# Measuring the Distribution of Education:
# Global Trends, Forecasts, and Inequality Metrics

Joseph Friedman

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Committee:

Emmanuela Gakidou

Kyle Foreman

Stephen Lim

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**Abstract**

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Joseph Friedman

Chair of the Supervisory Committee:

Professor Emmanuela Gakidou

Global Health, IHME

As perhaps the single most important social determinant of health, the measurement of educational attainment is of paramount importance for health research. There is substantial reason to believe that estimates of the distribution of educational, and measures of educational inequality, could be useful tools for population health research. In this study, we compile a large database detailing the distribution of educational attainment, and provide the first set of comprehensive estimates of the distribution of education by age, sex, geography, and time, that will allow further studies to explore the importance of the distribution of education for health. We provide the first description of the global course of educational inequality and a basic comparison of the implications of the choice of inequality metric. We also provide projections to 2040, by leveraging cohort information and the extrapolation of current trends.

## Introduction

As perhaps the single most important social determinant of health, the measurement of educational attainment is of paramount importance for health research. Educational attainment has been linked to a large number of health outcomes, at the individual and ecological level, in myriad contexts [1–10]. The relationship between maternal education and reductions in child mortality is especially robust, and has been studied extensively [11–17]. Population-level health studies routinely use education as a covariate or explanatory variable, in order to estimate demographic and disease trends in the absence of complete data, or to control for confounding by socioeconomic status [18–20]. In addition, education has been prioritized as a global development indicator, especially in the Millennium Development Goal 2 and Sustainable Development Goal 5 targets [21,22]. The accurate measurement of educational attainment is therefore of paramount importance for facilitating reliable and unbiased health research, and monitoring development targets.

Most population-level studies using education focus on the average years of schooling indicator [23–32], as it represents an easy to understand single number summary of attainment, and it is the only indicator comprehensively available over time and geography. Although an abundant number of data sources exist describing education by level, no comprehensive set of estimates of the complete distribution of educational attainment exists for all countries over time.

There is substantial reason to believe that estimates of the distribution of educational, and measures of educational inequality, could be useful tools for population health research. A number of studies have shown that the relationship between education and health exhibits dose response effects[33,34]. It has not been established that average years of schooling is the most predictive aspect of the distribution of education for modeling health outcomes. Furthermore, it has not been reliably established to what degree inequality in education, as opposed to simply the education experienced by each individual, may be related to health. Therefore, a closer examination of the distributional of categorical education within countries, and an assessment of other traits of the distribution of education for their relevance to health, could prove useful in predictive and inferential disease modeling.

In this study, we compile a large database detailing the distribution of educational attainment, and provide the first set of comprehensive estimates of the distribution of education by age, sex, geography, and time, that will allow further studies to explore the importance of the distribution of education for health. We provide the first description of the global course of educational inequality and a basic comparison of the implications of the choice of inequality metric. We also provide projections to 2040, by leveraging cohort information and the extrapolation of current trends.

# Methods

### *Data*

We compiled 2,017 census and surveys (tabulations by data family shown in table 1; see appendix for complete list), covering 194 countries and territories, from 1960-2015. Each source included information on educational attainment by country, year, sex, and 5-year age group, as well as data regarding the distribution of attainment within the population of interest. Ideally, each data source provided information on the distribution of education in single years of attainment. However, when larger bins of attainment were provided, a space-time distance crosswalk method was used to probabilistically split the larger bins into single year proportion (method to be published separately). Data are top-coded to 18 years, as it is a common choice among providers of single-year education data [35], and it is reasonable to assume that the importance of education for health diminishes greatly after the completion of 18 years, which represents 2 to 3 years of graduate education in most educational systems.

| Data Family | Country-Years |
|---|---|
| ISSP | 514 |
| EUROBAROMETER | 501 |
| IPUMS | 261 |
| DHS | 217 |
| Other Census | 169 |
| MICS | 119 |
| BRFSS | 68 |
| WHS | 56 |
| WFS | 40 |
| MCSS | 32 |
| RHS | 31 |
| Other Survey | 9 |
| **Total** | **2,017** |

Table 1. Sources by data family

### *Modeling Approach Summary*

A multi-stage categorical modeling framework was used to model the distribution of educational attainment over space and time. First, the proportion of each distribution within larger bins (0-2 years, 3-5 years, 6-8 years, 9-11 years, 12-14 years and 15-18 years) was modeled, to leverage the greater stability in the data of these larger categories. The predicted proportions of these groups were normalized to ensure they add to 100%. Subsequently, the proportion of the population with each single year of attainment was modelled, and normalized to the larger bins.

Figure 1 shows an example for one set of multi-year bin timeseries in each stage of the modeling process. To model the proportion of educational attainment within each single and multi-year bin, two types of models are used. An age-cohort model was used to project observed cohorts through time, accounting for differences in mortality and migration by education status, as well as education later in life. An age-period model was then used to extrapolate outside of observed birth cohorts, and complete all timeseries. Gaussian process regression was used to synthesize these models with the input data, ensuring a good model fit where data are available, and produce estimate uncertainty.

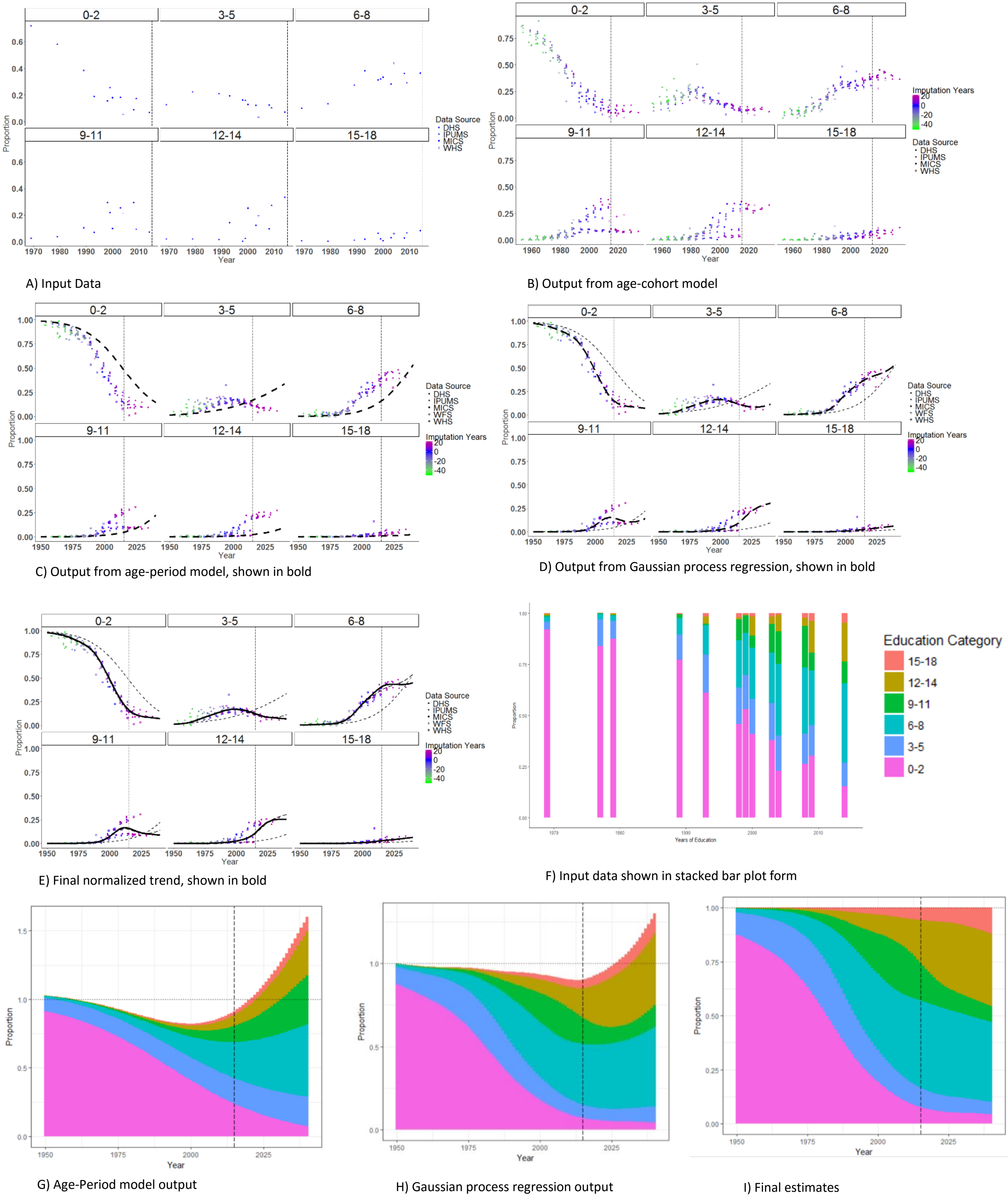


Figure 1. Illustration of the modeling process for a single time series, Nigerian men age 45-49. Input data and steps are shown both as line and scatter timeseries plots, as well as stacked bar plots. A vertical dashed line at 2016 indicates the first year of the forecasts. A dashed horizontal line indicates the 100% line.

### ***Modeling Approach Detailed Description***

*Age-Cohort Imputation Model*

Education is highly stable over time within a given birth cohort after the normal age for completion of education has passed, usually by 20 or 25 years of age. Past analyses have leveraged this stability to project the educational attainment of a cohort through time either by assuming no change[26,27], or modeling the effect of differential migration and mortality by educational status [23,36]. We take a similar approach, projecting cohorts through time after age 25. No cohort imputation is used for age groups 15-19 and 20-24.

We model the observed change in educational attainment for cohorts over time, based on data where the same cohort of individuals was observed in at least two censuses or surveys. We restricted the analyses to instances where cohorts were observed in data from the same data family, to remove noise from systematic differences between data providers. We fit the model using 23,801 pairs of observations of the same cohort at two different periods in time. The dependent variable $Y_{i,ts}$ is the annualized change in the logit-transformed proportion of the population in each single and multi-year bin of educational attainment for each cohort *i*, observed between points *t* and *s:*

$$Y_{i,ts} = \frac{logit(proportion_{i,t}) - logit(proportion_{i,s})}{t - s}$$

We then modelled $Y_{i,ts}$ using a mixed effect model, with a global intercept $\beta_0$, as well as super-regional random intercepts $\alpha_{sr}$:

$$Y_{i,ts} = \beta_0 + \alpha_{sr}$$

In order to propagate the uncertainty in the age-cohort process, the standard deviation of the model residual was calculated for each modelled proportion, separately for each super-region grouping used in the Global Burden of Disease 2015 study[37], and used in calculating final uncertainty intervals in the Gaussian process regression step detailed below.

*Age-Period Model*

Age-period models were fit on all original input data, as well as imputed cohort points, in order to interpolate data for observed cohorts, and extrapolate to all parts of the desired time series, producing single year estimates of attainment from 1950 through 2040. To model the proportion of the population in each multi-year bin, a series of shape-constrained additive models were used, allowing for the estimation of age-period trends, while enforcing the preservation of empirically observed trends in the data throughout extrapolation periods.

