Research article

On the relationship between COVID-19 reported fatalities early in the pandemic and national socio-economic status predating the pandemic

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Supplementary
### Appendix S1: Data sources

#### Supplementary Table of data sources for healthcare, demography, economy and environment

| Variable                                                                 | Source             | Link                                           |
|--------------------------------------------------------------------------|--------------------|------------------------------------------------|
| **Healthcare Infrastructure**                                            |                    |                                                |
| Physicians (/1000 people)                                               | World Bank Open Data | https://data.worldbank.org/                    |
| Nurses and midwives (/1000 people)                                      | World Bank Open Data | https://data.worldbank.org/                    |
| Hospital beds (/1000 people)                                            | World Bank Open Data | https://data.worldbank.org/                    |
| Essential health services (UHC) coverage index                          | World Bank Open Data | https://data.worldbank.org/                    |
| **Health Statistics**                                                    |                    |                                                |
| Birth rate (crude, /1000 people)                                       | World Bank Open Data | https://data.worldbank.org/                    |
| Death rate (crude, /1000 people)                                       | World Bank Open Data | https://data.worldbank.org/                    |
| Life expectancy at birth (years)                                       | World Bank Open Data | https://data.worldbank.org/                    |
| Prevalence of diabetes between ages 20-79 (% population)                | World Bank Open Data | https://data.worldbank.org/                    |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | World Bank Open Data | https://data.worldbank.org/                    |
| Completeness of death registration with cause-of-death information (%) | World Bank Open Data | https://data.worldbank.org/                    |
| **Economic Health**                                                     |                    |                                                |
| GDP (per capita, PPP $)                                                 | World Bank Open Data | https://data.worldbank.org/                    |
| Unemployment rate (most recent available, % labor force)               | International Monetary Fund | https://www.imf.org/en/data                 |
| Employment to population ratio for ages 15+ (modeled ILO estimate)     | World Bank Open Data | https://data.worldbank.org/                    |
| Domestic general government health expenditure (per capita, PPP $)      | World Bank Open Data | https://data.worldbank.org/                    |
| Government lending/borrowing (% GDP)                                    | International Monetary Fund | https://www.imf.org/en/data                 |
| Income distribution (GINI index)                                       | World Bank Open Data | https://data.worldbank.org/                    |
| Trade (% GDP)                                                           | World Bank Open Data | https://data.worldbank.org/                    |
| Number of airline passengers (per year)                                | World Bank Open Data | https://data.worldbank.org/                    |
| Number of tourist arrivals (per year)                                  | World Bank Open Data | https://data.worldbank.org/                    |
| **Demographic Structure**                                               |                    |                                                |
| Population aged 65+ (% population)                                     | World Bank Open Data | https://data.worldbank.org/                    |
| Population aged 0 – 14 (% population)                                  | World Bank Open Data | https://data.worldbank.org/                    |
| Population (total)                                                     | World Bank Open Data | https://data.worldbank.org/                    |
| Rural population (% population)                                         | World Bank Open Data | https://data.worldbank.org/                    |
| International migrant stock (% population)                             | World Bank Open Data | https://data.worldbank.org/                    |
| Population density (people per sq km)                                  | World Bank Open Data | https://data.worldbank.org/                    |
| **Environmental Health**                                               |                    |                                                |
| Ecological footprint (gha/person)                                      | Global Footprint Network | http://data.footprintnetwork.org/#             |
| Air pollution (avg PM 2.5 exposure per year)                           | State of Global Air  | https://www.stateofglobalair.org/ engage      |

AIMS Public Health

Volume 8, Issue 3, 439–455.
### Supplementary Table of data sources for societal and religious characteristics

| Variable | Source | Link |
|----------|--------|------|
| **Societal Characteristics** | | |
| Individuals using internet (% population) | World Bank Open Data | https://data.worldbank.org/ |
| Education level: Human capital index (0 – 1) | World Bank Open Data | https://data.worldbank.org/ |
| Government effectiveness | Worldwide Governance Indicators | http://info.worldbank.org/governance/wgi |
| Rule of law | Worldwide Governance Indicators | http://info.worldbank.org/governance/wgi |
| Control of corruption | Worldwide Governance Indicators | http://info.worldbank.org/governance/wgi |
| Avg number of persons per household | United Nations | https://population.un.org/Household/index.html#/countries/840 |
| Human Freedom (score) | CATO Institute | https://www.cato.org/human-freedom-index-new |
| Personal Freedom (score) | CATO Institute | https://www.cato.org/human-freedom-index-new |
| Economic Freedom (score) | CATO Institute | https://www.cato.org/human-freedom-index-new |
| **Religious Characteristics** | | |
| Buddhist (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Christian (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Folk Religion (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Jewish (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Hindu (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Irreligion (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Muslim (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |
| Other Religion (% population) | Pew Research Center - Global Religious Landscape | https://assets.pewresearch.org/wp-content/uploads/sites/11/2014/01/global-religion-full.pdf |

### Appendix S2: Statistical analysis

In this file, we collect some technical information in support of the statistical analysis and the results described in the main manuscript of the paper.

