Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis

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Summary

Background **In addition to the inherent importance of education and its essential role in economic growth, education and health are strongly related. We updated previous systematic assessments of educational attainment, and estimated the contribution of improvements in women's education to reductions in child mortality in the past 40 years.**

Methods **We compiled 915 censuses and nationally representative surveys, and estimated mean number of years of education by age and sex. By use of a first-differences model, we investigated the association between child mortality and women's educational attainment, controlling for income per person and HIV seroprevalence. We then computed counterfactual estimates of child mortality for every country year between 1970 and 2009.**

Findings **The global mean number of years of education increased from 4·7 years (95% uncertainty interval 4·4–5·1) to 8·3 years (8·0–8·6) for men (aged ≥25 years) and from 3·5 years (3·2–3·9) to 7·1 years (6·7–7·5) for women (aged ≥25 years). For women of reproductive age (15–44 years) in developing countries, the years of schooling increased from 2·2 years (2·0–2·4) to 7·2 years (6·8–7·6). By 2009, in 87 countries, women (aged 25–34 years) had higher educational attainment than had men (aged 25–34 years). Of 8·2 million fewer deaths in children younger than 5 years between 1970 and 2009, we estimated that 4·2 million (51·2%) could be attributed to increased educational attainment in women of reproductive age.**

Interpretation **The substantial increase in education, especially of women, and the reversal of the gender gap have important implications not only for health but also for the status and roles of women in society. The continued increase in educational attainment even in some of the poorest countries suggests that rapid progress in terms of Millennium Development Goal 4 might be possible.**

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Background

Increase in educational attainment is an important social goal. Examples to show the crucial role of education in national and international settings include Millennium Development Goal (MDG) 2, calling for universal primary education,[1] the Human Development Index, which includes education as one of three domains (income and health being the other two), and reviews of public expenditure, which show that spending on education makes up a large component of government expenditure in nearly all countries.[2] There has also been broad recognition in the development community that education plays a crucial part in economic development, especially since the publication of the 1980 World Development Report.[3]

Other than the intrinsic importance of education and its important role in economic growth, a causal link has been established between education and a range of health outcomes.[4–7] One of the most consistent and powerful findings in public health is the strong association between mothers' education and child mortality.[8–10] Results of previous studies have shown that a 1-year increment in the mother's education was associated with a 7–9% reduction in mortality in children younger than 5 years[11] and that child mortality rates among mothers with at least 7 years of schooling were 58% lower than among those without any education.[12] In the past 30 years, many hypotheses have been proposed for the mechanisms through which increased education could lead to reductions in child mortality rates, including individual-level effects through improved use of health services, economic advantages, empowerment and independence of women, and community-level effects.[9,11,13–16] Increases in educational attainment are also strongly linked to reductions in fertility,[11,17,18] which can contribute to reduced child and maternal mortality rates.[19,20] The Commission on Social Determinants of Health reinforced the importance of increasing educational attainment to reduce disparities in health.[21]

Even though the crucial role of education as a determinant of child mortality within countries has been widely studied,[8–10,22,23] the lack of a comprehensive time series of educational attainment for all countries has restricted the capacity to quantify the contribution of improvements in education to reductions in child mortality. A few periodic assessments of educational attainment have been undertaken,[24–26] but they have not provided educational attainment by age and sex, and with

time for many low-income countries. UN Educational, Scientific and Cultural Organization (UNESCO) mainly reports indicators for children in school and for the population excluded from the formal education sector.[27,28]

We updated and improved on previous systematic assessments of educational attainment by age and sex, and produced a complete time series of the mean number of years of education for 175 countries. By use of revised measurements of trends in child mortality,[29] we also investigated the association between child mortality and educational attainment over the past 40 years, and estimated the contribution of improvements in education to the reductions in child mortality.

Methods

Data

We compiled all publicly available censuses and nationally representative surveys of respondents' educational attainment. We used 915 sources of data from 219 countries, gathered between 1953 and 2008 (webappendix pp 25–35). Data from all countries were included in the estimation of the models, but here we present results for 175 countries for which all covariates used in this analysis were available.

See Online for webappendix

No primary data were gathered for this study. We used country-level data that were completely anonymous.

We were interested in the mean number of years of education by sex and 10-year age groups, ranging from 15–24 years to more than 65 years. For surveys in which individual-level data were available, we estimated the mean number of years of completed education taking into account their sampling design. When individual-level data were not accessible, we used tabulated information presented in reports or UN demographic yearbooks. For sources that gave estimates for age groups differing from those we used in our analysis, we adjusted the reported data (webappendix pp 35–36).

For surveys or censuses that included questions about the number of years of completed education, we used these data directly. When respondents were asked the highest form of education they had attended and the highest grade they had completed at that level, we computed the respondents' years of schooling with country-specific and year-specific information about the length of school cycles from UNESCO's database of national education systems.[30] We did not use data sources in which the education variables were missing for more than 10% of respondents.

We used previously reported estimates of child mortality, income per person and HIV seroprevalence.[29,31,32]

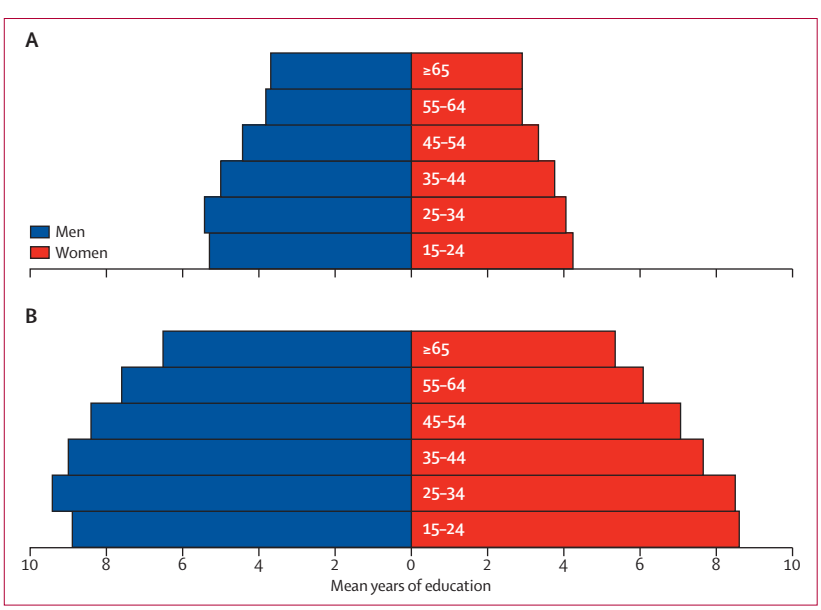

Figure 1: **Global estimates of mean years of education, by age and sex, for 1970 (A) and 2009 (B)**

Models for estimation of mean years of education

Details of the methods used to produce a time series of mean years of education are presented in the webappendix pp 1–8. To estimate educational attainment for country years without data, we used a cohort model and an age-group model. The cohort model shows the trend in educational attainment with time for a cohort of individuals, whereas the age-group model shows the trend with time for individuals in a particular age group. These models are used to produce estimates for country years without actual data, which are then combined with all available data by use of Loess regression. We produced time trends in educational attainment by age and sex for 175 countries between 1970 and 2009 based on Loess regression. We tested the predictive validity of our models against available data (webappendix pp 4–7) and also compared our estimates with previously reported estimates of educational attainment (webappendix p 8). Graphs showing the available data and model predictions for each country are presented in the webappendix p 39.

Effect of women's education on child mortality

We investigated the relation between child mortality and educational attainment among women of reproductive age (15–44 years) over time at the country level. Our model included only major determinants of child mortality that are not on the pathway between women's education and child health—namely, income per person and HIV seroprevalence, which is included because the HIV epidemic was a major shock to health in many countries that had an effect on child mortality. We also included a random effect on country to capture unchanging determinants of child mortality within each country, and a random effect on year to capture changes in technology and other time-varying factors that affect all countries. The model, after examination of the appropriate functional form for each univariate association, was

$$\ln(5q0)_{c,t} = \beta_0 + \beta_1 \ln(GDP)_{c,t} + \beta_2 Education_{c,t} + \beta_3 HIV_{c,t-3} + \alpha_c + \alpha_t + \varepsilon_{c,t}$$

in which ln(5q0) is the natural logarithm of the mortality rate in children younger than 5 years for country c in year t, GDP is gross domestic product, ln(GDP) is the natural log of the distributed lag of mean income per person in purchasing-power parity for country c in year t, education is the age-standardised average years of schooling for women of reproductive age (15–44 years) in country c at year t, HIV is the prevalence of HIV in country c at year t-3, α_c is a random intercept on country and α_t is a random intercept on year. To capture the long-term effects of rising income on child mortality, we used the mean GDP per person for 10 years that ended in year t. We also used a 3-year lag of HIV prevalence to accurately capture its effect on child mortality. We used a random effect for time rather than a fixed effect to minimise difficulties of colinearity.

We tried various model specifications and noted that the results for educational attainment were largely consistent (webappendix p 8). Here we report estimates based on a first-differences model because it has the advantage of having no residual serial autocorrelation.[33] The model is a mixed-effects regression analysis in which the dependent variable is the difference in the child mortality between year t+1 and year t, and the independent variables are the differences in GDP, education, and HIV seroprevalence between year t+1 and year t. The model also includes a random intercept for country and year.

We then used the estimated coefficients to compute counterfactual estimates of child mortality for every country year between 1970 and 2009. To assess progress since the start year of the MDGs, we also computed counterfactual estimates of child mortality between