Age-period trends in the terminal education bins, 0-2 and 15-18 were observed to be monotonic with respect to time, with the 0-2 year group only decreasing over time, and the 15-18 only increasing. These trends were therefore enforced using monotonic p-splines in extrapolation [38]. Trends in intermediate (non-terminal) bins were observed to be linear over time—constantly decreasing or increasing—or to have a single inflection point. There were no examples of timeseries with several credible inflection points in the observed timeseries of intermediate multi-year bins. As an example, in age groups with relatively low education, the proportion of the population with 3-5 years of education starts close to zero, as most individuals have almost no education. As the average educational attainment of the population rises, the proportion in the 3-5 bin increases, until it reaches an equilibrium point, and then decreases, as the population begins to achieve mostly at the 6-8 years level and higher. The resulting trend is a concave curve, with a single inflection point at the equilibrium point where the trend shifts from increasing to decreasing. Separately for each sex, and region grouping used in the GBD 2015 study[37], the proportion of the country-age-year specific population in each multi-year bin, $P_{c,a,t}$,was estimated:

$$logit(P_{c,a,t}) = \beta_0 + \ S_1 year + S_2 age$$

The secular trend, $S_1 year$, is a monotonically decreasing p-spline for the 0-2 group, a monotonically increasing p-spline for the 15-18 group, and a concave p-spline for all intermediate groups. The effect on age, $S_2 age$, is an unconstrained cubic regression spline for all modelled proportions. A global intercept $\beta_0$ was used for all proportions.

The proportion of the country-age-year specific population in each single-year bin, $P_{c,a,t,b}$was more variable with respect to secular trend, and no shape constraints were used in estimation of age-period trends. However, since these proportions were ultimately normalized to the larger multi-year bin proportions, constraints were imposed in a top-down fashion from the earlier models. The proportion in each bin was modeled separately for each region-sex group using a mixed effect model:

$$logit(P_{c,a,t}) = \beta_0 + \ \beta_1 year + S_2 age + \alpha_{c,a}$$

Where $\beta_0$ is a global intercept, $\beta_1 year$ captures the linear secular trend, $S_2 age$ is a natural spline on age to capture the non-linear age pattern, with knots at 35, 50, and 65 years of age, and $\alpha_{c,a}$ is a timeseries-specific random intercept.

*Gaussian Process Regression*

In the final estimation step, we used Gaussian process regression (GPR) to synthesize the results of both the age-period and age-cohort models, and ensure that the estimates fit the data well. GPR has been used extensively in the Global Burden of Disease estimation frameworkas a data synthesis tool [39,40]. GPR uses a covariance function to smooth the residuals from the age-period model, taking into account the uncertainty in each data point. GPR also synthesizes both data and model uncertainty, in order to produce estimate uncertainty intervals.

GPR assumes that the trend in the underlying data follows a Gaussian process, which is defined using a mean function $m(\cdot)$ and a covariance function $Cov(\cdot)$. Therefore, separately for each single and multi-year bin of education, the country-age-sex-year specific population proportions are defined:

$$logit(P_{c,s,a,t}) = g_{c,a,s}(t) + \ \epsilon_{c,a,s,t}$$

Where the error term is normally distributed:

$$\epsilon_{c,a,s,t} = Normal(0, \sigma_p^2$$

The error variance, $\sigma_p^2$, is composed of the squared standard error of the observed data point, as well as the prediction errors from the age-cohort imputation process. The mean function of the model is the age-period model predictions, as detailed above. The covariance function of the model is derived using a matern covariance function, consistent with prior applications of GPR in the Global Burden of Disease estimation process:

$$M(t,t') = \sigma^2 \; \frac{2^{1-\nu}}{\Gamma(\nu)} \left(\frac{d(t,t')\sqrt{2\nu}}{l}\right)^{\nu} \; \mathrm{K}_{\nu}\left(\frac{d(t,t')\sqrt{2\nu}}{l}\right)$$

Where $d(\cdot)$ is a distance function, $\sigma^2$ is the marginal variance, $\nu$ is a smoothness hyper parameter defining the differentiability of the function, $l$ is a link-scale parameter approximately equivalent to the number of years at which two points are no longer correlated, $\mathrm{K}_{\nu}$ is the Bessel function, and $\Gamma(\cdot)$ is the gamma function. Similar to previous applications of GPR, we approximate $\sigma^2$ as the super-region and sex specific residual from the mean function, set $\nu$ to 2, and $l$ to 40, to reflect the inherent smoothness of educational attainment trends overtime.

*Normalization Process*

The final estimated proportions obtained from the GPR process are then normalized, to ensure that all the multi-year bins add to 100%, and the single year bins add to their respective multi-year bins. In normalizing the multi-year bins, a multi-stage process is used, to attempt to prevent the normalization process from violating the same empirical phenomena enforced in the age-period model. Similarly to the age-period model, the monotonicity of the terminal education groups is enforced, and these groups are given priority in the normalization, as they are the most stable over time and therefore the easiest tends to reliably extrapolate. The intermediate groups are normalized to maintain a single inflection point, unless this is incompatible with the total proportions adding to 100%. We use the following multi-stage normalization algorithm:

- The proportion of the 15-19 age group with 15-18 years of educational attainment is set to zero, as this group is unable to ever achieve 15 years of education due to not having lived a sufficient number of years, even if they began schooling at age 4.
- In order to enforce the single inflection point assumption for intermediate multi-year bins, all inflection points in the timeseries-specific GPR output are detected, as the year in which a change in trend direction is observed. The most 'data centered' inflection point for each timeseries is identified, as the inflection point which has the minimum average absolute distance in years from all data used in the estimation of the timeseries in question.
- Moving forwards and backwards from this inflection point for each timeseries, any additional inflection points resulting from the extrapolation process are removed by forcing flat trends.
- Moving backwards in time, the proportion of individuals with 0-2 years of education is forced to monotonically increase by holding trends flat anywhere they are found to be decreasing. Similarly, moving forwards in time, the proportion of individuals with 15-18 years of education is forced to monotonically increase by holding trends flat where found to be decreasing.
- The terminal multi-year bins are used in their state at this stage of the process, while the intermediate bins are proportionally normalized, to ensure that the total proportion of individuals across all multi-year bins add to 100%.
- The single-year bins are then proportionally normalized to ensure they add to the normalized multi-year bin proportions from the prior step.

### *Aggregations and Counts of Population by Educational Attainment Level*

To obtain counts of the number of individuals with each category of educational attainment, the final normalized proportions where applied to population numbers obtained from the World Population Prospects 2015 files [41]. These populations were also used to produce all regional and global aggregations shown in the text.

## Results and Discussion

### *Global Trends in the Distribution of Educational Attainment*

Estimates and figures detailing the distribution of education for the 15+ adult population of 195 countries from 1950 to 2016 can be found in the supplemental materials. Table 2 provides values for 15+ adults by multi-year bins.

Globally, the world has seen a dramatic shift towards an increasingly educated population from 1950 to 2016, and our projections suggest that this trend will continue through 2040. Figure 2 shows the global distribution of the world's population by educational attainment categories over time. The proportion with the lowest category of attainment, 0-2 years, has fallen from 48.86% (95% CI: X.X- Y.Y%) to 12.90% (X.X- Y.Y%) in 2016, and is forecasted to reach 7.28% (X.X- Y.Y%) by 2040. Concurrently, the proportion of individuals attaining education in the tertiary 15+ bin has risen from only 1.50% (X.X- Y.Y%) in 1950 to 16.15% (X.X- Y.Y%) in 2016, and is projected to reach 35.46% percent (X.X- Y.Y%) by 2040.

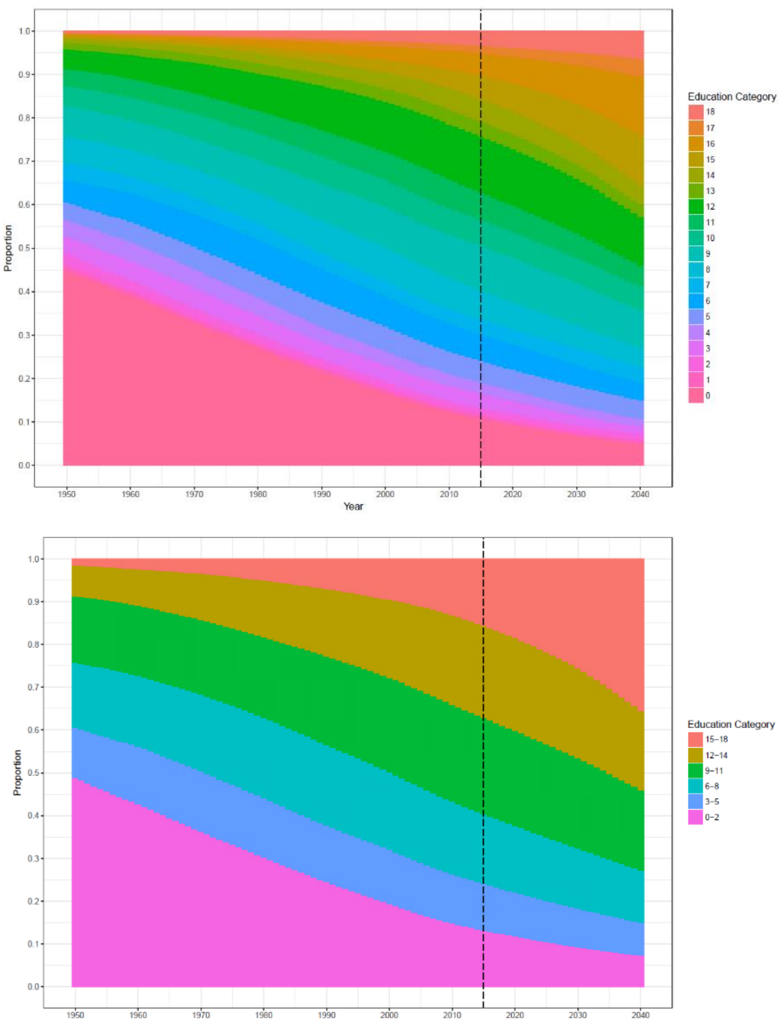


Figure 2. Global distribution of educational attainment shown in both single-year (top) and multi-year (bottom) bins. The vertical dashed line indicates 2016, the last year before forecasts begin.

Globally the world has seen a closing of genders gaps in absolute terms, although some disparities remain. Figure 3 shows the global distribution of educational attainment by gender. Over time the gender disparity in the lowest attainment group, 0-2 years, has shrunk, although not entirely closed by 2040, with proportions of 5.67% (X.X- Y.Y%) for men and 8.89% (X.X- Y.Y%) for women. In the 15-18 years

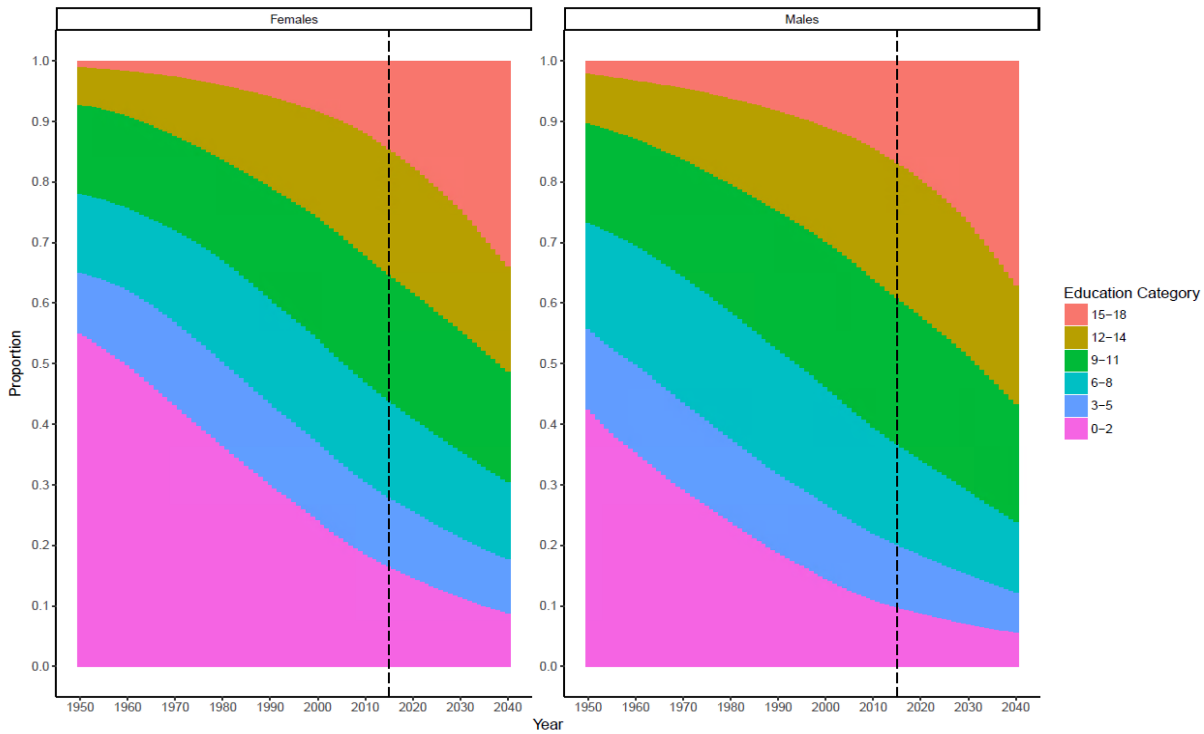


Figure 3. Global distribution of educational attainment shown multi-year bins for males (right) and females (left). The vertical dashed line indicates 2016, the last year before forecasts begin.

of attainment group, women have nearly caught up with men, by 2016 with proportions of 17.25% (X.X- Y.Y%) for men and 15.04% (X.X- Y.Y%) for women. By 2040 the proportion of the global population with tertiary education has grown substantially for both groups, but a small gap remains with 36.98% (X.X- Y.Y%) for men and 33.92% (X.X- Y.Y%) for women.

