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Schooling and wage income losses due to early-childhood growth faltering in developing countries: national, regional, and global estimates[1,2]

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ABSTRACT

Background: The growth of >300 million children <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.

Objective: We quantified the economic cost of growth faltering in developing countries.

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.

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).

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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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 >300 million children experience suboptimal linear growth (2). Although remarkable global progress has been made in reducing mortality for children <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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[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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largest economic losses but also to directly compare the cost of future interventions to the likely benefits they will generate.

METHODS

Our analysis was divided into 3 principal steps: In the first step, we used existing data to quantify the current country-specific prevalence and burden of growth faltering and used published estimates to quantify the educational deficits resulting from linear growth delays in developing countries. In the second step, we reviewed the literature on the economic returns to schooling in developing countries to quantify the relative losses in wages that children born today will experience as a result of their reduced educational attainment in the future. In the last step, we used current country-level data on total cohort size and wages to estimate the net present value of lost future earnings due to early-childhood growth faltering in 2010 US dollars per child and per birth cohort. **Figure 1** summarizes our conceptual model as well as the primary data source used in each step.

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).

[8] Abbreviations used: HAZ, height-for-age *z* score; IV, instrumental variable; NIMS, Nutrition Impact Model Study; OLS, ordinary least squares.

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

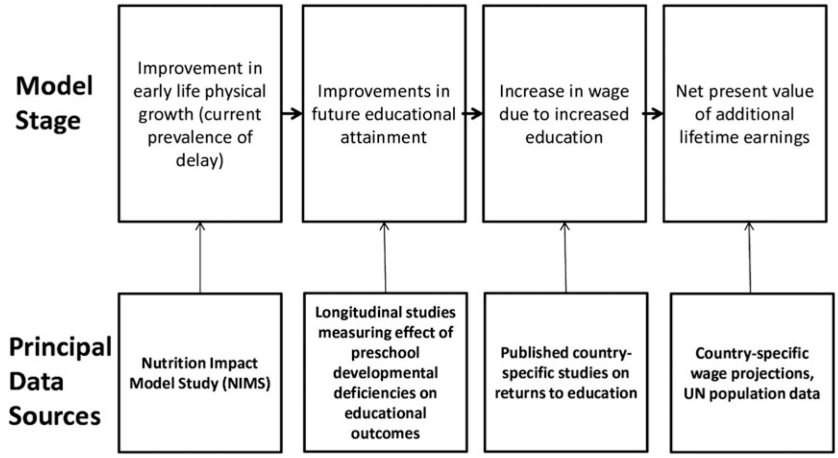

FIGURE 1 Conceptual model and data sources.

relative local value of these wages may vary because of local differences in purchasing parity, the primary objective of this project was to generate a unified benefit estimate, which can be directly compared with costs of potential intervention projects. We therefore opted to express benefits in US dollars (reference year 2010) as our main specification and show alternative estimates with purchasing power parity–adjusted rates in our sensitivity analysis.

Given that the additional wage earnings will accrue only once current birth cohorts enter the labor market, we projected current income in the future assuming an annual real-wage growth rate of 2%. Sensitivity analysis was conducted by using alternative assumptions of 1% and 3%/y. To compute the benefits for each child, we assumed that the average child will participate in the labor market for 40 y, entering the labor market at the age of 20 y and retiring at the age of 60 y. We assumed a 3% discount rate for future income in our main analysis as recommended by the WHO for cost-effectiveness (32) and conducted sensitivity analysis by using discounting rates of 0%, 5% and 10%. To aggregate the income loss per child into loss per annual birth cohort, we used birth cohort size estimates from the United Nations World Population Prospects 2015 Revision (33).

We used bootstrapped SEs to directly account for 3 sources of uncertainty. Uncertainty estimates regarding average HAZ levels at the country level were provided by the NIMS project. Uncertainty in the association between HAZ and schooling were available from Adair et al. (11). For returns to education, uncertainty estimates were generated by using random-effects meta-analysis at the country and regional levels as described above. Uncertainty in all inputs was propagated by using 10,000 bootstrapped simulations. The CIs around the final estimates were calculated by using the 2.5th and 97.5th percentiles of these draws.

All estimates were generated with the use of the Stata 14 Statistical Software package (StataCorp LP) (34).