**Regression methods**

In our analysis, we used linear regression methods with independent and dependent outcomes, together with variables selection techniques such as LASSO, complemented with imputation through MICE. Below some details about these methodologies.
Linear regression with independent observations

Consider a data set of \( n \) observations \( \{x_i, y_i\} \in \mathbb{R}^p \times \mathbb{R} \). A linear regression model assumes that there is a linear relationship between the outcome variable \( y \) and the input variables \( x \), in the form:

\[
y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_p x_{ip} + \varepsilon_i = x_i^T \beta + \varepsilon_i, \quad i = 1, \ldots, n,
\]

where \( T \) denotes the transpose, and \( \beta \in \mathbb{R}^p \) is a vector of coefficients. In matrix form, the relationship takes the form

\[
y = X \beta + \varepsilon,
\]

where

\[
y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \in \mathbb{R}^n, \quad X = \begin{pmatrix} x_1^T \\ x_2^T \\ \vdots \\ x_n^T \end{pmatrix} \in \mathbb{R}^{n \times p},
\]

and

\[
\beta = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_p \end{pmatrix} \in \mathbb{R}^p, \quad \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix} \in \mathbb{R}^n.
\]

The assumptions of the model are the following [22]:

1. **Weak exogeneity**: \( \{x_{i1}, \ldots, x_{ip}\} \) are nonstochastic variables.
2. **Unbiasedness of the error**: \( E[\varepsilon_i] = 0 \) for every \( i = 1, \ldots, n \).
3. **Homoscedasticity**: \( \text{Var}[\varepsilon_i] = \sigma^2 \), with \( \sigma^2 > 0 \) for every \( i = 1, \ldots, n \).
4. **Independence of errors** (and outcome variables): \( \{\varepsilon_i\}_{i=1}^n \) are independent random variables (and so are \( \{y_i\}_{i=1}^n \)).
5. **Normality**: \( \varepsilon_i \sim \mathcal{N}(0, \sigma^2) \) for every \( i = 1, \ldots, n \).

The parameters of the model can be estimated using ordinary least square methods and produce the explicit formula:

\[
\hat{\beta}_{LS} = \left[ X^T X \right]^{-1} X^T y \sim \mathcal{N}(\beta, \sigma^2 [X^T X]^{-1}),
\]

assuming \( X^T X \) is invertible (namely that the input variables are not linear combinations of one another) with \( l_2 \) error of the order of \( n^{1/2} \).

Linear regression with dependent observations

Several of the assumptions of standard linear regression models are too strong, for example the hypothesis of independence between the outcome variables \( y \). It has been shown that if the dependencies are sufficiently weak, then both the coefficient vector \( \beta \) and the strength \( A \) of the dependencies among the response variables can be estimated with an error of the order of \( n^{1/2} \), as the Central Limit Theorem guarantees in the case of iid random variables [16].

Our approach including geography dependency is simplified with respect to the framework of [16],
as we assume that \( A \), the matrix of geography relationship is known and not to be estimated from the variables \( X, y \). The parameters of the model can be then estimated using again ordinary least square methods and produce a similar explicit formula for the coefficients:

\[
\hat{\beta}_{LS} = [X^T X]^{-1} X^T A y \sim N(\beta, \sigma^2 [X^T X]^{-1}),
\]

as

\[
E[\hat{\beta}_{LS}] = E[(X^T X)^{-1} X^T A y] = [X^T X]^{-1} X^T E[A y] = \beta,
\]

and

\[
\text{Var}[\hat{\beta}_{LS}] = [X^T X]^{-1} X^T \text{Var}[A y] [X^T X]^{-1} = [X^T X]^{-1} \sigma^2 [X^T X]^{-1},
\]

since \( A \) is constant with respect to averages and variances taken with respect to the distributions of \( X \) and \( y \) by our assumptions.

**LASSO**

Suppose again to have a sample of \( n \) observations, \( \{y_i, x_i\}_{i=1}^n \). Then, the *Least Absolute Shrinkage and Selection Operator* (LASSO) optimizes the following functional [21,22]:

\[
J_\lambda(\beta) = \frac{1}{n} \|y - X\beta\|_2^2 + \lambda \|\beta\|,
\]

with \( \lambda \) is a pre-specified regularization parameter. The LASSO estimator can be written in explicit form as

\[
\hat{\beta}_{LASSO,j} = \begin{cases} 
    y_j - \lambda/2 & \text{if } y_j > \lambda/2 \\
    y_j + \lambda/2 & \text{if } y_j < -\lambda/2 \\
    0 & \text{otherwise}
\end{cases}
\]

(0.1)

**MICE**

For completeness we report here the main details of an algorithm for imputation called *Multiple Imputation by Chained Equations* (MICE), as discussed in [17,18]. Let \( X_j \) for \( j = 1, \ldots, p \) be one of the variables, with \( X_j^{\text{obs}} \) for \( j = 1, \ldots, p \) the observed data and \( X_j^{\text{mis}} \) for \( j = 1, \ldots, p \) the missing data. Suppose \( X \) has been partially observed from the multivariate conditional distribution \( P(X|\theta) \) with \( \theta \) unknown and with its distribution to be determined. MICE samples iteratively through the distributions

\[
P(X_j|X_{-j}, \theta_j), \quad j = 1, \ldots, p,
\]

where \( X_{-j} \) is the vector of input variables with \( X_j \) dropped. Starting from a simple draw from the marginals, the \( t \)-th iteration of the chained equations is a Gibbs sampler that draws

\[
\theta_j^{(t)} \sim P(\theta_j|X_j^{\text{obs}}, X_{-j}^{(t-1)}), \quad X_j^{(t)} \sim P(X_j|X_j^{\text{obs}}, X_{-j}^{(t-1)}, \theta_j^{(t)}),
\]

iteratively for \( j = 1, \ldots, p \). Here \( X_j^{(t)} = (X_j^{\text{obs}}, X_j^{(t)}) \) is the \( j \)-th imputed variable at iteration \( t \). For more details, we refer to [17,18].
Appendix S3: Descriptive statistics

In this appendix, we collect the descriptive statistics of the socio-economic variables and of the epidemiological variables. The values in all the tables have been computed using the raw data (no imputation), which is the reason for the different number of countries per variable.