Figure 4 shows the distribution of education by super-region used in the Global Burden of Disease 2015 study [42]. All regions show evidence of substantial progress, however clear disparities remain throughout the timeseries and projections. The proportion of individuals in North Africa and the Middle East, South Asia, and Sub-Saharan Africa with 0-2 years of education was quite high in 1950, with proportions of greater than 80% in each case. However, by 2016 these proportions have fallen substantially to 16.63% (X.X- Y.Y%), 29.23% (X.X- Y.Y%), and 27.57% (X.X- Y.Y%) respectively. Global gains in the tertiary education 15-18 years bin have been driven largely by progress in the High-income and Central Europe, Eastern Europe, and Central Asia super regions. The proportion in the High-income super region grew from 3.85% (X.X- Y.Y%) in 1950 to 34.82% (X.X- Y.Y%) in 2016, and is forecasted to reach 56.19% percent (95% CI X.X- Y.Y%) by 2040.

Figure 5. shows the distribution of education for the world's most populous countries. Interesting differences can be noted between the world's two most populous countries, China and India. While China has steadily reduced the number of individuals in the lowest educational category, a substantial number of individuals in this category remain in this category in India throughout the projections. Similarly, the number of individuals in China achieving tertiary education has grown rapidly in recent years, and will continue to grow at a rapid pace if current trends continue. By 2040, we expect

Bangladesh, India, Pakistan, and Nigeria will continue to have substantial numbers of individuals in the lowest education category.

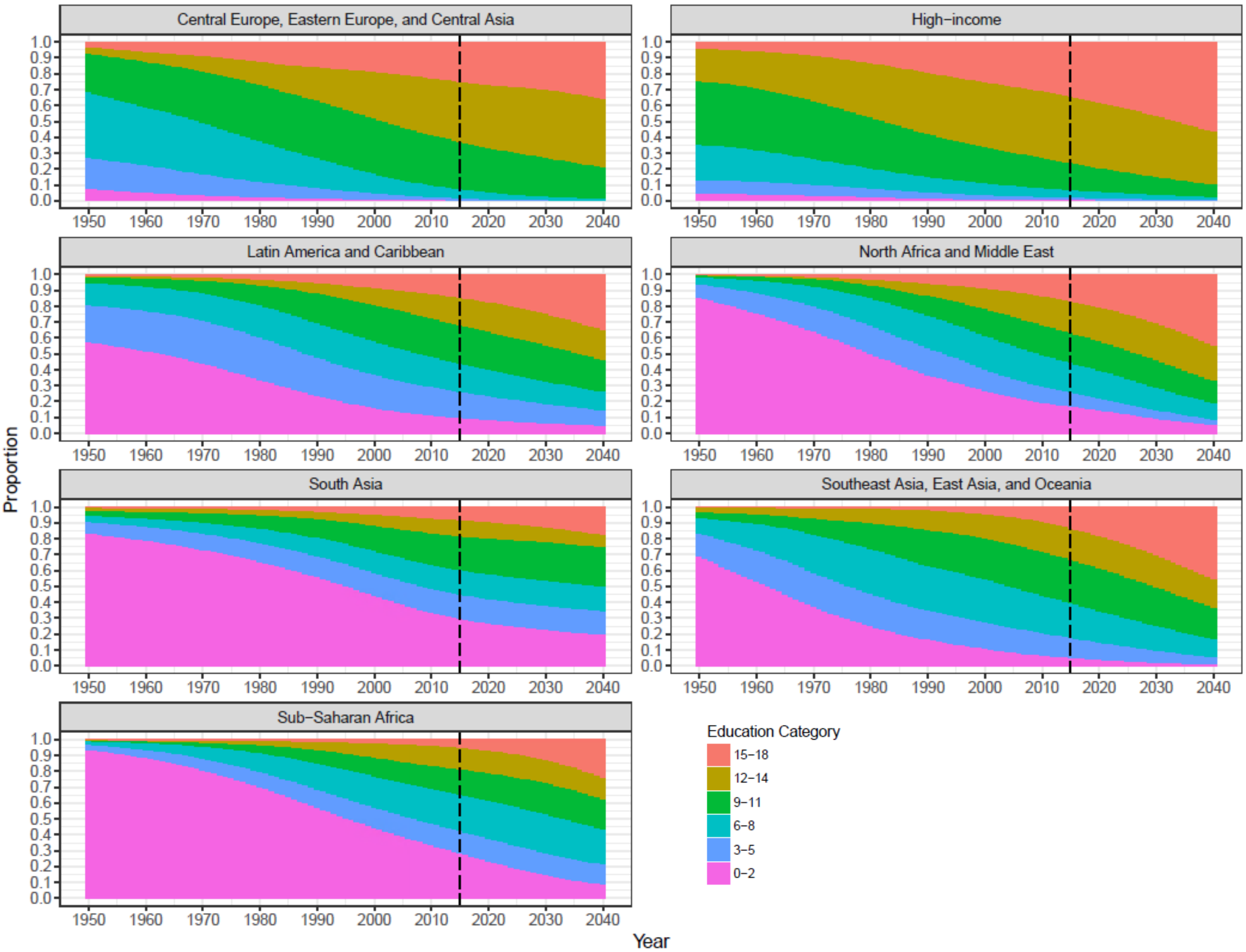


Figure 4. Distribution of educational attainment shown multi-year bins for each super-region used in the GBD 2015 study. The vertical dashed line indicates 2016, the last year before forecasts begin.

