

# 1 Associations Between National Plant-Based vs Animal- 2 Based Protein Supplies and Age-Specific Mortality in 3 Human Populations

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## Supplementary Information

### 1. Supplementary Methods

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#### 1. Supplementary Methods: Data Imputation for Sensitivity Analysis

Numerous country-year pairings have lifetables and population data available but lack complete GDP or nutrient supply data. As outlined in the methods, we evaluated the impact of these missing data through imputation. Supplementary Figure 1 to Supplementary Figure 3 illustrate outcomes following the same analysis as in the main text, however using the dataset with imputed values. Statistical significance is detailed in Supplementary Table 19 and Supplementary Table 20.

#### 2. Supplementary Tables

**Supplementary Table 1** Estimated change in protein supplies (in terms of kcal/capita/day) over time. Gaussian-GAMM, identity-link function. Deviance explained = 85.1%, n = 2000. Related to Figure 1. GAMM = generalized additive mixed model.

| Parametric     |          |               |         |             |
|----------------|----------|---------------|---------|-------------|
| Coef.          | Estimate | Std.<br>Error | t value | p-value     |
| (Intercept)    | 334.08   | 3.59          | 93.11   | $<2e^{-16}$ |
| Non-Parametric |          |               |         |             |
| Coef.          | edf      | Ref.df        | F       | p-value     |
| s(Year)        | 2.65     | 3.32          | 233.37  | $<2e^{-16}$ |
| s(Country)     | 87.68    | 100.00        | 97.02   | $<2e^{-16}$ |

**Supplementary Table 2** Estimated change in animal-based protein supplies (in terms of kcal/capita/day) over time. Gaussian-GAMM, identity-link function. Deviance explained = 89.3%, n = 2000. Related to Figure 1. GAMM = generalized additive mixed model.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 160.86   | 3.41       | 47.21   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(Year)        | 2.79     | 3.49       | 348.5   | $<2e^{-16}$ |
| s(Country)     | 89.35    | 100.00     | 145.1   | $<2e^{-16}$ |

**Supplementary Table 3** Estimated change in plant-based protein supplies (in terms of kcal/capita/day) over time. Gaussian-GAMM, identity-link function. Deviance explained = 73.8 %, n = 2000. Related to Figure 1. GAMM = generalized additive mixed model.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 171.97   | 1.77       | 96.99   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(Year)        | 2.08     | 2.59       | 13.49   | $<2e^{-16}$ |
| s(Country)     | 82.60    | 100.00     | 49.70   | $<2e^{-16}$ |

**Supplementary Table 4** Estimated change in protein supplies (in terms of kcal/capita/day) with GDP. Gaussian-GAMM, identity-link function. Deviance explained = 87.1%, n = 2000. Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 354.78   | 2.71       | 130.8   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 7.76     | 9.72       | 165.70  | $<2e^{-16}$ |
| s(Country)     | 82.34    | 100.00     | 42.18   | $<2e^{-16}$ |

**Supplementary Table 5** Estimated change in animal-based protein supplies (in terms of kcal/capita/day) with GDP. Gaussian-GAMM, identity-link function. Deviance explained = 91%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 186.04   | 2.22       | 83.86   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 7.81     | 9.80       | 262.4   | $<2e^{-16}$ |
| s(Country)     | 81.04    | 100.00     | 43.2    | $<2e^{-16}$ |

**Supplementary Table 6** Estimated change in plant-based protein supplies (in terms of kcal/capita/day) with GDP. Gaussian-GAMM, identity-link function. Deviance explained = 78.3%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 169.132  | 1.86       | 90.83   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 6.57     | 8.24       | 46.30   | $<2e^{-16}$ |
| s(Country)     | 85.37    | 100.00     | 59.34   | $<2e^{-16}$ |

**Supplementary Table 7** Estimated change in protein supplies with carbohydrate supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 80.8%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 332.26   | 3.58       | 92.87   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 2.05     | 2.61       | 73.92   | $<2e^{-16}$ |
| s(Country)     | 84.75    | 100.00     | 75.35   | $<2e^{-16}$ |

**Supplementary Table 8** Estimated change in animal-based protein supplies with carbohydrate supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 83.2%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 165.89   | 3.46       | 48      | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 2.53     | 3.23       | 39.42   | $<2e^{-16}$ |
| s(Country)     | 84.91    | 100.00     | 72.86   | $<2e^{-16}$ |

**Supplementary Table 9** Estimated change in plant-based protein supplies with carbohydrate supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 92.9%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 166.54   | 1.04       | 159.9   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 6.07     | 7.70       | 757.48  | $<2e^{-16}$ |
| s(Country)     | 85.08    | 100.00     | 74.66   | $<2e^{-16}$ |

**Supplementary Table 10** Estimated change in protein supplies with fat supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 87.4%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 363.46   | 2.05       | 177.4   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 1.42     | 1.71       | 1411.91 | $<2e^{-16}$ |
| s(Country)     | 74.34    | 100.00     | 31,29   | $<2e^{-16}$ |

**Supplementary Table 11** Estimated change in ABP supplies with fat supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 92.8%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 195.34   | 1.50       | 130.6   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 3.90     | 4.93       | 1005.91 | $<2e^{-16}$ |
| s(Country)     | 71.94    | 100.00     | 36.76   | $<2e^{-16}$ |

**Supplementary Table 12** Estimated change in PBP supplies with fat supplies (in terms of kcal/capita/day). Gaussian-GAMM, identity-link function. Deviance explained = 74.9%,  $n = 2000$ . Related to Figure 1. GAMM = generalized additive mixed model; GDP = gross domestic product per capita.

| Parametric     |          |            |         |             |
|----------------|----------|------------|---------|-------------|
| Coef.          | Estimate | Std. Error | t value | p-value     |
| (Intercept)    | 168.96   | 1.92       | 87.94   | $<2e^{-16}$ |
| Non-Parametric |          |            |         |             |
| Coef.          | edf      | Ref.df     | F       | p-value     |
| s(GDP)         | 3.82     | 4.86       | 18.52   | $<2e^{-16}$ |
| s(Country)     | 84.23    | 100.00     | 48.43   | $<2e^{-16}$ |

