Chapter 27

The Human Capital and Productivity Benefits of Early Childhood Nutritional Interventions

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INTRODUCTION

By 2012, child mortality had fallen to almost half its level in 1990.[1] The next major challenge is to improve early-life conditions to harness developmental potential. An estimated 200 million children under age five years in low- and middle-income countries (LMICs) are unlikely to reach their developmental potential because of inadequate health, nutritional, and other investments in early life (Grantham-McGregor and others 2007).[2] This inability to achieve full potential implies substantial losses of welfare and future economic productivity for these children and for their societies (Akresh and others 2012; Behrman, Alderman, and Hoddinott 2004; Bhalotra and Venkataramani 2011; Bhutta and others 2008; Currie and Vogl 2013; Hoddinott and others 2008; Horton, Alderman, and Rivera 2009) and increases the risk of adult morbidities and lower life expectancy (Bhalotra, Karlsson, and Nilsson 2015; Hjort, Solvesten, and Wust 2014). This chapter supplements previous work focusing on estimates of economic benefits from early-life nutritional interventions in LMICs.[3]

Figure 27.1 shows the pathways through which early-life interventions can affect later-life economic outcomes. Prenatal and early childhood interventions affect outcomes at every stage of the lifecycle. These impacts accumulate, making it important to study long-term dynamic effects of interventions. Familial and public investments enter during all lifecycle stages, often induced by the initial intervention. Later investments may in principle complement or substitute for those early in the lifecycle, but some evidence suggests they may be reinforcing (Almond and Mazumder 2013; Bhalotra and Venkataramani 2011, 2013), consistent with recent models that describe human capital production as involving dynamic complementarities across types of investment (for example, health and schooling) and across ages, such that investments early in life increase rates of return to investments later in life (Cunha and Heckman 2007; see also Alderman and others 2017, chapter 7 in this volume).

In the first section, we provide a selected review of evidence of long-term human capital and economic benefits from early-life interventions and then some illustrative calculations of benefit-cost ratios for these interventions. We focus on interventions affecting maternal and early childhood health, including micronutrient supplementation and breastfeeding, and maternal survival. We then present evidence of effects of early interventions on low birth weight (LBW), stunting, and cognitive development in the second section. The third section discusses issues in the estimation of benefit-cost ratios of early-life interventions and presents simulations, illustrating sensitivity of estimates to alternative parameters. The fourth section

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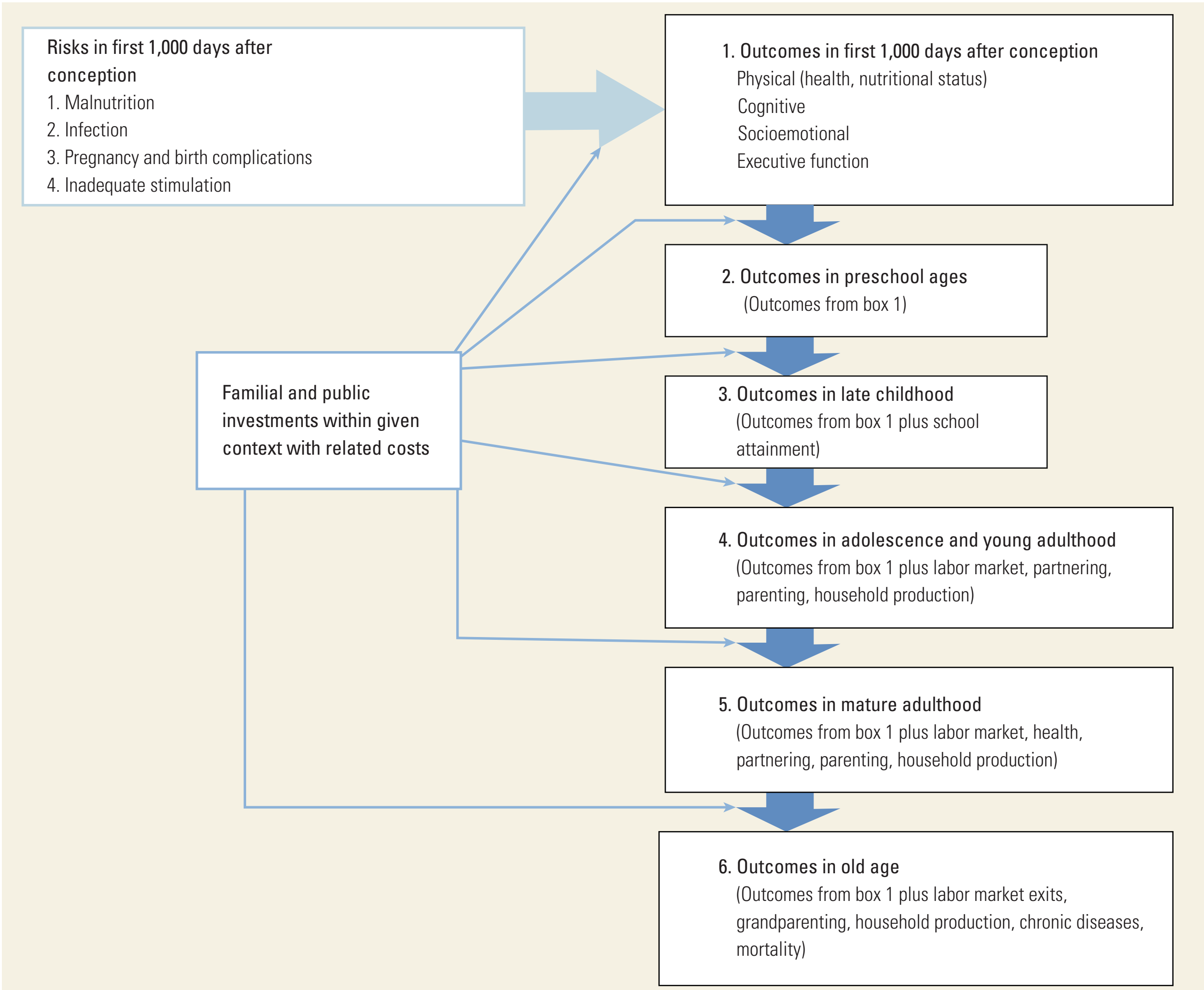
Figure 27.1 Lifecycle Approach to Early Childhood Interventions