| | 0-2 | | 3-5 | | 6-8 | | 9-11 | | 12-14 | | 15-18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Country** | ***2016*** | ***2040*** | ***2016*** | ***2040*** | ***2016*** | ***2040*** | ***2016*** | ***2040*** | ***2016*** | ***2040*** | ***2016*** | ***2040*** |
| Afghanistan | 82.499 | 20.376 | 11.321 | 9.496 | 1.564 | 9.641 | 2.319 | 16.378 | 1.532 | 25.762 | 0.764 | 18.347 |
| Albania | 1.278 | 0.354 | 4.846 | 0.778 | 30.967 | 10.42 | 6.386 | 3.413 | 44.228 | 60.213 | 12.295 | 24.822 |
| Algeria | 5.428 | 1.999 | 19.12 | 6.695 | 29.777 | 16.039 | 25.1 | 16.85 | 8.311 | 16.814 | 12.263 | 41.604 |
| Andorra | 0.282 | 0.182 | 0.392 | 0.147 | 2.4 | 0.585 | 19.616 | 8.263 | 36.272 | 29.002 | 41.038 | 61.821 |
| Angola | 16.15 | 2.279 | 29.847 | 17.633 | 30.462 | 22.247 | 14.452 | 20.135 | 7.718 | 12.21 | 1.371 | 25.496 |
| Antigua and Barbuda | 5.116 | 2.092 | 6.515 | 2.294 | 16.624 | 6.026 | 27.809 | 21.833 | 26.946 | 28.622 | 16.99 | 39.132 |
| Argentina | 1.919 | 0.518 | 4.575 | 1.49 | 26.367 | 15.227 | 16.49 | 12.455 | 29.574 | 29.012 | 21.075 | 41.298 |
| Armenia | 0.443 | 0.122 | 1.077 | 0.175 | 8.717 | 3.281 | 37.602 | 31.335 | 25.021 | 29.565 | 27.139 | 35.521 |
| Australia | 0.2 | 0.191 | 0.269 | 0.121 | 2.312 | 0.297 | 19.349 | 7.955 | 34.838 | 25.84 | 43.032 | 65.595 |
| Austria | 0.337 | 0.286 | 0.116 | 0.087 | 0.394 | 0.147 | 31.005 | 14.808 | 43.948 | 38.021 | 24.201 | 46.65 |
| Azerbaijan | 0.844 | 0.184 | 1.032 | 0.164 | 5.221 | 2.757 | 61.746 | 49.659 | 17.258 | 22.907 | 13.898 | 24.329 |
| Bahrain | 20.208 | 6.882 | 4.497 | 1.819 | 16.314 | 10.591 | 20.941 | 14.275 | 27.491 | 27.445 | 10.551 | 38.987 |
| Bangladesh | 35.509 | 25.238 | 21.833 | 21.382 | 15.558 | 16.98 | 19.083 | 22.485 | 5.74 | 4.698 | 2.277 | 9.217 |
| Barbados | 1.362 | 0.65 | 5.042 | 1.404 | 8.604 | 2.524 | 42.474 | 27.129 | 20.353 | 25.137 | 22.165 | 43.156 |
| Belarus | 0.327 | 0.108 | 1.694 | 0.049 | 3.01 | 0.319 | 21.504 | 10.065 | 41.633 | 47.085 | 31.834 | 42.374 |
| Belgium | 0.236 | 0.212 | 0.132 | 0.088 | 1.424 | 0.276 | 15.282 | 4.957 | 37.045 | 28.729 | 45.882 | 65.738 |
| Belize | 7.057 | 2.551 | 7.725 | 3.019 | 27.558 | 15.627 | 23.687 | 27.728 | 28.967 | 41.294 | 5.006 | 9.781 |
| Benin | 44.712 | 15.576 | 15.901 | 16.616 | 14.987 | 17.621 | 13.575 | 17.159 | 6.596 | 8.531 | 4.228 | 24.497 |
| Bhutan | 41.099 | 27.3 | 14.921 | 16.35 | 13.714 | 14.986 | 17.143 | 20.164 | 5.66 | 5.051 | 7.463 | 16.149 |
| Bolivia | 12.292 | 5.583 | 15.495 | 7.02 | 12.538 | 6.878 | 19.629 | 17.738 | 22.018 | 20.84 | 18.028 | 41.941 |
| Bosnia and Herzegovina | 4.5 | 0.708 | 7.312 | 1.63 | 16.073 | 6.117 | 21.463 | 10.5 | 41.425 | 59.483 | 9.227 | 21.563 |
| Botswana | 7.305 | 1.589 | 6.67 | 2.959 | 23.137 | 14.398 | 34.389 | 27.704 | 23.641 | 22.081 | 4.858 | 31.269 |
| Brazil | 11.834 | 7.388 | 27.1 | 18.828 | 18.675 | 15.418 | 18.582 | 17.18 | 12.045 | 14.14 | 11.764 | 27.047 |
| Brunei | 2.947 | 0.746 | 0.6 | 0.094 | 0.675 | 0.126 | 7.199 | 1.345 | 43.972 | 27.319 | 44.608 | 70.37 |
| Bulgaria | 0.333 | 0.263 | 0.761 | 0.343 | 4.134 | 1.599 | 16.236 | 6.169 | 45.916 | 51.945 | 32.621 | 39.681 |
| Burkina Faso | 60.571 | 19.983 | 10.482 | 16.544 | 13.916 | 19.778 | 10.29 | 19.694 | 3.167 | 7.834 | 1.574 | 16.167 |
| Burundi | 26.039 | 7.54 | 35.605 | 23.012 | 23.235 | 28.275 | 6.769 | 15.582 | 5.746 | 10.931 | 2.606 | 14.66 |
| Cambodia | 21.685 | 7.194 | 24.521 | 12.198 | 26.028 | 21.288 | 16.502 | 20.571 | 7.746 | 13.293 | 3.517 | 25.456 |
| Cameroon | 20.824 | 7.428 | 15.054 | 11.436 | 26.868 | 20.451 | 21.755 | 21.992 | 9.148 | 10.289 | 6.352 | 28.404 |
| Canada | 0.179 | 0.133 | 0.366 | 0.272 | 1.332 | 0.354 | 7.51 | 2.895 | 36.712 | 30.03 | 53.899 | 66.317 |
| Cape Verde | 24.373 | 12.109 | 28.452 | 20.347 | 22.677 | 19.235 | 16.027 | 16.634 | 4.243 | 6.545 | 4.228 | 25.13 |
| Central African Republic | 24.402 | 4.038 | 31.123 | 19.099 | 21.634 | 20.017 | 13.892 | 19.449 | 6.785 | 11.856 | 2.163 | 25.542 |
| Chad | 52.942 | 16.756 | 15.463 | 17.567 | 12.753 | 17.938 | 10.176 | 17.336 | 5.411 | 8.463 | 3.254 | 21.94 |
| Chile | 1.426 | 0.323 | 6.165 | 2.314 | 16.372 | 11.671 | 12.856 | 9.627 | 40.855 | 34.788 | 22.326 | 41.277 |
| China | 3.86 | 0.512 | 12.091 | 4.107 | 20.672 | 9.199 | 28.073 | 18.022 | 19.96 | 17.72 | 15.344 | 50.44 |
| Colombia | 11.451 | 5.918 | 20.353 | 9.455 | 13.928 | 9.744 | 30.837 | 24.22 | 12.186 | 16.602 | 11.245 | 34.061 |
| Comoros | 30.744 | 9.506 | 12.501 | 12.076 | 21.252 | 22.216 | 17.748 | 18.628 | 10.355 | 12.008 | 7.4 | 25.566 |
| Congo | 11.514 | 1.854 | 13.553 | 11.389 | 25.331 | 17.831 | 27.198 | 19.75 | 14.87 | 12.502 | 7.535 | 36.674 |
| Costa Rica | 7.308 | 3.987 | 9.381 | 4.869 | 33.701 | 18.582 | 25.383 | 21.286 | 10.011 | 14.407 | 14.216 | 36.868 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cote d'Ivoire | 38.491 | 12.171 | 15.746 | 15.962 | 16.835 | 18.199 | 15.207 | 17.625 | 8.106 | 8.953 | 5.616 | 27.09 |
| Croatia | 0.252 | 0.192 | 0.854 | 0.114 | 3.989 | 0.442 | 12.422 | 4.894 | 57.311 | 59.152 | 25.172 | 35.207 |
| Cuba | 3.246 | 0.951 | 1.357 | 0.651 | 9.958 | 3.649 | 26.37 | 20.006 | 47.618 | 45.602 | 11.451 | 29.141 |
| Cyprus | 0.285 | 0.202 | 1.355 | 0.12 | 10.141 | 1.907 | 7.851 | 4.623 | 43.114 | 32.872 | 37.254 | 60.276 |
| Czech Republic | 0.183 | 0.167 | 0.107 | 0.076 | 0.397 | 0.166 | 10.244 | 4.073 | 66.147 | 62.251 | 22.922 | 33.267 |
| Democratic Republic of the Congo | 12.28 | 2.027 | 20.748 | 11.681 | 26.968 | 19.961 | 21.849 | 20.368 | 13.313 | 13.277 | 4.841 | 32.686 |
| Denmark | 0.323 | 0.268 | 0.104 | 0.076 | 0.264 | 0.114 | 7.425 | 3.017 | 15.296 | 12.416 | 76.588 | 84.11 |
| Djibouti | 33.441 | 12.319 | 6.232 | 9.645 | 24.92 | 26.301 | 25.351 | 22.965 | 5.389 | 9.045 | 4.666 | 19.725 |
| Dominica | 4.193 | 1.581 | 12.759 | 4.052 | 13.633 | 5.239 | 18.158 | 16.519 | 28.93 | 28.06 | 22.328 | 44.549 |
| Dominican Republic | 12.327 | 5.316 | 11.918 | 3.91 | 17.357 | 6.645 | 19.507 | 17.841 | 24.927 | 30.83 | 13.965 | 35.458 |
| Ecuador | 7.078 | 4.081 | 7.601 | 4.058 | 24.987 | 11.443 | 17.704 | 16.904 | 24.73 | 22.166 | 17.9 | 41.348 |
| Egypt | 21.515 | 7.052 | 7.533 | 2.678 | 9.183 | 5.615 | 21.168 | 16.266 | 22.668 | 21.714 | 17.932 | 46.674 |
| El Salvador | 19.139 | 8.437 | 12.406 | 5.848 | 17.534 | 11.235 | 21.844 | 18.794 | 17.484 | 19.461 | 11.594 | 36.225 |
| Equatorial Guinea | 12.167 | 2.279 | 20.856 | 13.227 | 24.562 | 17.958 | 25.557 | 19.812 | 10.756 | 11.214 | 6.102 | 35.51 |
| Eritrea | 31.036 | 9.743 | 16.753 | 14.714 | 21.767 | 24.256 | 17.955 | 20.574 | 8.378 | 11.526 | 4.112 | 19.187 |
| Estonia | 0.193 | 0.142 | 0.107 | 0.056 | 0.425 | 0.094 | 11.903 | 5.646 | 44.926 | 44.404 | 42.447 | 49.659 |
| Ethiopia | 48.231 | 15.895 | 16.521 | 16.15 | 18.457 | 24.2 | 8.936 | 16.521 | 5.415 | 10.758 | 2.441 | 16.477 |
| Federated States of Micronesia | 4.611 | 0.743 | 3.012 | 0.378 | 10.491 | 3.023 | 26.286 | 15.068 | 34.751 | 22.948 | 20.85 | 57.841 |
| Fiji | 1.267 | 0.333 | 3.458 | 0.635 | 18.756 | 4.929 | 33.445 | 19.231 | 25.44 | 21.545 | 17.635 | 53.326 |
| Finland | 0.302 | 0.255 | 0.281 | 0.217 | 1.803 | 0.224 | 16.257 | 5.045 | 25.736 | 22.199 | 55.622 | 72.06 |
| France | 3.26 | 1.515 | 6.25 | 1.809 | 4.906 | 1.326 | 13.752 | 5.968 | 33.261 | 28.23 | 38.571 | 61.153 |
| Gabon | 11.538 | 1.979 | 14.601 | 9.429 | 26.101 | 17.095 | 25.695 | 18.765 | 12.4 | 11.291 | 9.666 | 41.44 |
| Georgia | 0.505 | 0.163 | 1.253 | 0.213 | 3.783 | 1.719 | 48.768 | 39.708 | 10.306 | 16.9 | 35.385 | 41.296 |