	Men			Women		
	1970	1990	2009	1970	1990	2009
Asia Pacific, high income						
Japan	8·8 (8·4–9·1)	10·7 (10·4–11·0)	12·2 (11·7–12·7)	8·2 (7·8–8·7)	10·4 (10·0–10·8)	12·2 (11·5–12·9)
Korea, South	7·9 (7·4–8·4)	11·0 (10·5–11·4)	13·1 (12·5–13·6)	4·8 (4·4–5·2)	8·6 (8·1–9·2)	11·9 (11·1–12·7)
Singapore	3·9 (3·8–4·1)	6·2 (6·0–6·4)	8·1 (7·5–8·6)	2·2 (2·0–2·3)	4·3 (4·1–4·5)	6·1 (5·4–6·9)
Asia, central						
Armenia	6·6 (5·9–7·3)	9·3 (9·1–9·6)	11·3 (11·0–11·7)	5·9 (5·1–6·8)	8·9 (8·5–9·2)	11·3 (10·9–11·7)
Azerbaijan	6·4 (5·7–7·1)	9·8 (9·5–10·1)	12·1 (11·9–12·3)	4·5 (3·7–5·3)	8·1 (7·8–8·5)	11·3 (11·0–11·6)
Georgia	7·5 (6·9–8·1)	10·5 (10·3–10·7)	12·5 (12·4–12·7)	7·4 (6·5–8·2)	10·3 (10·0–10·6)	12·5 (12·3–12·7)
Kazakhstan	5·4 (4·9–6·0)	9·0 (8·8–9·3)	11·9 (11·7–12·1)	4·7 (4·2–5·4)	8·5 (8·2–8·8)	11·9 (11·6–12·2)
Kyrgyzstan	5·8 (5·1–6·5)	9·1 (8·8–9·4)	11·6 (11·3–11·9)	4·9 (4·2–5·7)	8·4 (8·1–8·8)	11·4 (11·0–11·8)
Mongolia	5·5 (4·9–6·1)	7·6 (7·3–7·9)	9·0 (8·7–9·3)	3·7 (3·2–4·3)	6·5 (6·2–6·8)	9·2 (8·9–9·6)
Tajikistan	6·1 (5·7–6·6)	9·3 (9·1–9·4)	11·6 (11·4–11·8)	4·2 (3·7–4·7)	7·4 (7·3–7·6)	10·4 (10·1–10·7)
Turkmenistan	5·8 (5·4–6·2)	9·0 (8·9–9·1)	11·5 (11·2–11·8)	4·6 (4·1–5·1)	7·9 (7·7–8·0)	10·8 (10·3–11·3)
Uzbekistan	6·2 (5·6–6·8)	9·5 (9·3–9·8)	11·9 (11·6–12·2)	4·9 (4·3–5·7)	8·4 (8·1–8·7)	11·3 (10·9–11·7)
Asia, east						
China	3·1 (2·8–3·4)	5·4 (5·3–5·6)	7·7 (7·2–8·1)	1·2 (1·1–1·3)	3·3 (3·2–3·4)	6·4 (5·9–6·9)
Taiwan	4·4 (4·0–4·7)	8·4 (8·3–8·5)	11·8 (11·6–12·0)	2·3 (2·1–2·6)	6·4 (6·3–6·6)	10·9 (10·7–11·2)
Asia, south						
Afghanistan	0·7 (0·6–0·8)	1·5 (1·4–1·7)	2·6 (2·6–2·7)	0·0 (0·0–0·1)	0·1 (0·1–0·2)	0·4 (0·3–0·4)
Bangladesh	2·4 (2·0–2·8)	3·6 (3·5–3·8)	4·7 (4·5–4·8)	0·6 (0·5–0·7)	1·3 (1·2–1·4)	2·6 (2·5–2·7)
India	2·3 (2·1–2·6)	4·3 (4·1–4·5)	6·2 (5·9–6·5)	0·6 (0·5–0·7)	1·7 (1·6–1·8)	3·4 (3·2–3·7)
Nepal	1·0 (0·9–1·2)	2·4 (2·2–2·5)	4·2 (4·1–4·4)	0·1 (0·1–0·1)	0·4 (0·4–0·5)	1·3 (1·2–1·4)
Pakistan	1·5 (1·4–1·7)	3·2 (3·1–3·4)	5·4 (5·1–5·8)	0·3 (0·2–0·3)	0·9 (0·8–1·0)	2·4 (2·2–2·6)
Asia, southeast						
Cambodia	2·1 (1·8–2·6)	3·7 (3·5–4·0)	5·4 (5·1–5·6)	0·6 (0·5–0·8)	1·6 (1·4–1·7)	3·2 (3·0–3·4)
Indonesia	2·8 (2·5–3·0)	5·1 (4·9–5·2)	7·3 (7·1–7·6)	1·1 (1·0–1·3)	3·1 (3·0–3·2)	6·1 (5·7–6·4)
Laos	1·6 (1·3–1·9)	3·0 (2·8–3·2)	4·5 (4·3–4·7)	0·4 (0·3–0·5)	1·2 (1·1–1·3)	2·6 (2·5–2·8)
Malaysia	3·7 (3·4–3·9)	6·1 (5·8–6·3)	8·3 (7·8–8·8)	1·6 (1·4–1·7)	4·2 (4·0–4·5)	7·7 (7·2–8·3)
Maldives	2·5 (2·2–2·9)	3·4 (3·2–3·6)	4·1 (3·8–4·5)	2·0 (1·6–2·4)	2·7 (2·5–2·9)	3·4 (3·1–3·8)
Mauritius	2·6 (2·2–3·0)	5·6 (5·3–5·9)	9·1 (8·5–9·6)	1·4 (1·1–1·8)	4·0 (3·7–4·4)	8·1 (7·5–8·8)
Myanmar	2·3 (1·9–2·7)	3·8 (3·5–4·0)	5·1 (4·9–5·2)	1·3 (1·0–1·6)	2·8 (2·6–3·0)	4·6 (4·4–4·8)
Philippines	5·1 (4·6–5·6)	7·3 (7·1–7·5)	8·8 (8·6–9·1)	4·4 (3·9–5·0)	7·0 (6·7–7·2)	9·2 (8·9–9·5)
Seychelles	3·6 (3·2–3·9)	6·6 (5·8–7·4)	10·0 (8·6–11·2)	3·6 (3·2–4·0)	7·4 (6·3–8·6)	11·7 (10·1–13·2)
Sri Lanka	5·0 (4·6–5·4)	7·2 (7·0–7·4)	9·2 (8·9–9·6)	3·4 (3·0–3·7)	6·2 (5·9–6·4)	9·4 (8·9–9·9)

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	Men			Women		
	1970	1990	2009	1970	1990	2009
(Continued from previous page)						
Thailand	4·1 (3·7–4·6)	5·7 (5·5–5·9)	7·1 (6·7–7·4)	2·8 (2·4–3·2)	4·5 (4·3–4·8)	6·6 (6·2–7·0)
Timor-Leste	0·8 (0·7–0·9)	1·6 (1·5–1·7)	3·1 (3·0–3·2)	0·2 (0·2–0·3)	0·6 (0·6–0·7)	2·0 (1·9–2·1)
Vietnam	4·7 (4·2–5·2)	6·7 (6·4–6·9)	8·1 (7·8–8·3)	2·6 (2·2–3·0)	4·6 (4·4–4·8)	6·9 (6·6–7·2)
Australasia						
Australia	8·8 (8·3–9·2)	10·6 (10·4–10·8)	11·9 (11·6–12·2)	8·4 (7·8–9·1)	10·2 (9·9–10·5)	11·5 (11·1–11·9)
New Zealand	6·5 (6·0–6·9)	10·0 (9·8–10·2)	12·5 (12·2–12·9)	6·4 (5·8–7·1)	9·8 (9·6–10·0)	12·3 (11·9–12·7)
Caribbean						
Antigua and Barbuda	7·0 (6·7–7·3)	9·8 (9·1–10·5)	11·8 (10·9–12·7)	7·0 (6·6–7·3)	10·0 (9·0–10·9)	12·2 (10·7–13·4)
Bahamas	6·4 (6·0–6·8)	8·6 (8·5–8·7)	10·5 (10·2–10·8)	6·1 (5·6–6·7)	8·6 (8·5–8·8)	10·8 (10·4–11·3)
Belize	4·4 (3·8–5·1)	6·7 (6·4–7·1)	8·5 (8·4–8·7)	3·8 (3·0–4·7)	6·2 (5·7–6·7)	8·3 (8·1–8·5)
Cuba	5·6 (5·1–6·2)	8·3 (7·9–8·8)	10·5 (9·9–11·1)	5·3 (4·6–6·0)	7·9 (7·3–8·4)	10·2 (9·5–10·9)
Dominican Republic	3·1 (2·8–3·4)	5·4 (5·2–5·6)	7·5 (7·4–7·7)	2·3 (1·9–2·6)	4·7 (4·5–4·9)	7·7 (7·4–7·9)
Guyana	5·1 (4·6–5·7)	7·5 (7·2–7·8)	9·3 (9·2–9·5)	3·6 (3·0–4·3)	6·5 (6·2–6·8)	9·4 (9·1–9·6)
Haiti	1·1 (0·9–1·3)	2·5 (2·4–2·7)	4·7 (4·4–4·9)	0·5 (0·4–0·7)	1·5 (1·4–1·6)	3·4 (3·2–3·6)
Jamaica	4·9 (4·2–5·6)	7·7 (7·4–8·0)	9·9 (9·6–10·3)	4·6 (3·8–5·4)	7·7 (7·3–8·0)	10·3 (9·9–10·7)
Saint Lucia	4·7 (4·2–5·3)	7·0 (6·8–7·3)	8·9 (8·8–9·1)	4·5 (3·8–5·4)	7·1 (6·7–7·4)	9·4 (9·1–9·6)
Suriname	3·8 (3·4–4·3)	5·9 (5·7–6·2)	7·7 (7·5–7·9)	2·9 (2·4–3·4)	4·9 (4·7–5·2)	7·1 (6·8–7·3)
Trinidad and Tobago	5·3 (4·8–5·8)	7·7 (7·4–8·0)	9·6 (9·3–9·9)	4·7 (4·1–5·4)	7·3 (7·0–7·6)	9·7 (9·2–10·1)
Europe, central						
Albania	5·1 (4·3–5·9)	7·8 (7·3–8·2)	10·2 (10·0–10·5)	3·9 (3·2–4·8)	6·5 (6·0–6·9)	9·4 (9·1–9·7)
Bosnia and Herzegovina	3·8 (3·4–4·4)	6·5 (6·2–6·8)	9·4 (9·1–9·6)	2·2 (1·8–2·6)	4·3 (4·0–4·6)	7·5 (7·2–7·8)
Bulgaria	7·3 (7·0–7·6)	9·9 (9·5–10·3)	11·8 (11·2–12·4)	6·3 (5·9–6·8)	9·6 (9·1–10·1)	12·0 (11·3–12·8)
Croatia	5·4 (4·7–6·2)	8·5 (8·2–8·8)	11·1 (10·6–11·5)	3·3 (2·6–4·0)	7·0 (6·7–7·4)	10·8 (10·3–11·4)
Czech Republic	10·5 (10·0–11·1)	12·6 (12·5–12·8)	13·7 (13·6–13·8)	8·8 (7·9–9·6)	11·6 (11·4–11·8)	13·3 (13·1–13·4)
Hungary	7·5 (7·2–7·8)	9·7 (9·3–10·0)	11·3 (10·7–11·8)	7·0 (6·6–7·3)	9·3 (8·8–9·7)	11·1 (10·3–11·9)
Macedonia	5·6 (5·1–6·2)	8·5 (8·3–8·7)	10·8 (10·6–10·9)	3·8 (3·3–4·4)	6·6 (6·4–6·9)	9·6 (9·3–9·8)
Montenegro	6·7 (5·8–7·6)	9·6 (9·3–10·1)	11·7 (11·6–11·9)	4·8 (3·8–5·9)	7·8 (7·3–8·3)	10·6 (10·4–10·8)
Poland	8·1 (7·6–8·6)	10·6 (10·4–10·9)	12·4 (11·9–12·7)	7·3 (6·7–8·0)	10·3 (10·0–10·6)	12·4 (11·9–12·9)
Romania	6·8 (6·6–7·1)	10·0 (9·7–10·4)	12·2 (11·7–12·7)	5·7 (5·3–6·0)	8·9 (8·5–9·4)	11·5 (10·7–12·3)
Serbia	5·6 (4·9–6·3)	8·5 (8·2–8·8)	10·8 (10·7–11·0)	4·2 (3·5–5·1)	7·1 (6·7–7·5)	10·0 (9·9–10·2)
Slovakia	6·3 (5·5–7·1)	10·1 (9·8–10·4)	12·8 (12·5–13·2)	4·5 (3·7–5·4)	8·6 (8·2–9·0)	12·1 (11·6–12·6)
Slovenia	5·8 (5·2–6·5)	9·3 (9·1–9·6)	12·0 (11·7–12·3)	4·0 (3·4–4·7)	8·0 (7·7–8·4)	11·7 (11·3–12·1)
Europe, eastern						
Belarus	7·0 (6·4–7·5)	9·7 (9·5–9·9)	11·8 (11·6–11·9)	6·3 (5·6–7·0)	9·4 (9·1–9·6)	11·7 (11·5–12·0)
Estonia	6·3 (5·8–6·9)	9·0 (8·9–9·2)	11·1 (10·9–11·3)	6·5 (5·8–7·2)	9·5 (9·2–9·7)	11·7 (11·4–12·0)
Latvia	6·8 (6·2–7·4)	9·8 (9·5–10·0)	12·0 (11·8–12·2)	6·1 (5·3–6·9)	10·0 (9·7–10·4)	12·9 (12·5–13·1)
Lithuania	5·5 (4·9–6·1)	9·4 (9·1–9·7)	12·3 (11·9–12·6)	4·9 (4·3–5·6)	9·1 (8·8–9·5)	12·5 (12·1–12·9)
Moldova	6·4 (5·9–6·9)	9·2 (9·0–9·4)	11·3 (11·2–11·5)	5·6 (5·0–6·3)	8·6 (8·4–8·8)	11·2 (10·9–11·4)
Russia	6·8 (6·2–7·3)	10·2 (10·0–10·4)	12·7 (12·5–12·9)	5·7 (5·0–6·3)	9·7 (9·5–10·0)	12·9 (12·7–13·2)
Ukraine	7·5 (6·9–8·1)	10·2 (9·9–10·4)	12·1 (12·0–12·3)	6·8 (6·0–7·7)	9·9 (9·6–10·1)	12·2 (12·0–12·4)
Europe, western						
Austria	8·9 (8·5–9·3)	10·6 (10·4–10·8)	11·8 (11·4–12·2)	7·2 (6·7–7·7)	9·2 (9·0–9·5)	11·0 (10·3–11·6)
Belgium	7·5 (7·1–8·0)	10·2 (10·1–10·4)	12·1 (11·9–12·3)	6·6 (6·0–7·2)	9·6 (9·4–9·8)	11·9 (11·6–12·3)
Cyprus	6·5 (6·0–7·1)	9·9 (9·5–10·3)	12·3 (11·6–12·8)	4·5 (4·0–5·1)	8·5 (7·9–9·1)	11·8 (11·0–12·6)
Denmark	9·0 (8·3–9·7)	11·5 (11·3–11·7)	12·8 (12·8–12·9)	7·9 (6·9–8·9)	11·0 (10·7–11·3)	12·8 (12·7–12·9)
Finland	7·2 (6·6–7·8)	10·0 (9·8–10·2)	11·8 (11·5–12·1)	6·3 (5·5–7·1)	9·8 (9·6–10·1)	12·3 (12·0–12·7)
France	6·2 (5·9–6·4)	8·5 (8·2–8·8)	10·5 (10·0–11·1)	5·7 (5·4–6·0)	8·2 (7·9–8·6)	10·5 (9·7–11·2)
Germany	8·0 (7·5–8·5)	10·7 (10·5–10·9)	12·4 (12·0–12·7)	6·2 (5·6–6·9)	9·6 (9·3–9·8)	12·0 (11·5–12·5)
Greece	5·7 (5·4–6·1)	8·5 (8·3–8·8)	10·7 (10·3–11·2)	4·4 (4·0–4·8)	7·4 (7·1–7·6)	10·1 (9·5–10·6)