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)

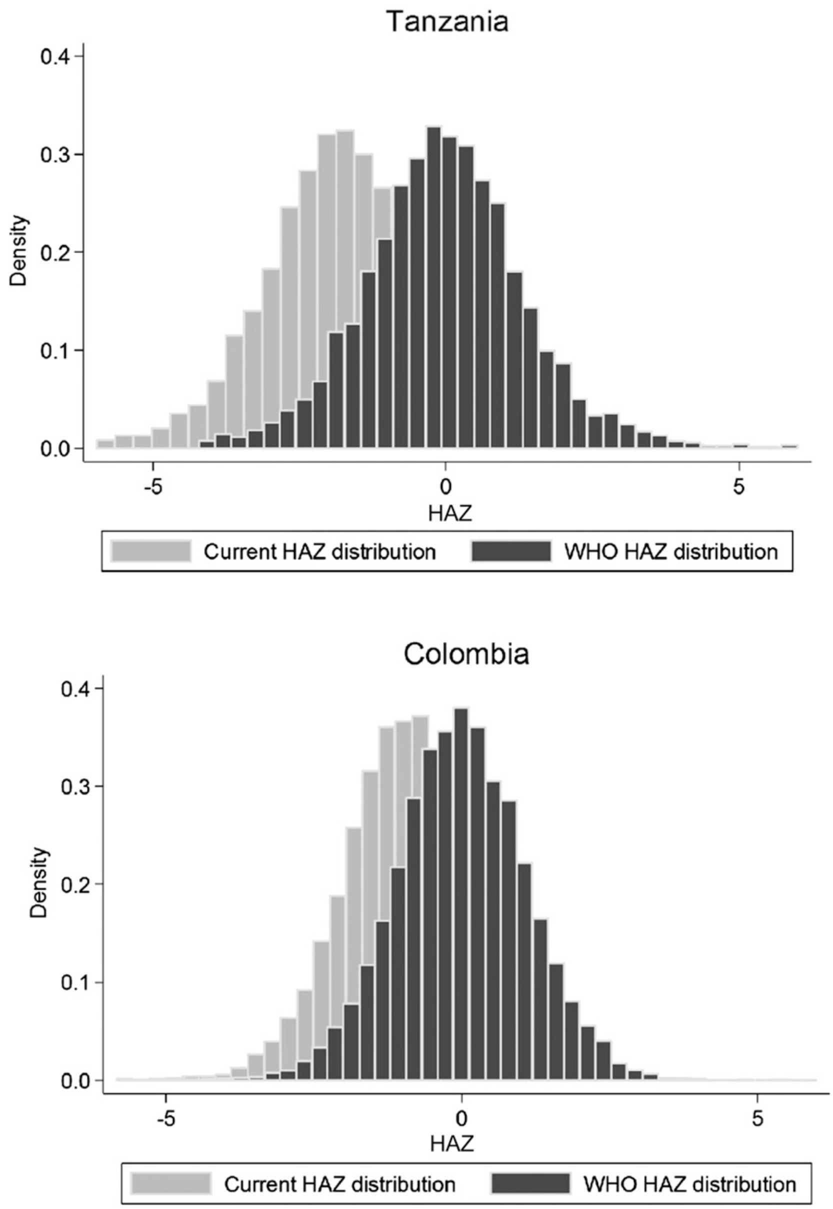

FIGURE 2 Modeled improvements in under-5 height distribution in Colombia and Tanzania. HAZ, height-for-age z score.

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

TABLE 1
Total years of educational attainment lost and net present value of lifetime wage losses due to growth faltering per birth cohort (millions of school years)[1]