**Supplementary Table 13** Relative fit of generalised additive mixed models testing predictors of lifetable parameter  $l_5$  (survivorship to age 5) in males and females. AIC = Akaike information criterion. GDP = gross domestic product.  $\Delta$ AIC is the difference between each model AIC score and the lowest AIC score across the model set. All models included country as a random effect, and the null model held no other terms. Supply was modelled as a 3-dimensional thin-plate regression spline for the nutritional variables: Animal-based protein (ABP), plant-based protein (PBP) and carbohydrates or ABP, PBP and fats (in terms of kcal/capita/day). Additive (+) and interactive effects (\*) were explored including the additive effects of carbohydrates or fats (whichever was not already included as part of the 3-d supply term). Economic and temporal trends were considered with the inclusion of cubic regression splines for Year and/or GDP.  $Supply^F = (ABP, PBP, Fat)$ ;  $Supply^C = (ABP, PBP, Carbohydrate)$ .

| Model                                                                                                                           | $l_5$ Females |        |              |        |              | $l_5$ Males  |        |              |        |              |
|---------------------------------------------------------------------------------------------------------------------------------|---------------|--------|--------------|--------|--------------|--------------|--------|--------------|--------|--------------|
|                                                                                                                                 | % Dev. Expl.  | AIC    | $\Delta$ AIC | Weight | $\Sigma$ EDF | % Dev. Expl. | AIC    | $\Delta$ AIC | Weight | $\Sigma$ EDF |
| <i>Null</i>                                                                                                                     | 71.1          | -21180 | 9389         | 0      | 78           | 68.3         | -20282 | 9854         | 0      | 77           |
| <i>Year</i>                                                                                                                     | 97.0          | -27768 | 2802         | 0      | 103          | 96.9         | -27262 | 2875         | 0      | 98           |
| <i>GDP</i>                                                                                                                      | 95.0          | -26312 | 4258         | 0      | 93           | 94.7         | -25612 | 4524         | 0      | 94           |
| <i>Year + GDP</i>                                                                                                               | 97.8          | -28854 | 1715         | 0      | 104          | 97.8         | -28422 | 1715         | 0      | 103          |
| <i>(Year <math>\times</math> GDP)</i>                                                                                           | 98.1          | -29229 | 1341         | <0.001 | 125          | 98.0         | -28684 | 1452         | <0.001 | 121          |
| <i>Supply<sup>F</sup> + Carbohydrate</i>                                                                                        | 95.2          | -26349 | 4220         | 0      | 124          | 94.6         | -25437 | 4700         | 0      | 125          |
| <i>Supply<sup>F</sup> + Carbohydrate + Year</i>                                                                                 | 98.1          | -29296 | 1273         | <0.001 | 132          | 98.2         | -28926 | 1211         | <0.001 | 132          |
| <i>Supply<sup>F</sup> + Carbohydrate + GDP</i>                                                                                  | 97.0          | -27807 | 2763         | 0      | 136          | 96.8         | -27115 | 3022         | 0      | 137          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time)</i>                                  | 98.8          | -30516 | 54           | <0.001 | 186          | 98.8         | -30021 | 116          | <0.001 | 187          |
| <i>(Supply<sup>F</sup> <math>\times</math> GDP) + (Carbohydrate <math>\times</math> GDP)</i>                                    | 97.2          | -27962 | 2608         | 0      | 145          | 97.1         | -27314 | 2823         | 0      | 149          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time) + GDP</i>                            | 98.8          | -30517 | 52           | <0.001 | 182          | 98.8         | -29991 | 145          | <0.001 | 180          |
| <i>(Supply<sup>F</sup> <math>\times</math> GDP) + (Carbohydrate <math>\times</math> GDP) + Time</i>                             | 98.3          | -29498 | 1071         | <0.001 | 140          | 98.3         | -29143 | 994          | <0.001 | 140          |
| <i>(Time <math>\times</math> GDP) + Supply<sup>F</sup> + Carbohydrate</i>                                                       | 98.5          | -29976 | 594          | <0.001 | 160          | 98.5         | -29418 | 719          | <0.001 | 155          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time) + (GDP <math>\times</math> Time)</i> | 98.8          | -30570 | 0            | >0.999 | 189          | 98.8         | -30137 | 0            | >0.99  | 192          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> GDP) + (GDP <math>\times</math> Time)</i>  | 98.5          | -29955 | 614          | <0.001 | 164          | 98.5         | -29462 | 675          | <0.001 | 161          |
| <i>Supply<sup>C</sup> + Fat</i>                                                                                                 | 71.1          | -21180 | 9389         | 0      | 78           | 68.3         | -20282 | 9854         | 0      | 77           |
| <i>Supply<sup>C</sup> + Fat + Year</i>                                                                                          | 96.9          | -27768 | 2802         | 0      | 103          | 96.9         | -27262 | 2875         | 0      | 98           |
| <i>Supply<sup>C</sup> + Fat + GDP</i>                                                                                           | 95.0          | -26312 | 4258         | 0      | 93           | 94.7         | -25612 | 4524         | 0      | 93           |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time)</i>                                           | 97.8          | -28854 | 1715         | 0      | 104          | 97.8         | -28422 | 1715         | 0      | 103          |
| <i>(Supply<sup>C</sup> <math>\times</math> GDP) + (Fat <math>\times</math> GDP)</i>                                             | 98.1          | -29229 | 1341         | <0.001 | 125          | 98.0         | -28684 | 1452         | <0.001 | 121          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time) + GDP</i>                                     | 95.2          | -26349 | 4220         | 0      | 124          | 94.6         | -25437 | 4700         | 0      | 125          |
| <i>(Supply<sup>C</sup> <math>\times</math> GDP) + (Fat <math>\times</math> GDP) + Time</i>                                      | 98.1          | -29296 | 1273         | <0.001 | 132          | 98.2         | -28926 | 1211         | <0.001 | 132          |
| <i>(Time <math>\times</math> GDP) + Supply<sup>C</sup> + Fat</i>                                                                | 97.0          | -27807 | 2763         | 0      | 136          | 96.8         | -27115 | 3022         | 0      | 137          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time) + (GDP <math>\times</math> Time)</i>          | 98.8          | -30516 | 54           | <0.001 | 186          | 98.8         | -30021 | 116          | <0.001 | 187          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> GDP) + (GDP <math>\times</math> Time)</i>           | 97.2          | -27962 | 2608         | 0      | 145          | 97.1         | -27314 | 2823         | 0      | 149          |

