



**XLV**  
Jornadas de  
**Economía de la Salud**

Datos, evidencia, decisiones:  
generando valor para la gestión  
y las políticas sanitarias

Sevilla, 17 al 19 de junio de 2026

## Assessing the economic burden of temperature-attributable mortality in five European settings with heterogeneous climatic contexts, and the impact of high pollution days

*Work in progress*

Authors: Roger Sabater Mezquita

Laia Maynou

Alexandrina Stoyanova

Universitat de Barcelona & Centre de Recerca en Economia i Salut de la Universitat Pompeu Fabra

*Part of the TRIGGER (SoluTions for  
mItiGatinG climate-induced hEalth  
thReats) European project*

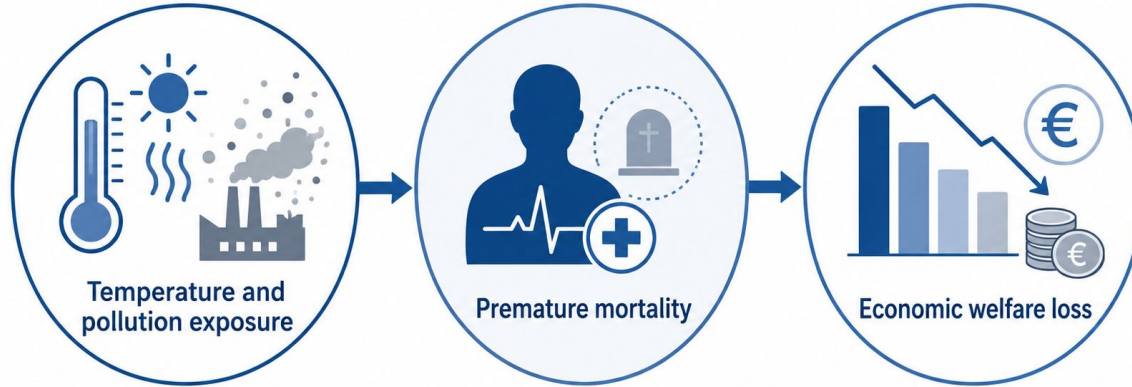
Marc Sáez Zafra  
Universitat de Girona & Centre de Recerca en Economia i Salut de la Universitat Pompeu Fabra

[www.aes.es/jornadas](http://www.aes.es/jornadas)

**AES**   
Asociación de Economía de la Salud



# Motivation



- Extreme temperatures are an increasing public-health concern ([IPCC, 2023](#))
- Mortality impacts vary across populations and climatic contexts
- Economic valuation:
  - Value of a Statistical Life ([OECD, 2025](#)) → Amount a person is willing to pay to avoid a small death risk divided by that risk size; equal valuation for every death
  - Value of a Life Year ([CE Delft, 2024](#)) → Valuation is relative to the remaining life expectancy, thus to age at death



# Study design

## Contributions:

- Full year considered; influence of both heat and cold
- Homogeneous modelisation for heterogeneous areas
- Control for humidity, holidays, and COVID lockdown
- Pollution control, and interaction with temperature

## Main data used:

- Daily mortality 2020-23:
  - All-cause
  - Men / women
  - 0-14 / 15-64 / +65 age groups
  - Cardiovascular / respiratory
- Temperature and humidity from [ERA5-Land](#)
- Pollution (O3 and PM2.5) from [CAM5](#)
- Population weighting from [Eurostat 2021](#)

## European study areas

Official Eurostat/GISCO NUTS and LAU boundaries



NUTS 2021 and LAU 2020 geometries: Eurostat/GISCO. Red diamond: Universitätsklinikum Augsburg main campus.



## Descriptives

### Climate:

Augsburg & Geneva → **Oceanic**

Bologna → **Subtropical**

Heraklion → **Mediterranean**

Oulu → **Continental**

### Population (1st Jan 2021):

Bologna (city) → **391,686**

Geneva (NUTS3 region) → **506,343**

Heraklion (NUTS3 region) → **306,587**

Oulu (NUTS3 region) → **413,830**

Augsburg (hospital) → Population denominator  
not applicable

Setting	Mean daily temperature	p5–p95 temperature	Mean daily deaths	Total deaths
Augsburg	9.6°C	-1.5 to 20.9°C	6.0	8,807
Bologna	15.3°C	3.4 to 28.1°C	11.4	16,607
Geneva	11.0°C	-0.2 to 23.2°C	10.4	15,264
Heraklion	18.0°C	9.1 to 27.4°C	8.8	12,866
Oulu	3.9°C	-11.7 to 18.7°C	10.5	15,298

