# Suicide mortality rates in England: a spatiotemporal study between 2002 – 2021

**Connor Gascoigne**

Imperial College London

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MRC
Centre for Environment & Health

UKRI Medical Research Council

Imperial College London

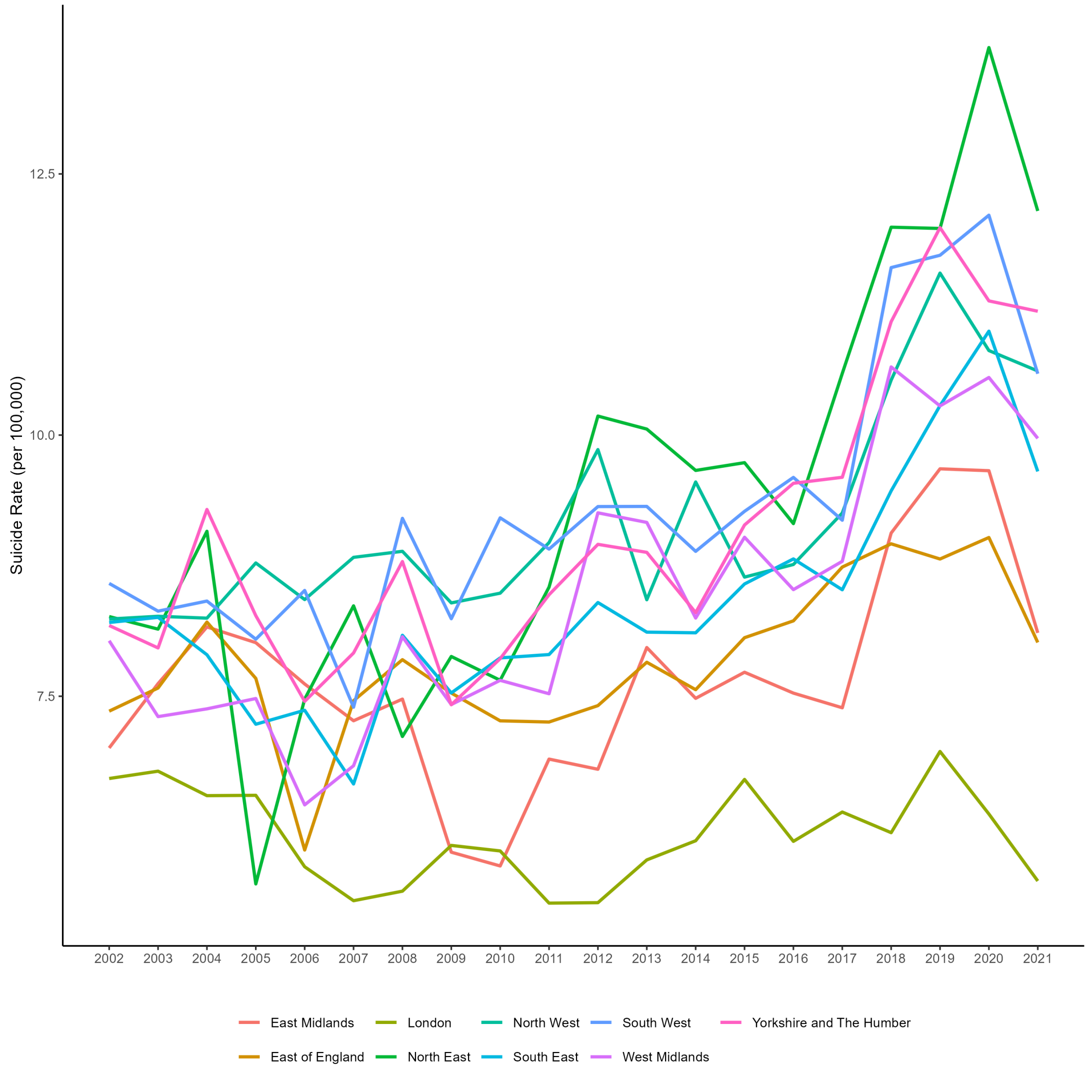
# Outline

- Introduction
- Methods
- Results
- Conclusion

# Introduction

# Suicide in England

- Globally, 700,000 deaths by suicide per year and the 4th leading cause of death amoung 15-29 year-olds
- In England:
  – 72,000+ deaths between 2002-2021
  – Increase of 18% between from 2002 to 2021
  – Largest increase from 2002 was 30% in 2020



# Aims

1. Build a flexible and robust model to explore and estimate suicide trends in England at a high spatio-temporal resolutions.
   - Account for correlations in both space and time.
   - Account for excess number of zeros due to high spatio-temporal resolution.
2. Understand the effect of local environment on suicide to identity area profiles most at risk.

# Methods

# Outcome

Outcome:

- Suicide deaths (ICD10 X60 - X84).
- Age (5-14, 15-24, ..., 75-84, 85+), sex and MSOA.

Population totals:

- Mid-year from ONS.
- Age (5-14, 15-24, ..., 75-84, 85+), Sex and MSOA.

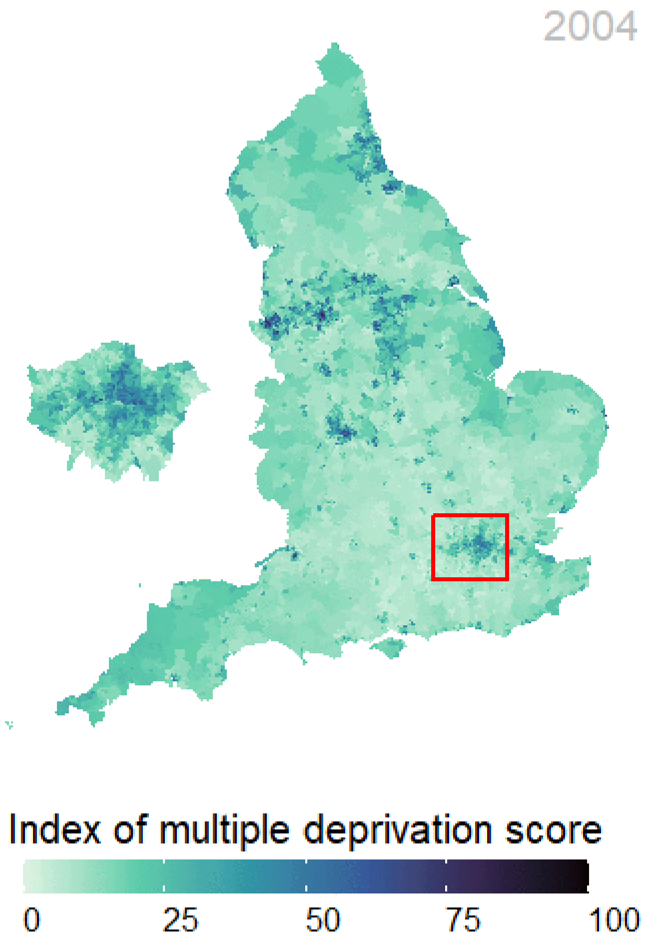
Middle Layer Super Output Area (MSOA):

- Administrative region in UK.
- Consist of 5,000 - 15,000 individuals.
- Updated every census (2001, 2011, 2021).
- From the 2011 Census, England consists of 6,971 MSOAs

# Covariates

Deprivation:

- ONS IMD releases in '04, '07, '10, '15, '19.



