Modeling age-space mortality dynamics in small areas

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The problem

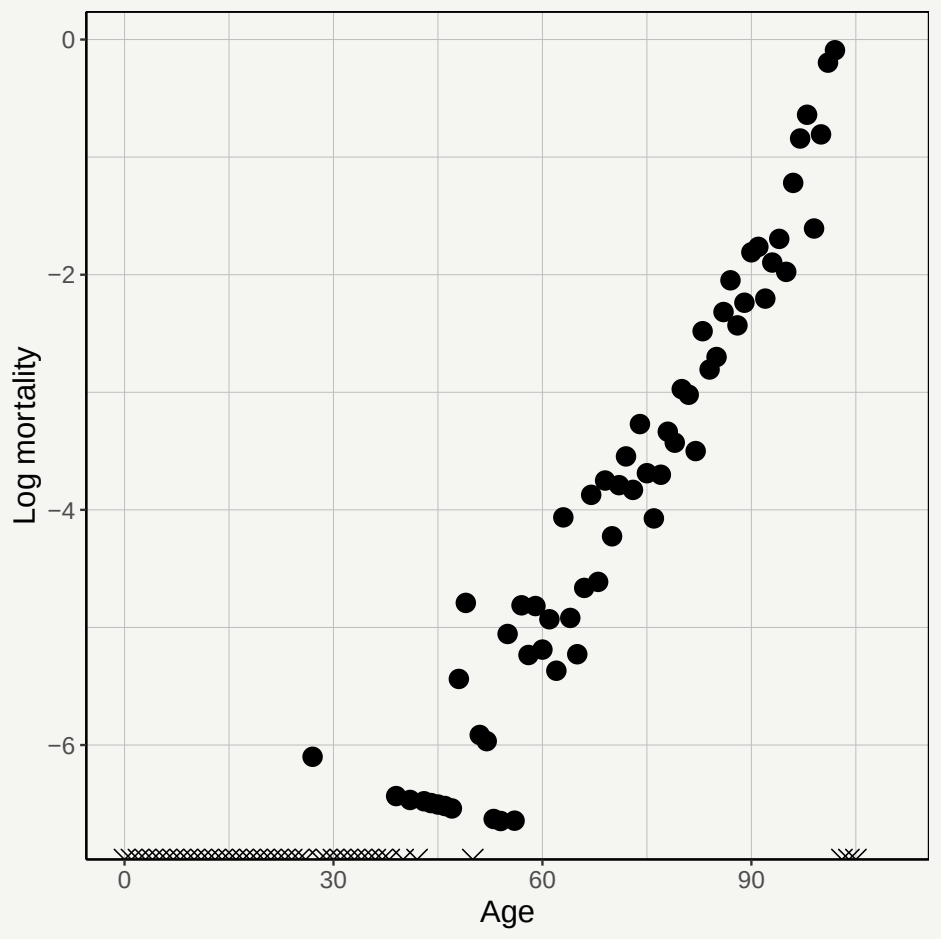

Figure: Observed log-mortality rates. Province of Soria, Males, 2019.

The problem

- Small populations lead to substantial fluctuations in observed death counts.
  - Difficult to distinguish between real differences and random variation in risk of death.
- Recently proposed models use prior demographic knowledge to make estimates of age-specific mortality, but suffer from several drawbacks:
  - They do not incorporate uncertainty surrounding the estimation of a standard schedule into the model.
  - Not all exploit the spatial structure of the data.

Methodology

- Data: two $m \times n$ matrices, m ages, n spatial units: deaths $\mathbf{Y}$, exposures $\mathbf{E}$. Centroids of territorial units serve as spatial information.
- Goal: model

$$\ln \boldsymbol{\mu} = \boldsymbol{\eta} = \begin{bmatrix} \boldsymbol{\eta}^0 \\ \boldsymbol{\eta}_1 \\ \boldsymbol{\eta}_2 \\ \vdots \\ \boldsymbol{\eta}_j \\ \vdots \\ \boldsymbol{\eta}_n \end{bmatrix} = \mathbf{X}\boldsymbol{\theta} \text{ where } \begin{cases} \boldsymbol{\eta}^0 & \text{a common age schedule,} \\ \boldsymbol{\eta}_j & = \boldsymbol{\eta}^0 + \boldsymbol{\delta}_j + \gamma_j \\ & = \text{region } j \text{ schedule} \end{cases}$$

  - $\boldsymbol{\delta}_j$ deviations from standard that vary smoothly in age and space
  - γ_j region-specific intercepts that allow for unsmooth variation.