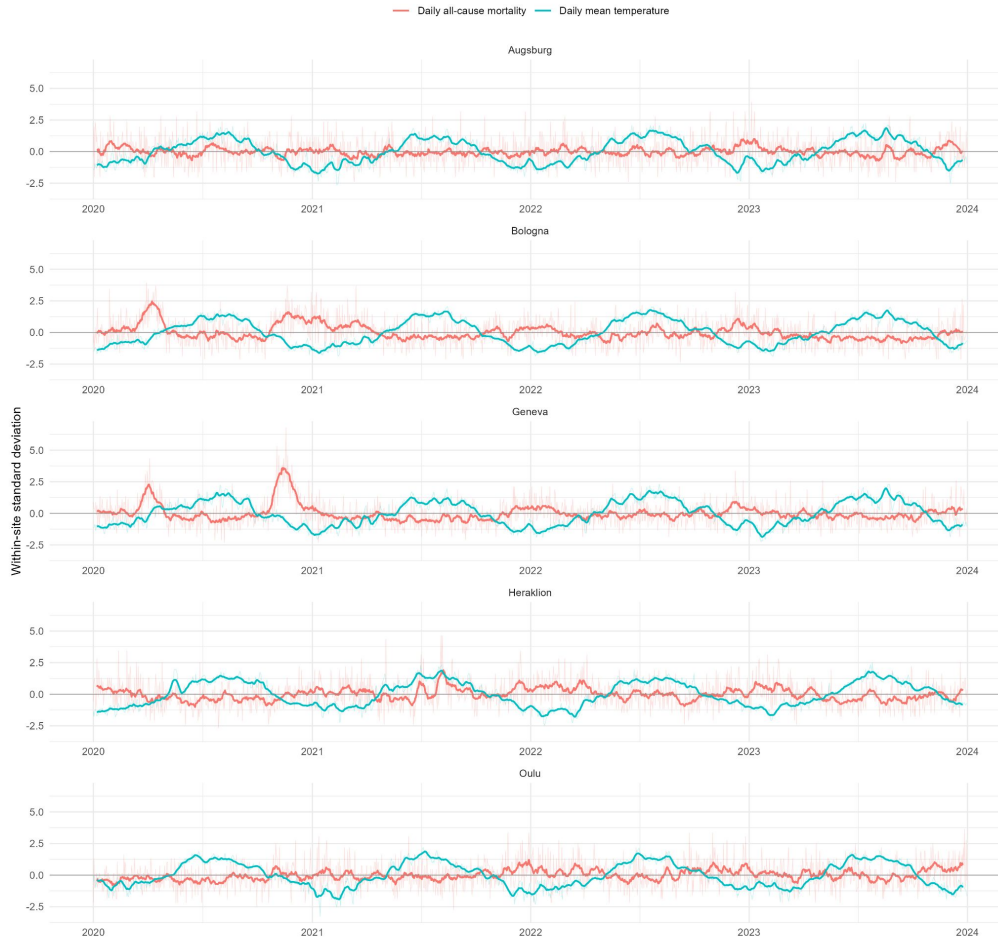


## Jornadas de Economía de la Salud

Datos, evidencia, decisiones:  
generando valor para la gestión  
y las políticas sanitarias

Sevilla, 17 al 19 de junio de 2026

Daily mean temperature and all-cause mortality over time  
Within-site standardised daily values; thick lines are centred 14-day moving averages



Standardisation permits comparison of timing, not absolute magnitude. Daily observations are shown as faint lines.