77 **Supplementary Table 14** Relative fit of generalised additive mixed models testing predictors of lifetable parameter  $l_{60}$  in females and males, as  
78 outlined in Table S13. AIC = Akaike information criterion; GDP = gross domestic product per capita; ABP = animal-based protein; PBP = plant-  
79 based protein.  $l_{60}$  = survivorship to age 60.  $Supply^F$  = (ABP, PBP, Fat);  $Supply^C$  = (ABP, PBP, Carbohydrate) all in terms of kcal/capita/day.

| Model                                                                                                                           | $l_{60}$ Females |        |              |        |              | $l_{60}$ Males |        |              |        |              |
|---------------------------------------------------------------------------------------------------------------------------------|------------------|--------|--------------|--------|--------------|----------------|--------|--------------|--------|--------------|
|                                                                                                                                 | % Dev. Expl.     | AIC    | $\Delta$ AIC | Weight | $\Sigma$ EDF | % Dev. Expl.   | AIC    | $\Delta$ AIC | Weight | $\Sigma$ EDF |
| <i>Null</i>                                                                                                                     | 70.3             | -10830 | 9034         | 0      | 72           | 70.7           | -9017  | 7875         | 0      | 72           |
| <i>Year</i>                                                                                                                     | 93.3             | -15195 | 4670         | 0      | 91           | 91.8           | -12748 | 4144         | 0      | 91           |
| <i>GDP</i>                                                                                                                      | 93.8             | -15435 | 4430         | 0      | 91           | 92.8           | -13151 | 3740         | 0      | 91           |
| <i>Year + GDP</i>                                                                                                               | 95.5             | -16370 | 3495         | 0      | 97           | 93.5           | -13457 | 3435         | 0      | 95           |
| <i>(Year <math>\times</math> GDP)</i>                                                                                           | 97.0             | -17547 | 2318         | 0      | 122          | 95.6           | -14558 | 2334         | 0      | 122          |
| <i>Supply<sup>F</sup> + Carbohydrate</i>                                                                                        | 95.3             | -16197 | 3668         | 0      | 128          | 93.1           | -13165 | 3726         | 0      | 130          |
| <i>Supply<sup>F</sup> + Carbohydrate + Year</i>                                                                                 | 98.0             | -18729 | 1136         | <0.001 | 150          | 97.0           | -15579 | 1312         | <0.001 | 159          |
| <i>Supply<sup>F</sup> + Carbohydrate + GDP</i>                                                                                  | 97.0             | -17518 | 2347         | 0      | 142          | 96.3           | -14982 | 1910         | 0      | 147          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time)</i>                                  | 98.6             | -19692 | 172          | <0.001 | 176          | 97.9           | -16583 | 309          | <0.001 | 185          |
| <i>(Supply<sup>F</sup> <math>\times</math> GDP) + (Carbohydrate <math>\times</math> GDP)</i>                                    | 97.3             | -17791 | 2074         | 0      | 152          | 96.9           | -15428 | 1464         | <0.001 | 168          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time) + GDP</i>                            | 98.7             | -19865 | 0            | >0.999 | 178          | 98.1           | -16851 | 40           | <0.001 | 184          |
| <i>(Supply<sup>F</sup> <math>\times</math> GDP) + (Carbohydrate <math>\times</math> GDP) + Time</i>                             | 98.3             | -19155 | 710          | <0.001 | 158          | 97.8           | -16478 | 413          | <0.001 | 177          |
| <i>(Time <math>\times</math> GDP) + Supply<sup>F</sup> + Carbohydrate</i>                                                       | 98.4             | -19196 | 668          | <0.001 | 174          | 97.7           | -16334 | 557          | <0.001 | 179          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> Time) + (GDP <math>\times</math> Time)</i> | 98.7             | -19849 | 16           | <0.001 | 177          | 98.1           | -16891 | 0            | >0.99  | 190          |
| <i>(Supply<sup>F</sup> <math>\times</math> Time) + (Carbohydrate <math>\times</math> GDP) + (GDP <math>\times</math> Time)</i>  | 98.6             | -19584 | 280          | <0.001 | 184          | 98.1           | -16882 | 10           | <0.01  | 200          |
| <i>Supply<sup>C</sup> + Fat</i>                                                                                                 | 70.3             | -10830 | 9034         | 0      | 72           | 70.7           | -9017  | 7875         | 0      | 72           |
| <i>Supply<sup>C</sup> + Fat + Year</i>                                                                                          | 93.3             | -15195 | 4670         | 0      | 91           | 91.8           | -12748 | 4144         | 0      | 91           |
| <i>Supply<sup>C</sup> + Fat + GDP</i>                                                                                           | 93.8             | -15435 | 4430         | 0      | 91           | 92.8           | -13151 | 3740         | 0      | 91           |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time)</i>                                           | 95.5             | -16370 | 3495         | 0      | 97           | 93.5           | -13457 | 3435         | 0      | 95           |
| <i>(Supply<sup>C</sup> <math>\times</math> GDP) + (Fat <math>\times</math> GDP)</i>                                             | 97.0             | -17547 | 2318         | 0      | 122          | 95.6           | -14558 | 2334         | 0      | 122          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time) + GDP</i>                                     | 95.3             | -16197 | 3668         | 0      | 128          | 93.1           | -13165 | 3726         | 0      | 130          |
| <i>(Supply<sup>C</sup> <math>\times</math> GDP) + (Fat <math>\times</math> GDP) + Time</i>                                      | 98.0             | -18729 | 1136         | <0.001 | 150          | 97.0           | -15579 | 1312         | <0.001 | 159          |
| <i>(Time <math>\times</math> GDP) + Supply<sup>C</sup> + Fat</i>                                                                | 97.0             | -17518 | 2347         | 0      | 142          | 96.3           | -14982 | 1910         | 0      | 147          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> Time) + (GDP <math>\times</math> Time)</i>          | 98.6             | -19692 | 172          | <0.001 | 176          | 97.9           | -16583 | 309          | <0.001 | 185          |
| <i>(Supply<sup>C</sup> <math>\times</math> Time) + (Fat <math>\times</math> GDP) + (GDP <math>\times</math> Time)</i>           | 97.3             | -17791 | 2074         | 0      | 152          | 96.9           | -15428 | 1464         | <0.001 | 168          |