| Variable                                                                 | Mean     | St. Dev. | Median | IQR   | Countries |
|--------------------------------------------------------------------------|----------|----------|--------|-------|-----------|
| Healthcare Infrastructure                                                |          |          |        |       |           |
| Physicians (/1000 people)                                                | 1.790656 | 1.584682 | 1.44805| 2.530125| 176       |
| Nurses and midwives (/1000 people)                                      | 4.21046  | 4.07985  | 2.6651 | 5.362225| 176       |
| Hospital beds (/1000 people)                                            | 3.053416 | 2.495021 | 2.4    | 2.9   | 161       |
| Essential health services (UHC) coverage index                         | 64.5954  | 15.6621  | 69     | 24    | 176       |
| Health Statistics                                                       |          |          |        |       |           |
| Birth rate (crude, /1000 people)                                       | 19.46667 | 9.94767  | 17.0605| 16.2905| 194       |
| Death rate (crude, /1000 people)                                       | 7.616619 | 2.628278 | 7.2095 | 3.39575| 194       |
| Life expectancy at birth (years)                                       | 72.86528 | 7.52362  | 74.3865| 10.91167 | 190       |
| Prevalence of diabetes between ages 20-79 (% population)                | 7.985505 | 4.198228 | 6.8    | 4.875 | 194       |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 12.63103 | 21.13193 | 1.1    | 18.325 | 174       |
| Completeness of death registration with cause-of-death information (%) | 88.14912 | 18.92893 | 96.5   | 13    | 114       |
| Economic Health                                                         |          |          |        |       |           |
| GDP (per capita, PPP $)                                                 | 22,452.38 | 22,512.14 | 15,012.93 | 26,552.91 | 193       |
| Unemployment rate (most recent available, % labor force)               | 7,408,505 | 5,075,014 | 6      | 5.384 | 107       |
| Employment to population ratio for ages 15+ (modeled ILO estimate)     | 57,968,79 | 11,5679  | 58,431 | 14,835 | 177       |
| Domestic general government health expenditure (per capita, PPP $)      | 982,6385 | 12,933,74 | 413,1464 | 1313,689 | 177       |
| Government lending/borrowing (% GDP)                                    | -2,365,106 | 4,166,177 | -1,954 | 4,7405 | 179       |
| Income distribution (GINI index)                                       | 37,9162  | 7.913718 | 36.4   | 10.125 | 142       |
| Trade (% GDP)                                                           | 91.39902 | 52.72362 | 80,18308 | 51,38322 | 182       |
| Number of airline passengers (per year)                                | 2713,6522 | 91,561319 | 2118,437 | 1311,698 | 154       |
| Number of tourist arrivals (per year)                                  | 737,2630 | 143,08081 | 1783,000 | 6820,750 | 186       |
| Demographic Structure                                                  |          |          |        |       |           |
| Population aged 65+ (% population)                                      | 8.985213 | 6.364412 | 6.954369 | 11.26835 | 182       |
| Population aged 0 – 14 (% population)                                  | 27,3903  | 10.47776 | 25.78908 | 19.20108 | 182       |
| Population (total)                                                     | 3,781,7312 | 142,371892 | 7650154 | 25819202 | 199       |
| Rural population (% population)                                         | 40.19286 | 22.5739 | 39.681 | 36.6165 | 191       |
| International migrant stock (% population)                             | 11.60912 | 16.49786 | 4.367402 | 11.97634 | 288       |
| Population density (people per sq km)                                  | 331,1683 | 1503,202 | 90,29942 | 181,5072 | 187       |
| Environmental Health                                                   |          |          |        |       |           |
| Ecological footprint (gha/person)                                      | 3.195826 | 2.515384 | 2.447478 | 2.873057 | 174       |
| Air pollution (avg PM 2.5 exposure per year)                            | 27.39739 | 19.16504 | 22.2   | 23.2  | 181       |
### Descriptive Statistics Table of Societal and Religious Characteristics

| Variable                                      | Mean   | St. Dev. | Median | IQR    | Countries |
|-----------------------------------------------|--------|----------|--------|--------|-----------|
| Societal Characteristics                      |        |          |        |        |           |
| Individuals using internet (% population)     | 57.82404 | 28.63345 | 64.39999 | 47.552 | 195       |
| Education level: Human capital index (0 − 1)  | 0.5680134 | 0.1517855 | 0.576 | 0.27 | 149       |
| Government effectiveness                     | -0.01962567 | 0.9971855 | -0.1 | 1.245 | 187       |
| Rule of law                                   | -0.04566845 | 1.002443 | -0.234 | 1.36 | 187       |
| Control of corruption                         | -0.04117847 | 0.9971855 | -0.1 | 1.245 | 187       |
| Avg number of persons per household           | 3.944129 | 1.388127 | 3.74 | 2 | 147       |
| Human Freedom (score)                         | 6.86553 | 1.096916 | 6.82 | 1.515 | 159       |
| Personal Freedom (score)                      | 6.956161 | 1.452738 | 6.933774 | 2.069753 | 159       |
| Economic Freedom (score)                      | 6.781069 | 0.9232247 | 6.86 | 1.275 | 159       |
| Religious Characteristics                     |        |          |        |        |           |
| Buddhist (% population)                       | 3.80102 | 14.98954 | 0 | 0.225 | 196       |
| Christian (% population)                      | 58.33531 | 36.89136 | 75.6 | 75.825 | 196       |
| Folk Religion (% population)                  | 2.03214 | 6.1582 | 0.4 | 1.625 | 196       |
| Jewish (% population)                         | 0.4739031 | 5.409602 | 0 | 0.00023 | 196       |
| Hindu (% population)                          | -2.304308 | 9.809877 | 0 | 0 | 196       |
| Irreligion (% population)                     | 8.146888 | 12.27533 | 3.2 | 9.725 | 196       |
| Muslim (% population)                         | 24.5157 | 36.41314 | 3.7 | 37.75 | 196       |
| Other Religion (% population)                 | 0.3854082 | 0.8901687 | 0.1 | 0.4 | 196       |