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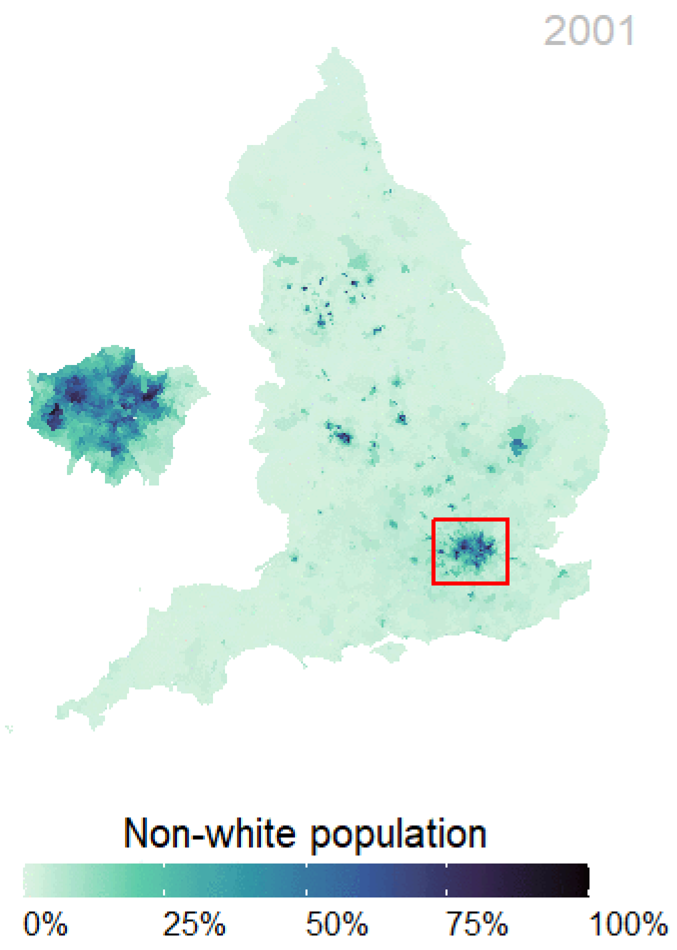

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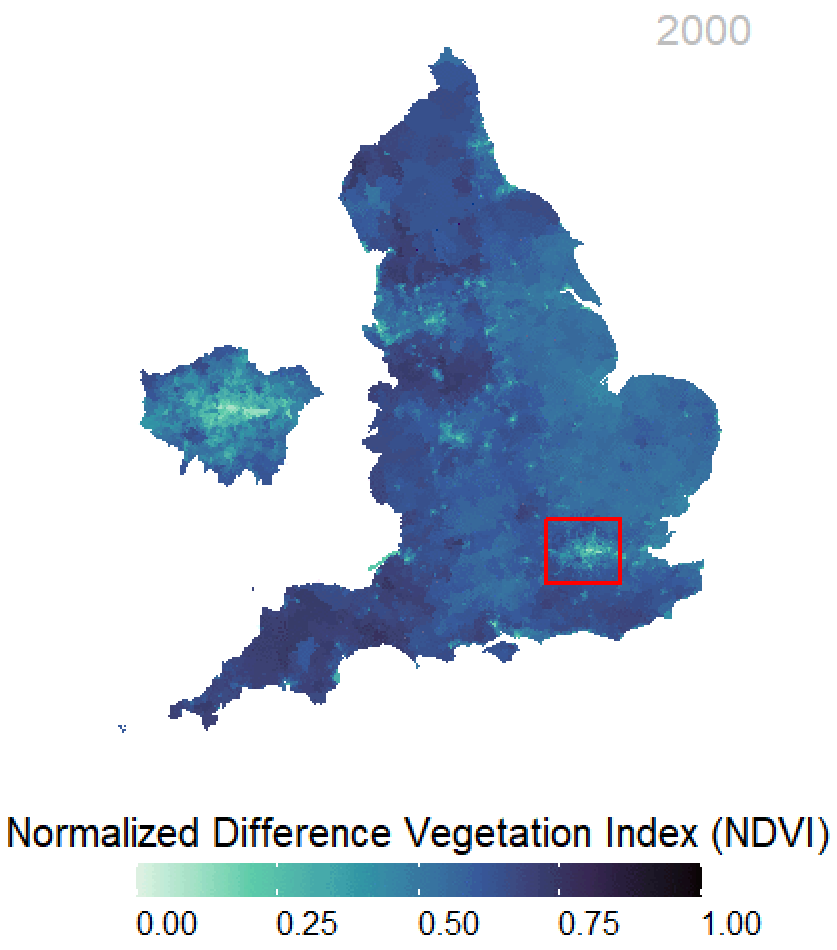

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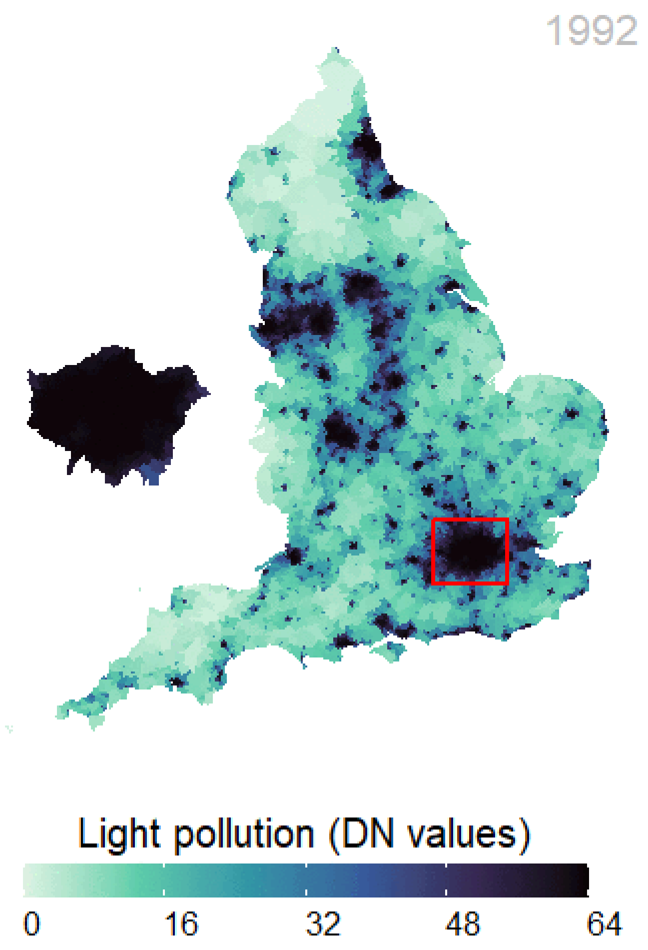