(Continues on next page)

	Men			Women		
	1970	1990	2009	1970	1990	2009
(Continued from previous page)						
Ireland	6·1 (5·7–6·6)	9·0 (8·8–9·2)	11·2 (10·9–11·4)	6·2 (5·6–6·9)	9·3 (9·0–9·5)	11·5 (11·1–11·8)
Israel	8·2 (7·8–8·5)	10·7 (10·4–11·1)	12·5 (12·0–13·1)	6·9 (6·4–7·3)	10·1 (9·6–10·5)	12·5 (11·7–13·2)
Italy	6·4 (5·8–7·0)	8·8 (8·5–9·0)	10·6 (10·4–10·9)	5·0 (4·3–5·7)	7·8 (7·4–8·1)	10·2 (9·9–10·6)
Luxembourg	7·2 (6·5–7·9)	9·9 (9·6–10·1)	11·6 (11·4–11·7)	5·5 (4·6–6·5)	8·6 (8·3–9·0)	11·0 (10·9–11·2)
Netherlands	7·4 (7·0–7·9)	9·9 (9·5–10·4)	11·8 (11·1–12·4)	6·2 (5·6–6·9)	9·1 (8·5–9·7)	11·4 (10·4–12·3)
Norway	7·2 (6·6–7·8)	11·3 (11·1–11·5)	13·6 (13·4–13·8)	6·1 (5·3–6·8)	10·9 (10·6–11·1)	13·6 (13·3–13·9)
Portugal	3·1 (2·8–3·4)	5·3 (5·1–5·5)	7·6 (7·1–8·1)	2·2 (1·9–2·5)	4·7 (4·5–4·9)	7·7 (7·1–8·4)
Spain	3·1 (2·8–3·5)	6·1 (5·9–6·3)	9·0 (8·6–9·5)	2·3 (2·0–2·6)	5·5 (5·2–5·7)	9·0 (8·4–9·6)
Sweden	7·6 (7·1–8·1)	10·5 (10·4–10·6)	12·4 (12·2–12·5)	7·0 (6·3–7·7)	10·4 (10·3–10·6)	12·8 (12·6–13·0)
Switzerland	9·6 (8·9–10·2)	12·3 (12·1–12·5)	13·5 (13·4–13·5)	7·4 (6·4–8·4)	10·8 (10·5–11·2)	12·6 (12·5–12·8)
UK	9·1 (8·6–9·7)	11·6 (11·4–11·7)	13·0 (12·9–13·1)	8·3 (7·4–9·1)	11·2 (11·0–11·4)	13·0 (12·8–13·2)
Latin America, Andean						
Bolivia	3·3 (3·0–3·6)	5·9 (5·8–6·1)	8·4 (8·1–8·7)	1·7 (1·5–2·0)	3·9 (3·8–4·1)	6·7 (6·4–7·1)
Ecuador	3·8 (3·5–4·1)	6·2 (5·9–6·4)	8·5 (8·1–8·9)	3·1 (2·8–3·4)	5·5 (5·2–5·7)	8·1 (7·6–8·6)
Peru	4·5 (4·1–4·8)	7·3 (7·1–7·5)	9·7 (9·4–10·0)	2·9 (2·5–3·3)	5·5 (5·3–5·8)	8·3 (7·8–8·8)
Latin America, central						
Colombia	3·7 (3·4–4·0)	5·2 (5·1–5·4)	6·6 (6·3–6·9)	3·2 (2·9–3·6)	4·8 (4·6–5·0)	6·4 (6·0–6·9)
Costa Rica	4·1 (3·9–4·3)	6·4 (6·1–6·7)	8·4 (7·7–9·0)	4·0 (3·8–4·2)	6·3 (6·0–6·7)	8·6 (7·8–9·4)
El Salvador	3·0 (2·7–3·3)	5·1 (4·8–5·4)	7·4 (6·9–8·0)	2·4 (2·0–2·7)	4·3 (4·0–4·6)	6·5 (6·1–7·0)
Guatemala	1·8 (1·5–2·1)	3·3 (3·1–3·5)	5·0 (4·8–5·3)	1·0 (0·8–1·3)	2·2 (2·1–2·4)	3·9 (3·7–4·1)
Honduras	2·2 (2·0–2·4)	3·9 (3·7–4·2)	5·9 (5·4–6·4)	1·8 (1·6–2·0)	3·5 (3·3–3·8)	5·7 (5·2–6·2)
Mexico	3·2 (3·0–3·5)	5·8 (5·6–6·0)	8·3 (8·0–8·5)	2·5 (2·2–2·8)	4·9 (4·7–5·1)	7·6 (7·2–7·9)
Nicaragua	2·4 (1·9–2·9)	4·0 (3·8–4·3)	5·7 (5·4–5·9)	1·9 (1·5–2·3)	3·6 (3·3–3·9)	5·8 (5·5–6·1)
Panama	4·8 (4·6–5·1)	7·2 (6·9–7·5)	9·3 (8·8–9·9)	4·7 (4·4–5·1)	7·3 (7·0–7·7)	9·7 (9·0–10·5)
Venezuela	3·8 (3·5–4·0)	6·3 (6·0–6·5)	8·6 (8·1–9·0)	2·9 (2·6–3·2)	5·8 (5·6–6·0)	8·9 (8·3–9·4)
Latin America, southern						
Argentina	5·9 (5·5–6·3)	8·0 (7·7–8·2)	9·8 (9·2–10·3)	5·5 (5·0–6·0)	7·9 (7·6–8·2)	10·1 (9·4–10·7)
Chile	5·7 (5·4–6·0)	8·1 (7·9–8·4)	10·2 (9·8–10·7)	5·3 (4·9–5·7)	7·8 (7·5–8·1)	10·1 (9·4–10·7)
Uruguay	5·2 (4·8–5·6)	7·5 (7·2–7·9)	9·5 (9·0–10·0)	5·2 (4·7–5·7)	7·8 (7·4–8·2)	10·0 (9·3–10·7)
Latin America, tropical						
Brazil	2·5 (2·3–2·8)	4·6 (4·4–4·7)	6·8 (6·4–7·2)	2·1 (1·9–2·4)	4·4 (4·2–4·6)	7·2 (6·7–7·6)
Paraguay	3·8 (3·3–4·2)	5·5 (5·3–5·7)	6·9 (6·6–7·2)	2·9 (2·5–3·4)	5·1 (4·8–5·3)	7·2 (6·8–7·5)
North Africa/Middle East						
Algeria	0·9 (0·8–1·0)	2·5 (2·4–2·6)	4·7 (4·4–5·1)	0·6 (0·5–0·6)	1·9 (1·8–2·0)	4·2 (3·9–4·5)
Bahrain	2·4 (2·2–2·5)	5·7 (5·4–6·0)	9·1 (8·4–9·7)	1·2 (1·1–1·3)	4·0 (3·7–4·2)	7·8 (7·1–8·4)
Egypt	2·7 (2·5–3·0)	5·3 (5·2–5·5)	7·9 (7·7–8·2)	0·9 (0·8–1·1)	2·7 (2·6–2·8)	5·3 (5·1–5·6)
Iran	2·1 (1·8–2·4)	4·4 (4·2–4·7)	7·3 (7·0–7·6)	0·8 (0·6–0·9)	2·3 (2·2–2·5)	5·1 (4·9–5·4)
Iraq	3·5 (3·1–4·0)	4·7 (4·5–4·9)	6·2 (6·0–6·4)	1·2 (1·0–1·5)	2·1 (2·0–2·3)	3·7 (3·5–3·8)
Jordan	3·5 (3·1–3·9)	7·2 (6·9–7·5)	10·6 (10·3–10·8)	1·2 (1·1–1·4)	4·2 (4·0–4·4)	8·6 (8·2–8·9)
Kuwait	2·6 (2·3–2·8)	5·0 (4·7–5·3)	7·5 (6·8–8·3)	1·4 (1·2–1·5)	3·7 (3·4–4·0)	7·0 (6·1–7·8)
Lebanon	3·0 (2·5–3·6)	5·9 (5·5–6·3)	8·8 (8·6–9·0)	1·6 (1·3–2·1)	4·6 (4·2–5·0)	8·5 (8·2–8·7)
Morocco	1·1 (0·9–1·3)	2·7 (2·5–2·8)	4·7 (4·4–5·0)	0·3 (0·2–0·3)	1·0 (1·0–1·1)	2·5 (2·4–2·7)
Occupied Palestinian territory	3·8 (3·3–4·3)	7·0 (6·8–7·2)	9·9 (9·6–10·1)	1·4 (1·2–1·7)	4·2 (4·0–4·4)	7·9 (7·6–8·3)
Oman	1·6 (1·4–1·8)	3·9 (3·8–4·1)	6·7 (6·4–7·0)	0·5 (0·5–0·6)	2·1 (2·0–2·2)	5·0 (4·6–5·4)
Qatar	2·5 (2·0–3·0)	5·1 (4·7–5·4)	7·8 (7·6–8·0)	1·5 (1·1–1·9)	4·3 (4·0–4·7)	7·9 (7·7–8·2)
Saudi Arabia	2·8 (2·4–3·3)	5·4 (5·1–5·7)	8·5 (8·3–8·6)	0·5 (0·4–0·6)	1·9 (1·8–2·1)	5·0 (4·7–5·2)
Syria	2·1 (1·9–2·2)	4·6 (4·5–4·8)	7·4 (7·1–7·7)	0·6 (0·6–0·7)	2·2 (2·1–2·3)	5·1 (4·8–5·5)
Tunisia	2·4 (2·1–2·7)	5·0 (4·9–5·2)	8·1 (7·9–8·4)	0·5 (0·4–0·5)	1·8 (1·7–2·0)	4·5 (4·0–5·0)
Turkey	2·7 (2·5–2·9)	5·4 (5·2–5·5)	8·2 (7·8–8·5)	1·2 (1·1–1·4)	3·1 (2·9–3·2)	5·8 (5·4–6·2)