### Descriptive Statistics Table of COVID-19 reported cases and deaths, and tests at 2nd May 2020

| Variable                                      | Mean   | St. Dev. | Median | IQR    | Countries |
|-----------------------------------------------|--------|----------|--------|--------|-----------|
| COVID-19 cases (#)                            | 16612.5 | 84030.05 | 690 | 5389 | 199       |
| COVID-19 deaths (#)                           | 1197.889 | 5944.167 | 16 | 117 | 199       |
| COVID-19 deaths/cases                         | 0.04247054 | 0.04660795 | 0.00000003 | 0.005090316 | 199 |
| COVID-19 tests (#)                            | 337429.3 | 798274.3 | 122240 | 121035.5 | 24       |
| COVID-19 tests/cases                          | 18.20855 | 25.0457 | 25.363636 | 19.06388 | 24       |
| COVID-19 tests/deaths                         | 2326.874 | 3701.545 | 1005.335 | 2187.746 | 24       |

### Appendix S4: Tables of the importance indices

This appendix contains the detailed tables of the importance indices Absolute Importance Index (AII) and Absolute Importance Index (SII) calculated across all our 32 × 2 models (geographically weighted + not geographically weighted). Tables with the title "Weighted" refer to the fact that the reported values in those tables are a percentage of the total number of models for that category. For example, there are twice as many models with $\tilde{Y}_1$ as models with $Y_1$, so transforming the integer scores in percentages corrects for that problem.

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| Variable | Percentage of Models With Variable | \( Y_1 \) (4) | \( Y_1 \) (8) | \( Y_2 \) (4) | \( Y_2 \) (8) | \( Y_3 \) (8) | Total (32) |
|----------|----------------------------------|----------------|----------------|----------------|----------------|----------------|---------------|
| Healthcare Infrastructure | | | | | | | |
| Physicians (/1000 people) | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Nurses and midwives (/1000 people) | 0 | 100 | 0 | 50 | 0 | 37.5 | 37.5 |
| Hospital beds (/1000 people) | 25 | 50 | 75 | 50 | 50 | 50 | 50 |
| Essential health services (UHC) coverage index | 50 | 0 | 50 | 0 | 50 | 25 | 25 |
| Health Statistics | | | | | | | |
| Birth rate (crude, /1000 people) | 25 | 25 | 0 | 50 | 0 | 21.88 |
| Death rate (crude, /1000 people) | 50 | 0 | 25 | 0 | 25 | 15.63 |
| Life expectancy at birth (years) | 0 | 0 | 25 | 0 | 0 | 3.13 |
| Prevalence of diabetes between ages 20-79 (% population) | 0 | 50 | 50 | 75 | 25 | 43.75 |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 0 | 0 | 0 | 0 | 0 | 0 |
| Completeness of death registration with cause-of-death information (%) | 0 | 0 | 0 | 25 | 0 | 6.25 |
| Economic Health | | | | | | | |
| GDP (per capita, PPP, $) | 0 | 50 | 0 | 0 | 0 | 12.5 |
| Unemployment rate (most recent available, % labor force) | 0 | 0 | 0 | 0 | 0 | 0 |
| Employment to population ratio for ages 15+ (modeled ILO estimate) | 50 | 37.5 | 50 | 37.5 | 50 | 43.75 |
| Domestic general government health expenditure (per capita, PPP, $) | 25 | 25 | 75 | 25 | 50 | 37.5 |
| Government lending/borrowing (% GDP) | 0 | 0 | 25 | 0 | 25 | 21.88 |
| Income distribution (GINI index) | 50 | 25 | 50 | 50 | 50 | 43.75 |
| Trade (% GDP) | 25 | 25 | 25 | 25 | 0 | 18.75 |
| Number of airline passengers (per year) | 100 | 0 | 75 | 0 | 0 | 21.88 |
| Number of tourist arrivals (per year) | 50 | 75 | 50 | 100 | 50 | 68.75 |
| Demographic Structure | | | | | | | |
| Population aged 65+ (% population) | 25 | 25 | 25 | 50 | 0 | 25 |
| Population aged 0 – 14 (% population) | 0* | 0 | 0 | 0 | 0 | 0* |
| Population (total) | 50 | 0 | 50 | 0 | 0 | 12.5 |
| Rural population (% population) | 25 | 50 | 25 | 30 | 25 | 37.5 |
| International migrant stock (% population) | 0 | 50 | 0 | 75 | 0 | 31.25 |
| Population density (people per sq km) | 0 | 50 | 25 | 50 | 0 | 28.13 |
| Environmental Health | | | | | | | |
| Ecological footprint (gha/person) | 25 | 0 | 25 | 0 | 25 | 12.5 |
| Air pollution (avg PM. 2.5 exposure per year) | 0 | 0 | 0 | 0 | 0 | 0 |

