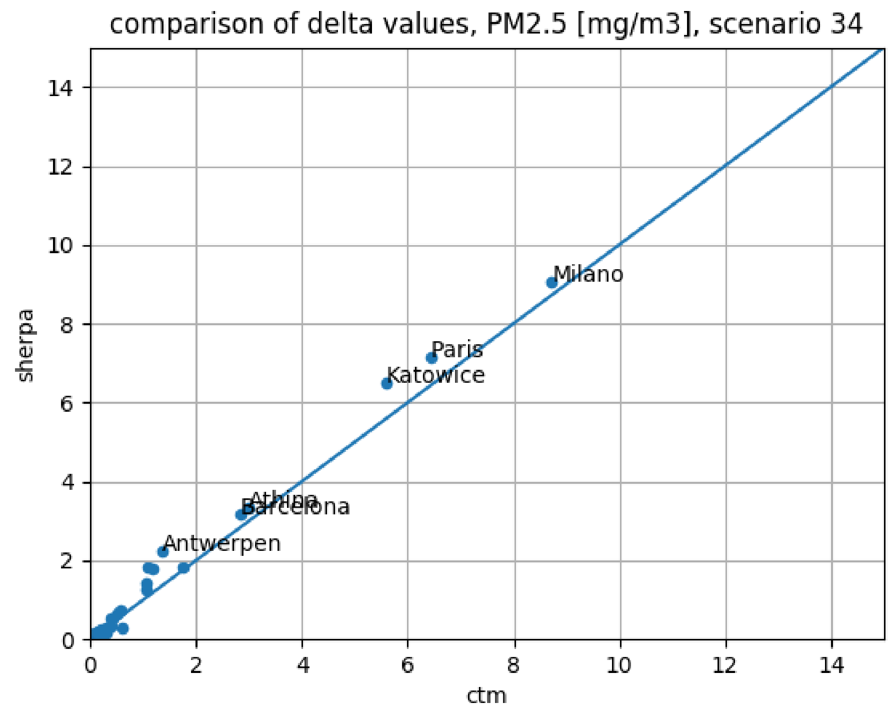
# A possible scheme for air quality plans…



# The SHERPA screening tool

**S**creening for **H**igh **E**mission **R**eduction **P**otentials on **A**ir quality




CPU time: **minutes** to simulate 1 year

- Urban background levels
- Yearly $PM_{2.5}$, $PM_{10}$, $NO_2$

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# How to verify the robustness of the model ?

- Is my model robust for policy applications ?

- Which are the main sources of uncertainty?
  - Model coefficients?
  - Input data
  - …

- Where should I put my efforts to further improve the model ?

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# Steps performed

Select sources of uncertainty

- Source receptor model coefficients ($\alpha$ and $\omega$…see next slide)
- Input (emissions)
- Policies (decisions on the measures)

Propagate the uncertainty with the model

- Simulating with SHERPA the combinations from the previous sources of uncertainties

Compute the sensitivity analysis indicators (see next slides)

- How much SHERPA results depend on the different sources of uncertainty?

# Sources of uncertainty: model coefficients

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1. Source receptor equation

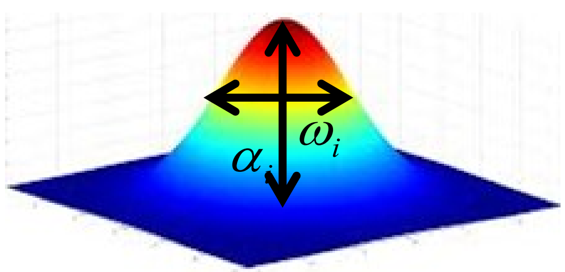
$$\Delta C_i = \sum_{j}^{N_{prec}} \sum_{k}^{N_{cell}} a_{i,j,k} \Delta E_{j,k}$$

Concentration change

Emissions change

2. Coefficients of the source receptor:

$$a_{i,j,k} = \alpha_{i,j} \left(1 + d_{ik}\right)^{-\omega^{i,j}}$$




3. Intervals for uncertainty sampling

| Coefficient | Nominal | Std |
|---|---|---|
| w__NOX | 1,97 | 0,02 |
| w__NH3 | 1,60 | 0,02 |
| w__PPM | 2,32 | 0,018 |
| w__SO2 | 1,34 | 0,01 |
| | | |
| a__NOX | 0,05 | 0,005 |
| a__NH3 | 0,07 | 0,01 |
| a__PPM | 1,97 | 0,04 |
| a__SO2 | 0,01 | 0,004 |