| Germany | 0.249 | 0.214 | 0.112 | 0.091 | 0.363 | 0.159 | 40.034 | 18.454 | 29.029 | 28.929 | 30.213 | 52.152 |
| Ghana | 21.831 | 8.319 | 10.306 | 13.609 | 20.409 | 20.603 | 29.163 | 16.563 | 9.502 | 9.005 | 8.788 | 31.901 |
| Greece | 0.338 | 0.217 | 2.316 | 0.172 | 17.459 | 4.394 | 9.888 | 5.196 | 34.796 | 30.662 | 35.202 | 59.359 |
| Grenada | 4.632 | 1.914 | 9.495 | 3.483 | 27.391 | 10.856 | 23.566 | 21.425 | 26.326 | 32.898 | 8.591 | 29.424 |
| Guam | 0.333 | 0.119 | 0.562 | 0.103 | 0.665 | 0.22 | 13.054 | 11.275 | 51.257 | 25.805 | 34.128 | 62.478 |
| Guatemala | 23.686 | 8.888 | 13.757 | 6.535 | 24.283 | 15.141 | 19.148 | 20.245 | 12.83 | 19.229 | 6.297 | 29.962 |
| Guinea | 53.432 | 18.654 | 12.082 | 15.19 | 12.483 | 16.266 | 10.759 | 16.04 | 6.158 | 8.518 | 5.086 | 25.331 |
| Guinea-Bissau | 42.559 | 14.147 | 19.666 | 18.514 | 17.812 | 20.895 | 15.034 | 20.823 | 2.711 | 6.801 | 2.218 | 18.821 |
| Guyana | 3.255 | 1.505 | 9.158 | 3.591 | 21.131 | 8.045 | 52.587 | 39.383 | 10.949 | 27.418 | 2.92 | 20.058 |
| Haiti | 26.797 | 9.189 | 15.117 | 5.79 | 15.967 | 6.825 | 23.208 | 22.632 | 13.059 | 27.027 | 5.852 | 28.538 |
| Honduras | 17.466 | 7.301 | 14.35 | 6.605 | 30.729 | 17.65 | 13.797 | 16.48 | 14.327 | 18.781 | 9.331 | 33.183 |
| Hungary | 0.204 | 0.168 | 0.273 | 0.092 | 3.913 | 0.678 | 22.936 | 10.107 | 50.198 | 56.4 | 22.476 | 32.555 |
| Iceland | 0.159 | 0.137 | 0.13 | 0.082 | 0.689 | 0.112 | 13.186 | 5.348 | 14.652 | 13.848 | 71.184 | 80.472 |
| India | 26.59 | 18.444 | 14.646 | 13.342 | 15.768 | 15.195 | 22.237 | 25.391 | 11.13 | 8.598 | 9.629 | 19.03 |
| Indonesia | 9.538 | 2.606 | 7.618 | 3.357 | 26.595 | 15.311 | 21.633 | 20.395 | 24.536 | 20.865 | 10.079 | 37.466 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iran | 6.055 | 2.736 | 6.257 | 2.334 | 15.039 | 7.827 | 19.28 | 11.594 | 28.57 | 23.27 | 24.798 | 52.239 |
| Iraq | 14.569 | 3.331 | 13.017 | 4.144 | 27.994 | 14.759 | 15.137 | 13.709 | 18.559 | 22.954 | 10.724 | 41.104 |
| Ireland | 0.261 | 0.219 | 0.14 | 0.092 | 2.558 | 0.612 | 21.279 | 8.472 | 40.587 | 32.596 | 35.175 | 58.008 |
| Israel | 0.244 | 0.155 | 0.367 | 0.094 | 3.361 | 0.695 | 8.128 | 4.446 | 52.106 | 37.61 | 35.793 | 57 |
| Italy | 0.5 | 0.364 | 5.571 | 0.286 | 10.635 | 3.158 | 15.871 | 8.431 | 37.464 | 34.493 | 29.959 | 53.268 |
| Jamaica | 0.918 | 0.451 | 2.392 | 0.787 | 15.326 | 5.37 | 56.207 | 41.269 | 19.737 | 30.241 | 5.42 | 21.882 |
| Japan | 0.111 | 0.096 | 0.105 | 0.058 | 0.786 | 0.055 | 13.916 | 2.4 | 54.761 | 38.243 | 30.321 | 59.148 |
| Jordan | 4.419 | 1.318 | 3.209 | 1.172 | 10.013 | 5.81 | 30.635 | 16.672 | 31.46 | 25.635 | 20.263 | 49.393 |
| Kazakhstan | 0.646 | 0.133 | 1.497 | 0.233 | 11.927 | 4.568 | 63.234 | 51.761 | 15.131 | 22.601 | 7.565 | 20.705 |
| Kenya | 10.003 | 3.559 | 10.338 | 8.331 | 38.552 | 32.484 | 15.345 | 13.988 | 20.383 | 20.532 | 5.379 | 21.106 |
| Kiribati | 26.329 | 6.076 | 6.282 | 1.7 | 13.7 | 5.266 | 44.725 | 38.281 | 6.354 | 21.162 | 2.61 | 27.514 |
| Kuwait | 6.133 | 2.579 | 3.629 | 1.46 | 16.232 | 8.877 | 19.553 | 11.501 | 28.402 | 20.841 | 26.051 | 54.742 |
| Kyrgyzstan | 0.424 | 0.092 | 0.654 | 0.119 | 3.743 | 1.315 | 41.889 | 34.419 | 31.304 | 31.989 | 21.986 | 32.066 |
| Laos | 16.472 | 4.118 | 26.837 | 9.897 | 19.206 | 16.01 | 15.346 | 18.579 | 13.878 | 15.928 | 8.261 | 35.467 |
| Latvia | 0.168 | 0.124 | 0.258 | 0.077 | 2.171 | 0.199 | 18.403 | 9.072 | 45.103 | 47.117 | 33.897 | 43.41 |
| Lebanon | 2.455 | 1.148 | 4.104 | 1.281 | 16.84 | 9.95 | 20.801 | 12.546 | 31.84 | 25.353 | 23.961 | 49.722 |
| Lesotho | 9.995 | 1.765 | 12.85 | 3.839 | 30.12 | 14.641 | 23.937 | 25.638 | 12.513 | 14.522 | 10.584 | 39.595 |
| Liberia | 35.677 | 12.182 | 15.243 | 16.134 | 18.865 | 20.102 | 14.148 | 19.092 | 13.075 | 12.797 | 2.991 | 19.693 |
| Libya | 5.726 | 1.998 | 4.028 | 1.83 | 23.369 | 11.756 | 17.791 | 11.814 | 32.335 | 24.148 | 16.751 | 48.455 |
| Lithuania | 0.228 | 0.144 | 0.549 | 0.071 | 2.373 | 0.078 | 12.575 | 5.325 | 42.871 | 43.602 | 41.405 | 50.779 |
| Luxembourg | 0.255 | 0.217 | 0.297 | 0.141 | 2.31 | 1.312 | 18.97 | 8.073 | 29.1 | 23.172 | 49.068 | 67.085 |
| Macedonia | 3.591 | 0.99 | 8.635 | 1.728 | 26.082 | 8.746 | 12.983 | 7.259 | 45.903 | 72.282 | 2.807 | 8.995 |
| Madagascar | 26.66 | 7.809 | 35.696 | 26.21 | 21.025 | 30.819 | 10.937 | 16.523 | 3.678 | 7.319 | 2.004 | 11.319 |
| Malawi | 17.674 | 5.672 | 23.378 | 17.948 | 30.484 | 27.025 | 16.194 | 22.241 | 10.692 | 14.98 | 1.577 | 12.133 |
| Malaysia | 6.394 | 1.876 | 6.812 | 3.29 | 19.157 | 11.87 | 39.663 | 26.071 | 12.863 | 13.665 | 15.111 | 43.228 |
| Maldives | 17.819 | 6.165 | 5.716 | 4.057 | 28.812 | 22.096 | 33.861 | 25.661 | 8.309 | 11.971 | 5.483 | 30.05 |
| Mali | 62.592 | 20.921 | 10.961 | 16.492 | 11.697 | 16.407 | 8.42 | 17.001 | 3.517 | 8.275 | 2.813 | 20.905 |
| Malta | 0.257 | 0.193 | 0.309 | 0.109 | 2.58 | 0.648 | 49.269 | 26.477 | 24.268 | 25.075 | 23.318 | 47.497 |
| Marshall Islands | 2.149 | 0.4 | 3.911 | 0.477 | 17.44 | 3.304 | 29.469 | 18.649 | 31.91 | 25.515 | 15.122 | 51.656 |
| Mauritania | 32.959 | 11.091 | 17.285 | 16.417 | 18.941 | 18.498 | 16.201 | 18.381 | 9.047 | 9.426 | 5.567 | 26.188 |
| Mauritius | 7.299 | 2.434 | 8.363 | 4.468 | 19.737 | 14.311 | 20.183 | 17.069 | 32.158 | 21.946 | 12.26 | 39.772 |
| Mexico | 4.179 | 1.753 | 4.824 | 2.302 | 15.781 | 8.863 | 26.211 | 20.202 | 25.384 | 20.934 | 23.62 | 45.946 |
| Moldova | 0.669 | 0.154 | 3.533 | 0.639 | 10.839 | 2.293 | 37.44 | 18.397 | 35.978 | 51.162 | 11.541 | 27.355 |
| Mongolia | 3.467 | 0.815 | 5.666 | 2.144 | 16.986 | 9.1 | 40.006 | 39.497 | 15.815 | 18.86 | 18.059 | 29.584 |
| Montenegro | 0.567 | 0.353 | 1.505 | 0.102 | 1.437 | 0.161 | 6.659 | 2.349 | 55.599 | 53.341 | 34.233 | 43.695 |
| Morocco | 23.349 | 8.644 | 12.27 | 4.444 | 12.941 | 8.602 | 17.538 | 12.347 | 21.486 | 23.581 | 12.416 | 42.383 |
| Mozambique | 34.428 | 9.587 | 28.844 | 21.086 | 22.228 | 27.731 | 9.728 | 19.538 | 3.599 | 9.901 | 1.173 | 12.158 |
| Myanmar | 13.344 | 3.554 | 25.006 | 9.615 | 18.511 | 15.072 | 20.34 | 19.526 | 12.929 | 14.072 | 9.869 | 38.161 |
| Namibia | 10.208 | 2.011 | 9.258 | 3.263 | 21.156 | 11.313 | 31.14 | 26.496 | 19.337 | 19.508 | 8.901 | 37.409 |
| Nepal | 44.482 | 28.906 | 15.858 | 19.757 | 16.134 | 18.439 | 20.68 | 26.145 | 2.348 | 2.623 | 0.499 | 4.131 |
| Netherlands | 0.224 | 0.193 | 0.132 | 0.082 | 1.654 | 0.256 | 16.524 | 5.753 | 28.677 | 22.316 | 52.789 | 71.4 |
| New Zealand | 0.343 | 0.244 | 0.739 | 0.331 | 0.93 | 0.207 | 20.574 | 8.306 | 36.689 | 26.086 | 40.725 | 64.825 |
| Nicaragua | 16.6 | 7.784 | 14.385 | 6.545 | 24.331 | 14.567 | 24.466 | 21.391 | 9.151 | 14.686 | 11.067 | 35.027 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Niger | 64.327 | 19.145 | 12.482 | 18.936 | 10.907 | 20.108 | 8.64 | 18.999 | 2.155 | 7.115 | 1.489 | 15.696 |
| Nigeria | 26.971 | 9.113 | 3.749 | 5.449 | 20.005 | 16.429 | 14.009 | 18.822 | 27.148 | 20.751 | 8.118 | 29.437 |
| North Korea | 0.534 | 0.032 | 12.555 | 1.563 | 44.653 | 12.194 | 16.19 | 12.296 | 15.281 | 21.234 | 10.788 | 52.681 |
| Norway | 0.209 | 0.169 | 0.252 | 0.187 | 0.252 | 0.121 | 12.383 | 4.355 | 32.874 | 24.886 | 54.03 | 70.281 |
| Oman | 14.214 | 5.897 | 6.258 | 2.91 | 18.686 | 10.916 | 19.263 | 12.52 | 26.661 | 24.101 | 14.917 | 43.655 |
| Pakistan | 41.003 | 23.693 | 14.437 | 17.281 | 13.1 | 15.483 | 18.877 | 22.87 | 8.109 | 6.762 | 4.473 | 13.911 |
| Palestine | 7.921 | 2.015 | 3.054 | 1.044 | 13.71 | 7.311 | 30.033 | 16.953 | 28.588 | 24.825 | 16.694 | 47.853 |