*Population aged 0-14 was the first variable identified in LASSO for the geographically weighted \( Y_1 \), but it dropped out with the addition of the second variable and never returned. Further, it was not identified as important in any other models. Therefore we think it is unlikely that it is a significant variable.
| Variable | Percentage of Models With Variable |
|----------|-----------------------------------|
|          | Y₁ (4) | Y₁ (8) | Y₂ (4) | Y₂ (8) | Total (52) |
| **Societal Characteristics** | | | | | |
| Individuals using internet (% population) | 0 25 25 25 25 | 28.13 |
| Education level. Human capital index (0 – 1) | 0 0 0 0 0 | 0 |
| Government effectiveness | 0 0 0 0 75 | 18.75 |
| Control of corruption | 0 0 0 0 0 | 0 |
| Avg number of persons per household | 0 25 25 0 0 | 6.25 |
| Human Freedom (score) | 0 25 25 0 50 | 25 |
| Personal Freedom (score) | 25 0 0 0 50 | 15.63 |
| Economic Freedom (score) | 0 0 0 0 75 | 18.75 |
| **Religious Characteristics** | | | | | |
| Buddhist (% population) | 50 0 50 0 50 | 25 |
| Christian (% population) | 25 50 50 25 | 40.63 |
| Folk Religion (% population) | 25 25 25 0 0 | 12.5 |
| Jewish (% population) | 0 0 0 0 0 | 0 |
| Hindu (% population) | 50 0 25 0 0 | 9.38 |
| Irreligion (% population) | 25 25 0 25 25 | 15.63 |
| Muslim (% population) | 0 25 0 25 25 | 18.75 |
| Other Religion (% population) | 0 0 25 0 25 | 9.38 |
| Variable                                      | \(F_1\) (4) | \(F_1\) (8) | \(F_2\) (4) | \(F_2\) (8) | \(F_3\) (8) | Total (32) |
|----------------------------------------------|-------------|-------------|-------------|-------------|-------------|------------|
| **Healthcare Infrastructure**                |             |             |             |             |             |            |
| Physicians (/1000 people)                    | 25          | 25          | 25          | -25         | 12.5        |            |
| Nurses and midwives (/1000 people)           | 0           | -100        | 0           | -50         | 0           | 43.75      |
| Hospital beds (/1000 people)                 | -25         | -50         | -75         | -50         | -50         | -37.5      |
| Essential health services (UHC) coverage index | 50          | 0           | 50          | 0           | 50          | 25         |
| **Health Statistics**                        |             |             |             |             |             |            |
| Birth rate (crude, /1000 people)             | -25         | -25         | 0           | -50         | 0           | 21.88      |
| Death rate (crude, /1000 people)             | 50          | 0           | 25          | 0           | 25          | 15.63      |
| Life expectancy at birth (years)              | 0           | 0           | 25          | 0           | 0           | 3.13       |
| Prevalence of diabetes between ages 20-79 (% population) | 0           | -50         | -50         | -75         | -25         | -43.75     |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 0           | 0           | 0           | 0           | 0           | 0          |
| Completeness of death registration with cause-of-death information (%) | 0           | 0           | 0           | 25          | 0           | 6.25       |
| **Economic Health**                          |             |             |             |             |             |            |
| GDP (per capita, PPP, $)                     | 0           | 50          | 0           | 0           | 0           | 12.5       |
| Unemployment rate (most recent available, % labor force) | 0           | 0           | 0           | 0           | 0           | 0          |
| Employment to population ratio for ages 15+ (modeled ILO estimate) | -50         | -37.5       | -50         | -37.5       | -50         | -43.75     |
| Domestic general government health expenditure (per capita, PPP, $) | 25          | 25          | 75          | 25          | 50          | 37.5       |
| Government lending/borrowing (% GDP)         | 0           | 0           | 25          | 0           | 25          | 9.38       |
| Income distribution (GINI index)              | -50         | -25         | -50         | -50         | -50         | -43.75     |
| Trade (% GDP)                                | -25         | 25          | -25         | 25          | 0           | 6.25       |
| Number of airline passengers (per year)      | 100         | 0           | 75          | 0           | 0           | 21.88      |
| Number of tourst arrivals (per year)         | 50          | -25         | 50          | 0           | 50          | 18.75      |
| **Demographic Structure**                    |             |             |             |             |             |            |
| Population aged 65+ (% population)            | 25          | 25          | 25          | 50          | 0           | 25         |
| Population aged 0 – 14 (% population)         | 0*          | 0           | 0           | 0           | 0           | 0*         |
| Population (total)                            | -50         | 0           | -50         | 0           | 0           | -12.5      |
| Rural population (% population)               | -25         | 30          | -25         | 30          | -25         | 12.5       |
| International migrant stock (% population)    | 0           | 50          | 0           | 75          | 0           | 31.25      |
| Population density (people per sq km)         | 0           | 50          | 25          | 50          | 0           | 28.13      |
| **Environmental Health**                     |             |             |             |             |             |            |
| Ecological footprint (gha/person)             | 25          | 0           | 25          | 0           | 25          | 12.5       |
| Air pollution (avg PM 2.5 exposure per year)  | 0           | 0           | 0           | 0           | 0           | 0          |

*Population aged 0-14 was the first variable identified in LASSO for the geographically weighted \(F_1\), but it dropped out with the addition of the second variable and never returned. Further, it was not identified as important in any other models. Therefore we think it is unlikely that it is a significant variable.
### Weighted Signed Index of Importance of Socio-Economic Variables, Divided by Category

| Variable                                      | $Y_1$ (4) | $Y_2$ (8) | $Y_3$ (4) | $Y_4$ (8) | Total (32) |
|------------------------------------------------|-----------|-----------|-----------|-----------|------------|
| **Societal Characteristics**                  |           |           |           |           |            |
| Individuals using internet (% population)     | 0         | -50       | 25        | -25       | -25        | -21.88     |
| Education level. Human capital index (0 – 1)  | 0         | 0         | 0         | 0         | 0          | 0          |
| Government effectiveness                      | 0         | 0         | 0         | 0         | -75        | -18.75     |
| Rule of law                                   | 0         | 0         | 0         | 0         | 0          | 0          |
| Control of corruption                         | 0         | 0         | 0         | 0         | 0          | 0          |
| Avg number of persons per household           | 0         | 25        | 0         | 0         | 0          | 6.25       |
| Human Freedom (score)                         | 0         | -25       | 0         | -25       | 50         | 0          |
| Personal Freedom (score)                      | 25        | 0         | 0         | 0         | -50        | -9.38      |
| Economic Freedom (score)                      | 0         | 0         | 0         | 0         | -75        | -18.75     |
| **Religious Characteristics**                 |           |           |           |           |            |
| Buddhist (% population)                       | -50       | 0         | -50       | 0         | -50        | -25        |
| Christian (% population)                      | 25        | 50        | 50        | 25        | 0          | 40.63      |
| Folk Religion (% population)                   | -25       | 25        | -25       | 0         | 0          | 0          |
| Jewish (% population)                         | 0         | 0         | 0         | 0         | 0          | 0          |
| Hindu (% population)                          | 0         | 0         | -25       | 0         | 0          | -3.13      |
| Irreligion (% population)                     | -25       | -25       | 0         | 0         | 25         | -3.13      |
| Muslim (% population)                         | 0         | -25       | 0         | -25       | 25         | -6.25      |
| Other Religion (% population)                  | 0         | 0         | -25       | 0         | -25        | -9.38      |
## Index of Importance of Socio-Economic Variables, Divided by Category