Illustration - Spanish Provinces

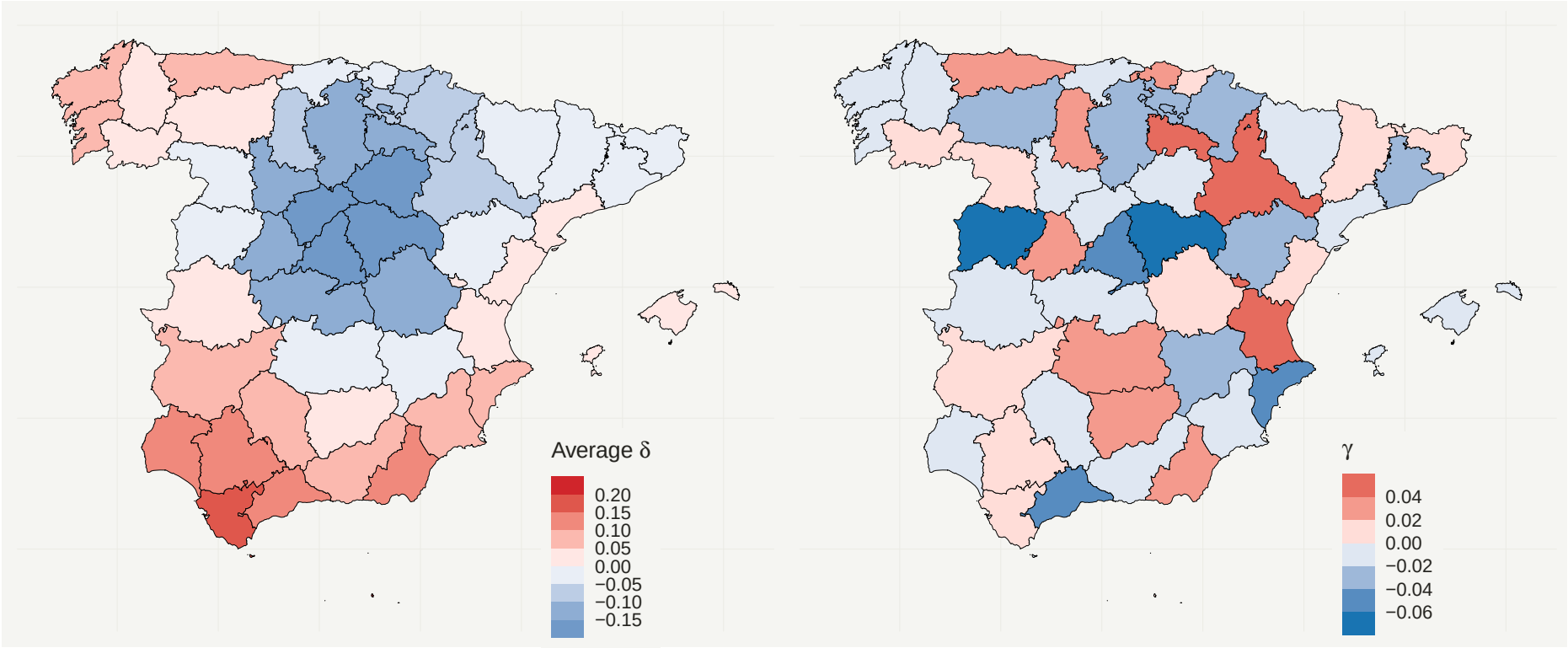

Figure: Estimated average $\boldsymbol{\delta}$ and γ components. Males, Spanish provinces, 2019.

Application - life expectancy at the sub-municipal level

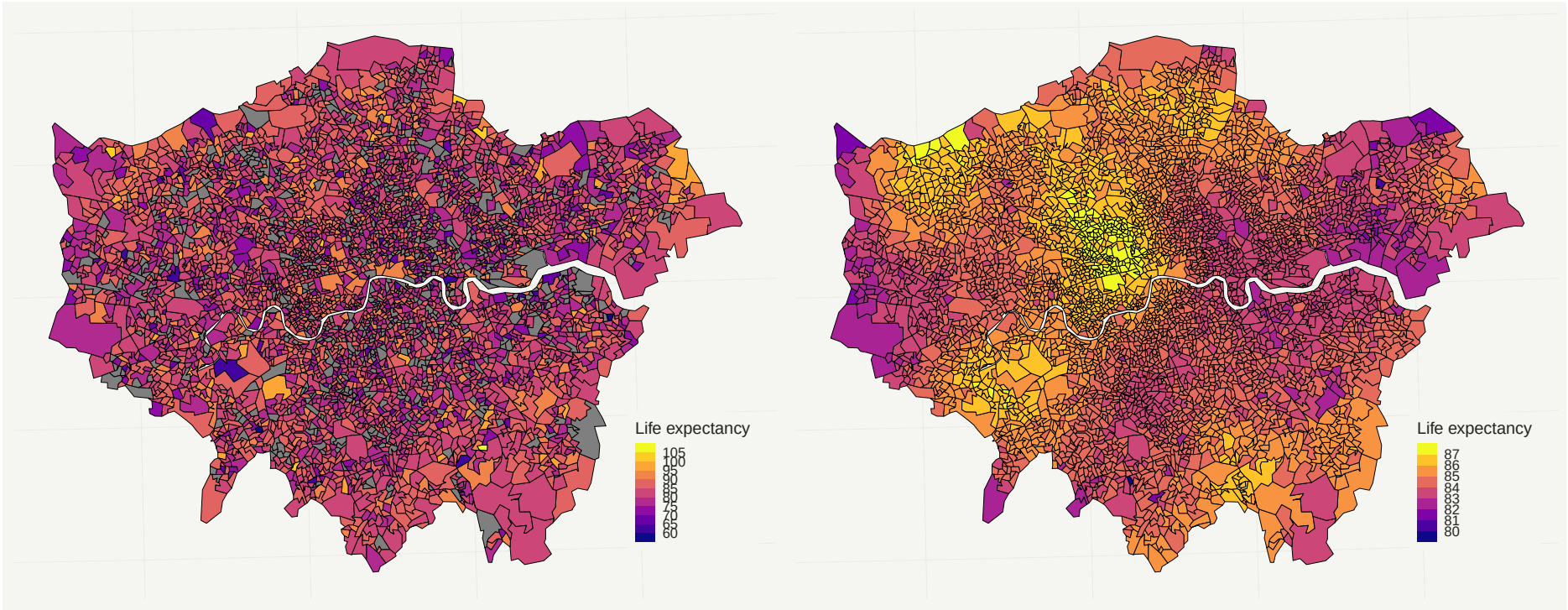

Figure: Observed and estimated life expectancy. Females, 4835 small areas (LSOA) in London metropolitan area, 2012–2016.