# Analytical framework

## Workflow:

1. **Average temperature DLNM** ([Gasparrini et al., 2010](#))

$$Deaths_t \sim quasi-Poisson$$

*DLNM(Tmean, lag 0–21) + time + day of week + humidity + holidays + lockdown*

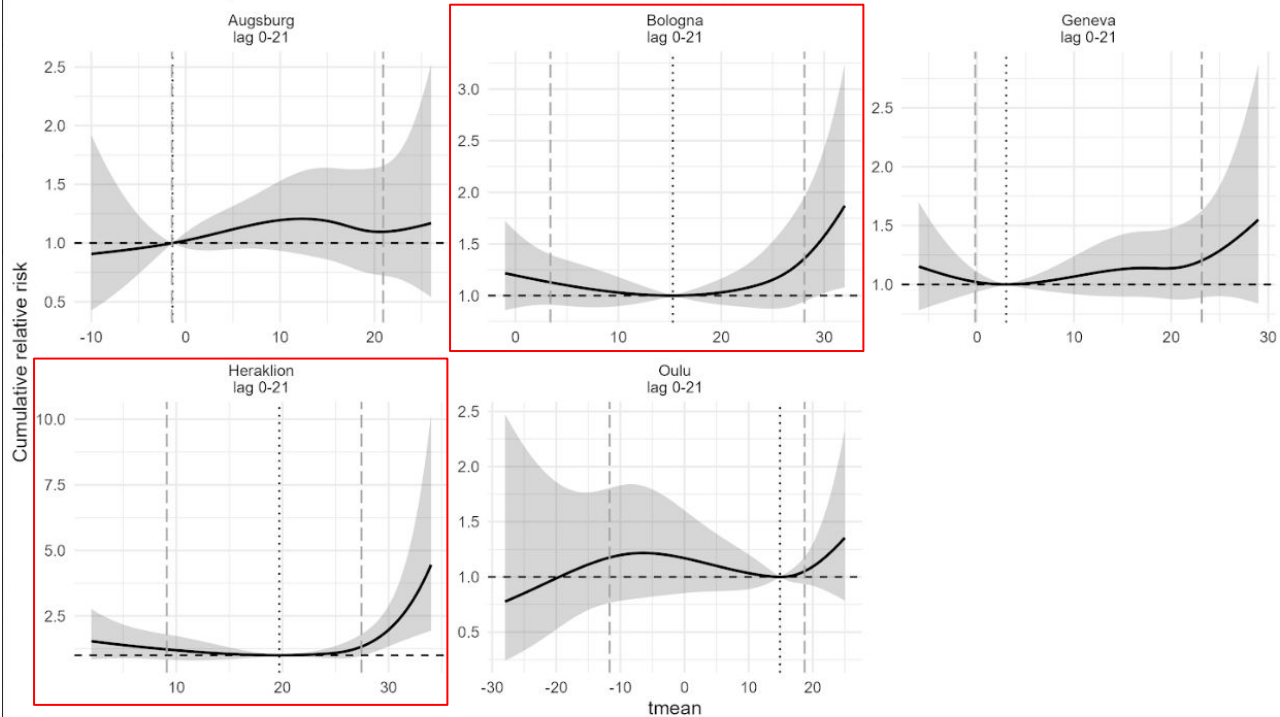
2. **Attributable deaths**
3. **VSL and VoLY valuation**
4. **Pollution-adjusted models**
5. **Temperature x pollution models**
6. Bayesian temporal model (negative binomial) for sparse outcomes
7. Temperature sensitivities (maximum, minimum, UTCI)
8. Augsburg sensitivities (cells or observatories closest to the hospital)