| Panama | 7.407 | 3.91 | 6.285 | 3.053 | 22.928 | 12.099 | 19.832 | 17.159 | 24.201 | 21.085 | 19.347 | 42.694 |
| Papua New Guinea | 24.111 | 3.995 | 6.142 | 1.003 | 15.857 | 4.193 | 18.051 | 16.456 | 21.988 | 24.932 | 13.851 | 49.42 |
| Paraguay | 8.131 | 5.006 | 20.543 | 14.247 | 26.707 | 19.192 | 14.768 | 16.223 | 17.05 | 16.243 | 12.801 | 29.089 |
| Peru | 8.601 | 4.51 | 11.613 | 5.512 | 11.727 | 7.005 | 37.736 | 27.585 | 16.385 | 20.397 | 13.937 | 34.991 |
| Philippines | 1.512 | 0.665 | 7.031 | 3.496 | 22.49 | 15.614 | 42.276 | 37.445 | 20.749 | 17.135 | 5.942 | 25.644 |
| Poland | 0.281 | 0.232 | 0.3 | 0.104 | 2.559 | 0.389 | 14.774 | 5.482 | 47.808 | 49.194 | 34.279 | 44.599 |
| Portugal | 0.985 | 0.37 | 11.379 | 3.298 | 23.898 | 11.418 | 19.941 | 13.608 | 21.759 | 25.251 | 22.039 | 46.054 |
| Puerto Rico | 1.844 | 0.641 | 2.705 | 0.706 | 4.288 | 1.463 | 8.185 | 6.054 | 49.357 | 37.388 | 33.622 | 53.748 |
| Qatar | 15.271 | 5.339 | 4.63 | 1.627 | 15.224 | 7.814 | 18.076 | 10.895 | 19.81 | 18.63 | 26.989 | 55.695 |
| Romania | 1.727 | 0.458 | 2.138 | 0.338 | 5.317 | 0.69 | 21.225 | 8.605 | 55.28 | 61.404 | 14.313 | 28.507 |
| Russia | 0.139 | 0.09 | 0.954 | 0.094 | 6.021 | 0.665 | 26.753 | 13.724 | 40.119 | 47.968 | 26.014 | 37.459 |
| Rwanda | 25.009 | 8.281 | 30.218 | 21.02 | 29.858 | 31.166 | 8.015 | 15.853 | 5.312 | 10.743 | 1.589 | 12.936 |
| Saint Lucia | 2.801 | 1.114 | 6.78 | 2.554 | 26 | 10.936 | 15.793 | 16.018 | 40.258 | 42.188 | 8.368 | 27.19 |
| Saint Vincent and the Grenadines | 6.592 | 2.761 | 14.601 | 5.131 | 21.35 | 7.714 | 28.051 | 22.922 | 21.155 | 30.307 | 8.251 | 31.165 |
| Samoa | 2.331 | 0.513 | 3.476 | 0.68 | 12.104 | 3.311 | 46.046 | 25.825 | 24.016 | 21.972 | 12.029 | 47.699 |
| Sao Tome and Principe | 10.772 | 4.451 | 35.22 | 24.377 | 32.752 | 26.104 | 17.123 | 20.237 | 1.883 | 5.57 | 2.25 | 19.26 |
| Saudi Arabia | 15.758 | 6.036 | 1.494 | 0.67 | 16.25 | 6.503 | 18.537 | 11.214 | 24.621 | 21.592 | 23.341 | 53.984 |
| Senegal | 49.951 | 17.572 | 15.731 | 21.132 | 12.814 | 10.753 | 11.745 | 19.465 | 6.054 | 9.859 | 3.705 | 21.22 |
| Serbia | 1.661 | 0.545 | 2.908 | 0.36 | 3.781 | 0.839 | 12.748 | 4.389 | 55.096 | 62.267 | 23.806 | 31.6 |
| Seychelles | 6.175 | 1.76 | 3.746 | 2.092 | 27.349 | 17.354 | 35.129 | 26.532 | 14.696 | 15.366 | 12.906 | 36.896 |
| Sierra Leone | 48.947 | 18.059 | 9.326 | 14.27 | 17.858 | 19.856 | 16.355 | 20.004 | 4.909 | 9.403 | 2.605 | 18.409 |
| Singapore | 3.286 | 0.576 | 0.879 | 0.397 | 10.491 | 3.42 | 21.112 | 5.295 | 24.221 | 23.066 | 40.011 | 67.247 |
| Slovakia | 0.255 | 0.2 | 0.121 | 0.086 | 0.376 | 0.142 | 9.25 | 3.385 | 66.421 | 62.881 | 23.576 | 33.307 |
| Slovenia | 0.26 | 0.209 | 0.437 | 0.134 | 3.274 | 0.752 | 15.961 | 6.452 | 46.213 | 48.417 | 33.855 | 44.035 |
| Solomon Islands | 12.653 | 2.315 | 12 | 1.976 | 26.283 | 6.94 | 32.717 | 25.049 | 7.342 | 19.327 | 9.005 | 44.393 |
| Somalia | 46.904 | 12.53 | 10.503 | 13.194 | 18.887 | 25.96 | 10.569 | 17.639 | 9.032 | 12.576 | 4.105 | 18.1 |
| South Africa | 1.834 | 0.491 | 4.225 | 1.642 | 12.558 | 7.004 | 29.942 | 24.901 | 39.9 | 27.011 | 11.541 | 38.951 |
| South Korea | 1.576 | 0.123 | 0.54 | 0.097 | 7.609 | 1.428 | 5.961 | 2.574 | 45.908 | 32.357 | 38.406 | 63.422 |
| South Sudan | 58.562 | 16.941 | 12.173 | 13.298 | 14.787 | 25.845 | 8.985 | 19.589 | 3.212 | 9.317 | 2.281 | 15.011 |
| Spain | 1.238 | 0.302 | 3.798 | 0.539 | 11.251 | 3.606 | 26.067 | 14.343 | 24.81 | 25.349 | 32.836 | 55.861 |
| Sri Lanka | 7.253 | 2.369 | 10.214 | 5.075 | 16.128 | 11.486 | 35.774 | 27.193 | 21.599 | 18.607 | 9.031 | 35.27 |
| Sudan | 33.241 | 8.538 | 10.112 | 3.877 | 21.796 | 13.686 | 18.865 | 16.494 | 7.966 | 18.988 | 8.02 | 38.417 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Suriname | 6.533 | 2.656 | 12.385 | 4.283 | 22.505 | 7.94 | 32.633 | 27.002 | 20.095 | 31.881 | 5.848 | 26.238 |
| Swaziland | 12.096 | 1.896 | 9.443 | 2.985 | 23.039 | 12.781 | 26.181 | 24.061 | 20.182 | 19.401 | 9.059 | 38.875 |
| Sweden | 0.368 | 0.291 | 0.284 | 0.189 | 1.805 | 0.172 | 15.514 | 5.799 | 40.334 | 35.573 | 41.695 | 57.977 |
| Switzerland | 1.554 | 0.715 | 0.096 | 0.068 | 0.103 | 0.075 | 0.411 | 0.958 | 70.536 | 45.401 | 27.3 | 52.782 |
| Syria | 12.158 | 3.535 | 6.192 | 2.446 | 30.249 | 14.795 | 19.637 | 13.717 | 21.838 | 23.206 | 9.927 | 42.302 |
| Taiwan | 0.865 | 0.081 | 0.953 | 0.122 | 12.296 | 3.542 | 12.928 | 8.195 | 39.673 | 21.336 | 33.284 | 66.724 |
| Tajikistan | 1.822 | 0.33 | 1.673 | 0.376 | 9.072 | 3.073 | 57.45 | 47.927 | 16.766 | 23.818 | 13.218 | 24.476 |
| Tanzania | 17.448 | 5.278 | 12.681 | 9.624 | 53.475 | 40.905 | 10.802 | 20.545 | 4.092 | 10.571 | 1.502 | 13.078 |
| Thailand | 4.473 | 1.713 | 25.468 | 11.159 | 19.401 | 13.293 | 15.698 | 13.433 | 11.226 | 9.619 | 23.733 | 50.782 |
| The Bahamas | 3.264 | 1.402 | 2.392 | 0.913 | 7.628 | 3.113 | 48.891 | 32.047 | 26.655 | 32.14 | 11.171 | 30.385 |
| The Gambia | 41.555 | 13.846 | 8.217 | 12.365 | 16.356 | 18.546 | 18.157 | 20.59 | 12.02 | 13.298 | 3.695 | 21.354 |
| Timor-Leste | 26.641 | 5.295 | 10.913 | 4.133 | 19.264 | 14.828 | 17.194 | 19.165 | 15.925 | 16.205 | 10.063 | 40.374 |
| Togo | 29.239 | 10.474 | 19.025 | 16.621 | 23.055 | 20.287 | 18.792 | 19.23 | 6.457 | 9.079 | 3.433 | 24.308 |
| Tonga | 3.439 | 0.623 | 3.476 | 0.614 | 15.354 | 3.789 | 42.078 | 26.034 | 28.858 | 28.488 | 6.796 | 40.452 |
| Trinidad and Tobago | 3.624 | 1.568 | 15.832 | 5.854 | 34.618 | 19.242 | 20.155 | 22.294 | 10.608 | 14.872 | 15.163 | 36.171 |
| Tunisia | 17.793 | 6.133 | 8.513 | 3.611 | 21.015 | 11.688 | 15.441 | 11.441 | 21.583 | 23.235 | 15.655 | 43.893 |
| Turkey | 1.116 | 0.544 | 7.605 | 2.725 | 27.427 | 12.747 | 19.067 | 12.192 | 21.771 | 25.157 | 23.013 | 46.634 |
| Turkmenistan | 1.048 | 0.216 | 1.08 | 0.187 | 6.686 | 2.377 | 68.198 | 50.318 | 11.019 | 20.1 | 11.97 | 26.803 |
| Uganda | 16.996 | 5.429 | 24.205 | 16.74 | 31.166 | 26.873 | 16.668 | 19.577 | 4.706 | 8.48 | 6.259 | 22.901 |
| Ukraine | 0.247 | 0.112 | 0.967 | 0.083 | 3.744 | 0.278 | 24.382 | 11.556 | 32.235 | 41.209 | 38.425 | 46.763 |
| United Arab Emirates | 4.107 | 1.905 | 2.807 | 1.1 | 9.333 | 4.153 | 17.782 | 10.654 | 33.329 | 22.877 | 32.642 | 59.311 |
| United Kingdom | 0.124 | 0.121 | 0.102 | 0.072 | 0.161 | 0.107 | 43.691 | 18.656 | 28.418 | 28.454 | 27.505 | 52.59 |
| United States | 0.329 | 0.209 | 0.511 | 0.386 | 1.798 | 1.054 | 8.786 | 5.474 | 51.864 | 38.484 | 36.711 | 54.393 |
| Uruguay | 1.212 | 0.298 | 5.983 | 1.743 | 30.655 | 18.037 | 25.382 | 18.314 | 18.105 | 22.653 | 18.664 | 38.956 |
| Uzbekistan | 0.494 | 0.1 | 0.853 | 0.103 | 4.075 | 1.534 | 67.779 | 50.445 | 13.338 | 21.261 | 13.462 | 26.557 |
| Vanuatu | 10.782 | 2.071 | 9.182 | 1.78 | 35.297 | 10.077 | 21.276 | 20.428 | 14.485 | 22.853 | 8.977 | 42.791 |
| Venezuela | 2.923 | 1.205 | 3.864 | 2.036 | 18.913 | 10.425 | 40.916 | 28.77 | 19.517 | 20.81 | 13.867 | 36.754 |
| Vietnam | 7.474 | 2.713 | 17.984 | 9.339 | 21.51 | 19.834 | 32.57 | 29.406 | 16.187 | 14.939 | 4.276 | 23.769 |
| Virgin Islands, U.S. | 1.274 | 0.584 | 2.196 | 0.759 | 3.18 | 1.38 | 9.739 | 8.189 | 51.618 | 39.907 | 31.993 | 49.181 |
| Yemen | 29.363 | 7.91 | 11.989 | 4.472 | 25.742 | 14.463 | 15.367 | 13.083 | 7.912 | 17.909 | 9.627 | 42.163 |
| Zambia | 12.26 | 4.286 | 15.609 | 14.336 | 32.576 | 23.589 | 21.855 | 23.226 | 14.712 | 18.886 | 2.988 | 15.677 |
| Zimbabwe | 4.643 | 0.89 | 6.169 | 2.508 | 26.84 | 16.505 | 52.057 | 38.436 | 3.191 | 7.507 | 7.1 | 34.155 |