(Continues on next page)

	Men			Women		
	1970	1990	2009	1970	1990	2009
(Continued from previous page)						
United Arab Emirates	3·0 (2·7–3·2)	6·2 (6·0–6·4)	9·5 (9·1–9·8)	1·5 (1·4–1·7)	4·4 (4·2–4·6)	8·3 (7·8–8·8)
Yemen	0·5 (0·5–0·6)	1·7 (1·6–1·8)	3·6 (3·5–3·7)	0·1 (0·0–0·1)	0·2 (0·2–0·2)	0·7 (0·7–0·8)
North America, high income						
Canada	8·8 (8·5–9·2)	12·4 (12·2–12·5)	14·2 (14·0–14·4)	8·7 (8·2–9·1)	12·3 (12·0–12·5)	14·2 (13·9–14·5)
USA	11·3 (11·0–11·6)	12·9 (12·8–13·0)	13·7 (13·6–13·9)	11·0 (10·6–11·5)	12·7 (12·6–12·8)	13·7 (13·4–13·9)
Oceania						
Fiji	5·3 (5·0–5·6)	7·5 (7·2–7·9)	9·5 (8·8–10·2)	3·7 (3·5–4·0)	6·3 (6·0–6·7)	9·2 (8·3–10·1)
Kiribati	4·2 (3·9–4·5)	6·6 (6·4–6·8)	8·9 (8·5–9·2)	2·7 (2·4–3·0)	5·6 (5·3–5·8)	9·2 (8·6–9·8)
Marshall Islands	5·6 (4·8–6·4)	8·5 (8·1–8·9)	9·9 (9·8–10·1)	2·6 (2·0–3·3)	5·9 (5·4–6·4)	8·9 (8·7–9·1)
Papua New Guinea	1·6 (1·4–1·7)	3·0 (2·9–3·2)	4·9 (4·7–5·1)	0·5 (0·4–0·6)	1·4 (1·3–1·5)	3·2 (3·0–3·5)
Samoa	4·7 (4·6–4·9)	7·5 (6·9–8·0)	9·9 (8·9–10·8)	4·3 (4·2–4·5)	8·2 (7·5–9·0)	12·0 (10·8–13·1)
Solomon Islands	2·0 (1·9–2·2)	4·1 (3·9–4·2)	6·2 (5·9–6·5)	0·9 (0·8–1·0)	2·5 (2·3–2·6)	5·0 (4·6–5·4)
Tonga	6·4 (5·8–7·1)	9·2 (8·9–9·4)	11·3 (10·9–11·7)	4·8 (4·1–5·5)	8·4 (8·1–8·7)	11·5 (11·0–12·1)
Vanuatu	3·0 (2·6–3·4)	5·0 (4·8–5·2)	6·9 (6·7–7·1)	1·5 (1·3–1·8)	3·6 (3·4–3·8)	6·3 (6·1–6·6)
Sub-Saharan Africa, central						
Angola	1·4 (1·2–1·6)	3·0 (2·8–3·2)	5·1 (4·9–5·3)	0·5 (0·4–0·6)	1·2 (1·1–1·3)	2·8 (2·6–2·9)
Central African Republic	1·3 (1·2–1·4)	2·8 (2·7–2·9)	4·6 (4·5–4·8)	0·2 (0·2–0·3)	0·8 (0·8–0·9)	2·1 (2·0–2·3)
Congo	2·8 (2·5–3·0)	5·6 (5·4–5·7)	8·1 (7·9–8·3)	0·7 (0·7–0·9)	2·5 (2·4–2·6)	5·3 (5·0–5·5)
Congo, Democratic Republic of	2·9 (2·5–3·3)	5·4 (5·1–5·6)	7·6 (7·5–7·7)	0·6 (0·5–0·8)	1·9 (1·7–2·0)	4·0 (3·8–4·1)
Equatorial Guinea	2·7 (2·3–3·1)	5·3 (5·0–5·5)	7·7 (7·5–8·0)	0·9 (0·7–1·0)	2·2 (2·0–2·4)	4·5 (4·2–4·8)
Gabon	2·6 (2·2–3·0)	5·1 (4·9–5·4)	7·6 (7·4–7·8)	1·2 (1·0–1·4)	3·0 (2·8–3·2)	5·7 (5·4–6·0)
Sub-Saharan Africa, east						
Burundi	1·1 (0·9–1·2)	2·2 (2·0–2·3)	3·5 (3·3–3·7)	0·3 (0·2–0·3)	0·9 (0·8–0·9)	2·0 (1·8–2·2)
Comoros	0·9 (0·8–1·0)	2·1 (2·0–2·2)	4·1 (3·9–4·3)	0·2 (0·2–0·3)	0·8 (0·8–0·9)	2·3 (2·2–2·5)
Djibouti	1·6 (1·3–1·9)	3·2 (3·0–3·4)	5·3 (5·1–5·5)	0·2 (0·2–0·3)	0·7 (0·6–0·7)	1·8 (1·7–1·8)
Eritrea	0·7 (0·5–0·8)	1·9 (1·8–2·0)	3·9 (3·7–4·2)	0·2 (0·1–0·2)	0·7 (0·6–0·7)	2·1 (1·9–2·3)
Ethiopia	0·5 (0·4–0·6)	1·1 (1·0–1·3)	2·3 (2·1–2·4)	0·1 (0·1–0·1)	0·3 (0·3–0·3)	1·0 (0·9–1·0)
Kenya	2·5 (2·3–2·7)	5·0 (4·8–5·1)	7·6 (7·3–8·0)	0·8 (0·7–0·8)	2·6 (2·5–2·7)	5·9 (5·6–6·2)
Madagascar	1·4 (1·2–1·7)	3·2 (3·0–3·4)	5·4 (5·0–5·7)	0·8 (0·7–1·0)	2·2 (2·0–2·3)	4·5 (4·1–4·9)
Malawi	1·9 (1·7–2·1)	3·7 (3·6–3·9)	5·8 (5·5–6·0)	0·6 (0·5–0·6)	1·6 (1·5–1·7)	3·3 (3·1–3·5)
Mozambique	1·0 (0·8–1·3)	2·2 (2·0–2·3)	3·6 (3·4–3·9)	0·2 (0·2–0·3)	0·7 (0·6–0·8)	1·7 (1·5–1·9)
Rwanda	1·2 (1·1–1·4)	2·6 (2·4–2·7)	4·1 (3·9–4·4)	0·4 (0·3–0·4)	1·2 (1·1–1·3)	2·8 (2·6–3·0)
Somalia	0·7 (0·6–0·9)	1·7 (1·5–1·8)	2·8 (2·6–2·9)	0·1 (0·1–0·2)	0·4 (0·3–0·4)	1·0 (0·9–1·0)
Sudan	1·5 (1·4–1·7)	3·3 (3·2–3·4)	5·6 (5·4–5·8)	0·3 (0·3–0·4)	1·2 (1·1–1·2)	3·1 (2·9–3·3)
Tanzania	2·0 (1·8–2·2)	3·8 (3·7–4·0)	5·7 (5·5–5·9)	0·6 (0·5–0·7)	1·9 (1·8–2·0)	4·0 (3·9–4·2)
Uganda	2·2 (1·9–2·5)	4·1 (4·0–4·3)	6·1 (5·9–6·4)	0·7 (0·6–0·8)	1·8 (1·7–1·9)	3·7 (3·5–3·9)
Zambia	3·0 (2·7–3·3)	5·3 (5·1–5·5)	7·5 (7·2–7·8)	1·1 (1·0–1·3)	2·8 (2·6–2·9)	5·2 (4·9–5·5)
Sub-Saharan Africa, southern						
Botswana	1·3 (1·2–1·4)	2·9 (2·6–3·2)	5·3 (4·3–6·3)	1·1 (0·9–1·2)	2·9 (2·6–3·2)	6·0 (5·0–7·1)
Lesotho	2·0 (1·9–2·2)	3·8 (3·6–4·0)	5·9 (5·6–6·2)	2·3 (2·1–2·6)	5·1 (4·8–5·3)	8·4 (7·9–9·0)
Namibia	2·2 (1·8–2·5)	4·4 (4·2–4·7)	6·9 (6·6–7·2)	1·5 (1·2–1·8)	3·9 (3·6–4·1)	6·9 (6·6–7·3)
South Africa	3·4 (3·0–3·9)	6·0 (5·8–6·2)	8·5 (8·2–8·8)	2·5 (2·1–3·0)	5·4 (5·1–5·6)	8·5 (8·1–8·9)
Swaziland	1·9 (1·7–2·1)	4·4 (4·2–4·6)	7·3 (7·0–7·6)	1·3 (1·1–1·5)	3·7 (3·4–3·9)	7·3 (6·9–7·7)
Zimbabwe	2·9 (2·6–3·3)	5·6 (5·4–5·9)	8·3 (8·1–8·6)	1·4 (1·2–1·7)	3·7 (3·5–3·9)	6·7 (6·4–7·0)
Sub-Saharan Africa, west						
Benin	0·9 (0·8–1·1)	2·1 (1·9–2·2)	3·7 (3·5–4·0)	0·2 (0·2–0·3)	0·7 (0·6–0·7)	1·6 (1·5–1·8)
Burkina Faso	0·3 (0·3–0·4)	0·8 (0·8–0·9)	1·7 (1·6–1·8)	0·1 (0·1–0·1)	0·3 (0·3–0·3)	0·8 (0·7–0·8)
Cameroon	1·9 (1·6–2·1)	4·0 (3·8–4·2)	6·6 (6·4–6·8)	0·6 (0·5–0·7)	1·9 (1·7–2·0)	4·2 (4·0–4·5)