# Sources of uncertainty: emissions and policies

Input considered are emissions of:

- NOx (30%)
- NH3 (50%)
- PPM (50%)
- SO2 (10%)

Policies have been defined between Current Legislation and Maximum Feasible Reductions:

- 25%
- 50%
- 75%
- 100%

# Propagate uncertainty and compute indicators

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.9728270 | 1.5775009 | 2.3517550 | 1.3347041 | 0.0481775 | 0.0546555 | 2.0381985 | 0.0103756 |
| 1.9615385 | 1.5843100 | 2.3227385 | 1.3426583 | 0.0492404 | 0.0879418 | 1.9297483 | 0.0022419 |
| 1.9615385 | 1.5775009 | 2.3517550 | 1.3347041 | 0.0481775 | 0.0546555 | 2.0381985 | 0.0103756 |
| 1.9728270 | 1.5843100 | 2.3517550 | 1.3347041 | 0.0481775 | 0.0546555 | 2.0381985 | 0.0103756 |
| 1.9728270 | 1.5775009 | 2.3227385 | 1.3347041 | 0.0481775 | 0.0546555 | 2.0381985 | 0.0103756 |
| 1.9728270 | 1.5775009 | 2.3517550 | 1.3426583 | 0.0481775 | 0.0546555 | 2.0381985 | 0.0103756 |
| : | : | : | : | : | : | : | : |
| : | : | : | : | : | : | : | : |
| 1.9401762 | 1.5955876 | 2.3189332 | 1.3345709 | 0.0482430 | 0.0860395 | 1.9534254 | 0.0086029 |
| 1.9401762 | 1.5955876 | 2.3189332 | 1.3212162 | 0.0400640 | 0.0860395 | 1.9534254 | 0.0086029 |
| 1.9401762 | 1.5955876 | 2.3189332 | 1.3212162 | 0.0482430 | 0.0503413 | 1.9534254 | 0.0086029 |
| 1.9401762 | 1.5955876 | 2.3189332 | 1.3212162 | 0.0482430 | 0.0860395 | 1.9433326 | 0.0086029 |
| 1.9401762 | 1.5955876 | 2.3189332 | 1.3212162 | 0.0482430 | 0.0860395 | 1.9534254 | 0.0195561 |

Combination of model coefficient, emissions and policy perturbation

SHERPA →

| |
|---|
| 35.79223 |
| 34.99098 |
| 35.88423 |
| 35.75833 |
| 36.4947 |
| 35.7454 |
| : |
| : |
| 36.25576 |
| 35.23081 |
| 35.33825 |
| 36.18899 |
| 38.02076 |

Concentrations

SENSITIVITY INDEX: how much of the output variance depends on the variance of Y when perturbing i

$$S_i = \frac{V[E(Y|X_i)]}{V(Y)}$$

TOTAL EFFECT SENSITIVITY INDEX : as the Si, but considering the interactions terms

$$T_i = 1 - \frac{V[E(Y|X_{\sim i})]}{V(Y)}$$

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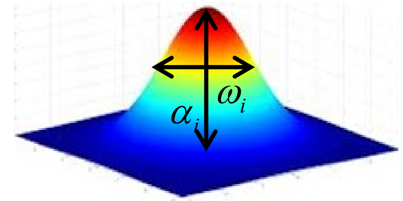
# Model coefficient perturbation results

Analysis performed at the moment on 15 cities
(here showing the results only for 3)