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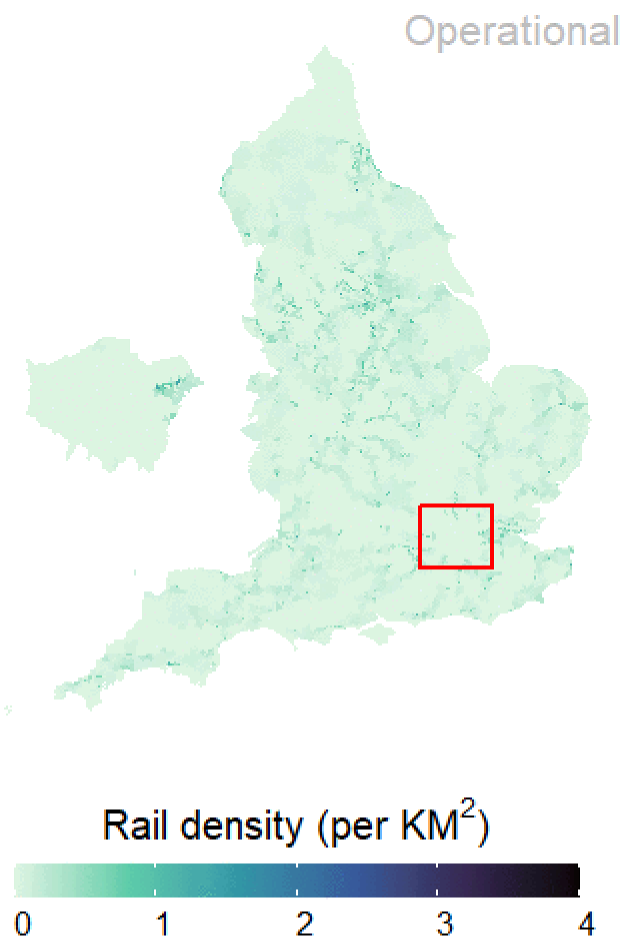
- OpenStreepMap for rail or no-rail per MSOA.



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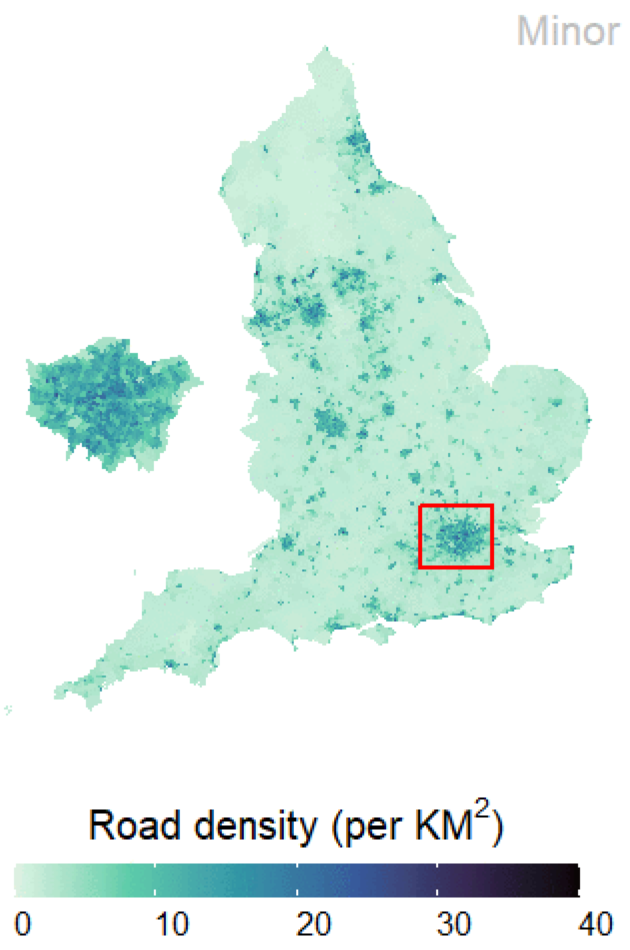