Table 2. Distribution of adult 15+ population by educational attainment in 2016 and 2040, for 191 countries and territories.

***Measuring Inequality in Education***

*Implications of Absolute and Relative Inequality Metrics*

Educational attainment is a social indicator with somewhat different properties from other indicators typically measured with inequality metrics, such as wealth or income. Unlike income, where huge variations in average levels exists between countries, educational attainment is relatively bounded by the human lifespan, with almost all individuals attaining less than 19 years of education. Furthermore, the presence of individuals with zero education, who in some developing contexts represent the majority of the distribution, complicate which metrics can be applied to education. Studies examining inequality in education are limited, with the most comprehensive publication by Vinod et al. in 2001 examining data from 85 country-years [43]. The authors use the Gini coefficient as their metric of inequality in education, and look at the standard deviation of education to describe a Kuznets curve effect, where inequality first grows over time as average education increases, and then begins to shrink as higher levels of education are attained.

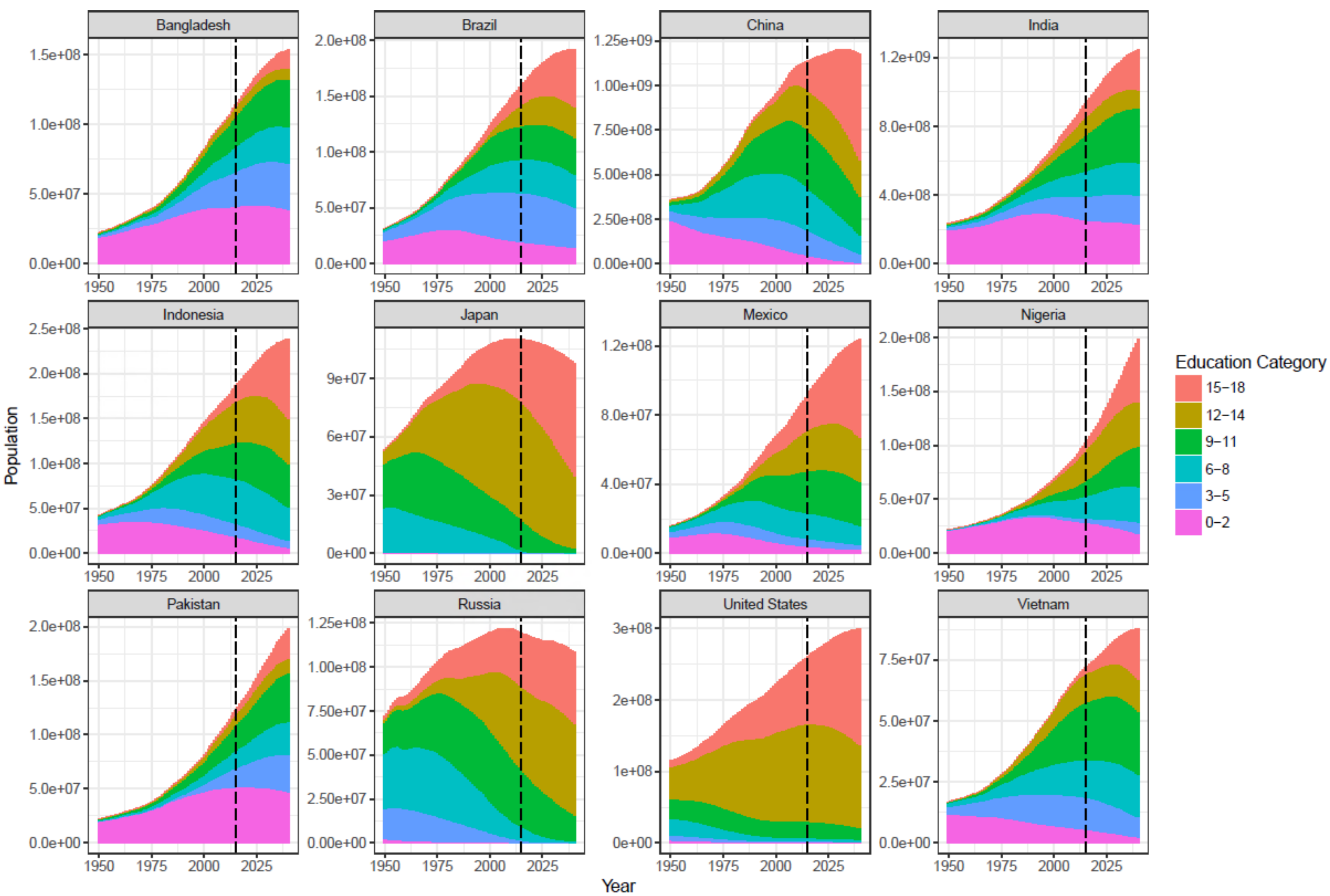


Figure 5. Population of 12 countries with largest number of 15+ individuals in the year 2016, according to WPP 2015 estimates. Shown by multi-year bin of educational. The vertical dashed line indicates 2016, the last year before forecasts begin.

Figure 6 details the relationship between average years of schooling and the Gini coefficient, and the absolute individual difference (AID), an absolute metric equal to the average absolute difference between every possible pair of individuals in a population. The Gini coefficient of education is highly collinear with average years of schooling, with a global correlation coefficient of -0.933, which is a result of the Gini coefficient's formulation as a *relative* inequality metric. As the Gini coefficient can be calculated as the absolute individual difference divided by two times the average years of schooling, average attainment can be thought of as "in the denominator" of the Gini coefficient. In the context of a highly bounded indicator like education, this effect induces very high correlation. Highly uneducated populations have misleadingly high Gini coefficients as only a few individuals have more than zero years of schooling. As populations become more educated, their Gini coefficient heads steadily towards zero, with minimal variation between populations.

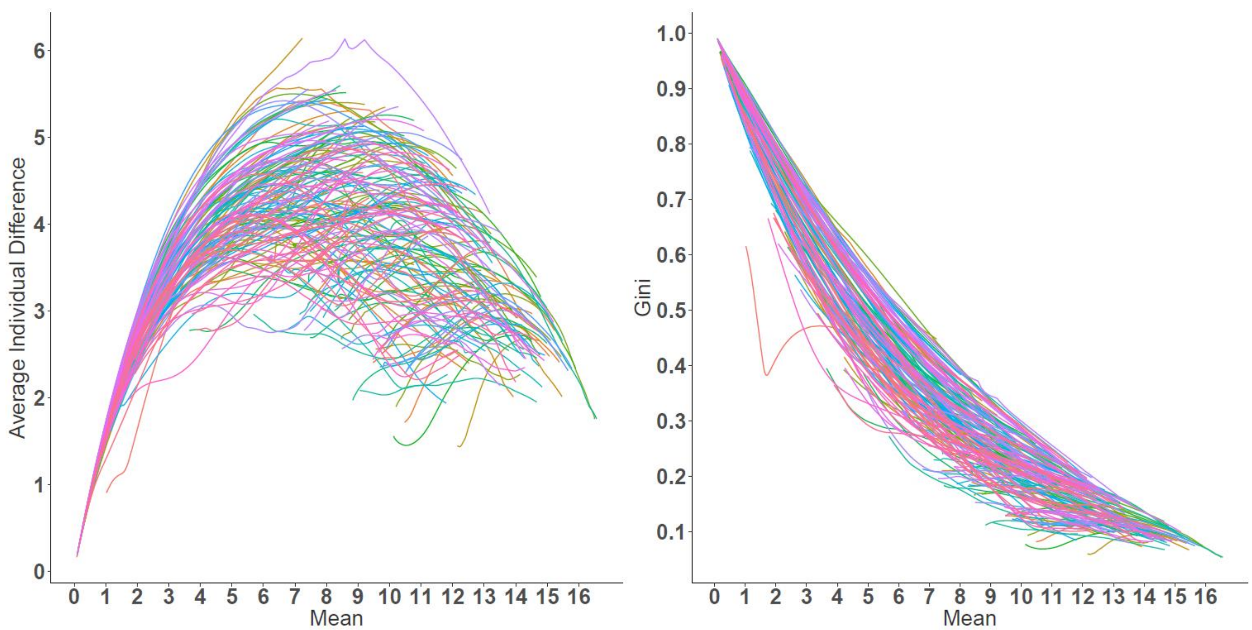


Figure 6. Relationship between average attainment and the average individual difference (left) and Gini coefficient (right) of educational attainment

The AID has a much more intuitive relationship with average attainment for representing inequality in education. Overall the relationship is much less correlated, with a global correlation coefficient of 0.397. We confirm the Kuznets curve pattern observed by Vinod et al. in their 2001 analysis; this trend is very clear in figure 6. All populations have near zero inequality when the total amount of education is very low, but as average education increases in a population, a variety of levels of inequality are observed for the same mean attainment, suggesting different populations have differing levels of equality in distributing the social good of education. Although the discussion of which metric inherently best captures inequality is epistemological in nature[44], our results suggest that relative metrics like the Gini coefficient that include average attainment in the denominator are unlikely to provide additional predictive power in estimating health trends after accounting for average attainment. We argue that absolute metrics such as the average individual difference are more appropriate for examining inequality in education globally.

*Global Trends in Educational Inequality*

Figure 7 shows the AID of educational attainment over time for each region used in the Global Burden of Disease 2015 study, as well as the global average. Importantly, these are the population-weighted averages of all the country-year-age-sex specific AID values in the region in question, and they do not represent AID values calculated using all individuals in the region. They should be considered to be the average level of country-age-sex specific inequality experiences by an individual in the given region. Figure 7 also shows the same regional average AID values against the average attainment values for each region. The global trend in AID reveals a similar Kuznets curve process, with the inflection point towards greater equality occurring in the 2020's.

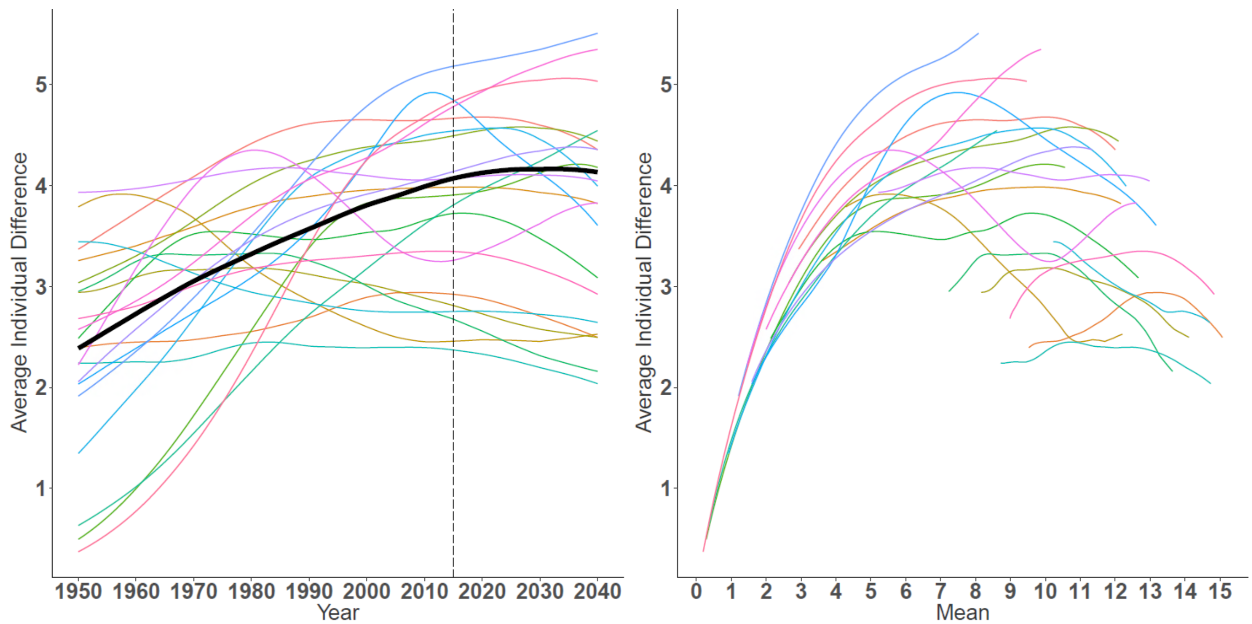


Figure 6. Average individual difference shown over time (left) for each region in color, with the global trend in black. The relationship between the average individual difference and mean attainment is also shown (right) for each region.

Examining the regional trends, it is clear that a large degree of the variation in AID between regions in 2016 can be explained by the average level of attainment, with each region experiencing a slightly different moment of its Kuznets curve. However, it is also clear that substantial region variation exists in the degree of inequality experienced for a given amount of average attainment. So while we do find that the world is becoming more equal, simply as a product of increasing average education, the importance of these differences in the height of the Kuznets curve experienced in each country should be further explored.

# Conclusions and Future Directions

***Summary***

Here we provide the first set of comprehensive estimates of the full distribution of educational attainment from 1950 to 2016 for 195 countries and territories, with projections through 2040. Building on previous attempts to model categorical education, we provide estimates of the proportion of the population of each location by single years of educational attainment, single temporal year, five-year age groups, and gender. We also provide the first set of projections through 2040 of categorical education that leverage country specific information where available to make the best possible of individual nation's attainment trajectories. Using these estimates, we have also provided the first description of inequality in education over time, using the absolute individual difference metric. We identify important differences in the implications of using absolute or relative inequality metrics, and we determine that absolute inequality metrics may be more appropriate for measuring inequality in education. We also show that using absolute inequality metrics, substantial differences are observed in the level of inequality between countries with the same level of average attainment. The health implications of these differences remain to be explored.

***Comparison to Other Estimates***

The main notable previous works that have modelled the distribution of educational attainment include the set of estimates published by Samir KC et al. in 2010 [36], and those of Barro and Lee in 2013[25]. Here we compare our methods to both previous approached. As each analysis only offers distributional information in ISCED categories, and not number of years, it is not possible to directly compare our timeseries to the previous estimates. Furthermore, as the other analyses have major differences in methodology and purpose from our own, it is not clear that such a comparison would be fruitful.