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	Men			Women		
	1970	1990	2009	1970	1990	2009
(Continued from previous page)						
Cape Verde	1·3 (1·1–1·4)	2·8 (2·7–3·0)	5·0 (4·8–5·3)	0·5 (0·4–0·6)	1·4 (1·4–1·5)	3·5 (3·3–3·7)
Chad	0·6 (0·5–0·7)	1·4 (1·3–1·5)	2·7 (2·6–2·9)	0·1 (0·1–0·1)	0·2 (0·2–0·3)	0·7 (0·7–0·8)
Côte d'Ivoire	1·2 (1·1–1·4)	2·5 (2·4–2·6)	4·1 (4·0–4·3)	0·2 (0·2–0·3)	0·8 (0·8–0·9)	2·0 (1·8–2·1)
Gambia	0·9 (0·8–1·0)	2·0 (1·9–2·1)	3·9 (3·7–4·1)	0·3 (0·2–0·3)	0·8 (0·7–0·8)	2·0 (1·8–2·1)
Ghana	3·0 (2·6–3·4)	5·5 (5·2–5·7)	7·8 (7·5–8·0)	1·2 (1·0–1·4)	2·8 (2·6–3·0)	5·2 (4·9–5·5)
Guinea	0·6 (0·5–0·7)	1·6 (1·5–1·7)	3·0 (2·8–3·2)	0·1 (0·1–0·1)	0·4 (0·4–0·4)	1·0 (0·9–1·1)
Guinea-Bissau	0·6 (0·5–0·8)	1·6 (1·5–1·7)	3·1 (2·9–3·3)	0·1 (0·1–0·1)	0·4 (0·4–0·4)	1·1 (1·0–1·2)
Liberia	1·5 (1·3–1·7)	3·5 (3·2–3·7)	5·9 (5·6–6·1)	0·3 (0·3–0·4)	0·9 (0·8–1·0)	2·2 (2·0–2·4)
Mali	0·4 (0·4–0·5)	1·1 (1·0–1·1)	2·0 (1·8–2·2)	0·1 (0·1–0·1)	0·4 (0·3–0·4)	0·8 (0·8–1·0)
Mauritania	0·7 (0·6–0·8)	1·6 (1·5–1·7)	3·1 (3·0–3·2)	0·2 (0·1–0·2)	0·5 (0·5–0·5)	1·5 (1·4–1·5)
Niger	0·2 (0·2–0·2)	0·6 (0·6–0·6)	1·5 (1·4–1·6)	0·1 (0·0–0·1)	0·2 (0·2–0·2)	0·6 (0·6–0·7)
Nigeria	1·8 (1·5–2·0)	4·0 (3·8–4·2)	6·7 (6·5–6·9)	0·5 (0·4–0·6)	1·7 (1·6–1·9)	4·1 (3·9–4·3)
Sao Tome and Principe	1·7 (1·5–1·9)	3·6 (3·4–3·7)	5·9 (5·6–6·1)	0·7 (0·6–0·8)	1·8 (1·6–1·9)	3·8 (3·6–4·1)
Senegal	0·8 (0·7–0·9)	1·8 (1·7–2·0)	3·3 (3·1–3·6)	0·3 (0·2–0·3)	0·7 (0·6–0·7)	1·5 (1·4–1·6)
Sierra Leone	0·8 (0·7–1·0)	1·8 (1·7–2·0)	3·2 (2·9–3·4)	0·2 (0·2–0·3)	0·6 (0·6–0·7)	1·5 (1·3–1·7)
Togo	1·3 (1·1–1·6)	3·0 (2·8–3·2)	5·2 (5·0–5·5)	0·3 (0·2–0·4)	0·9 (0·9–1·0)	2·3 (2·2–2·5)

Table 1: **Age-standardised mean years of education (95% uncertainty intervals) for men and women aged 25 years or older, by country, for 1970, 1990, and 2009**

1990 and 2009. We computed four sets of counterfactual scenarios. First, we estimated how many child deaths have been averted every year as a result of improvements in the education of women of reproductive age by replacing the value of the mean number of years of schooling in each country year with the mean number of years of young women in that country in 1970 for the first analysis and in 1990 for the MDG analysis. That is, we estimated the answer to the question: what would the rate of child mortality be, if education of women of reproductive age had stayed constant at its 1970 (or 1990) value? Second, we estimated the effect of economic growth on child mortality by replacing the value of GDP per person in every year with the value it had in 1970 (or 1990). Third, we estimated the counterfactual scenario in which both women's education and GDP per person had stayed at their 1970 (or 1990) values. Last, we computed the contribution of HIV infection to child mortality in two ways. We estimated the predicted rate of child mortality in the absence of HIV infection by replacing the value of HIV prevalence with 0 for all country years, and for the MDG analysis we also assessed what child mortality would have been if HIV prevalence in a particular country had stayed at the same rate it was in 1990. Our estimate of the number of deaths attributable to HIV infection is similar to and within the uncertainty bounds of the UNAIDS estimate of the number of deaths in children younger than 15 years, derived from disease progression models:[31] UNAIDS estimated 280 000 deaths in children younger than 5 years, possibly ranging from 150 000 to 410 000. About 86% of deaths in children younger than 15 years occur before the age of 5 years in South Africa, a country with one of the largest HIV/AIDS epidemics (unpublished).

All analyses were done with Stata (version 11.0), except the Loess regression, for which we used R (version 2.10.1). All estimates and the code used to produce the findings are available from the authors on request.

Role of the funding source

The funders had no role in the study design, data gathering and analysis, interpretation of data, decision to publish, or preparation of the report. The corresponding author had full access to all data that were analysed and had final responsibility for the decision to submit the report for publication.

Results

Figure 1 shows that there has been substantial progress in the global attainment of education between 1970 and 2009. For individuals aged 15 years or older, the global mean number of years of education in 1970 was 4·7 years (95% uncertainty interval [UI] 4·4–5·1) for men and 3·5 years (3·2–3·9) for women. By 2009, the mean number had increased to 8·3 years (8·0–8·6) for men and 7·1 years (6·7–7·5) for women. For men aged 15–24 years, mean duration of education increased from 5·3 years (5·0–5·7) to 8·8 years (8·4–9·1), whereas for women the mean duration increased from 4·3 years (3·9–4·6) to 8·5 years (8·0–9·0) in the past 40 years. In developing countries, the duration of education has increased from a mean of 2·8 years (95% UI 2·5–3·1) to 7·0 years (6·6–7·3) in men (aged ≥25 years), and from

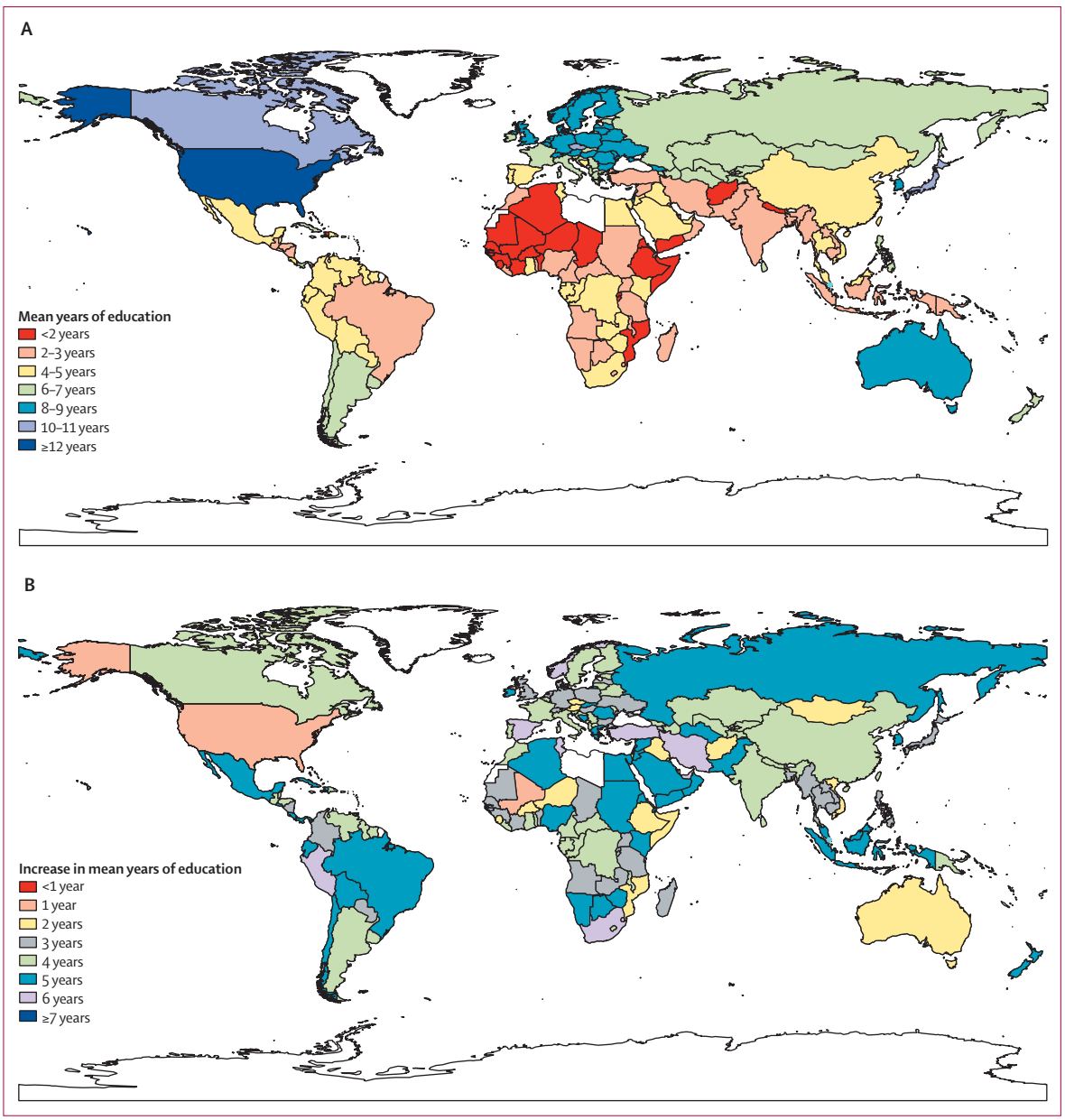

Figure 2: **Mean years of education in 1970 (A) and increase in mean years of education between 1970 and 2009 (B) in men aged 25–34 years**

1·3 years (1·2–1·5) to 5·3 years (5·0–5·7) in women (aged ≥25 years) between 1970 and 2009. For women of reproductive age (15–44 years) in developing countries, mean years of schooling increased from 2·2 years (2·0–2·4) to 7·2 years (6·8–7·6) between 1970 and 2009.

Since younger cohorts of women in developing countries have higher educational attainment (mean 7·9 years [95% UI 7·4–8·4] in women aged 15–24 years, 7·4 years [7·0–7·7] in those aged 25–34 years, and 6·2 years [5·9–6·6] in those aged 35–44 years), educational attainment for women of reproductive age as a group will continue to steadily rise.