80 **Supplementary Table 15** Sex-specific global standard life table, obtained from Wilmoth et al (2012) <sup>1</sup>.

| Age $x$<br>(years) | $\gamma_x^{male}$ | $\theta_x^{male}$ | $l_x^{male}$ | $\gamma_x^{female}$ | $\theta_x^{female}$ | $l_x^{female}$ |
|--------------------|-------------------|-------------------|--------------|---------------------|---------------------|----------------|
| 0                  | 0                 | 0                 | 1            | 0                   | 0                   | 1              |
| 1                  | 0.232             | -0.003            | 0.964        | 0.098               | 0.084               | 0.971          |
| 5                  | 0                 | 0                 | 0.952        | 0                   | 0                   | 0.96           |
| 10                 | -0.035            | -0.002            | 0.946        | 0.014               | -0.034              | 0.956          |
| 15                 | -0.045            | -0.001            | 0.941        | 0.036               | -0.056              | 0.952          |
| 20                 | -0.001            | -0.006            | 0.931        | 0.1                 | -0.094              | 0.946          |
| 25                 | 0.068             | -0.029            | 0.916        | 0.137               | -0.122              | 0.939          |
| 30                 | 0.123             | -0.051            | 0.901        | 0.157               | -0.142              | 0.931          |
| 35                 | 0.17              | -0.072            | 0.885        | 0.178               | -0.159              | 0.921          |
| 40                 | 0.207             | -0.088            | 0.864        | 0.202               | -0.17               | 0.908          |
| 45                 | 0.228             | -0.096            | 0.837        | 0.22                | -0.169              | 0.889          |
| 50                 | 0.21              | -0.086            | 0.8          | 0.205               | -0.141              | 0.864          |
| 55                 | 0.139             | -0.055            | 0.749        | 0.137               | -0.086              | 0.829          |
| 60                 | 0                 | 0                 | 0.68         | 0                   | 0                   | 0.782          |
| 65                 | -0.206            | 0.072             | 0.588        | -0.252              | 0.132               | 0.715          |
| 70                 | -0.489            | 0.161             | 0.474        | -0.627              | 0.312               | 0.62           |
| 75                 | -0.869            | 0.264             | 0.341        | -1.147              | 0.54                | 0.489          |
| 80                 | -1.383            | 0.391             | 0.204        | -1.819              | 0.816               | 0.328          |
| 85                 | -2.076            | 0.548             | 0.093        | -2.645              | 1.13                | 0.171          |
| 90                 | -3.064            | 0.77              | 0.029        | -3.75               | 1.536               | 0.062          |
| 95                 | -4.391            | 1.074             | 0.005        | -5.194              | 2.053               | 0.014          |
| 100                | -6.251            | 1.528             | 0.001        | -7.204              | 2.809               | 0.002          |
| 105                | -8.607            | 2.134             | 0            | -9.727              | 3.8                 | 0              |
| 110                | -11.392           | 2.875             | 0            | -12.698             | 5.007               | 0              |

81 **Supplementary Table 16** Estimated effects of macronutrient supplies (in terms of kcal/capita/day) by time and GDP per capita on  $l_5$  in females  
82 and males based on the complete cases. Beta GAMM, logit link function. Female deviance explained = 98.8%, male deviance explained = 98.8%,  
83 n per sex = 2000. Related to Figure 2. GAMM = generalized-additive mixed model; GDP = gross domestic product; ABP = animal-based protein;  
84 PBP = plant-based protein.  $l_5$  = survivorship to age 5.

|                                        |          |            |          |             |
|----------------------------------------|----------|------------|----------|-------------|
| <b>Males</b>                           |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_5$                      | 3.94     | 0.03       | 123.30   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 73.61    | 94.22      | 1319.41  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 11.64    | 13.92      | 78.15    | $<2e^{-16}$ |
| te(GDP_perCapita, Year)                | 14.20    | 94.00      | 2681.56  | $<2e^{-16}$ |
| s(Country)                             | 92.70    | 100.00     | 10325.42 | $<2e^{-16}$ |
| <b>Females</b>                         |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_5$                      | 4.14     | 0.03       | 124.60   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 72.08    | 92.28      | 1366.70  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 12.24    | 14.56      | 109.40   | $<2e^{-16}$ |
| te(GDP_perCapita, Year)                | 12.56    | 94.00      | 2877.60  | $<2e^{-16}$ |
| s(Country)                             | 92.44    | 100.00     | 9756.30  | $<2e^{-16}$ |

85 **Supplementary Table 17** Estimated effects of macronutrient supplies (in terms of kcal/capita/day) by time and GDP per capita on  $l_{60}$  in females  
86 and males based on the complete cases. Beta GAMM, logit link function. Female deviance explained = 98.7%, male deviance explained = 98.1%,  
87  $n$  per sex = 200. Related to Figure 3. GAMM = generalized-additive mixed model; GDP = gross domestic product; ABP = animal-based protein;  
88 PBP = plant-based protein.  $l_{60}$  = survivorship to age 60.