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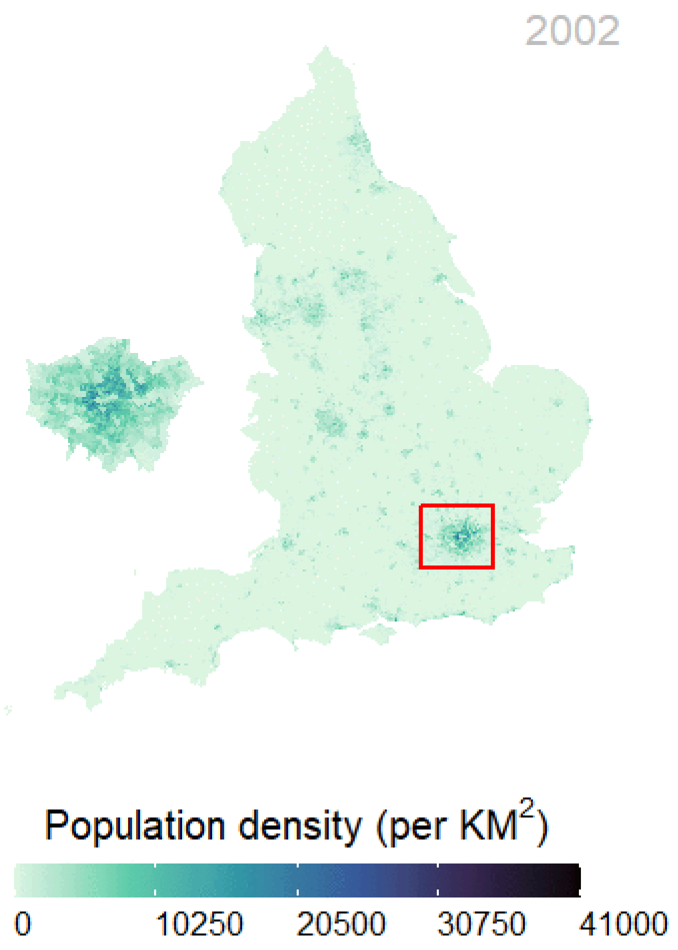
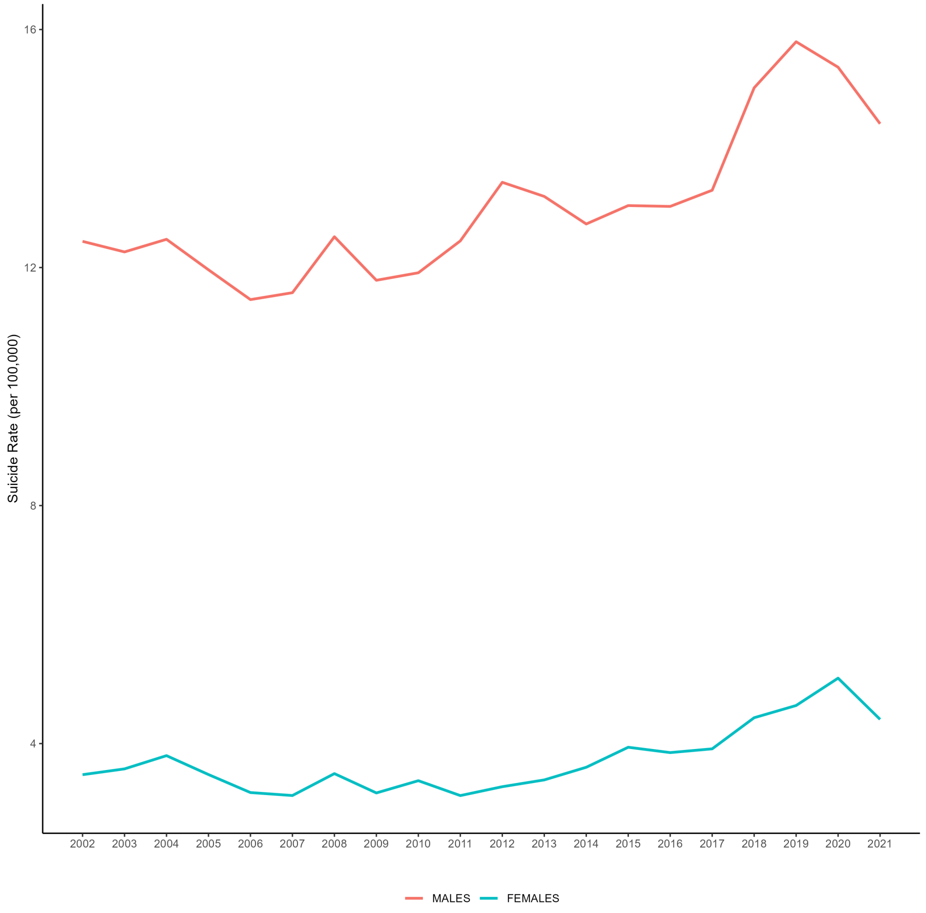
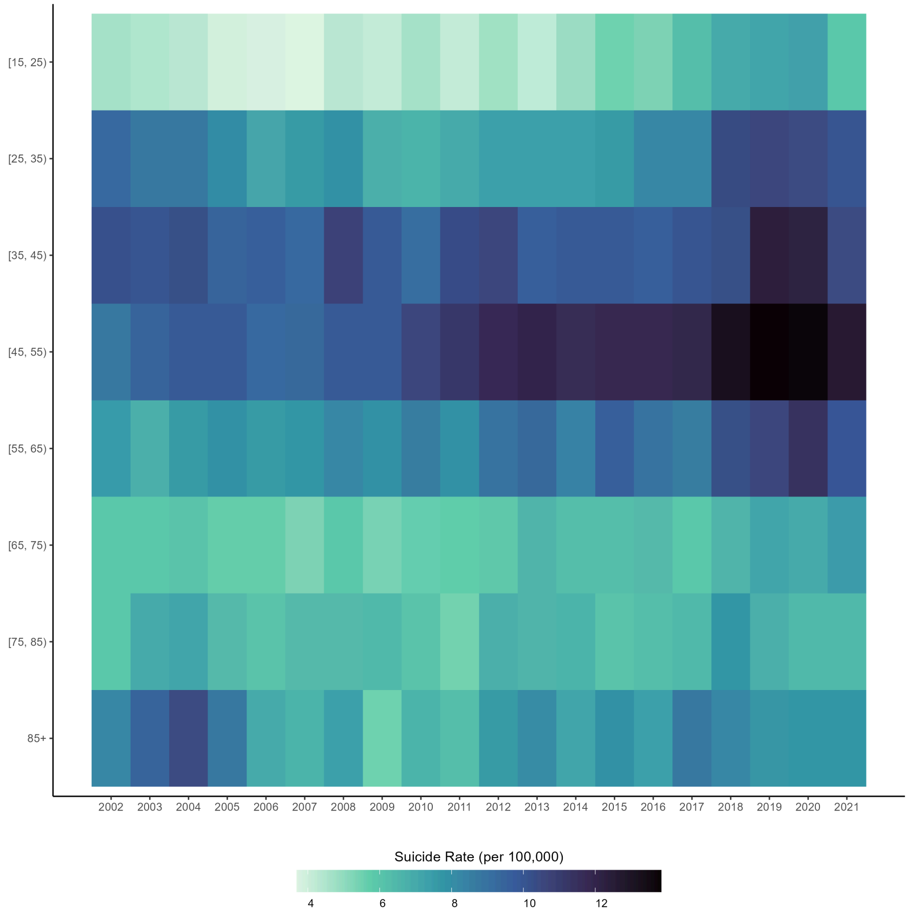


# Statistical Model

Indirect Standardisation | Hurdle Model Framework | Linear Predictor

Age and sex structures vary throughout the study period:



Let $Y_{it}$ and $E_{it}$ be the count and (age-sex adjusted) expected value for $i^{\text{th}}$ MSOA and $t^{\text{th}}$ year. We define $\boldsymbol{Y} = (\boldsymbol{Z}, \boldsymbol{O})$ where the probability of event $y_{it}$ is defined:

$$\Pr(\boldsymbol{Y} = y_{it}) = \begin{cases} \Pr(\boldsymbol{Z} = y_{it}), & \text{if } y_{it} = 0 \\ [1 - \Pr(\boldsymbol{Z} = y_{it})] \times \frac{\Pr(\boldsymbol{O}=y_{it})}{1-\Pr(\boldsymbol{O}=0)}, & \text{if } y_{it} \geq 1 \end{cases}$$

Where:

- $\boldsymbol{Z}$ indicates if a suicide has occurred or not:

$$z_{it} = \begin{cases} 1, \text{if } y_{it} \neq 0 \\ 0, \text{otherwise} \end{cases}$$

- $\boldsymbol{O}$ indicates the observed number of suicides:

$$o_{it} = \begin{cases} \text{NA}, \text{if } y_{it} = 0 \\ y_{it}, \text{otherwise} \end{cases}$$

# Statistical Model

Indirect Standardisation | Hurdle Model Framework | Linear Predictor

Let $Y_{it} \sim \text{HurdlePoisson}\left(\pi_{it}, \lambda_{it} = \rho_{it} E_{it}\right)$. We model the zero and occurrence parts as:

$$z_{it} \sim \text{Binomial}\left(\pi_{it}\right)$$
$$\text{logit}\left(\pi_{it}\right) = \beta_0^z + \boldsymbol{X}\boldsymbol{\beta}^z + \delta_i + \gamma_t + \xi_{it}$$

where:

- $\beta_0^z$ is the zero-model specific intercept.
- $\boldsymbol{\beta}^z$ are the zero-model regression coefficients for environmental factors.
- $\delta_i$ is the shared spatial effect.
- $\gamma_t$ is the shared temporal effect.
- $\xi_{it}$ is a shared spatio-temporal effect.

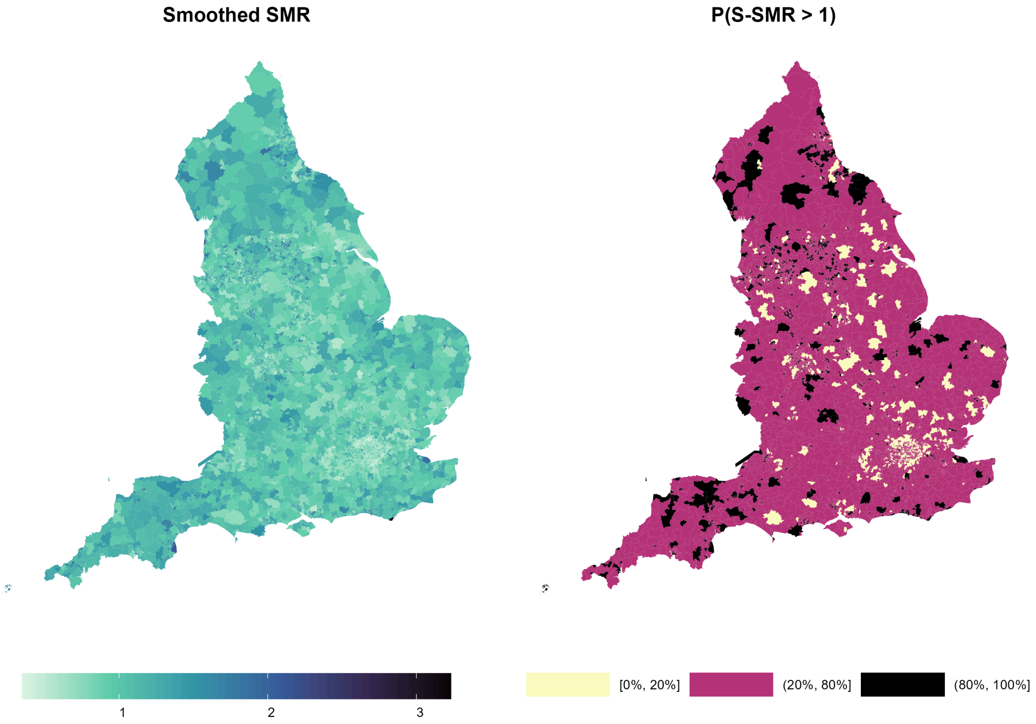
$$o_{it} \sim \text{Poisson}\left(\lambda_{it} = \rho_{it} E_{it} \middle| \, o_{it} > 0\right)$$
$$\log\left(\rho_{it}\right) = \beta_0^o + \boldsymbol{X}\boldsymbol{\beta}^o + \beta_\delta^o \delta_i + \beta_\gamma^o \gamma_t + \beta_\xi^o \xi_{it}$$

where:

- $\beta_0^o$ is the count-model specific intercept.
- $\boldsymbol{\beta}^o$ are the count-model regression coefficients for environmental factors.
- $\delta_i$ is a shared spatial effect with $\beta_\delta^o$ a scale parameter for the count-model.
- $\gamma_t$ is a shared temporal effect with $\beta_\gamma^o$ a scale parameter for the count model.
- $\xi_{it}$ is a shared spatio-temporal effect with $\beta_\xi^o$ a scale parameter for the count model.