In 2009, mean educational attainment was greater than 12 years in 23 countries for men and in 20 countries for women (table 1). However, mean educational attainment was less than 2 years in two countries for men, and 17 countries for women. In six of these countries (Afghanistan, Burkina Faso, Chad, Mali, Niger, and Yemen), adult women received less than 1 year of education (table 1). Although substantial progress has been achieved globally, the gap between the countries with the highest and lowest educational attainment has widened since 1970 and remains large—12·7 years for men and 13·8 years for women in 2009.

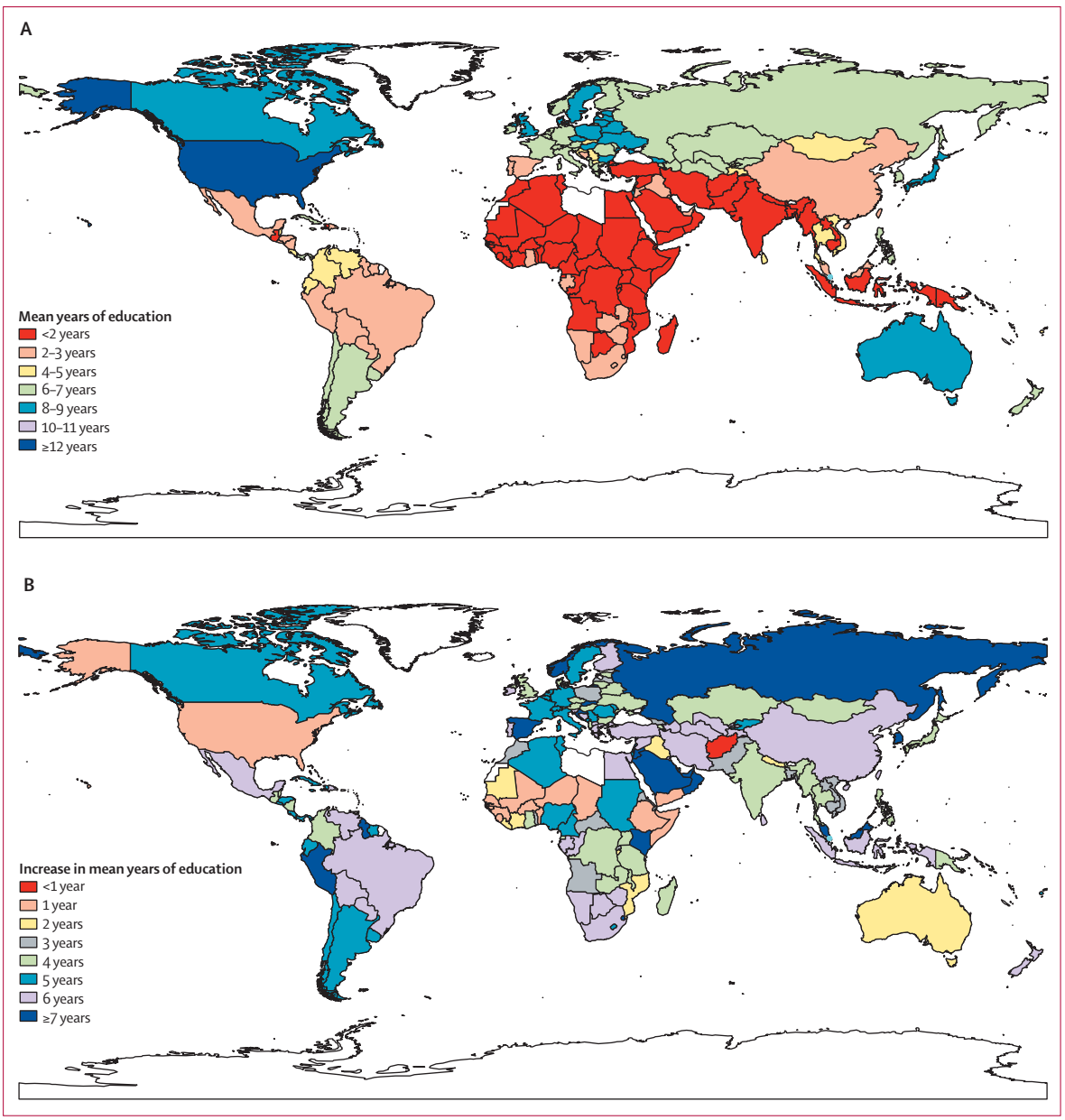

Figure 3: **Mean years of education in 1970 (A) and increase in mean years of education between 1970 and 2009 (B) in women aged 25–34 years**

The USA is notable for its high educational attainment among men and women in 1970 (figure 2; figure 3). Brazil, China, Indonesia, and Mexico, four of the world's most populous countries, had low educational attainment in 1970, but have shown substantial gains in the past 40 years for men and women (figure 2; figure 3). By contrast, women in Afghanistan, Benin, Burkina Faso, Chad, Ethiopia, Guinea, Guinea-Bissau, Mali, Niger, Senegal, Somalia, Sierra Leone, and Yemen had low educational attainment in 1970 and have shown a mean increase of less than 2 years in the past four decades (figure 3).

Of the ten most populous countries, which jointly make up almost 60% of the global population, the greatest increases in education among individuals aged 25–34 years were noted for men in Nigeria and Indonesia, and for women in Russia and Indonesia (table 2). Smaller increases than in the other populous countries were noted for men in Bangladesh, and for women in Pakistan and Bangladesh. Table 2 shows the wide variation across countries in the difference in educational attainment between women and men. Men had more education than did women in all ten countries in 1970 (table 2). By 2009, women aged 25–34 years in Brazil, Japan, Russia, and the

	Increase in years of schooling, 1970–2009		Gender gap between men and women in years of schooling	
	Men	Women	1970	2009
China	4·8 (4·2 to 5·3)	6·5 (6·0 to 7·1)	2·1 (1·7 to 2·4)	0·4 (–0·3 to 1·1)
India	4·8 (4·5 to 5·2)	4·6 (4·2 to 4·9)	2·2 (2·0 to 2·5)	2·5 (2·1 to 2·9)
USA	1·2 (1·0 to 1·4)	1·9 (1·6 to 2·2)	0·5 (0·1 to 0·9)	–0·3 (–0·4 to –0·1)
Indonesia	5·4 (5·1 to 5·7)	6·9 (6·7 to 7·2)	2·0 (1·6 to 2·3)	0·4 (0·2 to 0·7)
Brazil	5·1 (4·8 to 5·5)	6·4 (6·0 to 6·8)	0·3 (0·0 to 0·6)	–1·0 (–1·5 to –0·4)
Pakistan	5·3 (5·0 to 5·7)	3·8 (3·6 to 4·1)	1·6 (1·4 to 1·8)	3·1 (2·8 to 3·4)
Bangladesh	3·4 (3·2 to 3·6)	3·5 (3·3 to 3·7)	1·5 (1·3 to 1·8)	1·4 (1·2 to 1·6)
Nigeria	5·7 (5·3 to 6·1)	5·4 (5·1 to 5·7)	2·0 (1·6 to 2·3)	2·2 (1·9 to 2·5)
Russia	5·3 (4·8 to 5·7)	7·3 (6·8 to 7·7)	1·3 (0·6 to 2·0)	–0·6 (–0·8 to –0·5)
Japan	3·5 (3·1 to 3·9)	4·1 (3·7 to 4·6)	0·4 (0·0 to 0·8)	–0·2 (–0·6 to 0·2)

Data are increase in mean (95% uncertainty intervals). Countries are shown in order of the size of their populations.

Table 2: **Changes in educational attainment between 1970 and 2009 for men and women aged 25–34 years in the world's most populous countries**

USA had more years of schooling than did men. In three countries, the gap in education between men and women increased in the past 40 years; the increase was small in India and Nigeria, whereas in Pakistan it nearly doubled (table 2).

Globally, the gap between male and female educational attainment in the age group 15–44 years peaked in 1977 at 1·4 years (95% UI 1·0–1·8) and fell to 0·8 years (0·3–1·2) in 2009. Progress in the reduction of the gender gap in education has been achieved in almost all 21 regions of the world (figure 4). For most of Africa (except for southern Africa), the gap increased until the mid-1980s, but has been decreasing since, and in southern Africa women aged 25–34 years have achieved higher educational attainment than have men since 2008 (figure 4). No progress has been achieved in western sub-Saharan Africa, where the gender gap increased until the mid-1990s and is greater now than it was in 1970. The gender gap also increased in countries in south Asia and Oceania until the early 1990s and is still wider today than it was in 1970 (figure 4). By 2009, in 87 countries, including countries in all high-income regions, women aged 25–34 years had achieved higher levels of educational attainment than had men.

Mean increases in educational attainment among women of reproductive age (15–44 years) of more than 3 years were achieved in 31 countries between 1990 and 2009 (figure 5). In the Americas, great progress has been achieved in Brazil, Bolivia, and Mexico in the education of women of reproductive age. Notably, several countries in the Middle East with low educational attainment in women in 1990 achieved increases of greater than 3 years in the past two decades. In seven of ten most populous countries in the world, women of reproductive age in 2009 had achieved an average of more than 6 years of education; India (mean 5·7 years, 95% UI 5·3–6·0), Bangladesh (4·7 years, 4·5–4·9), and

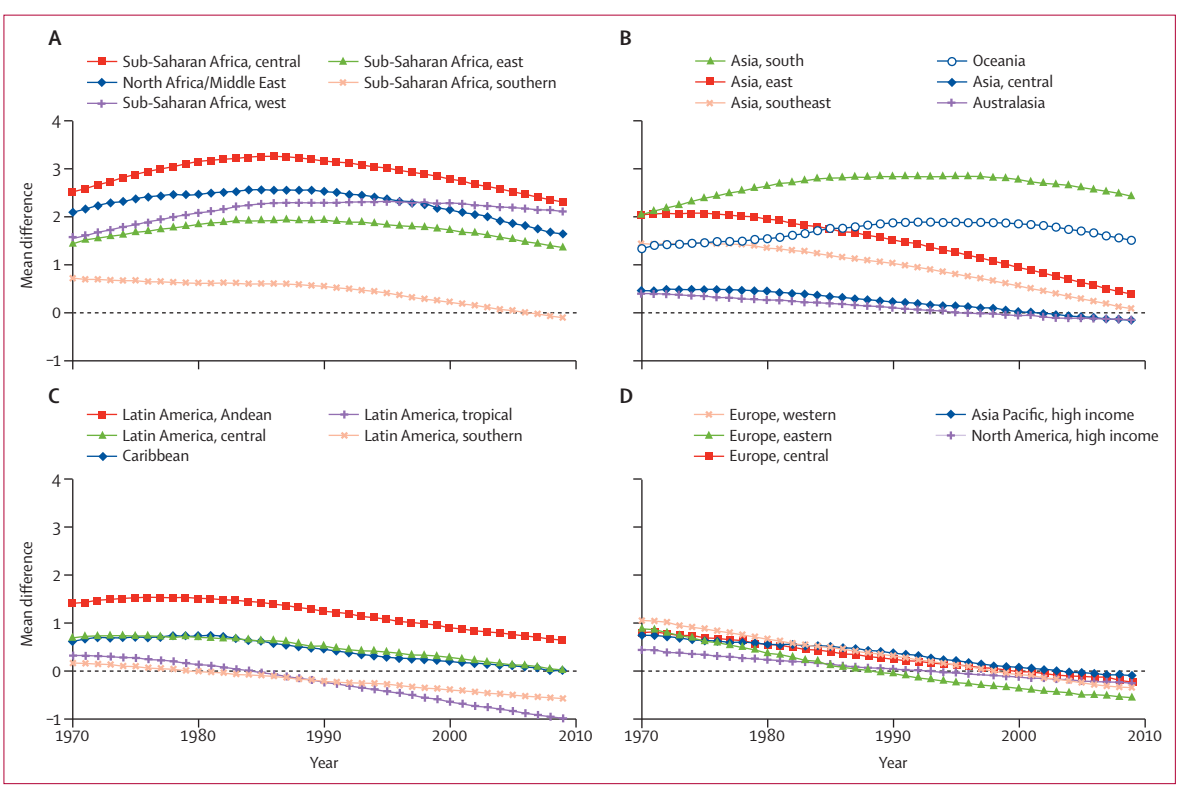

Figure 4: **Difference in mean years of education between men and women aged 25–34 years with time for 21 regions**
(A) Africa. (B) Asia. (C) Latin America. (D) High-income countries.