# Temperature-mortality curves

Primary cumulative temperature-mortality association: deaths\_all

Full observed range; RR centred at the site-specific MMT constrained to p5-p95

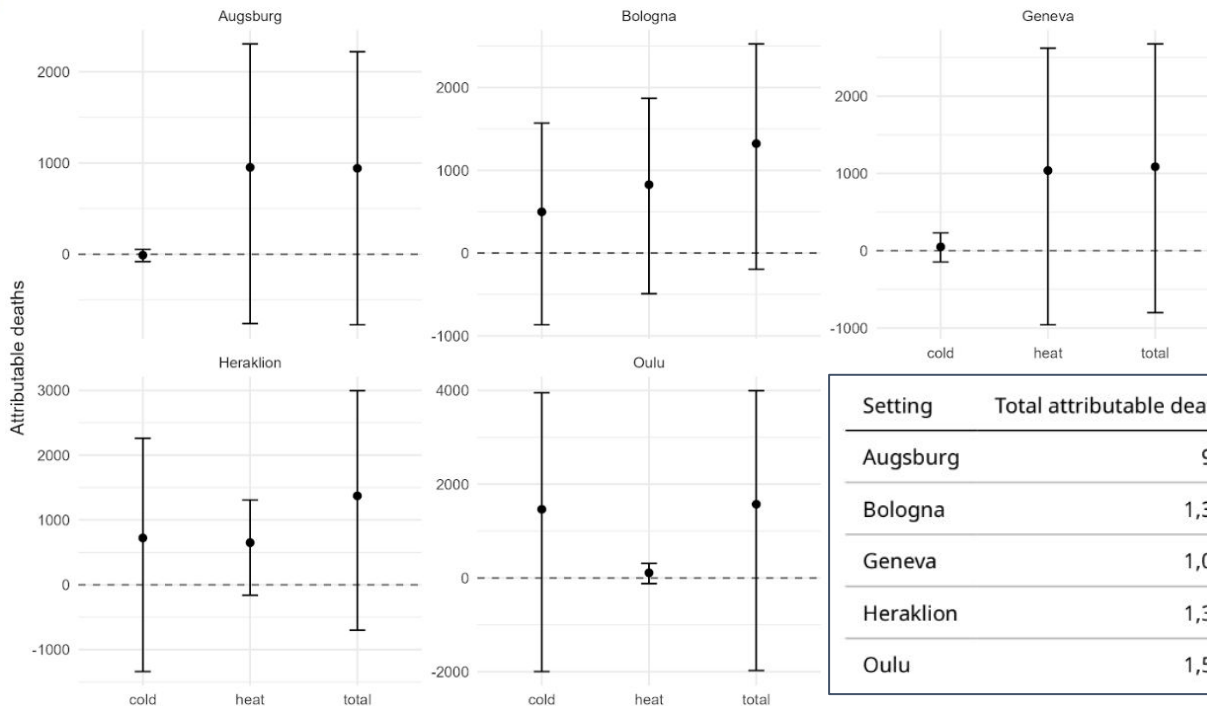


95% CI; dotted line: constrained MMT; grey long-dashed lines: p5-p95 search bounds. Values below 1 outside these bounds indicate that the constrained MMT is not the global minimum.



# Attributable deaths

Temperature-attributable deaths with 95% CI: deaths\_all  
Full study period; burden relative to the p5-p95-constrained MMT



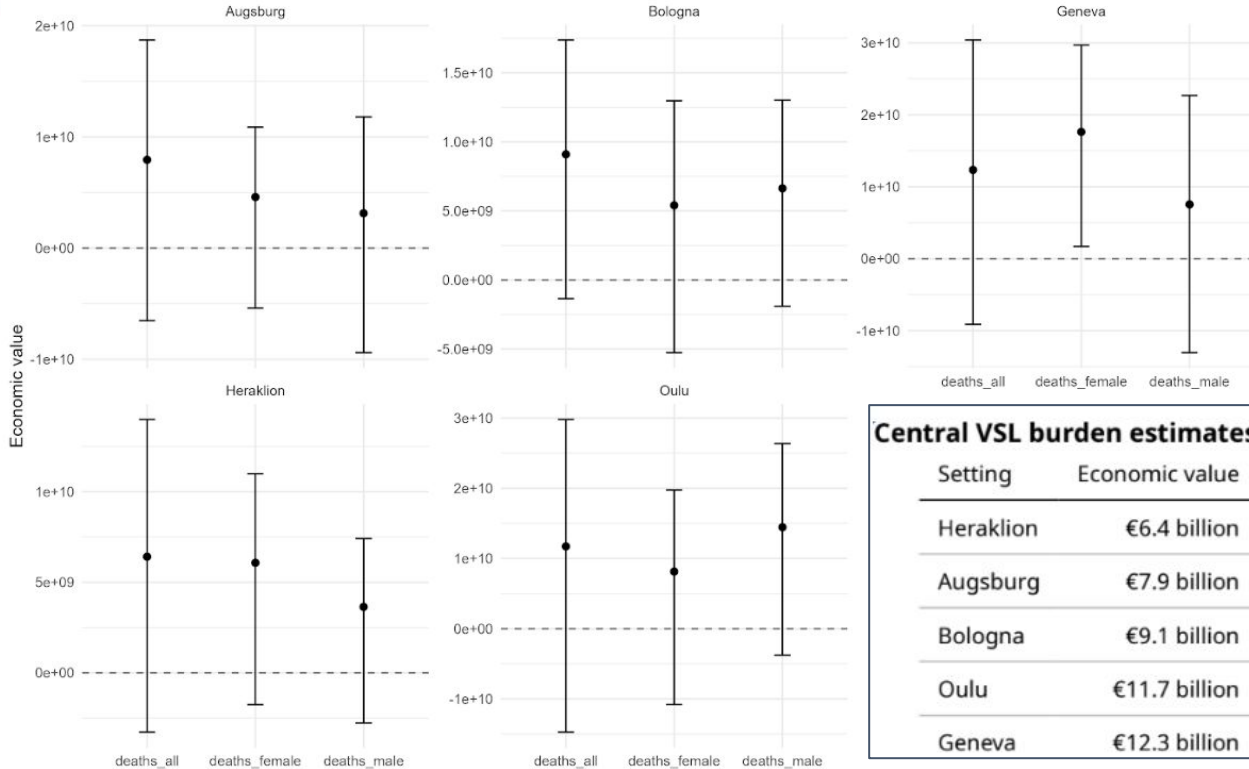
Setting	Total attributable deaths	95% CI
Augsburg	942	-773 to 2,220
Bologna	1,323	-196 to 2,527
Geneva	1,087	-802 to 2,675
Heraklion	1,372	-701 to 2,994
Oulu	1,572	-1,974 to 3,994