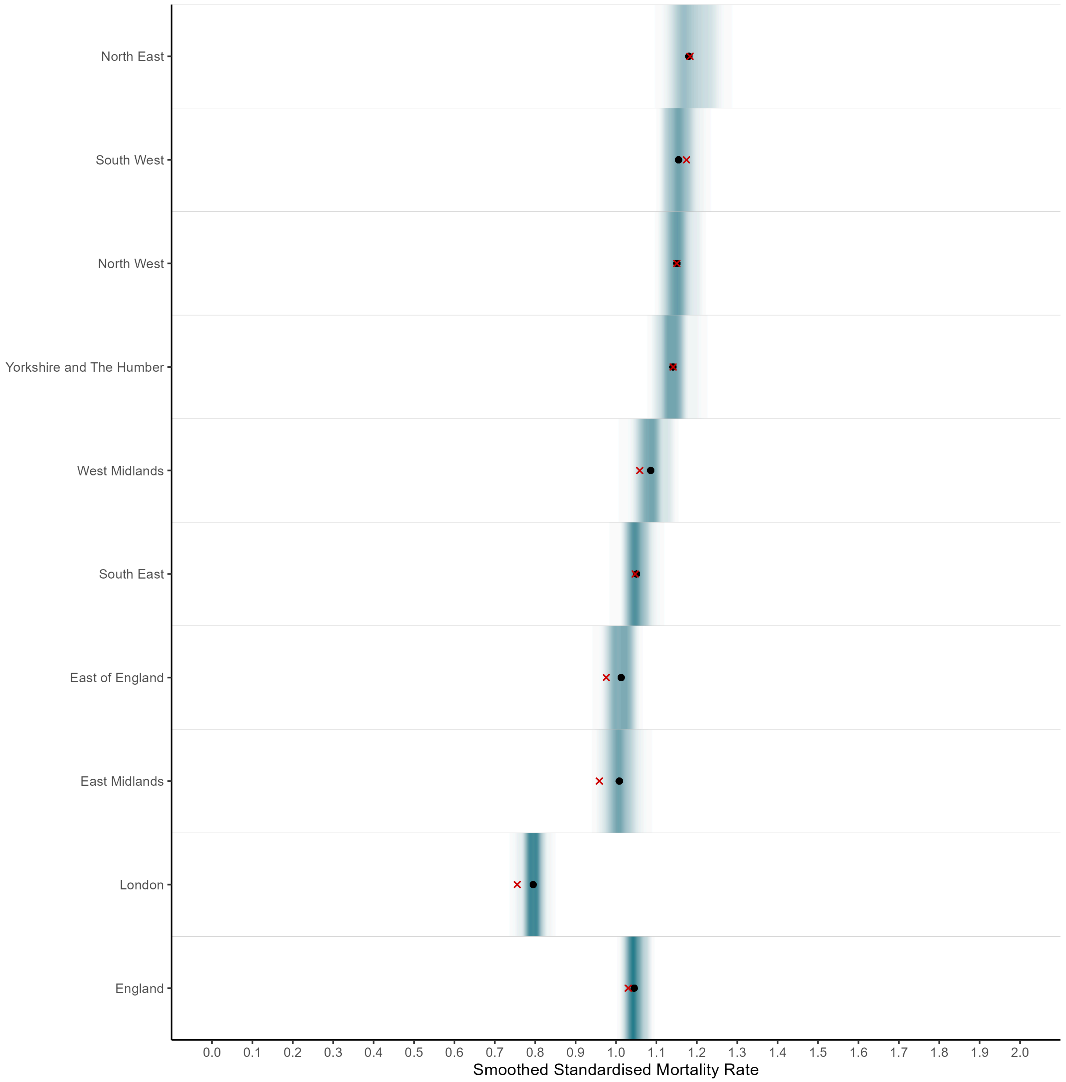
# Results

## MSOA smoothed-SMR and S-SMR exceedance of 1



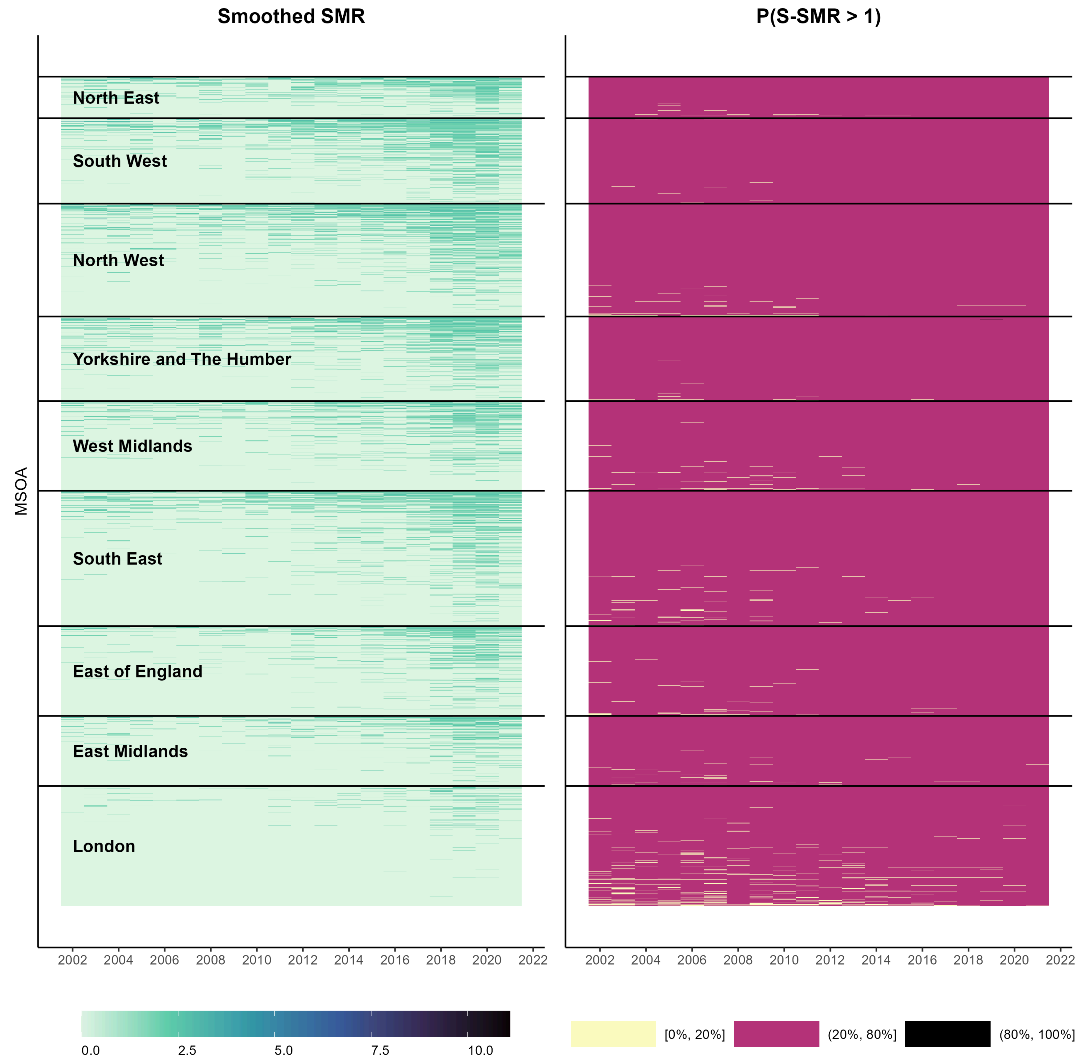

$\phi = 0.68\,(0.60, 0.75)$ indicating strong spatial correlation.