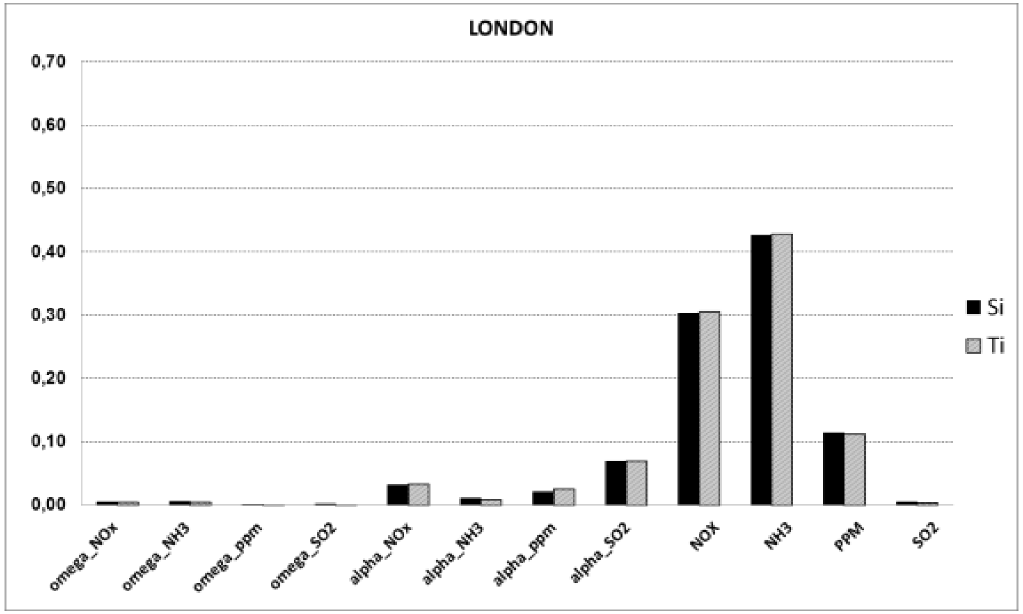



| Policy profile | Total order Sensitivity Indices | | | | | | | | Sum |
|---|---|---|---|---|---|---|---|---|---|
| | **ω-NOx** | **ω-NH3** | **ω-ppm** | **ω-SO2** | **α_NOx** | **α_NH3** | **α_ppm** | **α_SO2** | |
| 100-100-100-100 | 0.01 | 0.01 | 0.11 | 0.01 | 0.24 | 0.09 | 0.16 | 0.35 | 0.98 |
| C: **75**-25-25-25 | 0.04 | 0.00 | 0.03 | 0.01 | 0.69 | 0.03 | 0.04 | 0.11 | 0.95 |
| B: 25-**75**-25-25 | 0.00 | 0.05 | 0.06 | 0.01 | 0.13 | 0.45 | 0.09 | 0.20 | 0.99 |
| A: 25-25-25-**75** | 0.01 | 0.01 | 0.11 | 0.01 | 0.24 | 0.09 | 0.16 | 0.35 | 0.98 |

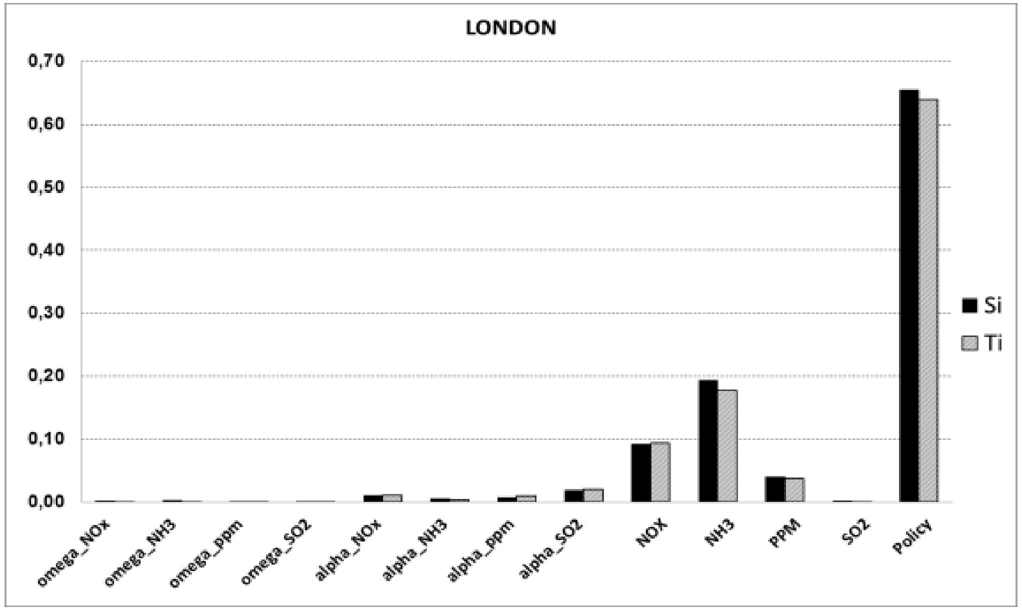
α's show higher values: a good way to reduce the uncertainty on the $\Delta C_i$ is to reduce uncertainty of the α's.