# Economic valuation - VSL

VSL valuation of temperature-attributable mortality  
Overall, male and female outcomes; epidemiological 95% CI only

$$VSL_i = VSL_{ref} \left( \frac{GDP_{pc_i}}{GDP_{pc_{ref}}} \right)^{\beta_{VSL}}$$



## Central VSL burden estimates

Setting	Economic value
Heraklion	€6.4 billion
Augsburg	€7.9 billion
Bologna	€9.1 billion
Oulu	€11.7 billion
Geneva	€12.3 billion

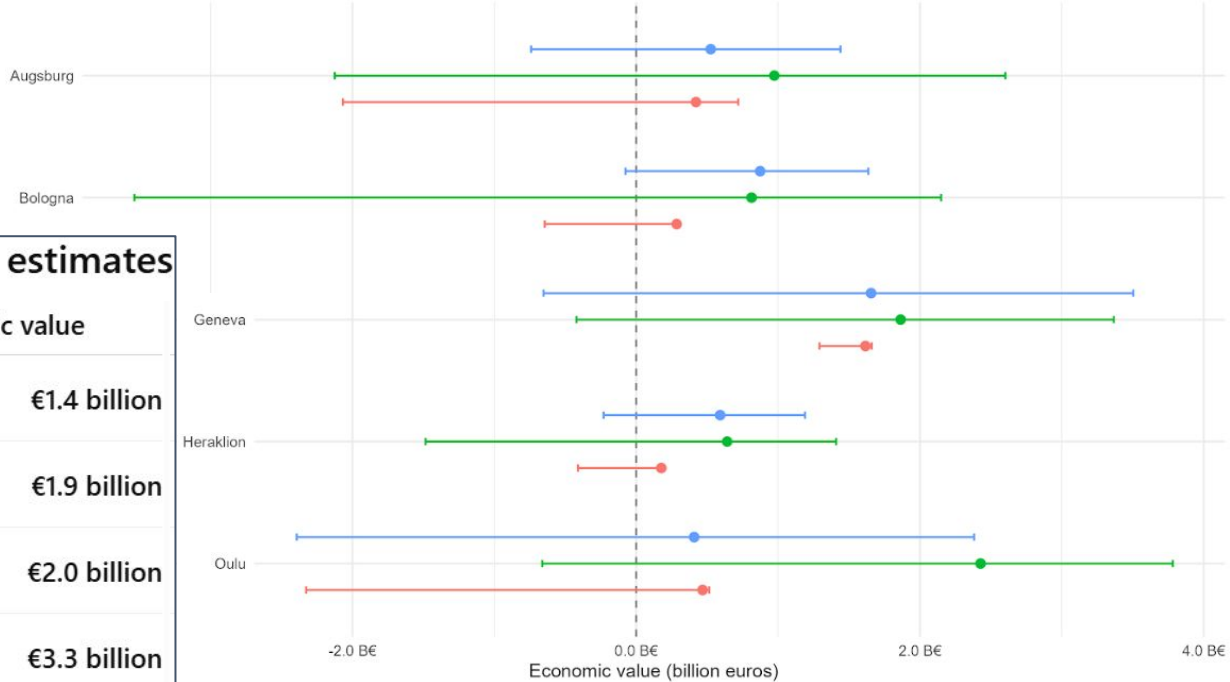


# Economic valuation - VoLY

$$VoLY_i = VoLY_{ref} \left( \frac{GDPpc_i}{GDPpc_{ref}} \right)^{\beta_{VoLY}}$$

