Schooling and wage income losses due to early-childhood growth faltering in developing countries: national, regional, and global estimates\textsuperscript{1,2}

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ABSTRACT

\textbf{Background:} The growth of \textgreater 300 million children \textless 5 y old was mildly, moderately, or severely stunted worldwide in 2010. However, national estimates of the human capital and financial losses due to growth faltering in early childhood are not available.

\textbf{Objective:} We quantified the economic cost of growth faltering in developing countries.

\textbf{Design:} We combined the most recent country-level estimates of linear growth delays from the Nutrition Impact Model Study with estimates of returns to education in developing countries to estimate the impact of early-life growth faltering on educational attainment and future incomes. Primary outcomes were total years of educational attainment lost as well as the net present value of future wage earnings lost per child and birth cohort due to growth faltering in 137 developing countries. Bootstrapped standard errors were computed to account for uncertainty in modeling inputs.

\textbf{Results:} Our estimates suggest that early-life growth faltering in developing countries caused a total loss of 69.4 million y of educational attainment (95\% CI: 41.7 million, 92.6 million y) per birth cohort. Educational attainment losses were largest in South Asia (27.6 million y; 95\% CI: 20.0 million, 35.8 million y) as well as in Eastern (10.3 million y; 95\% CI: 7.2 million, 12.9 million y) and Western sub-Saharan Africa (8.8 million y; 95\% CI: 6.4 million, 11.5 million y). Globally, growth faltering in developing countries caused a total economic cost of $176.8 billion (95\% CI: $100.9 billion, $262.6 billion)/birth cohort at nominal exchange rates, and $616.5 billion (95\% CI: $365.3 billion, $898.9 billion) at purchasing power parity–adjusted exchange rates. At the regional level, economic costs were largest in South Asia ($46.6 billion; 95\% CI: $33.3 billion, $61.1 billion), followed by Latin America ($44.7 billion; 95\% CI: $19.2 billion, $74.6 billion) and sub-Saharan Africa ($34.2 billion; 95\% CI: $24.4 billion, $45.3 billion).

\textbf{Conclusions:} Our results indicate that the annual cost of early-childhood growth faltering is substantial. Further investment in scaling up effective interventions in this area is urgently needed and likely to yield long run benefits of $3 for every $1 invested.

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\textbf{Keywords:} child nutrition, growth faltering, developmental potential, global estimates, educational attainment

INTRODUCTION

More than 200 million children in low- and middle-income countries are currently not reaching their developmental potential (1), and \textgreater 300 million children experience suboptimal linear growth (2). Although remarkable global progress has been made in reducing mortality for children \textless 5 y old over the past decades (3–5), progress in improving early-childhood physical development has been comparatively slow (2, 6). Early-life growth delays not only may inhibit children’s ability to interact with their environment (7) but also are associated with lasting deficits in broader developmental and linear growth trajectories (8, 9). Early growth deficits have also been shown to be associated with late school enrollment (10) and reduced educational attainment (10–13), which is highly predictive of adult income (14–16), health (17), and well-being (18).

Although studies have argued that the economic burden caused by early-life growth delays is likely large (1, 19), country- or region-specific estimates of the economic consequences of growth delays are not currently available. In this article, we combine all available evidence linking early-life physical growth to labor market outcomes via schooling with the latest estimates on country-specific labor market returns to quantify the total value of lifetime earnings lost because of impaired early-life growth at the individual, country, regional, and global levels. The resulting estimates are designed not only to allow researchers and policy makers to identify the areas and risk factors causing the

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\textsuperscript{2}Supplemental Figures 1 and 2 and Supplemental Tables 1–3 are available from the “Online Supporting Material” link in the online posting of the article and from the same link in the online table of contents at http://ajcn.nutrition.org.

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ECONOMIC IMPACT OF EARLY-CHILDHOOD GROWTH FALTERING

Quantifying current early-life linear growth deficits and resulting educational gaps

To quantify the prevalence of growth faltering, we used data from the Nutrition Impact Model Study (NIMS)\(^8\) for the year 2010 (2). Our main objective was to compute the economic impact of completely eliminating early-childhood growth faltering. To do so, we computed the improvements in children’s growth needed for each country to achieve the ideal (unrestricted) height distribution defined by the WHO reference population (20). Empirically, the current height distribution of children <5 y old in most developing countries is close to normal with a negative mean and an SD slightly >1. To close the gap to the WHO reference population, the entire height distribution for children <5 y old in developing countries needs to be shifted to the right such that it is centered on a mean of zero. Figure 2 shows examples of the modeled shifts in the distribution of height-for-age z scores (HAZs) for Tanzania (mean HAZ in 2010 was −1.75) and Colombia (mean HAZ in 2010 was −0.90).