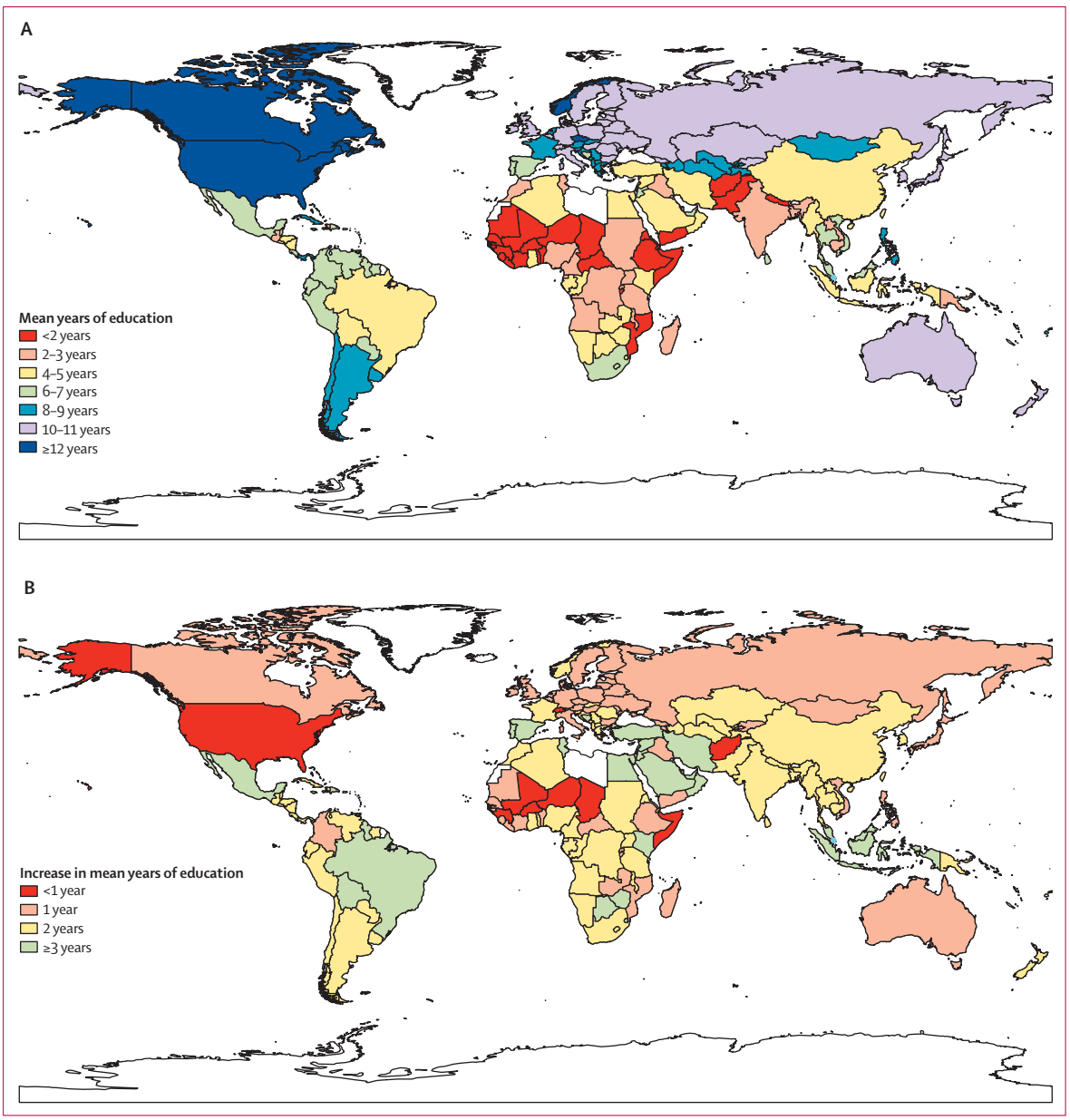

Figure 5: **Age-standardised mean years of education in 1990 (A) and increase in mean years of education between 1990 and 2009 (B) in women of reproductive age (15–44 years)**

Pakistan (4·2 years, 3·9–4·5) have also achieved smaller but significant gains since 1990. However, women of reproductive age still received an average of less than 6 years of education in 46 countries. Most of these countries are in sub-Saharan Africa, where the rates of child mortality remain the highest.

Improvements in GDP per person, HIV prevalence, and women's education were all significantly associated with reductions in the child mortality rate (table 3). The coefficient for women's education implied that for every 1 year of increase in the education of women of reproductive age, the child mortality decreased by 9·5%. Globally, about half the reduction in child mortality during the past four decades can be attributed to improvements in educational attainment in young women (figure 6; graphs for each of the 21 regions are presented in the webappendix pp 9–24). Globally, compared with 1970, there were about 8·20 million fewer deaths among children younger than 5 years in 2009, of which 4·20 million deaths (51·2%) were averted as a result of increases in educational attainment. In the MDG analysis, compared with 1990, 4·04 million fewer children younger than 5 years died in 2009, and 2·06 million deaths (50·8%) that were averted could be

	Coefficient	Standard error	p value
Income per person (international $)	–0·121	0·011	<0·0001
Education of reproductive-age women	–0·100	0·007	<0·0001
HIV prevalence (3-year lag)	1·849	0·128	<0·0001
Constant	–0·021	0·001	<0·0001

Table 3: **Coefficients from first-differences model for the effect of income per person, education of women of reproductive age (15–44 years), and HIV prevalence on child mortality between 1970 and 2009**

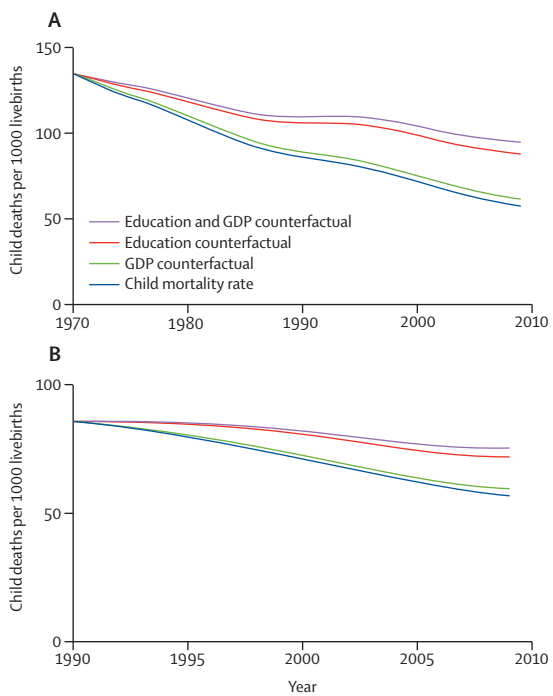

Figure 6: **Counterfactual analysis of effect of education and gross domestic product (GDP) on child mortality globally with 1970 (A) and 1990 (B) as base years**

The lines represent the actual child mortality rate (blue); estimated child mortality rate if GDP for each country had remained at the level it was in 1970 or 1990 (green); estimated child mortality rate if education of reproductive-age women for each country had remained at the level it was in 1970 or 1990 (red); and estimated child mortality rate if both GDP and education of reproductive-age women had remained at their 1970 or 1990 levels (purple).

attributed to increases in educational attainment (table 4; table 5).

Economic growth was also significantly associated with reductions in child mortality but the magnitude of the association was much smaller than that of increased education (table 4; table 5). For sub-Saharan Africa as a whole, with 48·9% of all deaths in children younger than 5 years in 2009, expansion of women's education accounted for a reduction of 902 799 child deaths since 1990 and 1 854 000 since 1970. In south Asia, with 33·4% of deaths in children younger than 5 years, the expansion of women's education accounted for 39·1% of the reduction in the number of child deaths. Globally, 275 000 excess deaths in children younger than 5 years were attributable to HIV, according to our model.

Discussion

Substantial progress has been made in education in the past 40 years, especially in developing countries, where the mean number of years of education has increased substantially in men and women aged 15 years and older between 1970 and 2009. For women of reproductive age (15–44 years) in developing countries, the increase was much greater. The rapid progress in educational attainment in women has resulted in significant reductions in the gender gap in education. The effect of educational expansion on child health has been enormous. 4·2 million deaths averted can be attributed to the increase in women's education. Our estimate of the effect of women's education on child mortality is very similar to that reported in 1988 by Cleland and van Ginneken.[11] In sub-Saharan Africa, if women's education had not increased, the number of child deaths would have increased during the period of the MDGs as a result of the HIV epidemic.

In developing countries, since women aged 15–24 years have higher educational attainment than do those aged 25–34 years and 35–44 years, educational attainment for women of reproductive age as a group will continue to steadily rise. The expansion of women's education will have serious implications for global health in the next few decades. Increases in educational attainment will probably lead to more rapid reductions in the total fertility rate, even in sub-Saharan Africa. Research suggests that education is associated with a reduction in the demand for children and thus increased demand for family planning services.[34,35] Our findings might be important to individuals advocating increased investment in the provision of family planning services in sub-Saharan Africa.[36–38] Since more educated women are more likely to use health services, and specifically preventive interventions, the steadily rising women's educational attainment in all areas of sub-Saharan Africa, except for the Sahel, will probably result in greater uptake of new maternal, newborn, and child interventions.[39–41]

By contrast with the substantial effect of increased education, economic growth has contributed to a reduction of 586 388 child deaths (7·2%) since 1970, partly because economic growth has been slow in regions such as sub-Saharan Africa, where 48·9% of child deaths occur. Analysis of the past four decades has shown that trends in educational attainment and income per person are not always closely correlated—the correlation of yearly rates of change was 0·27. In countries with less than 1% growth per year in GDP from 1990 to 2009, educational attainment in adults older than 25 years has increased by a mean of 1·9 years (40%) during the same period. The rise in educational attainment in regions without economic growth is probably attributable to a combination of increased domestic financing of education and enhanced

development assistance for education. This effect is an important demonstration of how global, regional, and national policies emphasising the expansion of primary education have led to changes that are disconnected from general economic growth, even if in the long term these policy changes will encourage rapid growth.