|                                        |          |            |          |             |
|----------------------------------------|----------|------------|----------|-------------|
| <b>Males</b>                           |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_{60}$                   | 1.43     | 0.02       | 64.38    | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 74.92    | 96.10      | 2397.2   | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 7.15     | 8.022      | 76.4     | $<2e^{-16}$ |
| te(GDP_perCapita, Year)                | 17.72    | 94.00      | 4665.3   | $<2e^{-16}$ |
| s(Country)                             | 90.43    | 100.00     | 11305.5  | $<2e^{-16}$ |
| <b>Females</b>                         |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_{60}$                   | 2.06     | 0.02       | 97.12    | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 71.544   | 91.80      | 3147.60  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 7.58     | 8.35       | 126.90   | $<2e^{-16}$ |
| te(GDP_perCapita, Year)                | 6.495    | 92.00      | 3030.10  | $<2e^{-16}$ |
| s(Country)                             | 91.10    | 100.00     | 10371.00 | $<2e^{-16}$ |

89 **Supplementary Table 18** Sex specific nutritional environment compositions used to derive  $q_x$  across age classes, as shown in Figure 5.  $q_x =$   
90 probability of mortality at age  $x$ .

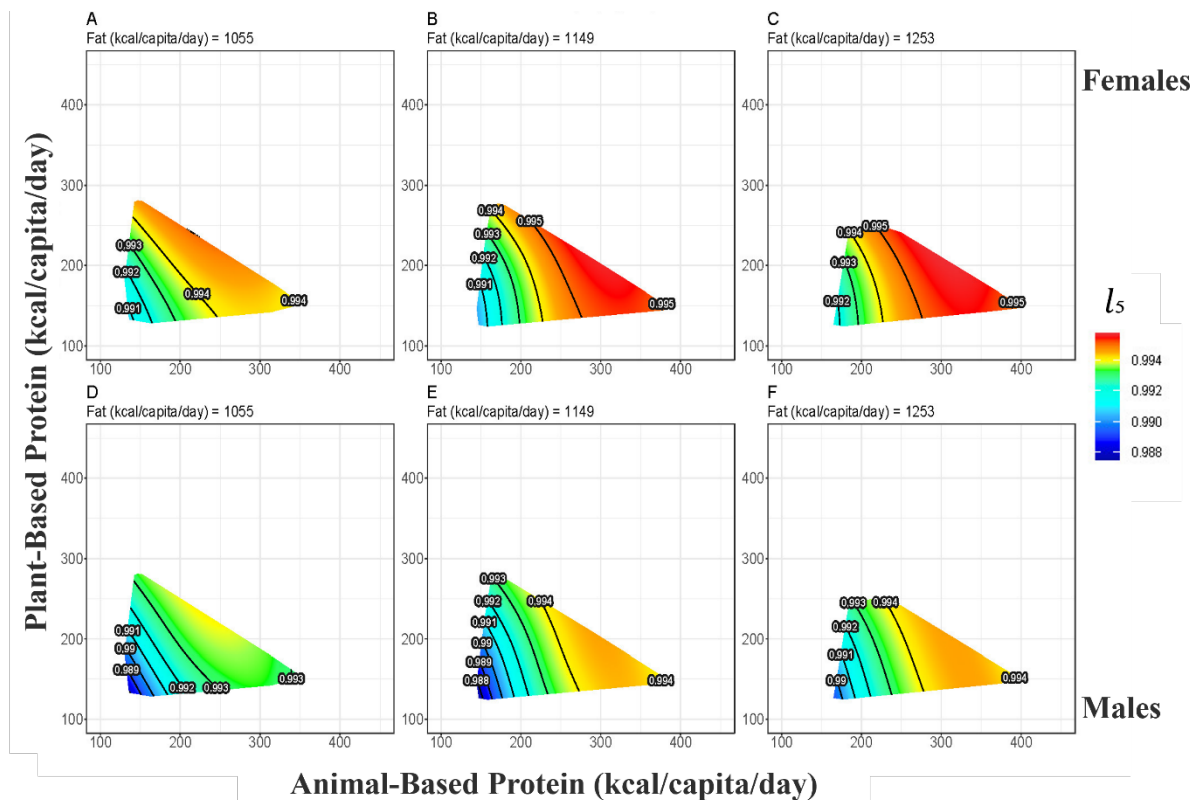
|         | High ABP:PBP Supply |        |       |        |      |               |       |         |       | Low ABP:PBP Supply |        |      |        |      |               |       |         |       |
|---------|---------------------|--------|-------|--------|------|---------------|-------|---------|-------|--------------------|--------|------|--------|------|---------------|-------|---------|-------|
|         | Total Energy        | ABP    |       | PBP    |      | Carbohydrates |       | Fats    |       | Total Energy       | ABP    |      | PBP    |      | Carbohydrates |       | Fats    |       |
|         | (TE)                | kcal   | % TE  | kcal   | % TE | kcal          | % TE  | kcal    | % TE  | (TE)               | kcal   | % TE | kcal   | % TE | kcal          | % TE  | kcal    | % TE  |
| Males   | 3150                | 352.63 | 11.19 | 151.90 | 4.82 | 1415.79       | 44.95 | 1229.67 | 39.04 | 3710               | 153.71 | 4.14 | 287.68 | 7.75 | 2162.54       | 58.29 | 1106.07 | 29.81 |
| Females | 3110                | 334.17 | 10.75 | 153.81 | 4.95 | 1395.02       | 44.86 | 1227.00 | 39.45 | 3700               | 151.83 | 4.10 | 286.48 | 7.74 | 2164.92       | 58.51 | 1096.77 | 29.64 |

91 **Supplementary Table 19** Estimated effects of macronutrient supplies (in terms of kcal/capita/day) by time and GDP per capita on  $l_5$  in females  
92 and males based on the imputed dataset. Beta GAMM, logit link function. Female deviance explained = 98.9%, male deviance explained = 98.7%,  
93  $n$  per sex = 2163. Related to Supplementary Figure 1. GAMM = generalized-additive mixed model; GDP = gross domestic product; ABP = animal-  
94 based protein; PBP = plant-based protein.  $l_5$  = survivorship to age 5.