To estimate the impact of early-life growth deficits on highest grade attained, we relied on the most recent longitudinal estimates of associations between early-life HAZ and completed (adult) educational outcomes. Five major cohort studies have linked early-childhood growth to adult educational attainment (11). The pooled estimate from these studies suggests that each unit increase in HAZ at age 2 y is associated with an additional 0.47 y of educational attainment (95% CI: 0.39, 0.56 y). We assumed that the educational improvements resulting from improved early-childhood growth are a linear function of HAZ as suggested in Adair et al. (11); in Supplemental Figure 1, we show the empirical relation between HAZ and adult educational attainment observed in the Cebu Longitudinal Health and Nutrition Survey as supporting evidence for this linearity assumption and further discuss this assumption below (11).

Quantifying wage losses resulting from reduced educational attainment

A large economic literature has analyzed the economic returns to schooling. Following the seminal work by Mincer (21), most of the empirical literature uses years of completed schooling (highest grade attained) as the primary measure of human capital and estimates the return on human capital as the percentage increase in wages associated with each additional year of schooling. Estimates for the returns to schooling vary widely across countries, with developing countries generally perceived to have higher returns because of the lower availability of skilled labor (22–24). We systematically reviewed published economics literature on the returns to education in developing countries listed on EconLit and extracted estimates from published articles. Most of the published literature uses basic ordinary least squares (OLS) models to estimate the associations between highest grade attained and wage income. These estimates may overestimate the true causal effect of education on labor market incomes because of potential confounding or omitted variable bias, but they could also underestimate the true returns to education if educational attainment data were subject to measurement error. Whereas evidence based on twin studies suggests that cross-sectional estimates on the returns to schooling may be marginally upward biased (25, 26), reviews comparing OLS to instrumental variable (IV) estimates generally find IV estimates to be larger than OLS estimates (14, 27), suggesting that confounding biases could be dominated by measurement error bias empirically. Given this, we use OLS estimates as our main specification and investigate alternative returns to education scenarios in our sensitivity analysis. In cases in which a single article reported multiple estimates for a given country, we extracted the estimate based on the largest sample from the article. In cases in which multiple estimates were available for a given country from different studies, random-effects meta-analysis was used to generate country-level estimates. For countries without any published estimate, we used random-effects meta-analysis to compute average rates of return at the subregional and regional levels. For regional definitions, we followed the classification used by the Global Burden of Disease project (28). Supplemental Table 1 provides a list of countries and regional classifications.

Computation of the net present value of lifetime earnings at the individual and national level

Representative data on wages and current earnings are not available for a majority of developing countries. To translate the marginal (%) increases in wage rates into current US dollars, we computed mean wage rates for each country based on per-capita income in 2010 as published in the World Bank’s World Development Indicator database (29). Although the share of national income captured by labor (as opposed to capital) can vary across countries, labor shares appear to be relatively constant across countries and time, accounting for two-thirds of national income (gross domestic product) (30, 31). On the basis of this empirical relation (illustrated in Supplemental Figure 2), we computed country-level average wage rates as two-thirds of national income in our main analysis and used 50% and 75% in sensitivity analyses. To ensure comparability across countries, we computed all wages in 2010 US dollars. Although the

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\(^8\) Abbreviations used: HAZ, height-for-age z score; IV, instrumental variable; NIMS, Nutrition Impact Model Study; OLS, ordinary least squares.
RESULTS

According to the NIMS estimates, the growth of 30.3% of children in the 137 developing countries analyzed was stunted in 2010, with a global mean HAZ of $-1.0$. Table 1 summarizes the total estimated number of years of educational attainment lost because of early-childhood growth faltering. Our estimates suggest that early-life growth faltering caused a total loss of 69.4 million $y$ of grades attained (95% CI: 48.1 million, 92.6 million $y$ of grades attained) per birth cohort. Human capital losses were largest in South Asia (27.6 million $y$ lost; 95% CI: 20.0 million, 35.8 million $y$ lost) as well as Eastern (10.3 million $y$ lost; 95% CI: 7.9 million, 12.9 million $y$ lost) and Western sub-Saharan Africa (8.8 million $y$ lost; 95% CI: 6.4 million, 11.5 million $y$ lost). Figure 3 illustrates the global distribution of educational attainment losses.