We have not quantified the investments that each country has made in expanding access to education, and the comparison of the cost-effectiveness of investment in girls' education with direct health investments is beyond the scope of this report. However, the findings raise the question of whether more resources should be invested in the expansion of educational attainment in developing countries, particularly those with high child mortality rates. In many of these countries, new cohorts of mothers have nearly completed primary school education. Further expansion in these settings will require increases in secondary school attendance, with the associated increased need for investments in school infrastructure and teachers.[42,43]

A pattern that is obvious from our results is the global progress in the reduction of the gender gap in educational attainment. In view of the current trends, the number of countries in which women will be more educated than are men will increase steadily. This reversal of the gender gap has serious implications not only for health but also for the status and roles of women in society, and these changes should be tracked closely over the coming years. Because higher education is associated with lower adult mortality,[4,44,45] the reversal of the gender gap in education might suggest a continued widening of the gap between mortality rates of men and women.[46] In 1970, the mortality rate in women was higher than in men in nine countries compared with three countries in 2010.[46]

Special efforts are needed in 40 countries, including several populous countries such as India, Pakistan, Nigeria, and Ethiopia, where the gap in education between young (age 25–34 years) men and women remains large and is actually larger now than it was in 1970. In these countries, intensified efforts are needed to ensure that young girls are not lagging behind in terms of education. MDG3, which focuses on gender equality, places special emphasis on the gender gap in primary and secondary education. Data for estimation of where we are and how much has been achieved since 1990 are sparse; nevertheless, the findings of our study provide optimism that progress toward MDG3 has been made in a large number of countries. Our study also draws

	Total number of child deaths×1000 in 2009	Difference in deaths×1000 in 2009 versus 1970	Deaths×1000 averted in 2009 because of improvements			Excess deaths×1000 in 2009 due to HIV versus no HIV	Education of reproductive-age women	
			Education	GDP	Education and GDP		Mean years (95% UI) in 1970	Change 1970–2009 (95% UI)
Asia Pacific, high income	6	–88	5	1	7	<1	8·8 (8·3 to 9·2)	4·8 (4·5 to 6·0)
Asia, central	64	–90	49	2	53	<1	6·5 (5·9 to 7·1)	5·4 (4·7 to 6·0)
Asia, east	307	–2132	256	100	438	<1	2·5 (2·3 to 2·8)	6·0 (5·4 to 6·7)
Asia, south	2610	–3101	1337	333	1857	13	1·0 (0·9 to 1·1)	4·2 (3·9 to 4·6)
Asia, southeast	361	–1115	253	54	346	2	3·1 (2·8 to 3·4)	5·5 (5·0 to 5·9)
Australasia	2	–5	1	<1	1	<1	8·9 (8·4 to 9·4)	3·9 (3·3 to 4·5)
Caribbean	30	–57	21	1	23	1	4·3 (3·9 to 4·7)	5·4 (4·9 to 5·9)
Europe, central	10	–72	7	1	8	<1	7·4 (6·9 to 7·9)	4·7 (4·0 to 5·2)
Europe, eastern	33	–68	25	1	27	<1	7·6 (7·0 to 8·2)	5·5 (4·9 to 6·2)
Europe, western	19	–141	13	2	16	<1	6·9 (6·5 to 7·4)	5·1 (4·5 to 5·8)
Latin America, Andean	35	–129	31	1	34	<1	3·6 (3·3 to 3·9)	6·3 (5·9 to 6·8)
Latin America, central	90	–365	66	5	75	<1	3·5 (3·3 to 3·9)	5·7 (5·3 to 6·2)
Latin America, southern	12	–57	8	1	9	<1	6·5 (6·1 to 6·9)	5·1 (4·5 to 5·8)
Latin America, tropical	68	–352	57	7	70	<1	2·8 (2·6 to 3·1)	6·1 (5·7 to 6·6)
North Africa/Middle East	296	–1119	199	25	241	<1	1·6 (1·4 to 1·8)	5·7 (5·3 to 6·2)
North America, high income	32	–66	7	3	11	<1	11·5 (11·3 to 11·8)	2·0 (1·7 to 2·3)
Oceania	19	2	11	2	13	<1	2·1 (2·0 to 2·3)	4·2 (3·8 to 4·6)
Sub-Saharan Africa, central	541	187	268	–51	193	17	1·3 (1·1 to 1·5)	4·1 (3·8 to 4·4)
Sub-Saharan Africa, east	1366	179	616	43	678	120	0·9 (0·8 to 1·0)	3·8 (3·5 to 4·1)
Sub-Saharan Africa, southern	102	–57	90	4	97	30	3·5 (3·1 to 3·9)	6·2 (5·7 to 6·8)
Sub-Saharan Africa, west	1815	448	880	51	964	89	1·0 (0·8 to 1·1)	3·9 (3·6 to 4·2)
Global	7817	–8199	4198	586	5160	275	4·1 (3·8 to 4·4)	4·1 (3·6 to 4·6)

GDP=gross domestic product. UI=uncertainty interval.

Table 4: **Results of counterfactual analysis of the effect of education in women of reproductive age, income per person, and HIV on child mortality by use of 1970 as the year of comparison**

	Total number of child deaths ×1000 in 2009	Difference in deaths×1000 in 2009 versus 1990	Deaths×1000 averted in 2009 because of improvements			Excess deaths×1000 in 2009 due to HIV, compared to:		Education of reproductive-age women	
			Education	GDP	Education and GDP	No HIV	1990 HIV	Mean years (95% UI) in 1990	Change 1990–2009 (95% UI)
Asia Pacific, high income	6	–10	1	<1	2	<1	<1	11·7 (11·4 to 12·0)	1·8 (1·0 to 2·6)
Asia, central	64	–78	15	–1	14	<1	<1	10·0 (9·7 to 10·2)	1·9 (1·5 to 2·3)
Asia, east	307	–694	105	55	178	<1	<1	5·6 (5·4 to 5·8)	2·9 (2·3 to 3·5)
Asia, south	2610	–1885	737	198	998	13	13	2·7 (2·6 to 2·9)	2·5 (2·1 to 2·8)
Asia, southeast	361	–461	107	29	144	2	2	6·0 (5·8 to 6·2)	2·6 (2·2 to 3·0)
Australasia	2	–1	<1	<1	<1	<1	<1	11·3 (11·0 to 11·5)	1·5 (1·0 to 1·9)
Caribbean	30	–32	10	<1	10	1	1	7·4 (7·1 to 7·7)	2·2 (1·8 to 2·7)
Europe, central	10	–25	2	<1	3	<1	<1	10·4 (10·1 to 10·6)	1·8 (1·3 to 2·2)
Europe, eastern	33	–45	6	<1	6	<1	<1	11·3 (11·1 to 11·5)	1·8 (1·6 to 2·0)
Europe, western	19	–25	4	1	5	<1	<1	10·1 (9·9 to 10·4)	1·9 (1·5 to 2·4)
Latin America, Andean	35	–55	12	1	13	<1	<1	7·1 (6·9 to 7·3)	2·9 (2·4 to 3·2)
Latin America, central	90	–120	27	2	30	<1	<1	6·6 (6·4 to 6·8)	2·6 (2·2 to 3·0)
Latin America, southern	12	–15	3	1	3	<1	<1	9·4 (9·2 to 9·7)	2·2 (1·6 to 2·7)
Latin America, tropical	68	–133	24	1	26	<1	<1	5·9 (5·7 to 6·1)	3·1 (2·6 to 3·5)
North Africa/Middle East	296	–407	93	8	103	<1	<1	4·3 (4·1 to 4·5)	3·1 (2·6 to 3·5)
North America, high income	32	–18	2	1	3	<1	<1	13·0 (12·9 to 13·1)	0·6 (0·4 to 0·8)
Oceania	19	2	6	<1	6	<1	<1	4·1 (3·9 to 4·3)	2·3 (1·8 to 2·7)
Sub-Saharan Africa, central	541	41	128	–33	88	17	6	3·2 (3·0 to 3·4)	2·1 (1·9 to 2·4)
Sub-Saharan Africa, east	1366	–182	305	50	366	120	69	2·6 (2·5 to 2·8)	2·1 (1·8 to 2·4)
Sub-Saharan Africa, southern	102	–5	35	1	37	30	27	6·8 (6·6 to 7·0)	2·9 (2·5 to 3·3)
Sub-Saharan Africa, west	1815	103	434	40	485	89	79	2·7 (2·6 to 2·9)	2·1 (1·8 to 2·5)
Global	7817	–4044	2056	355	2520	275	199	6·3 (6·1 to 6·5)	1·9 (1·5 to 2·3)

GDP=gross domestic product. UI=uncertainty interval.

Table 5: **Results of counterfactual analysis of the effect of education of women of reproductive age, income per person, and HIV on child mortality rate by use of 1990 as the year of comparison**

attention to areas, specifically south Asia and western sub-Saharan Africa, where intensified efforts are needed to eliminate gender disparity, and countries such as Afghanistan, Burkina Faso, Chad, Mali, Niger, and Somalia that have achieved little progress in the education of women.

Although tracking of the mean number of years of schooling in countries is important, these average numbers mask inequalities within countries. Inequalities in educational attainment should be measured and monitored to make sure that the most socioeconomically disadvantaged populations are not lagging behind. Inequalities in educational attainment have been quantified in only a few studies.[47,48] Since the mean numbers of years of education are increasing in all countries, tracking of gains achieved by the most disadvantaged groups becomes increasingly important.

There were four main limitations to our study. First, despite our efforts to compile all available census and survey data, for 23 countries we have reconstructed the time series of educational attainment using only one data source. Also, some of the sources provide information only about the highest level of education completed, not the exact number of years, and therefore might lead to an underestimation of the number of years of education completed. Second, in the analysis of the contribution of educational attainment to child mortality, we have implicitly assumed that a year of education is comparable across countries and periods, since our data do not include any measurements of quality. Although quality of education is likely to vary across settings, data for the quality of education are rare. We investigated the relation with data for 54 countries that are available from PISA, an international standardised test of 15-year-old students, administered by the Organisation for Economic Co-operation and Development[49] (webappendix pp 24–25). We noted that with the same degree of educational attainment there can be substantial variation in the amount learned, but most of the variation can be attributed to country effects in the 7 years covered by the PISA data. Since our analytical model includes country effects, our results are robust as long as quality of education within a country does not change substantially over the period of analysis. Furthermore, there is evidence that the effect of education on the behaviour of mothers might be less related to quality and more related to changing gender roles and women's empowerment.[50] Therefore, although monitoring of the quality of

education is crucial, we believe that our results for the effect of education on child mortality are valid. Third, we have probably underestimated the full effect of education on child mortality because we only captured the direct effect of education on reductions in the death rate among children younger than 5 years. We have not, for example, taken into account the effect of education on the number of child deaths as a result of reductions in fertility. Fourth, our models include a random effect on country, which might not fully capture all residual confounding and omitted variables.

Even though progress on reduction of child mortality has not been at the pace needed to achieve the ambitious goal of reducing child mortality by two-thirds between 1990 and 2015, evidence indicates that reductions in child mortality are occurring, especially in sub-Saharan Africa. The continued expansion of educational attainment even in some of the poorest countries holds out the real prospect that accelerated progress on MDG4 might be possible. The global health community should take advantage of the opportunity presented by more educated cohorts of women of reproductive age to intensify efforts to deliver key services to women, babies, and children.

Contributors

EG and CJLM conceptualised the study and guided the data analysis. KC identified and acquired all the data and did all analyses. EG, KC, RL and CJLM wrote the report.

Conflicts of interest

We declare that we have no conflicts of interest.

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