| Variable                                                                 | Number of Models With Variable | $F_1$ (4) | $F_2$ (4) | $F_3$ (8) | $F_4$ (8) | $F_5$ (8) | Total (32) |
|-------------------------------------------------------------------------|-------------------------------|-----------|-----------|-----------|-----------|-----------|------------|
| **Healthcare Infrastructure**                                           |                               |           |           |           |           |           |            |
| Physicians (/1000 people)                                               | 1                             | 2         | 2         | 1         | 2         | 2         | 8          |
| Nurses and midwives (/1000 people)                                      | 0                             | 0         | 0         | 0         | 4         | 0         | 12         |
| Hospital beds (/1000 people)                                            | 1                             | 4         | 3         | 4         | 4         | 16        |             |
| Essential health services (UHC) coverage index                          | 2                             | 0         | 2         | 0         | 4         | 8         |             |
| **Health Statistics**                                                   |                               |           |           |           |           |           |            |
| Birth rate (crude, /1000 people)                                       | 1                             | 2         | 0         | 4         | 0         | 7         |            |
| Death rate (crude, /1000 people)                                       | 2                             | 0         | 1         | 0         | 2         | 3         |            |
| Life expectancy at birth (years)                                       | 0                             | 0         | 1         | 0         | 0         | 1         |            |
| Prevalence of diabetes between ages 20-79 (% population)                | 0                             | 4         | 2         | 6         | 2         | 14        |            |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 0                             | 0         | 0         | 0         | 0         | 0         |            |
| Completeness of death registration with cause-of-death informa-         | 0                             | 0         | 0         | 2         | 0         | 2         |            |
| tion (%)                                                                |                               |           |           |           |           |           |            |
| **Economic Health**                                                     |                               |           |           |           |           |           |            |
| GDP (per capita, PPP, $)                                               | 0                             | 0         | 0         | 0         | 0         | 0         | 4          |
| Unemployment rate (most recent available, % labor force)               | 0                             | 0         | 0         | 0         | 0         | 0         | 0          |
| Employment to population ratio for ages 15+ (modeled ILO estimate)    | 2                             | 3         | 2         | 3         | 4         | 14        |            |
| Domestic general government health expenditure (per capita, PPP, $)     | 1                             | 2         | 3         | 2         | 4         | 12        |            |
| Government lending/borrowing (% GDP)                                   | 0                             | 0         | 1         | 2         | 4         | 7         |            |
| Income distribution (GINI index)                                       | 2                             | 2         | 2         | 4         | 4         | 14        |            |
| Trade (% GDP)                                                          | 1                             | 2         | 1         | 2         | 0         | 6         |            |
| Number of airline passengers (per year)                                | 2                             | 6         | 2         | 8         | 4         | 22        |            |
| Number of tourist arrivals (per year)                                  | 4                             | 0         | 3         | 0         | 0         | 7         |            |
| **Demographic Structure**                                              |                               |           |           |           |           |           |            |
| Population aged 65+ (% population)                                     | 1                             | 2         | 1         | 4         | 0         | 8         |            |
| Population aged 0 – 14 (% population)                                  | 0                             | 0         | 0         | 0         | 0         | 0         | 0*         |
| Population (total)                                                     | 2                             | 0         | 2         | 0         | 0         | 4         |            |
| Rural population (% population)                                        | 1                             | 4         | 1         | 4         | 2         | 12        |            |
| International migrant stock (% population)                             | 0                             | 4         | 0         | 6         | 0         | 10        |            |
| Population density (people per sq km)                                  | 0                             | 4         | 1         | 4         | 0         | 9         |            |
| **Environmental Health**                                               |                               |           |           |           |           |           |            |
| Ecological footprint (gha/person)                                      | 1                             | 0         | 1         | 0         | 2         | 4         |            |
| Air pollution (avg PM 2.5 exposure per year)                            | 0                             | 0         | 0         | 0         | 4         | 4         |            |

*Population aged 0-14 was the first variable identified in LASSO for the geographically weighted $F_1$, but it dropped out with the addition of the second variable and never returned. Further, it was not identified as important in any other models. Therefore we think it is unlikely that it is a significant variable.
## Index of Importance of Socio-Economic Variables, Divided by Category