We extracted 197 estimates from 88 studies for the returns to education in developing countries. The country-level average estimated return to each additional year of schooling was 7.9%. Supplemental Table 2 shows the full list of extracted estimates. Average returns to schooling were highest in Latin America (10.0%/y of educational attainment) and sub-Saharan Africa (9.7%/y); lowest returns to education were found for East Asia (6.1%/y) and the North Africa/Middle East region (6.2%/y).

Estimated lifetime income losses due to growth faltering varied from a total of $<300$ in Tajikistan and Liberia to values $>$30,000 in the Bahamas, the United Arab Emirates, Kuwait, and Qatar (Figure 4).

Globally, our estimates indicated that removing all growth deficits among the 122.9 million children born in 2010 would increase the net present value of future incomes by $176.8 billion/y or birth cohort (95% CI: $100.9 billion, $262.6 billion) (Table 1). At the regional level, the highest benefits were expected for South Asia ($46.6 billion; 95% CI: $33.4 billion, $61.1 billion), where stunting rates continued to be high, and rates of return were relatively high compared with other parts of the larger Asian region. Despite the relatively small population, the second highest annual benefits were found in Central America ($27.2 billion; 95% CI: $13.6 billion, $43.9 billion), owing to both the relatively high local wage rates and the generally large returns to education in the region. Large benefits were also found for sub-Saharan Africa, with a total estimated benefit of $34.2 billion (95% CI: $24.4 billion, $45.3 billion).

The country with the largest expected gains in schooling and future incomes from eliminating suboptimal growth was India, with a total estimated gain of $37.9 billion (95% CI: $26.8 billion, $50.0 billion) (Supplemental Table 3). In sub-Saharan Africa, the 3 countries with the highest expected benefits were South Africa ($9.5 billion; 95% CI: $6.7 billion, $12.8 billion), Nigeria ($6.4 billion; 95% CI: $4.7 billion, $8.4 billion).
and Angola ($2.2 billion; 95% CI: $1.4 billion, $3.0 billion). In Latin America, the largest benefits were expected for Mexico ($18.5 billion; 95% CI: $9.0 billion, $30.8 billion) and Brazil ($11.4 billion; 95% CI: $2.5 billion, $20.6 billion).

Table 2 shows the results of our sensitivity analyses. As expected, total benefits varied substantially with alternative discounting rates: when future wage gains were discounted at an annual rate of 5% (instead of 3% in our main specification), the estimated total benefits by cohort declined from $177 billion to $86 billion; with alternative discounting rates of 0% and 10%, estimated benefits were $590 billion and $18 billion, respectively. The variation in estimates was smaller when the 2 other key assumptions of our model were varied: when average wages were assumed to be only 50% of a country’s income per capita, total benefits declined to $133 billion; with a more optimistic assumption of a wage:income per capita ratio of 0.75, the estimated global benefits per cohort increased to $199 billion. Varying the real-wage growth assumption, estimated benefits declined to $122 billion with 1% real-wage growth per year, and increased to $260 billion with an annual real-wage growth rate of 3%. Using purchasing power parity–adjusted instead of nominal wage rates increased estimated global benefits from $177 billion to $617 billion.

**DISCUSSION**

The results presented in this article suggest that the economic costs of growth faltering in developing countries are substantial. On average, children in developing countries lost 0.5 y of educational attainment because of early-life growth faltering, resulting in a global economic loss of $176.7 billion, and an average loss of lifetime earnings of $1400/child. Several studies have estimated the cost of providing a comprehensive package of
critical interventions to children. At the global level, the total cost for a package of interventions to reduce malnutrition with a coverage level of 90% in the 34 countries with the highest burden of malnutrition was estimated to be $10 billion (35). At the country level, the annual intervention cost for such a package was estimated to be $100/child for the majority of developing countries (19, 35–37). Assuming that this comprehensive package could prevent 20% of all growth faltering (35), a cost of $100 · child⁻¹ · y⁻¹ suggests a benefit:cost ratio of ~3:1, not taking into account other long-term benefits generated by increased human capital and improved long-term health outcomes. The large estimated returns to investing in early-childhood nutrition naturally raise the question of why investment in this area remains limited. Although this project was not designed to directly answer this question, several factors are likely to contribute to the current lack of investment: First, growth faltering is not easy to diagnose for parents or local organizations, particularly in settings where chronic malnutrition is common.