Subregion	Countries, *n*	Cohort size, millions of births/y	Total years of educational attainment lost, millions of school years attained	Total wage losses at 3% discounting, US$ billions
Asia				
Central	9	1.8	0.7 (0.3, 1)	2.0 (0.9, 3.2)
East	3	17.1	3.8 (1.5, 6.2)	14.4 (5.2, 24.3)
South	6	36.7	27.6 (20, 35.8)	46.6 (33.4, 61.1)
Southeast	13	12.1	6.9 (4.9, 9.1)	18.0 (11.5, 25.6)
Caribbean	15	0.7	0.2 (0.1, 0.3)	1.1 (0.4, 1.8)
Latin America				
Andean	3	1.2	0.7 (0.5, 0.8)	2.9 (2.1, 3.8)
Central	9	4.7	1.9 (1.2, 2.6)	27.2 (13.6, 43.9)
Southern	3	1.0	0.1 (0, 0.3)	1.9 (0.4, 4.1)
Tropical	2	3.3	0.5 (0.1, 1)	11.7 (2.6, 21)
North Africa/Middle East	19	10.4	3.8 (1.9, 5.7)	16.3 (6, 27.8)
Oceania	9	0.3	0.2 (0.1, 0.3)	0.6 (0.4, 0.8)
Sub-Saharan Africa				
Central	6	4.3	2.9 (2.2, 3.8)	3.4 (2.2, 4.7)
East	15	13.5	10.3 (7.9, 12.9)	10.5 (7.7, 13.5)
Southern	6	1.8	1.0 (0.7, 1.3)	10.8 (7.6, 14.5)
West	19	13.9	8.8 (6.4, 11.5)	9.6 (6.9, 12.5)
Developing countries, total *n*	137	122.9	69.4 (48.1, 92.6)	176.8 (100.9, 262.6)

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

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 $\$100 \cdot \text{child}^{-1} \cdot \text{y}^{-1}$ 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.

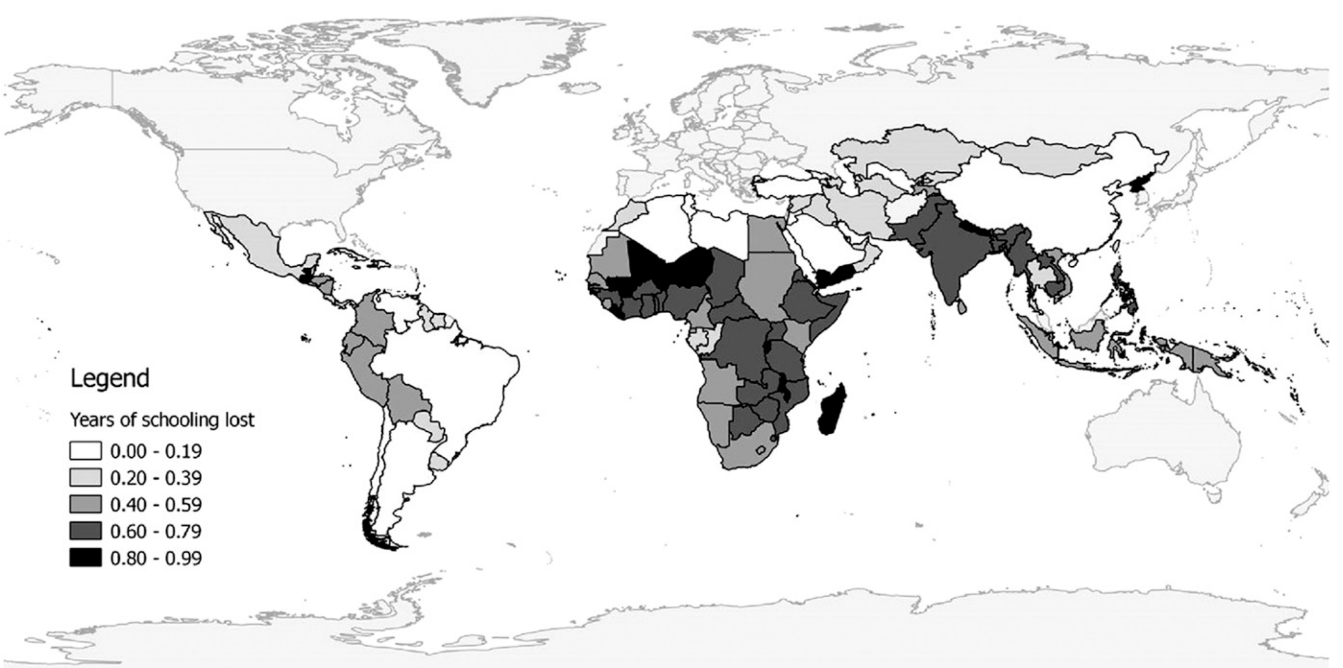

FIGURE 3 Estimated average educational losses due to early-life growth faltering (years of educational attainment per child born in 2010).