| Variable                                | Y_1 (4) | Y_1 (8) | Y_2 (4) | Y_2 (8) | Y_3 (8) | Total (52) |
|-----------------------------------------|---------|---------|---------|---------|---------|------------|
| **Societal Characteristics**            |         |         |         |         |         |            |
| Individuals using internet (% population) | 0       | 4       | 1       | 2       | 2       | 9          |
| Education level. Human capital index (0 – 1) | 0       | 0       | 0       | 0       | 0       | 0          |
| Government effectiveness    | 0       | 0       | 0       | 0       | 6       | 6          |
| Rule of law                            | 0       | 0       | 0       | 0       | 0       | 0          |
| Control of corruption                   | 0       | 0       | 0       | 0       | 0       | 0          |
| Avg number of persons per household     | 0       | 2       | 0       | 0       | 0       | 2          |
| Human Freedom (score)                   | 0       | 2       | 0       | 2       | 4       | 8          |
| Personal Freedom (score)               | 1       | 0       | 0       | 0       | 4       | 5          |
| Economic Freedom (score)                | 0       | 0       | 0       | 0       | 6       | 6          |
| **Religious Characteristics**           |         |         |         |         |         |            |
| Buddhist (% population)                 | 2       | 0       | 2       | 0       | 4       | 8          |
| Christian (% population)                | 1       | 4       | 2       | 4       | 2       | 13         |
| Folk Religion (% population)            | 1       | 2       | 1       | 0       | 0       | 4          |
| Jewish (% population)                   | 0       | 0       | 0       | 0       | 0       | 0          |
| Hindu (% population)                    | 2       | 0       | 1       | 0       | 0       | 3          |
| Irreligion (% population)               | 1       | 2       | 0       | 0       | 2       | 5          |
| Muslim (% population)                   | 0       | 2       | 0       | 2       | 2       | 6          |
| Other Religion (% population)           | 0       | 0       | 1       | 0       | 2       | 3          |
| Variable | $\tilde{Y}_1$ (4) | $Y_1$ (8) | $\tilde{Y}_2$ (4) | $Y_2$ (8) | $Y_0$ (8) | Total (32) |
|----------|------------------|-----------|------------------|-----------|-----------|------------|
| **Healthcare Infrastructure** | | | | | | |
| Physicians (/1000 people) | 1 | 2 | 1 | 2 | -2 | 8 |
| Nurses and midwives (/1000 people) | 0 | -8 | 0 | -4 | 0 | -12 |
| Hospital beds (/1000 people) | -1 | -4 | -3 | -4 | -4 | -16 |
| Essential health services (UHC) coverage index | 2 | 0 | 2 | 0 | 4 | 8 |
| **Health Statistics** | | | | | | |
| Birth rate (crude, /1000 people) | -1 | -2 | 0 | -4 | 0 | 7 |
| Death rate (crude, /1000 people) | 2 | 0 | 1 | 0 | 2 | 5 |
| Life expectancy at birth (years) | 0 | 0 | 1 | 0 | 0 | 1 |
| Prevalence of diabetes between ages 20-79 (% population) | 0 | -4 | -2 | -6 | -2 | -14 |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 0 | 0 | 0 | 0 | 0 | 0 |
| Completeness of death registration with cause-of-death information (%) | 0 | 0 | 0 | 2 | 0 | 2 |
| **Economic Health** | | | | | | |
| GDP (per capita, PPP, $) | 0 | 4 | 0 | 0 | 0 | 4 |
| Unemployment rate (most recent available, % labor force) | 0 | 0 | 0 | 0 | 0 | 0 |
| Employment to population ratio for ages 15+ (modeled ILO estimate) | -2 | -3 | -2 | -3 | -4 | -14 |
| Domestic general government health expenditure (per capita, PPP, $) | 1 | 2 | 3 | 2 | 4 | 12 |
| Government lending/borrowing (% GDP) | 0 | 0 | 1 | -2 | 4 | 3 |
| Income distribution (GINI index) | -2 | -2 | -2 | -4 | -4 | -14 |
| Trade (% GDP) | -1 | 2 | -1 | 2 | 0 | 2 |
| Number of airline passengers (per year) | 4 | 0 | 3 | 0 | 0 | 7 |
| Number of tourist arrivals (per year) | 2 | -2 | 2 | 0 | 4 | 6 |
| **Demographic Structure** | | | | | | |
| Population aged 65+ (% population) | 1 | 2 | 1 | 4 | 0 | 8 |
| Population aged 0 – 14 (% population) | 0* | 0 | 0 | 0 | 0 | 0* |
| Population (total) | -2 | 0 | -2 | 0 | 0 | -4 |
| Rural population (% population) | -1 | 4 | -1 | 4 | -2 | 4 |
| International migrant stock (% population) | 0 | 4 | 0 | 0 | 0 | 10 |
| Population density (people per sq km) | 0 | 4 | 1 | 4 | 0 | 9 |
| **Environmental Health** | | | | | | |
| Ecological footprint (gha/person) | 1 | 0 | 1 | 0 | 2 | 4 |
| Air pollution (avg PM 2.5 exposure per year) | 0 | 0 | 0 | 0 | 0 | 0 |

*Population aged 0-14 was the first variable identified in LASSO for the geographically weighted $\tilde{Y}_1$, but it dropped out with the addition of the second variable and never returned. Further, it was not identified as important in any other models. Therefore we think it is unlikely that it is a significant variable.
| Variable                                         | Percentage of Models With Variable |
|-------------------------------------------------|-----------------------------------|
|                                                 | $Y_1 (4)$ | $Y_1 (8)$ | $Y_2 (4)$ | $Y_2 (8)$ | $Y_0 (8)$ | Total (22) |
| **Societal Characteristics**                    |           |           |           |           |           |            |
| Individuals using internet (% population)       | 0         | 4         | 1         | -2        | -2        | -7         |
| Education level: Human capital index (0 – 1)    | 0         | 0         | 0         | 0         | 0         | 0          |
| Government effectiveness                        | 0         | 0         | 0         | -6        | -6        | -12        |
| Rule of law                                     | 0         | 0         | 0         | 0         | 0         | 0          |
| Control of corruption                           | 0         | 0         | 0         | 0         | 0         | 0          |
| Average number of persons per household         | 0         | 2         | 0         | 0         | 0         | 2          |
| Human Freedom (score)                           | 0         | -2        | 0         | -2        | 4         | 0          |
| Personal Freedom (score)                        | 1         | 0         | 0         | 0         | -4        | -3         |
| Economic Freedom (score)                        | 0         | 0         | 0         | 0         | -6        | -6         |
| **Religious Characteristics**                   |           |           |           |           |           |            |
| Buddhist (% population)                          | -2        | 0         | -2        | 0         | -4        | -8         |
| Christian (% population)                        | 1         | 4         | 2         | 4         | 2         | 13         |
| Folk Religion (% population)                    | -1        | 2         | -1        | 0         | 0         | 0          |
| Jewish (% population)                            | 0         | 0         | 0         | 0         | 0         | 0          |
| Hindu (% population)                             | 0         | 0         | -1        | 0         | 0         | -1         |
| Irreligion (% population)                       | -1        | 2         | 0         | 0         | 2         | 3          |
| Muslim (% population)                            | 0         | -2        | 0         | 0         | -2        | -2         |
| Other Religion (% population)                    | 0         | 0         | -1        | 0         | -2        | -3         |