### TABLE 1

<table>
<thead>
<tr>
<th>Subregion</th>
<th>Countries, n</th>
<th>Cohort size, millions of births/y</th>
<th>Total years of educational attainment lost, millions of school years attained</th>
<th>Total wage losses at 3% discounting, US$ billions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>9</td>
<td>1.8</td>
<td>0.7 (0.3, 1)</td>
<td>2.0 (0.9, 3.2)</td>
</tr>
<tr>
<td>East</td>
<td>3</td>
<td>17.1</td>
<td>3.8 (1.5, 6.2)</td>
<td>14.4 (5.2, 24.3)</td>
</tr>
<tr>
<td>South</td>
<td>6</td>
<td>36.7</td>
<td>27.6 (20, 35.8)</td>
<td>46.6 (33.4, 61.1)</td>
</tr>
<tr>
<td>Southeast</td>
<td>13</td>
<td>12.1</td>
<td>6.9 (4.9, 9.1)</td>
<td>18.0 (11.5, 25.6)</td>
</tr>
<tr>
<td>Caribbean</td>
<td>15</td>
<td>0.7</td>
<td>0.2 (0.1, 0.3)</td>
<td>1.1 (0.4, 1.8)</td>
</tr>
<tr>
<td><strong>Latin America</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andean</td>
<td>3</td>
<td>1.2</td>
<td>0.7 (0.5, 0.8)</td>
<td>2.9 (2.1, 3.8)</td>
</tr>
<tr>
<td>Central</td>
<td>9</td>
<td>4.7</td>
<td>1.9 (1.2, 2.6)</td>
<td>27.2 (13.6, 43.9)</td>
</tr>
<tr>
<td>Southern</td>
<td>3</td>
<td>1.0</td>
<td>0.1 (0, 0.3)</td>
<td>1.9 (0.4, 4.1)</td>
</tr>
<tr>
<td>Tropical</td>
<td>2</td>
<td>3.3</td>
<td>0.5 (0.1, 1)</td>
<td>11.7 (2.6, 21)</td>
</tr>
<tr>
<td>North Africa/Middle East</td>
<td>19</td>
<td>10.4</td>
<td>3.8 (1.9, 5.7)</td>
<td>16.3 (6.27, 8)</td>
</tr>
<tr>
<td>Oceania</td>
<td>9</td>
<td>0.3</td>
<td>0.2 (0.1, 0.3)</td>
<td>0.6 (0.4, 0.8)</td>
</tr>
<tr>
<td><strong>Sub-Saharan Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>6</td>
<td>4.3</td>
<td>2.9 (2.2, 3.8)</td>
<td>3.4 (2.2, 4.7)</td>
</tr>
<tr>
<td>East</td>
<td>15</td>
<td>13.5</td>
<td>10.3 (7.9, 12.9)</td>
<td>10.5 (7.7, 13.5)</td>
</tr>
<tr>
<td>Southern</td>
<td>6</td>
<td>1.8</td>
<td>1.0 (0.7, 1.3)</td>
<td>10.8 (7.6, 14.5)</td>
</tr>
<tr>
<td>West</td>
<td>19</td>
<td>13.9</td>
<td>8.8 (6.4, 11.5)</td>
<td>9.6 (6.9, 12.5)</td>
</tr>
<tr>
<td>Developing countries, total n</td>
<td>137</td>
<td>122.9</td>
<td>69.4 (48.1, 92.6)</td>
<td>176.8 (100.9, 262.6)</td>
</tr>
</tbody>
</table>

Note: Total estimated educational and wage benefits by birth cohort. Values in parentheses are 95% CIs based on bootstrapped SEs.

FIGURE 3 Estimated average educational losses due to early-life growth faltering (years of educational attainment per child born in 2010).
Second, compared with other areas of investment, such as child survival and child education, investing in childhood nutrition has the disadvantage of generating benefits only in the relatively distant future and may thus appear as a less pressing or less rewarding investment from a political or funder perspective. Last, and most importantly for this article, awareness of the long-run consequences of growth faltering is still limited; this article can be seen as a first step to address this knowledge or awareness gap.

Although this analysis is to our knowledge the most comprehensive assessment of country-specific educational and income losses due to growth faltering done to date, the work presented has several important limitations. First, and perhaps most importantly, causal evidence linking early-childhood growth intervention to schooling is very limited (38). To link early-life interventions to educational attainment, longitudinal studies following children for ≥20 y are needed. The analysis presented in this article relies on the Consortium of Health-Orientated Research in Transitioning Societies data used in Adair et al. (11), which suggest large and positive associations between early-life growth and educational attainment across 5 countries. Although these associations do not necessarily represent causal effects, the assumed causal magnitudes (a 0.47 improvement in highest grade attained for a 1-SD increase in HAZ) seem to be well aligned with trial evidence from Guatemala (39), as well as IV and sibling fixed-effects estimators from South Africa (40) and Zimbabwe (41). Our estimates imply that a 2-SD increase in early-childhood HAZ leads on average to ~1 additional year of schooling and an 8% increase in lifetime wage income, which is very conservative compared with consumption and wage differentials observed in long-run trial follow-ups in Guatemala (42) and Jamaica (43), and substantially below the wage assumptions made in previous cost-benefit estimates that directly account for cognitive improvements in addition to increases in highest grade attained (1, 19).