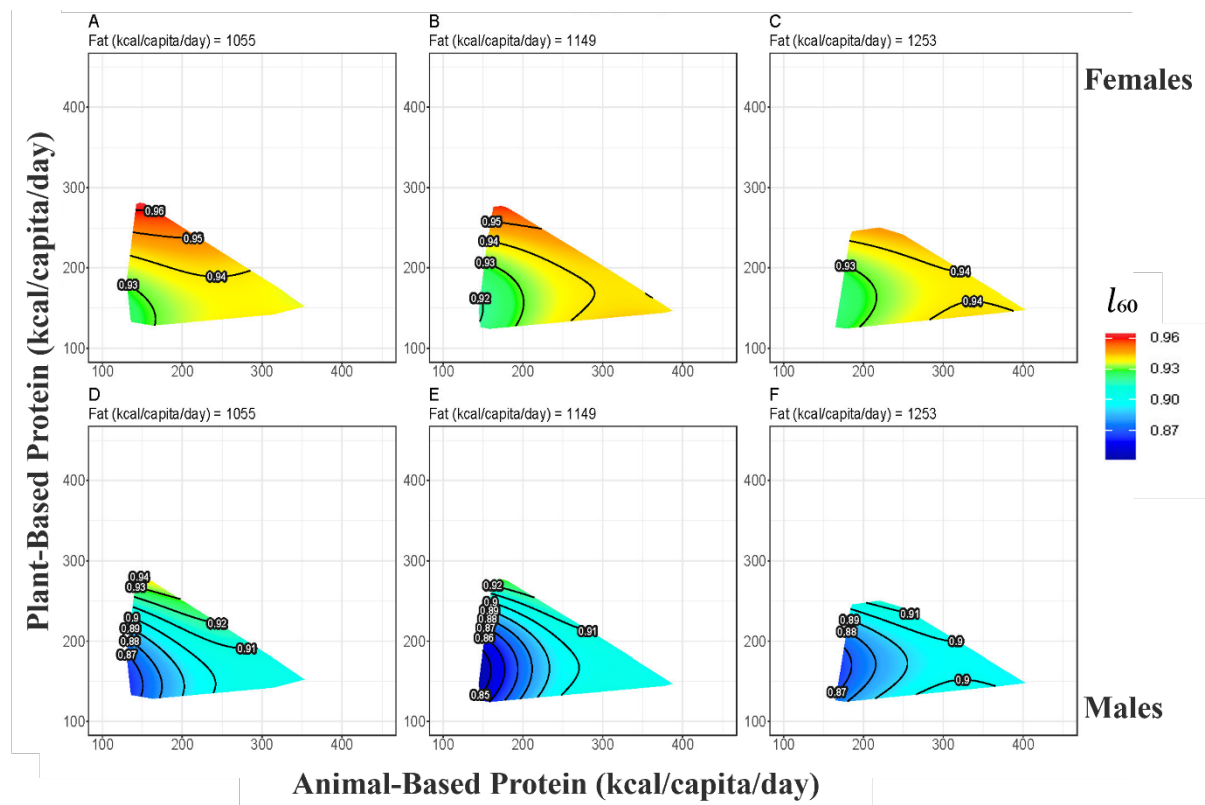
|                                        |          |            |          |             |
|----------------------------------------|----------|------------|----------|-------------|
| <b>Females</b>                         |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_5$                      | 4.14     | 0.03       | 129.90   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 68.83    | 88.16      | 1185.80  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 12.76    | 15.06      | 119.70   | $<2e^{-16}$ |
| s(GDP_perCapita, Year)                 | 14.85    | 94.00      | 6022.20  | $<2e^{-16}$ |
| s(Country)                             | 103.26   | 113.00     | 10349.20 | $<2e^{-16}$ |
| <b>Males</b>                           |          |            |          |             |
| Parametric                             |          |            |          |             |
| Coef.                                  | Estimate | Std. Error | z value  | p-value     |
| (Intercept) $l_5$                      | 3.94     | 0.03       | 128.10   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |          |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq   | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 68.09    | 87.22      | 1103.27  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 11.49    | 13.76      | 81.86    | $<2e^{-16}$ |
| s(GDP_perCapita, Year)                 | 15.85    | 94.00      | 5730.83  | $<2e^{-16}$ |
| s(Country)                             | 103.60   | 113.00     | 10545.71 | $<2e^{-16}$ |

95 **Supplementary Table 20** Estimated effects of macronutrient supplies (in terms of kcal/capita/day) by time and GDP per capita on  $l_{60}$  in females  
96 and males based on the imputed dataset. Beta GAMM, logit link function. Female deviance explained = 98.4%, male deviance explained = 97.6%,  
97  $n$  per sex = 2163. Related to Supplementary Figure 2. GDP = gross domestic product; ABP = animal-based protein; PBP = plant-based protein.  $l_{60}$   
98 = survivorship to age 60.