Signed Index of Importance of Socio-Economic Variables, Divided by Category

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### Table of Pooled Index of Importance of Socio-Economic Variables, Divided by Category

| Variable                                                                 | Number of Models With Variable |
|-------------------------------------------------------------------------|-------------------------------|
|                                                                         | $Y_1$ & $Y_2$ (12) | $Y_3$ & $Y_4$ (12) | $Y_5$ (8) | Total (32) |
| **Healthcare Infrastructure**                                           |                             |                   |           |            |
| Physicians (/1000 people)                                               | 3                            | 3                  | 2         | 8          |
| Nurses and midwives (/1000 people)                                      | 8                            | 4                  | 0         | 12         |
| Hospital beds (/1000 people)                                            | 5                            | 7                  | 4         | 16         |
| Essential health services (UHC) coverage index                          | 2                            | 2                  | 4         | 8          |
| **Health Statistics**                                                   |                             |                   |           |            |
| Birth rate (crude, /1000 people)                                       | 3                            | 4                  | 0         | 7          |
| Death rate (crude, /1000 people)                                       | 2                            | 1                  | 2         | 5          |
| Life expectancy at birth (years)                                       | 0                            | 1                  | 0         | 1          |
| Prevalence of diabetes between ages 20-79 (% population)                | 4                            | 8                  | 2         | 14         |
| Mortality from unsafe water, or sanitation, lack of hygiene combined (/100k people) | 0                            | 0                  | 0         | 0          |
| Completeness of death registration with cause-of-death information (%) | 0                            | 2                  | 0         | 2          |
| **Economic Health**                                                     |                             |                   |           |            |
| GDP (per capita, PPP, $)                                                | 4                            | 0                  | 0         | 4          |
| Unemployment rate (most recent available, % labor force)               | 0                            | 0                  | 0         | 0          |
| Employment to population ratio for ages 15+ (modeled ILO estimate)     | 5                            | 5                  | 4         | 14         |
| Domestic general government health expenditure (per capita, PPP, $)     | 3                            | 5                  | 4         | 12         |
| Government lending/borrowing (% GDP)                                   | 3                            | 3                  | 4         | 7          |
| Income distribution (GINI index)                                       | 4                            | 6                  | 4         | 14         |
| Trade (% GDP)                                                           | 3                            | 3                  | 0         | 6          |
| Number of airline passengers (per year)                                | 4                            | 3                  | 0         | 7          |
| Number of tourist arrivals (per year)                                  | 8                            | 10                 | 4         | 22         |
| **Demographic Structure**                                               |                             |                   |           |            |
| Population aged 65+ (% population)                                     | 3                            | 5                  | 0         | 8          |
| Population aged 0 – 14 (% population)                                  | 0*                           | 0                  | 0         | 0*         |
| Population (total)                                                     | 2                            | 2                  | 0         | 4          |
| Rural population (% population)                                         | 5                            | 5                  | 2         | 12         |
| International migrant stock (% population)                             | 4                            | 6                  | 0         | 10         |
| Population density (people per sq km)                                  | 4                            | 5                  | 0         | 9          |
| **Environmental Health**                                                |                             |                   |           |            |
| Ecological footprint (gha/person)                                      | 1                            | 1                  | 2         | 4          |
| Air pollution (avg PM 2.5 exposure per year)                            | 0                            | 0                  | 4         | 4          |

*Population aged 0-14 was the first variable identified in LASSO for the geographically weighted $Y_1$, but it dropped out with the addition of the second variable and never returned. Further, it was not identified as important in any other models. Therefore we think it is unlikely that it is a significant variable.
| Variable                                      | Number of Models With Variable |
|----------------------------------------------|--------------------------------|
|                                              | $Y_1 \& Y_2 (12)$ | $Y_2 \& Y_2 (12)$ | $Y_0 (8)$ | Total (32) |
| **Societal Characteristics**                |                          |                  |            |            |
| Individuals using internet (% population)    | 4                         | 3                 | 2          | 9          |
| Education level: Human capital index (0 – 1) | 0                         | 0                 | 0          | 0          |
| Government effectiveness                     | 0                         | 0                 | 6          | 6          |
| Rule of law                                  | 0                         | 0                 | 0          | 0          |
| Control of corruption                        | 0                         | 0                 | 0          | 0          |
| Avg number of persons per household          | 2                         | 0                 | 0          | 2          |
| Human Freedom (score)                        | 2                         | 2                 | 4          | 8          |
| Personal Freedom (score)                     | 1                         | 0                 | 4          | 5          |
| Economic Freedom (score)                     | 0                         | 0                 | 6          | 6          |
| **Religious Characteristics**               |                          |                  |            |            |
| Buddhist (% population)                      | 2                         | 2                 | 4          | 8          |
| Christian (% population)                     | 5                         | 6                 | 2          | 13         |
| Folk Religion (% population)                 | 3                         | 1                 | 0          | 4          |
| Jewish (% population)                        | 0                         | 0                 | 0          | 0          |
| Hindu (% population)                         | 2                         | 1                 | 0          | 3          |
| Irreligion (% population)                    | 3                         | 0                 | 2          | 5          |
| Muslim (% population)                        | 2                         | 2                 | 2          | 6          |
| Other Religion (% population)                | 0                         | 1                 | 2          | 3          |