Both analyses differ in their approach from our own in several important ways. Samir et al. used a demographic model, inputting only data from a single census or survey for each country in the year 2000, for 120 countries. They extrapolate forwards in time for observed cohorts by using a set of assumptions about differential mortality by educational attainment status after age 65. The authors do not attempt to most accurately predict the future course of attainment in unobserved cohorts, such as new cohorts of young individuals entering their model after the year 2000, using any kind of country-specific information. Instead, they have various 'scenarios' of growth that impose a mixture of global trends estimates from statistical models and expert knowledge.

Barro and Lee use 621 census and survey datasets, available over the period of 1960-2010, heaping to the closest 5$^{th}$ year. They also use cohort information to extrapolate, assuming no differential mortality by educational level until age 65. Where multiple imputed datapoints are available for the same year, they take a weighted average of the two points to produce a single estimate. Barro and Lee do leverage country specific information about completion ratios to estimate education for new unobserved cohorts. However, the authors do not project past the year 2010.

Both the demographic model approach undertaken by Samir KC et al. and the timeseries approach undertaken in this study and by Barro and Lee have distinct advantages. The timeseries approach allows for the use of all available data, instead of limiting the analysis to data sources available in years proximate to a single year.  Given the substantial degree to which different sources of ostensibly reliable data may disagree in details of the distribution of education, having a model that can use all available sources of information and rectify differences by assessing data uncertainty is desirable. The demographic model approach does have the advantage of producing implicitly coherent proportions; while we rely on normalization to ensure proportions add to 100%. The model allows for the direct inclusion of mortality and migration assumptions into the model. We instead model age-cohort changes with a single correction factor. It is not clear which approach is more predictive of true age-cohort patterns, but their approach is closer to representing the underlying mechanisms, and may be more versatile in assessing the importance of factors like differential mortality and migration for educational inequality.

Both previous analyses produce results only for every five years, which do not reflect the uncertainty in either their modeling processes or data. The authors also only estimate educational attainment by broad categories, which are not years of attainment, rather ISCED categories such as "Primary Attainment," which differ from country to country in the number of years of duration. Both analyses therefore require heaping data into large bins, which limits the usability of their results. For example, they are required to make crude assumptions to calculate distributional features such as the average years of schooling, while our single-year estimates allow for the direct calculation of any distributional feature. Our approach differs in that it can input data from any available year, and therefore uses all available data in estimating trends, and produces estimates for every single year from 1950 to 2040. We also use country-specific information to forecast outside of observed cohorts, attempting to extrapolate based on the continuation of previously observed trends. Our approach also reflects the uncertainty in both data and the modeling process, and combines conflicting data sources while taking into account the data uncertainty of each source.

***Limitations***

Our analysis is, like any exercise in prediction, limited by data availability. Although we have at least one input data source for 194 of the 195 countries modeled in the analysis (all except Andorra), data quality and the number of available data points differs by country. Therefore, we leverage regional information to make predictions about temporal trends in many countries. Although in this way we may be missing important country-specific trends in data-sparse countries that do not follow regional patterns, no better alternative exists that leveraging all existing data and smoothing over region. Furthermore, the uncertainty intervals in data-sparse locations are larger, and likely include possible unexpected deviations. One possible exception is that our current analysis does not attempt to incorporate timeseries disjunctions or 'shocks' that may entail large scale differential mortality by educational status. To our knowledge no database detailing differential mortality by educational status in genocides or other mass mortality events exists, however this remains an important area for further study.

Our projections assume that trends in recent decades continue into the future. We have not attempted to leverage any expert knowledge nor have we modelled the capacity of the education system directly. We are merely projecting what we would expect is existing trends in the demographic composition by educational status continue to progress at a similar rate. It is possible that this will be unrealistic in some cases. For example, we would expect that if current trends continue, the number of individuals attaining tertiary education in China will increase dramatically in the next 25 years. However, it is possible that the tertiary education system will not be able to continue to increase capacity at the current rate, and growth will slow.

Our analysis is also simply a measurement of the quantity of education, and we cannot comment on the distribution of the quality of education. Our estimates may therefore not fully represent the fully inequality in educational attainment.

***Future Directions***

This analysis is in many ways the first description of educational inequality globally, and more work is required to understand important differences in the equality of educational trajectories between and within countries. Although we believe that understanding and ameliorating educational inequality is a valuable goal in its own right, it is also our hope that these estimates will allow for a better understanding of the effects of educational inequality on health. Ideally, our estimates of the distribution of education can be used to model the role of education as a risk factor in a more granular fashion, and explore how social inequality is related to inequality in health.

## References

1. Albano JD, Ward E, Jemal A, Anderson R, Cokkinides VE, Murray T, et al. Cancer Mortality in the United States by Education Level and Race. J. Natl. Cancer Inst. 2007;99:1384–94.

2. Boyle MH, Racine Y, Georgiades K, Snelling D, Hong S, Omariba W, et al. The influence of economic development level, household wealth and maternal education on child health in the developing world. Soc. Sci. Med. 1982. 2006;63:2242–54.

3. Chou S-Y, Liu J-T, Grossman M, Joyce TJ. Parental Education and Child Health: Evidence from a Natural Experiment in Taiwan [Internet]. National Bureau of Economic Research; 2007 Oct. Report No.: 13466. Available from: http://www.nber.org/papers/w13466

4. Cutler D, Lleras-Muney A. Education and Health: Evaluating Theories and Evidence. Mak. Am. Heal. Soc. Econ. Policy Health Policy. New York: Russell Sage Foundation.;

5. Feldman JJ, Makuc DM, Kleinman JC, Cornoni-Huntley J. National Trends in Educational Differentials in Mortality. Am. J. Epidemiol. 1989;129:919–33.

6. Lynch SM. Cohort and life-course patterns in the relationship between education and health: a hierarchical approach. Demography. 2003;40:309–31.

7. Ott A, Breteler MMB, Harskamp F, Claus JJ, Cammen TJM, Grobbee DE, et al. Prevalence of Alzheimer’s disease and vascular dementia: association with education. The Rotterdam study. BMJ. 1995;310:970–3.

8. Ross CE, Wu C. The Links Between Education and Health. Am. Sociol. Rev. 1995;60:719–45.

9. Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. Am. J. Public Health. 1992;82:816–20.

10. Zhang W, Chen H, Feng Q. Education and Psychological Distress of Older Chinese Exploring the Longitudinal Relationship and Its Subgroup Variations. J. Aging Health. 2015;27:1170–98.

11. Literacy and Mothering: How Women's Schooling Changes the Lives of the World's Children. Oxford, New York: Oxford University Press; 2012.

12. Basu AM, Stephenson R. Low levels of maternal education and the proximate determinants of childhood mortality: a little learning is not a dangerous thing. Soc. Sci. Med. 1982. 2005;60:2011–23.

13. Bicego GT, Boerma JT. Maternal education and child survival: a comparative study of survey data from 17 countries. Soc. Sci. Med. 1982. 1993;36:1207–27.

14. Cleland JG, Van Ginneken JK. Maternal education and child survival in developing countries: the search for pathways of influence. Soc. Sci. Med. 1982. 1988;27:1357–68.

15. Desai S, Alva S. Maternal education and child health: is there a strong causal relationship? Demography. 1998;35:71–81.

16. Hobcraft J. Women's education, child welfare and child survival: a review of the evidence. Health Transit. Rev. 1993;3:159–75.

17. Bhuiya A, Streatfield K. Mothers' Education and Survival of Female Children in a Rural Area of Bangladesh. Popul. Stud. 1991;45:253–64.

18. MacNab YC. Bayesian multivariate disease mapping and ecological regression with errors in covariates: Bayesian estimation of DALYs and "preventable" DALYs. Stat. Med. 2009;28:1369–85.

19. Land KC, Guralnik JM, Blazer DG. Estimating Increment-Decrement Life Tables with Multiple Covariates from Panel Data: The Case of Active Life Expectancy*. Demography. 31:297–319.

20. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012;380:2095–128.

21. Millenium Development Goals Report 2015 [Internet]. New York: United Nations; 2015. Available from: http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

22. The Sustainable Development Goals Report 2016 [Internet]. New York: United Nations; 2016. Available from: http://unstats.un.org/sdgs/report/2016/The%20Sustainable%20Development%20Goals%20Report%202016.pdf

23. Gakidou E, Cowling K, Lozano R, Murray CJ. Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis. The Lancet. 2010;376:959–74.

24. Psacharopoulos G, Arriagada A-M. The Educational Attainment of the Labor Force: An International Comparison [Internet]. World Bank; 1986 Oct. Available from: http://documents.worldbank.org/curated/en/663961468135311923/pdf/edt38.pdf

25. Barro RJ, Lee JW. A new data set of educational attainment in the world, 1950–2010. J. Dev. Econ. 2013;104:184–98.

26. Barro RJ, Lee J-W. International comparisons of educational attainment. J. Monet. Econ. 1993;32:363–394.

27. Barro RJ, Lee JW. International Measures of Schooling Years and Schooling Quality. Am. Econ. Rev. 1996;86:218–23.

28. Barro RJ, Lee J-W. Sources of economic growth. Carnegie-Rochester Conf. Ser. Public Policy [Internet]. Elsevier; 1994 [cited 2016 Aug 22]. p. 1–46. Available from: http://www.sciencedirect.com/science/article/pii/0167223194900027

29. Nehru V, Swanson E, Dubey A. A new database on human capital stock in developing and industrial countries: Sources, methodology, and results. J. Dev. Econ. 1995;46:379–401.

30. de la Fuente A, Doménech R. Educational attainment in the OECD, 1960–2010. Updated series and a comparison with other sources. Econ. Educ. Rev. 2015;48:56–74.

31. De la Fuente Á, Doménech R. Educational Attainment in the OECD, 1960-95. 2002 [cited 2016 Aug 22]; Available from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=317689

32. de la Fuente A, Doménech R. Human Capital in Growth Regressions: How Much Difference Does Data Quality Make? J. Eur. Econ. Assoc. 2006;4:1–36.

33. Christenson BA, Johnson NE. Educational Inequality in Adult Mortality: An Assessment with Death Certificate Data from Michigan. Demography. 1995;32:215–29.

34. Kunst AE, Mackenbach JP. The size of mortality differences associated with educational level in nine industrialized countries. Am. J. Public Health. 1994;84:932–937.

35. IPUMS-I: descr: YRSCHOOL [Internet]. [cited 2016 Aug 25]. Available from: https://international.ipums.org/international-action/variables/YRSCHOOL#comparability_section

36. Kc S, Barakat B, Goujon A, Skirbekk V, Lutz W. Projection of populations by level of educational attainment, age, and sex for 120 countries for 2005-2050. Demogr. Res. 2010;22:383–472.

37. Vos T, Allen C, Arora M, Barber RM, Bhutta ZA, Brown A, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet. 2016;388:1545–602.

38. Pya N, Wood SN. Shape constrained additive models. Stat. Comput. 2015;25:543–59.

39. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet. 2014;384:766–81.

40. Ng M, Freeman MK, Fleming TD, Robinson M, Dwyer-Lindgren L, Thomson B, et al. Smoking Prevalence and Cigarette Consumption in 187 Countries, 1980-2012. JAMA. 2014;311:183–92.

41. The World Population Prospects: 2015 Revision [Internet]. 2015. Available from: world-population-prospects-2015-revision.html

42. Wang H, Naghavi M, Allen C, Barber RM, Bhutta ZA, Carter A, et al. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet. 2016;388:1459–544.

43. Thomas V, Wang Y, Fan X. Measuring education inequality: Gini coefficients of education. World Bank Publications; 2001.

44. Temkin LS. Inequality. New York: Oxford University Press; 1993.