## Regional S-SMR density

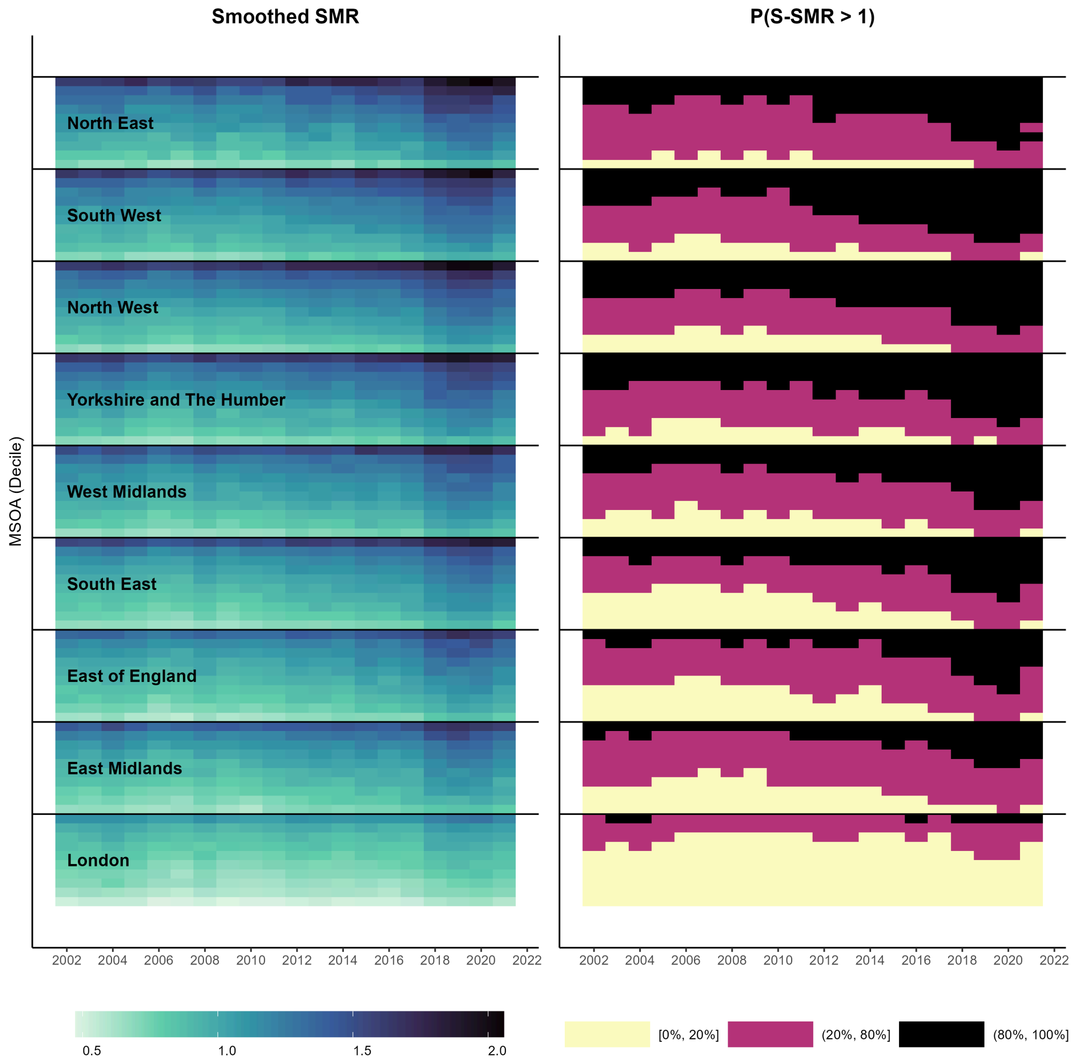


# Spatio-Temporal Trends

## MSOA-year

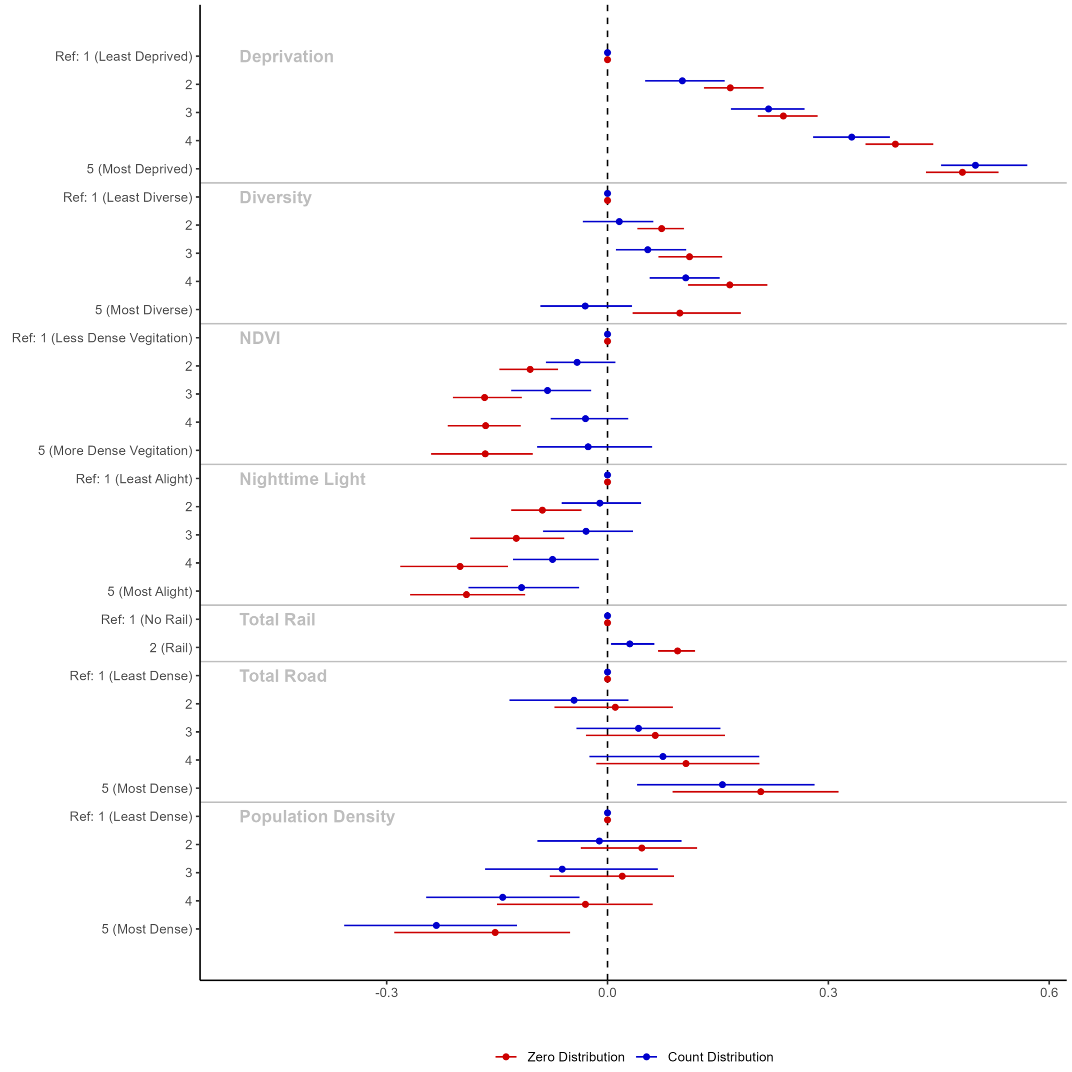



## MSOA Decile-year

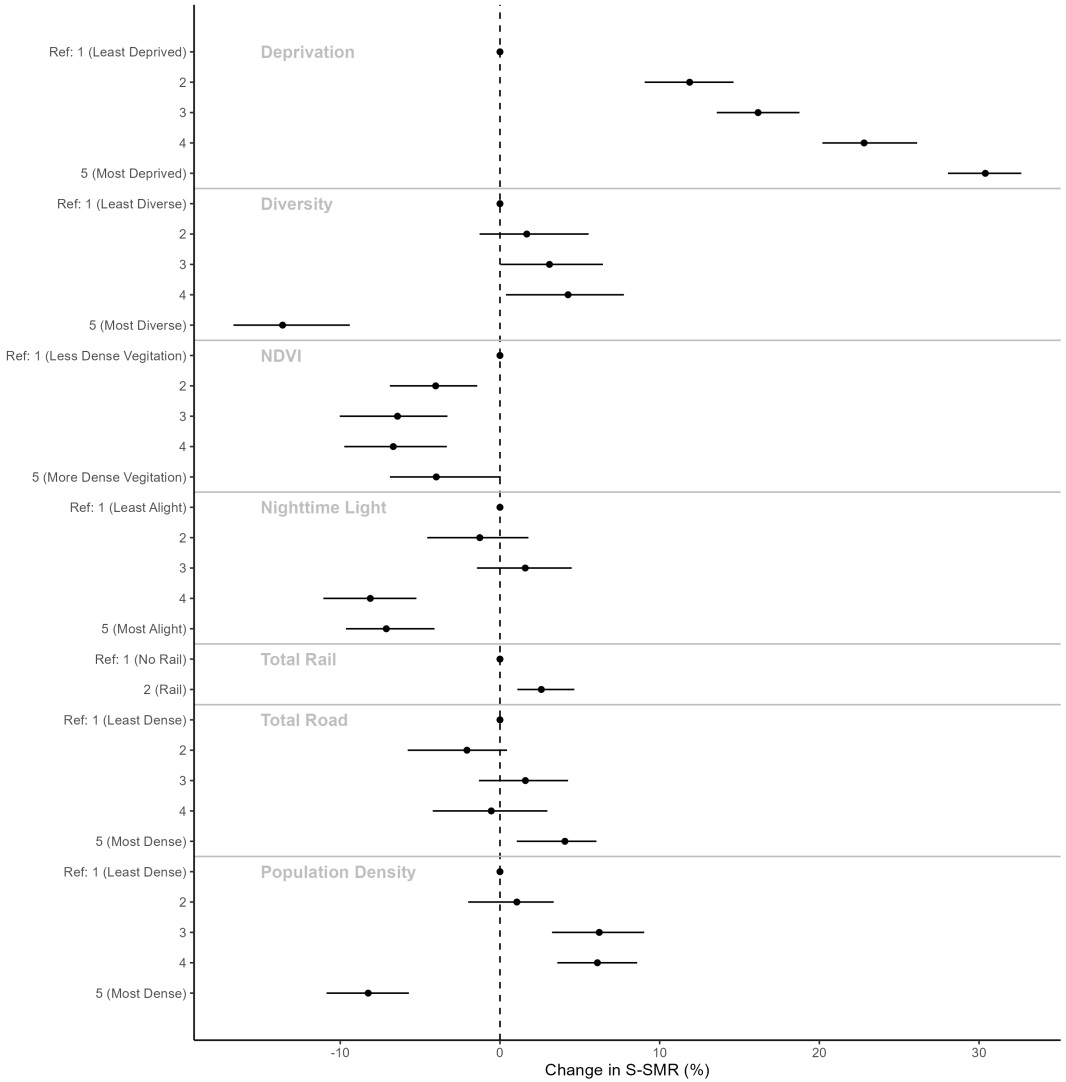


# Environmental Factors

## Model parameters




## Change in smoothed SMR



# Conclusion

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   - Spatial correlation: $\phi = 0.68\,(0.60, 0.75)$ indicates strong spatial correlation in the event of- and number of- suicides.
   - Regional disparities: London has a substantially lower SMR than all other regions and the national average. Northern regions have the highest.
   - Trends in time: Increased in national suicide rates over the study period is reflect in both the regional and MSOA level SMR.

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   - Regional disparities: London has a substantially lower SMR than all other regions and the national average. Northern regions have the highest.
   - Trends in time: Increased in national suicide rates over the study period is reflect in both the regional and MSOA level SMR.
3. Environmental factors
   - Local environmental factors are influential on both a suicide occurring in an area and the number of suicides occurring in the area
   - Areas that are more deprived and rural are most at risk of both suicide occurring and increased number of suicides.

# Strengths and limitations

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- Strengths:
  1. Hurdle model allows flexible modelling of the zeros and non-zeros as they can be defined by different data generating processes.