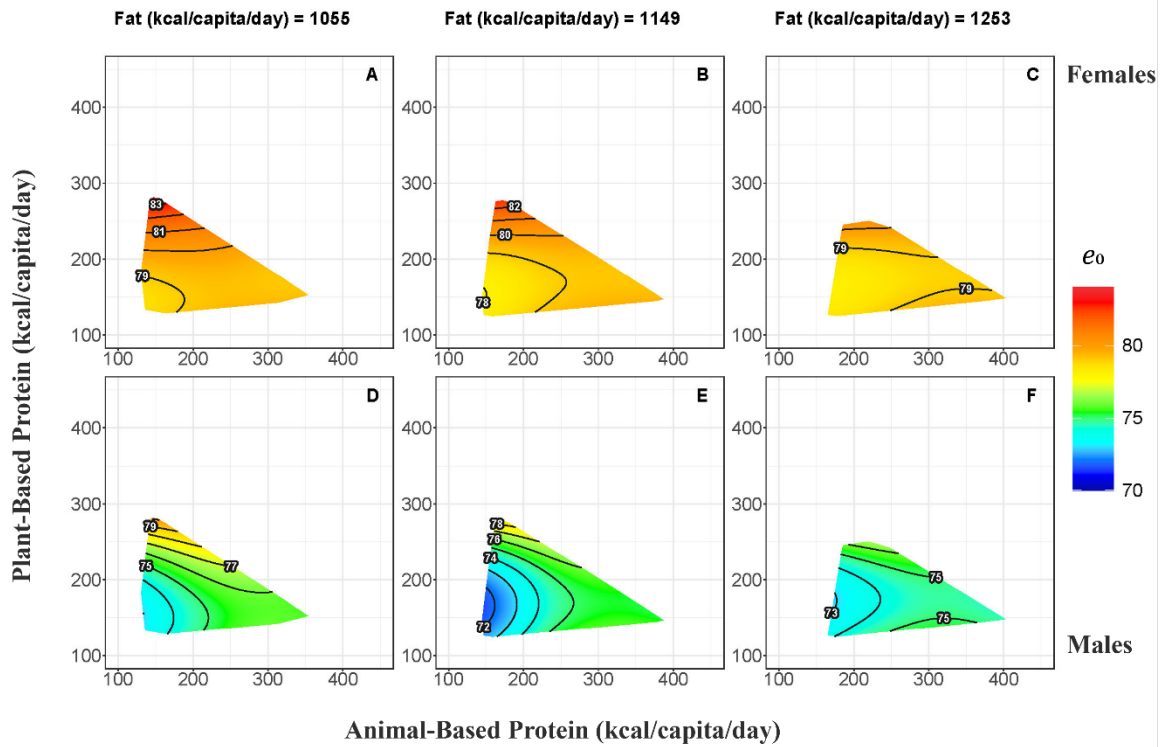
|                                        |          |            |         |             |
|----------------------------------------|----------|------------|---------|-------------|
| <b>Females</b>                         |          |            |         |             |
| Parametric                             |          |            |         |             |
| Coef.                                  | Estimate | Std. Error | z value | p-value     |
| (Intercept) $l_{60}$                   | 2.03     | 0.02       | 93.86   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |         |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq  | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 69.882   | 90.01      | 2560.1  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 8.75     | 9.89       | 189.3   | $<2e^{-16}$ |
| s(GDP_perCapita, Year)                 | 10.58    | 94.00      | 6146.3  | $<2e^{-16}$ |
| s(Country)                             | 104.17   | 113.00     | 11159.4 | $<2e^{-16}$ |
| <b>Males</b>                           |          |            |         |             |
| Parametric                             |          |            |         |             |
| Coef.                                  | Estimate | Std. Error | z value | p-value     |
| (Intercept) $l_{60}$                   | 1.43     | 0.02       | 66.86   | $<2e^{-16}$ |
| Non-Parametric                         |          |            |         |             |
| Coef.                                  | edf      | Ref.df     | Chi.sq  | p-value     |
| te(ABP.kcal, PBP.kcal, Fat.kcal, Year) | 76.893   | 99.07      | 2502.4  | $<2e^{-16}$ |
| te(Carb.kcal, Year)                    | 9.32     | 10.88      | 131.1   | $<2e^{-16}$ |
| s(GDP_perCapita, Year)                 | 15.37    | 94.00      | 6253.6  | $<2e^{-16}$ |
| s(Country)                             | 101.99   | 113.00     | 12657.7 | $<2e^{-16}$ |



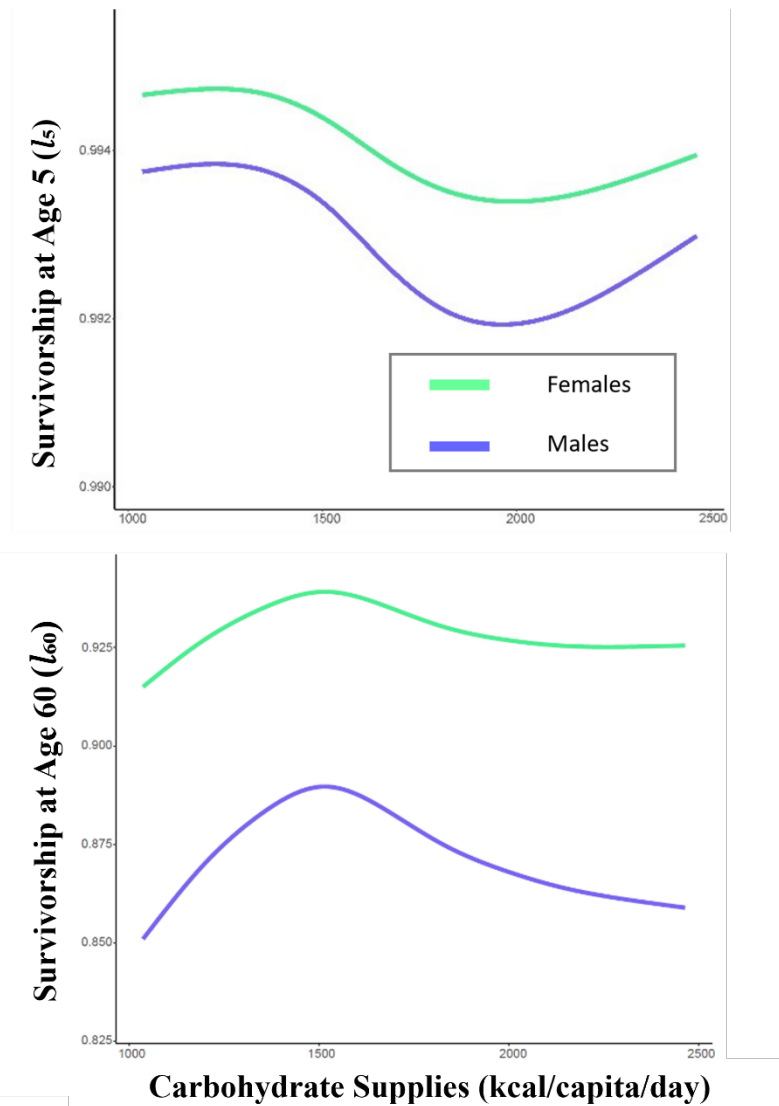
**Supplementary Figure 1** Surfaces showing the predicted effects of macronutrient supplies (in terms of kcal/capita/day) on life table survivorship to age 5 ( $l_5$ ), based on the imputed dataset. Survivorship outcomes were predicted based on 2017 global nutrient supply, GDP, and population data, after imputation, using the generalized-additive mixed model selected as the best approximating model for the complete dataset. (A-C) show the effects of animal-based protein (ABP;  $x$ -axis), plant-based protein (PBP;  $y$ -axis), and fat supplies on  $l_5$  in females. (D-F) show the effects of ABP ( $x$ -axis), PBP ( $y$ -axis), and fat supplies on  $l_5$  in males. The colour map and contour lines on each surface indicate the predicted  $l_5$  associated with the aligning protein supplies given by the ( $x,y$ ) coordinates.  $l_5$  survivorship values increase from blue to red, as specified by the colour bar legend (min = 0.988, max = 0.996). Moving from left to right across each row of surfaces, the quantity of fat supplies increases. (A, D), (B,E), and (C, F) show predicted effects at the first, second and third quartiles of global fat supplies in 2017, respectively. (A-F) assume the median carbohydrate supplies for 2017, after imputation (1579 kcal/capita/day). The smooth terms for macronutrient supply were statistically significant in both sexes (Supplementary Table 19).