ω's values have low 'influence' values

# London Results



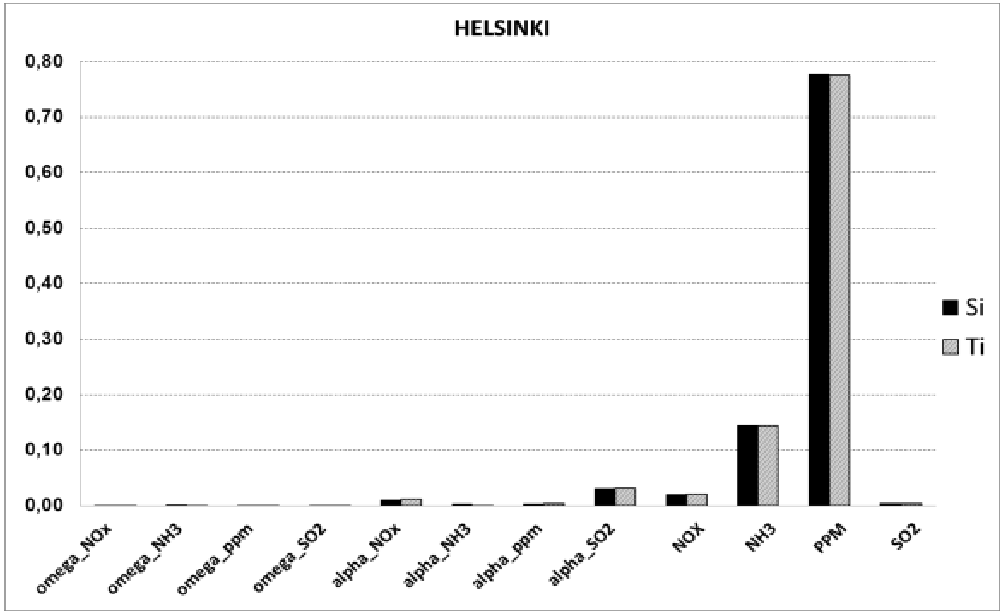

Emission uncertainty is higher than
Model coefficient uncertainty

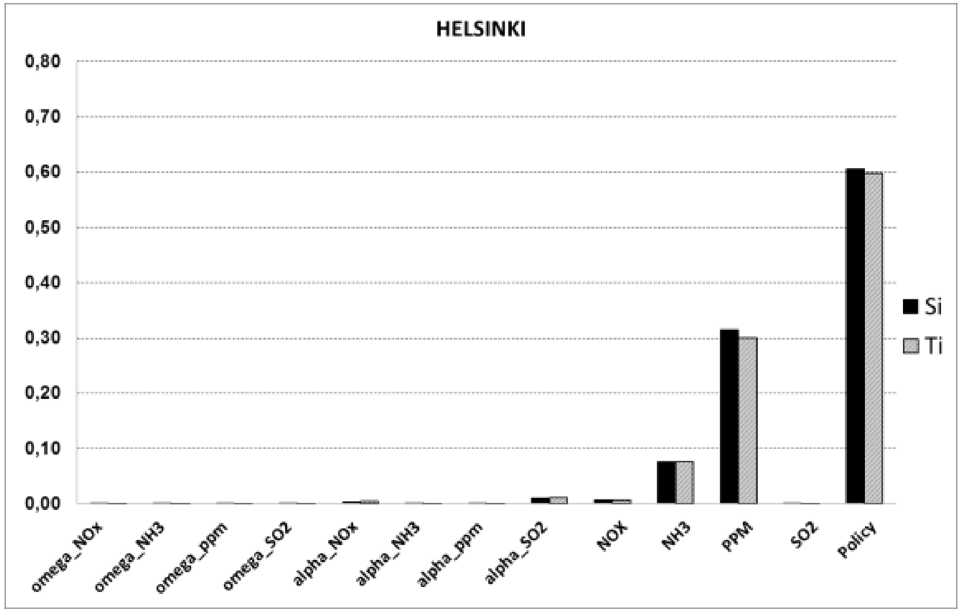



As wished, the policy variability
is higher than the uncertainties

# Perturbing the model, coefficient and policy

## Helsinki

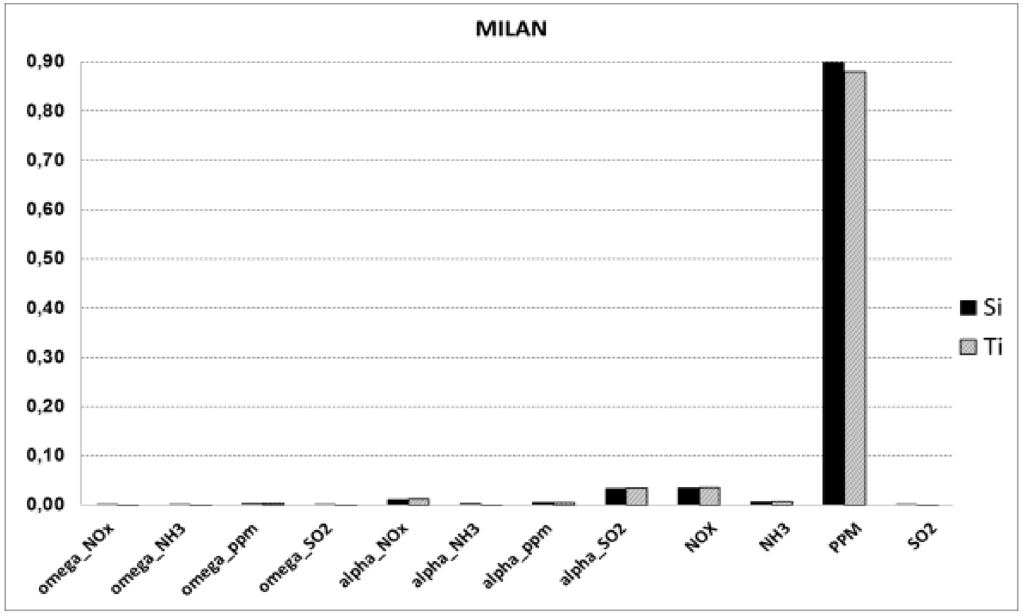


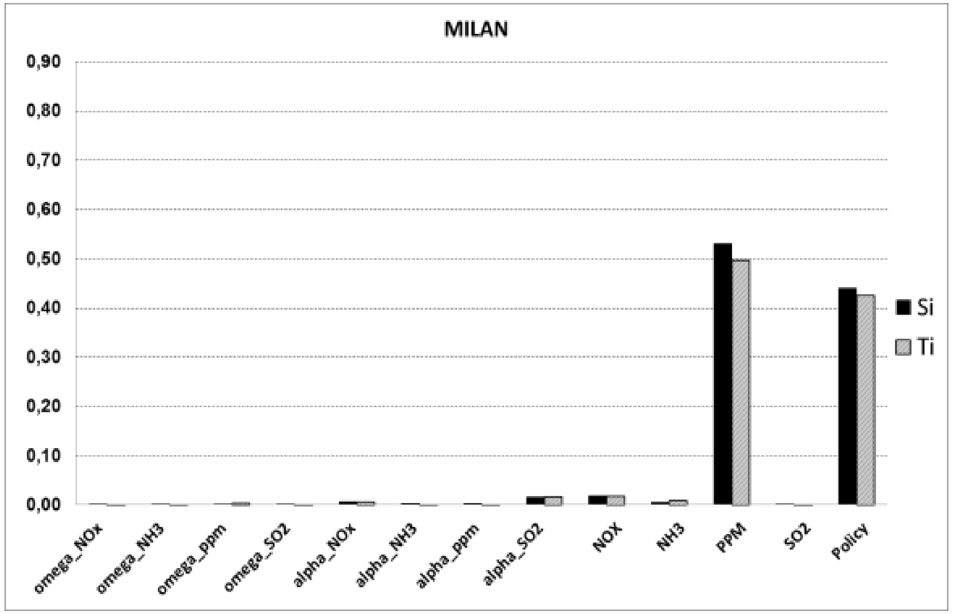

Same as London, with higher sensitivity to primary PM

# Perturbing the model, coefficient and policy

## Milan




Same as London, with higher sensitivity to primary PM




Policy and emission uncertainty are at a similar level

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# Conclusions

Sensitivity analysis allows to:

- Understand the key source of uncertainty (model? input? policy?)
  (In our case input are very important!)

- Understand where to put effort in model development

- Identify that the ‘policy’ is an important factor (but in some cases further work is needed to improve input data)