Although the estimates presented in this article are based on a large number of assumptions, we believe that the numbers presented are overall much more likely to underestimate than to overestimate the true benefits of reducing early-childhood growth delays. All assumptions in the model were intentionally chosen to be conservative: we discount all benefits by using a discounting rate of 3%, which means that long-run benefits are only marginally considered, as discussed in a large literature debating the validity of discount rates arising from time preference or opportunity costs (32, 44–46). We also restrict years of work to ages 20–60 y, which seems low in an era of rapidly increasing life expectancies; recent evidence suggests that close to one-third of individuals in developing countries work beyond age 65 y (47). The same holds for our assumption of an annual income per-capita growth of 2%, which is substantially below the 5.9% average growth rates experienced by developing countries in the 2003–2013 period (48). Assuming a more optimistic growth rate of 3%/y would increase all estimated benefits by nearly 50%; assuming a more ambitious growth rate of 4%/y would more than double the estimated benefits reported here. The opposite would of course be true if the more conservative discounting rates of 5% or 10% suggested in previous nutrition impact studies were applied (49).

The likely most important reason why the presented estimates can be presumed to be conservative estimates of the true benefits is our exclusive focus on educational attainment as mediator between early childhood experiences and adult outcomes. By restricting our causal mechanisms to educational attainment alone, we are accounting for only a fraction of the benefits of improving early-life growth. Several studies suggest that improved early-life growth can promote increases in adult incomes...
TABLE 2
Univariate sensitivity analyses: regional and global economic losses due to growth faltering under alternative assumptions

<table>
<thead>
<tr>
<th>Wage as % of GDP per capita</th>
<th>Annual real-wage growth</th>
<th>Returns to education</th>
<th>PPP adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>3%</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td>110.0</td>
<td>22.8</td>
<td>19.7</td>
</tr>
<tr>
<td>(56.9, 169.2)</td>
<td>(12.8, 38)</td>
<td>(11.8, 35.1)</td>
<td>(1.7, 3.5)</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>149.4</td>
<td>33.6</td>
<td>31.0</td>
</tr>
<tr>
<td>(64.1, 249.1)</td>
<td>(14.4, 55.9)</td>
<td>(13.3, 51.6)</td>
<td>(4.7, 21.5)</td>
</tr>
<tr>
<td>North Africa, Middle East</td>
<td>61.1</td>
<td>13.7</td>
<td>12.7</td>
</tr>
<tr>
<td>and Central Asia</td>
<td>(22.9, 103.5)</td>
<td>(5.1, 23.3)</td>
<td>(4.8, 21.7)</td>
</tr>
<tr>
<td>South Asia</td>
<td>155.5</td>
<td>34.9</td>
<td>22.2</td>
</tr>
<tr>
<td>(111.4, 203.9)</td>
<td>(25.4, 45.2)</td>
<td>(23.1, 42.3)</td>
<td>(4.8, 21.7)</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>114.3</td>
<td>25.7</td>
<td>23.7</td>
</tr>
<tr>
<td>(81.6, 151.2)</td>
<td>(18.3, 34)</td>
<td>(16.9, 31)</td>
<td>(4.8, 21.7)</td>
</tr>
<tr>
<td>Global benefits per cohort, billion US$</td>
<td>590.3</td>
<td>132.6</td>
<td>122.4</td>
</tr>
<tr>
<td>(336.9, 876.8)</td>
<td>(75.7, 197)</td>
<td>(69.8, 181.8)</td>
<td>(82.4, 216.5)</td>
</tr>
</tbody>
</table>

1Global benefit estimates in 2010 billion US$. Values in parentheses are 95% CIs based on bootstrapped SEs. GDP, gross domestic product; PPP, purchasing power parity.

The authors’ responsibilities were as follows—GF: developed and designed the overall study together with ME and WWF and completed the executive functioning skills are likely pathways (54). Finally, our estimates do not take into account larger societal benefits, such as increased social status (55), higher labor market earnings due to enhanced productivity and economic growth generated by aggregate human capital gains and improved population health (56, 57).
analysis in collaboration with EP, GD, and KA; and all authors: reviewed multiple drafts of the manuscript and contributed to both earlier drafts and the final manuscript. None of the authors reported a conflict of interest related to the study.

REFERENCES