  2. Posteriors distribution from the Bayesian approach allow for straight forward calculation of summary statistics (i.e., SMR) at range of different aggregated level (i.e, regional, national) with the uncertainty well-defined.
  3. Hierarchical framework allows for the spatial, temporal and spatio-temporal dependencies to be flexibly considered along with numerous other covariates.
  4. High spatio-temporal resolution of the analysis important for future policy makers when assessing high risk areas.

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  4. High spatio-temporal resolution of the analysis important for future policy makers when assessing high risk areas.

- Limitations:
  1. Area level characteristic may not reflect individual characteristics.
  2. Interpretation of scale of effects can be difficult.
  3. Do not consider more complicated relationships i.e., interactions between covariates and time.

# Thanks For Listening, Any Questions?

Email: c.gascoigne@imperial.ac.uk
GitHub: cgascoigne
X: @connorgascoigne

# Prior Distributions

Fixed effects:

- $\beta_0^z, \beta_0^z \sim \mathrm{N}\left(0, 0\right)$.
- $\boldsymbol{\beta}^z, \boldsymbol{\beta}^o \sim \mathrm{N}\left(0, 1000\right)$.
- $\beta_\delta^o, \beta_\gamma^o, \beta_\xi^o \sim \mathrm{N}\left(1, 10\right)$.

Spatial effects:

- Structured (ICAR) and unstructured (exchangeable/IID) spatial effects together.
- $\delta_i = \sigma_\gamma \left(\sqrt{\phi} u_t^* + \sqrt{1-\phi} v_t^*\right)$.
- $\phi \in \{0, 1\}$ describes how much of the spatial variation is structured and unstructured.

Temporal effects:

- Random Walk of Order 1.
- $\gamma_t | \gamma_{t-1} \sim \mathrm{Normal}\left(\gamma_{t-1}, \sigma_\gamma\right)$.

Spatio-temporal effects:

- Type I interaction.
- $\xi_{it} \sim \mathrm{N}\left(0, \sigma_\xi\right)$.