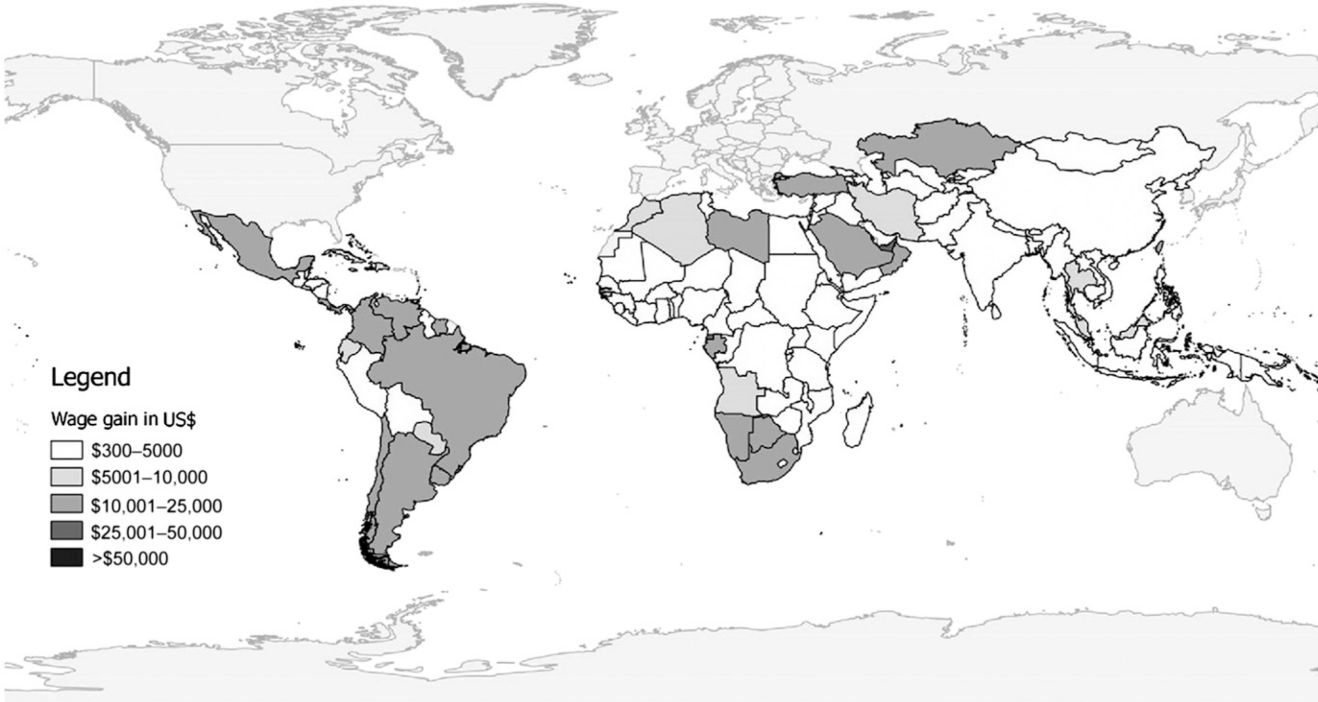

FIGURE 4 Estimated income loss per child due to early-life growth faltering (2015 US dollars).

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[1]