VoLY valuation by age group

Temperature-attributable years of life lost, 2020–2023; points are estimates and bars are 95% epidemiological CIs



## Central VoLY burden estimates

Setting	Economic value
Heraklion	€1.4 billion
Augsburg	€1.9 billion
Bologna	€2.0 billion
Oulu	€3.3 billion
Geneva	€5.1 billion

Age group — 0–14 years — 15–64 years — 65+ years

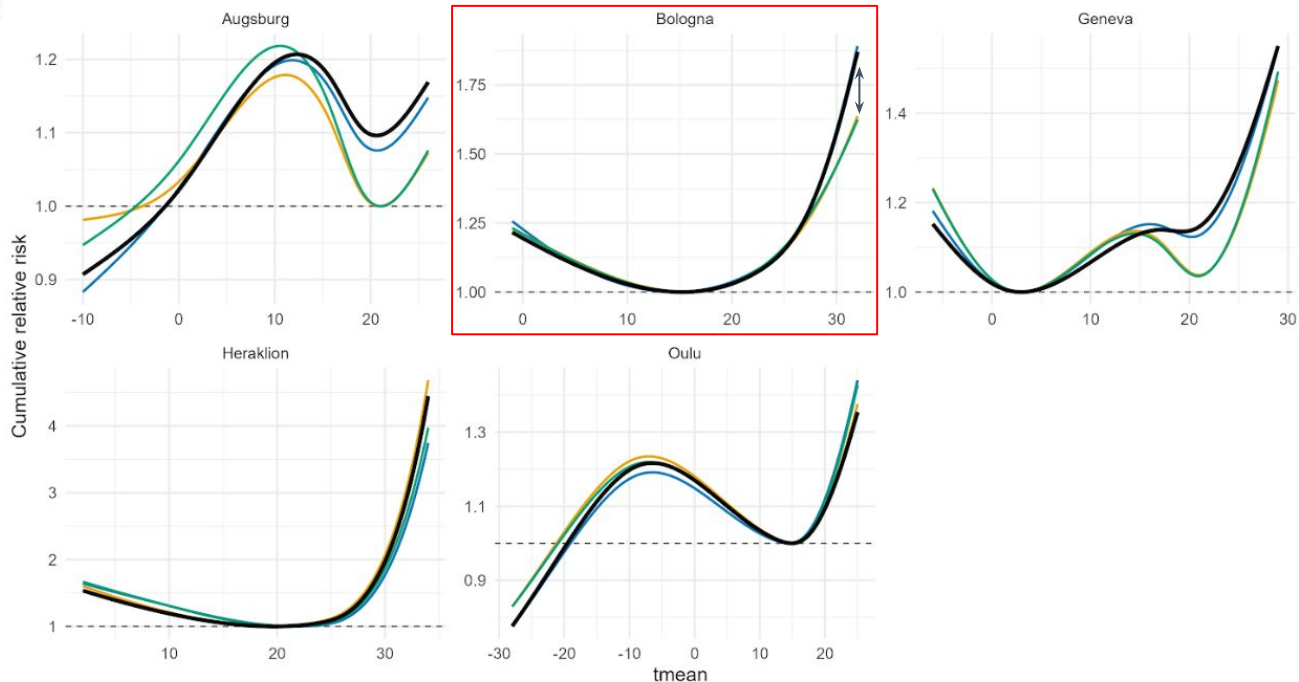
Each age group uses its own DLNM, MMT and weighted remaining life expectancy. Negative lower bounds reflect epidemiological uncertainty.