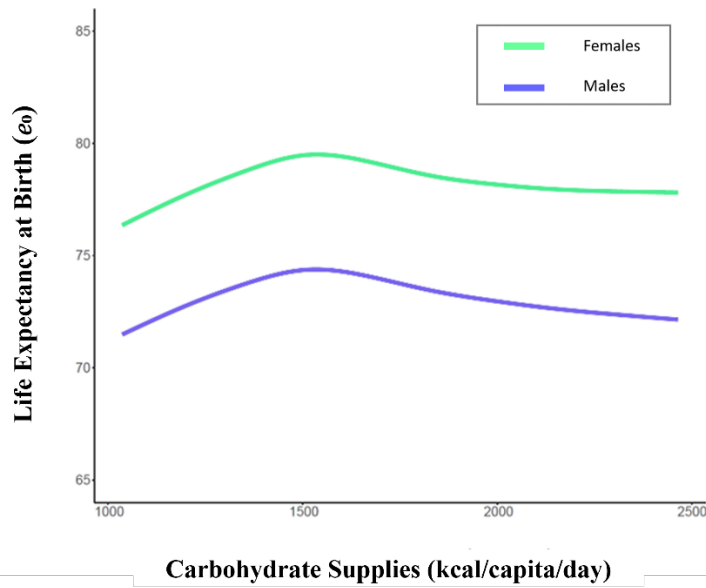
**Supplementary Figure 2** Surfaces showing the predicted effects of animal-based protein ( $x$ -axis) and plant-based protein ( $y$ -axis) supplies (kcal/cap/day) on survivorship to age 60 ( $l_{60}$ ), based on the imputed dataset. Survivorship outcomes were predicted based the imputed dataset, as described in Supplementary Figure 1. (A-C) and (D-F) show female and male  $l_{60}$  outcomes, respectively. The colour map and contour lines show predicted  $l_{60}$  survivorship, as described in Supplementary Figure 1.  $l_{60}$  survivorship values increase from blue to red, as per the colour bar legend (min = 0.842, max = 0.963). (A, D), (B,E), and (C, F) show predicted effects for low, median and high fat supplies, respectively, and as specified in Supplementary Figure 1. The smooth terms for macronutrient supply were statistically significant in both sexes (Supplementary Table 20).



**Supplementary Figure 3** Surfaces showing the predicted effects of animal-based protein ( $x$ -axis) and plant-based protein ( $y$ -axis) supplies (kcal/cap/day) on life expectancy at birth ( $e_0$ ), based on imputed dataset.  $e_0$  values were derived from pairs of corresponding survivorship to ages 5 and 60 values ( $l_5$  and  $l_{60}$ ), as shown in Supplementary Figure 1 and Supplementary Figure 2, and visualised across the same nutrient supply space. (A-C) and (D-F) show female and male  $e_0$  outcomes, respectively. The colour map and contour lines in (A – F) show the  $e_0$  in years, corresponding to the aligning proportions of protein supplies on the  $x$  and  $y$  axes. In (A – F),  $e_0$  values increase from blue to red, as specified by the colour bar legend (min = 70 years, max = 85 years). The quantity of fat and carbohydrate supplies is fixed on each surface. Carbohydrate supplies are fixed at 1579 kcal/capita/day for (A-F), based on the median carbohydrate supply for 2017, after imputation. Fat supplies, specified above surfaces (A-C), are held constant at the first, second and third quartiles of global fat supplies in 2017 for surfaces (A and D), (B and E) and (C and F) respectively.



**Supplementary Figure 4** Predicted effects of carbohydrate supplies (in terms of kcal/capita/day) on life table survivorship to (A) age 5 ( $l_5$ ) and (B) age 60 ( $l_{60}$ ), in males (purple) and females (green). Survivorship outcomes are predicted based on 2017 global nutrient supply, GDP, and population data, using the generalized-additive mixed model selected as the best approximating model for the complete dataset. (A and B) assume median animal-based protein (219 kcal/capita/day), plant-based protein (174 kcal/capita/day) and fat (1148 kcal/capita/day) supplies in 2017.



**Supplementary Figure 5** Predicted effects of carbohydrate supplies (in terms of kcal/capita/day) on life expectancy at birth ( $e_0$ ) in females (green) and males (purple).  $e_0$  values are derived from pairs of corresponding  $l_5$  and  $l_{60}$  shown in Supplementary Figure 4 and visualised across the same nutrient supply space. Carbohydrate effects are predicted for median animal-based protein, plant-based protein and fat supplies in 2017, as specified in Supplementary Figure 4.

151    **Supplementary References**

- 152    1.    Wilmoth, J., Zureick, S., Canudas-Romo, V., Inoue, M. & Sawyer, C. A flexible two-  
153        dimensional mortality model for use in indirect estimation. *Popul. Stud.*    **66**, 1–28  
154        (2012).