	Discounting				Wage as % of GDP per capita		Annual real-wage growth		Returns to education		PPP adjustment	
	0%	3%	5%	10%	50%	75%	1%	3%	Low	High	Nominal	PPP
East Asia and Pacific	110.0 (56.9, 169.2)	32.9 (17.1, 50.7)	16.0 (8.3, 24.7)	3.4 (1.7, 5.2)	24.7 (12.8, 38)	37.1 (19.2, 57)	22.8 (11.8, 35.1)	48.4 (25, 74.4)	19.7 (10.2, 30.3)	77.2 (40, 118.8)	32.9 (17.1, 50.7)	114.8 (59.4, 176.6)
Latin America and Caribbean	149.4 (64.1, 249.1)	44.8 (19.2, 74.6)	21.8 (9.3, 36.3)	4.6 (2, 7.7)	33.6 (14.4, 55.9)	50.3 (21.6, 83.9)	31.0 (13.3, 51.6)	65.7 (28.2, 109.6)	46.2 (19.8, 77)	85.3 (36.6, 142.1)	44.8 (19.2, 74.6)	106.9 (45.9, 178.2)
North Africa, Middle East, and Central Asia	61.1 (22.9, 103.5)	18.3 (6.8, 31)	8.9 (3.3, 15.1)	1.9 (0.7, 3.2)	13.7 (5.1, 23.3)	20.6 (7.7, 34.9)	12.7 (4.7, 21.5)	26.9 (10.1, 45.6)	12.8 (4.8, 21.7)	42.5 (15.9, 72)	18.3 (6.8, 31)	65.8 (24.7, 111.7)
South Asia	155.5 (111.4, 203.9)	46.6 (33.4, 61.1)	22.7 (16.2, 29.7)	4.8 (3.4, 6.3)	34.9 (25, 45.8)	52.4 (37.5, 68.7)	32.2 (23.1, 42.3)	68.4 (49, 89.7)	39.8 (28.5, 52.2)	97.0 (69.5, 127.2)	46.6 (33.4, 61.1)	222.2 (159.1, 291.2)
Sub-Saharan Africa	114.3 (81.6, 151.2)	34.2 (24.4, 45.3)	16.7 (11.9, 22)	3.5 (2.5, 9.5)	25.7 (18.3, 34)	38.5 (27.5, 50.9)	23.7 (16.9, 31.3)	50.3 (35.9, 66.5)	26.7 (19.1, 35.3)	73.9 (52.8, 97.7)	34.2 (24.4, 45.3)	106.8 (76.2, 141.2)
Global benefits per cohort, billion US$	590.3 (336.9, 876.8)	176.8 (100.9, 262.6)	86.0 (49.1, 127.8)	18.1 (10.4, 31.8)	132.6 (75.7, 197)	198.9 (113.5, 295.4)	122.4 (69.8, 181.8)	259.7 (148.2, 385.8)	145.2 (82.4, 216.5)	375.9 (214.7, 557.9)	176.8 (100.9, 262.6)	616.53 (365.3, 898.9)

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

that go substantially beyond observable improvements in schooling attainment (43, 50, 51). Although the causal mechanisms underlying these improvements remain somewhat unclear (43), higher labor market earnings due to enhancements in adult height (52), cognitive functioning (53), and socio-emotional or executive functioning skills are likely pathways (54). We also do not account for the perceived large benefits of improved early-life circumstances for adult health (11, 13) or a range of other adult outcomes, including increased likelihood of marriage (54), lower probability of divorce, and increased social status (55). Finally, our estimates do not take into account larger societal benefits, such as increased survival, as well as increased rates of productivity and economic growth generated by aggregate human capital gains and improved population health (56, 57).

One of the limitations of the population- or cohort-level approach chosen in this article is that it does not allow us to directly account for heterogeneity within countries. Although growth faltering affects a large fraction of the current child population in most developing countries, the cohort-level benefits identified will clearly not affect all children equally. A second and important limitation of the work presented is that we show detailed estimates of the economic benefits but do not show data on intervention cost. As stated above, all currently available cost estimates suggest that the intervention cost is relatively small compared with the estimated benefits. However, interventions needed to reduce growth faltering are likely to be highly heterogeneous across and within countries, and locally collected data will be needed to identify the most cost-effective interventions at national and subnational levels. Even if these costs are higher than the cost estimates presented here, returns to further investment in this area will remain positive and large.

A final limitation of global financial benefit analyses like the one presented here is that total monetary benefits computed across different countries are strongly affected by local income and wage differentials. As a result, total economic losses can be larger in countries with relatively low rates of growth faltering than in comparable countries with a higher prevalence of growth faltering. To make the distinction between potential improvements and economic benefits as clear as possible, we show results for both educational attainment, which are independent of local income levels, and total wage gains in this article. Similar rates of human capital gains will mechanically lead to higher benefits in countries with higher wages; these relatively higher economic benefits are mostly a reflection of improved local living conditions but also general labor cost, which will typically also be reflected in higher implementation cost of key interventions. The same is not true for educational attainment benefits, which capture potential human capital gains across countries independent of local wage rates, as well as foreign exchange and discounting rates.

Our results indicate that the economic burden of early-life growth faltering is substantial. Increased efforts to deliver at-scale interventions that reduce this burden are not only urgently needed from a public health perspective but are also likely to yield very large economic returns in the long run.

The authors' responsibilities were as follows—GF: developed and designed the overall study together with ME and WWF and completed the

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.

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