# Effect of pollution

Temperature-mortality RR under alternative pollution adjustments

All curves centred at their p5-p95-constrained MMT; black = no-pollution main model



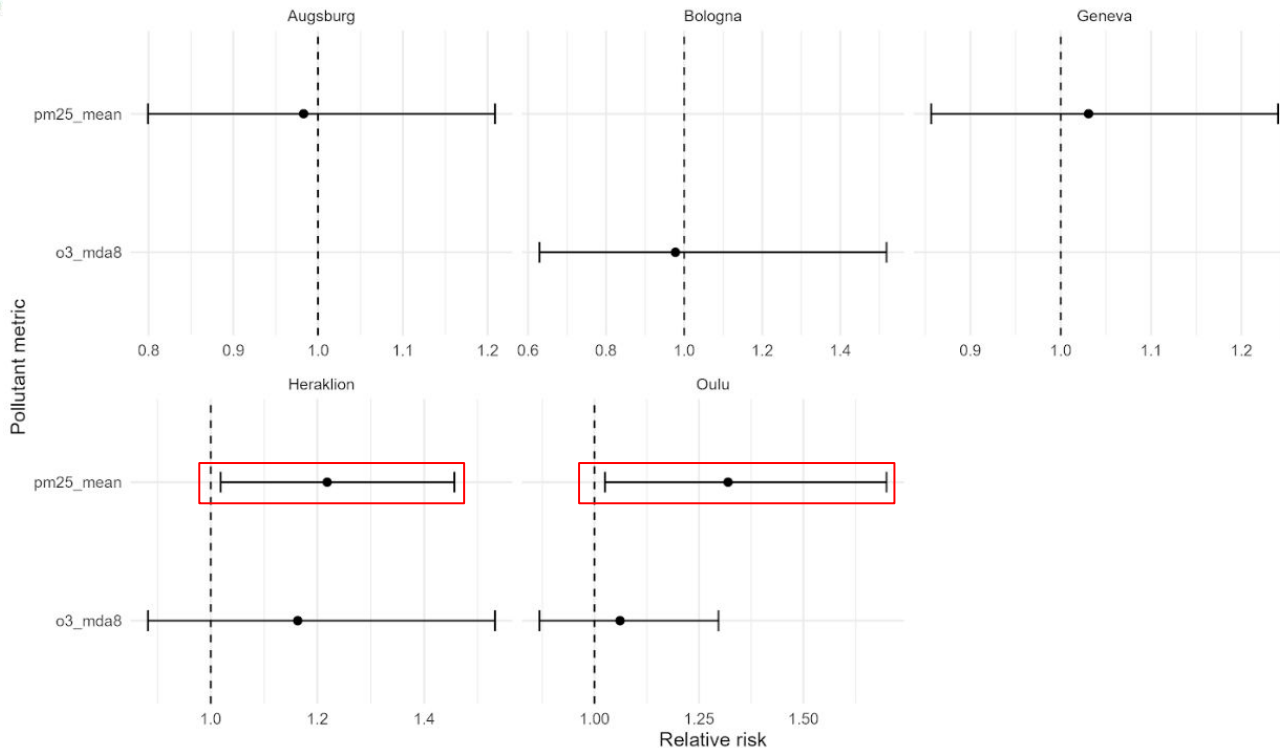
Pollution adjustment — No pollution adjustment (main) — Adjusted for PM2.5 — Adjusted for O3 MDA8 — Adjusted for PM2.5 + O3



# Effect of pollution

Temperature extreme × high-pollution interaction

Term: heat\_extreme:high\_pollution; high pollution = site-specific p75





## Conclusions

- Extreme heat was associated with higher mortality in Bologna and Heraklion
- Point estimates of attributable mortality were substantial but highly uncertain
- High PM2.5 amplified the extreme-heat association in Heraklion and Oulu
- Economic burden estimates reached several billion euros, but inherited the epidemiological uncertainty

### Next steps:

- Analyse how to improve the model (site-specific adjustments...)
- Sensitivity with different time windows (summer months, winter months)
- Sensitivity with different temperature measures (max, min, UTCI)
- Sensitivity with different definitions of Augsburg
- Assess lag-window sensitivity ([Yang et al., 2012](#))
- Bayesian temporal modelisation for sparse strata (youngest group...)



Jornadas de  
**Economía de la Salud**

Datos, evidencia, decisiones:  
generando valor para la gestión  
y las políticas sanitarias

Sevilla, 17 al 19 de junio de 2026

# THANK YOU!