Source: Adapted from Hoddinott, Alderman, and others 2013.

discusses issues of designing policy based on the growing body of estimates from randomized trials in LMICs. Definitions of age groupings and age-specific terminology used in this volume can be found in chapter 1 (Bundy and others 2017).

MATERNAL AND CHILDHOOD INTERVENTIONS

Since Barker's (1990) pioneering "fetal origins" hypothesis linking the prenatal environment to indicators of adult health, including diabetes and heart disease risk, the importance of in utero influences on physical and cognitive development during the first thousand days after conception (figure 27.1, top right box) has gained increasing recognition. Maternal stress and nutritional deprivation tend to stimulate permanent changes in tissue structure and function that help the fetus survive but that are associated with abnormal structure, function, and disease in adult life. Almond and Currie (2011, 167) summarize the implications of the fetal origins hypothesis: "One can best help children (throughout their life course) by helping their mothers. That is, we need to focus on pregnant women or perhaps women of child-bearing age if the key period turns out to be so early in pregnancy that many women are unaware of the pregnancy. Such preemptive targeting would constitute a radical departure from current policies that steer nearly all healthcare resources to the sick."

Maternal health could improve later-life child outcomes through at least two avenues. First, improved maternal health can lead to better delivery outcomes, such as avoidance of premature birth and reduced likelihood of LBW, which are associated with negative economic consequences in later life (Alderman and Behrman 2006).[4] Bhalotra and Rawlings (2011) show that, by numerous indicators, poor maternal health is significantly associated with risks of LBW, infant mortality, and growth faltering. A one standard deviation decrease in a mother's height is associated with increased LBW risks of 7.4 percent of the sample mean rate and with increased neonatal mortality risk of 9.3 percent of the sample rate. A one standard deviation decrease in body mass index is associated with higher LBW risks by 10.8 percent of the mean and with higher neonatal mortality risks by 13.1 percent of the mean. LBW and neonatal mortality risks are lower by 5.7 percent and 16.9 percent of their mean rates, respectively, among nonanemic mothers relative to anemic mothers. These tendencies are widespread. Many current interventions focus on improving mothers' health during pregnancy and tend to influence mothers' body mass index and anemia status. However, the estimated associations of maternal height with birth and early childhood outcomes underscore that mothers' health *stocks* when they give birth, in the accumulation of which nutritional investments in mothers' childhoods count, are also important for reproductive and next-generation outcomes. In addition to maternal health indicators, evidence suggests that maternal behaviors, such as smoking and drinking during pregnancy, compromise fetal development (Almond and Currie 2011; Currie and Vogl 2013; Gilman, Gardener, and Buka 2008; Nilsson 2008; Stratton, Howe, and Battaglia 1996; Victora and others 2008; Weitzman, Gortmaker, and Sobol 1992).

Second, maternal health can affect later-life economic outcomes conditional on birth outcomes. For instance, breastfeeding and stimulation are associated with children's cognitive and socioemotional skills, and maternal mental health tends to influence breastfeeding, stimulation, and mother-child bonding (Attanasio and others 2014; Bennett and others 2014; Krutikova and others 2015; Maselko and others 2015; Rahman and others 2008; Rees and Sabia 2009).

The limiting case of poor maternal health, of course, is maternal death. Deaths of mothers who contribute to household resources reduce such resources and thereby investments in children. Fathers' deaths tend to reduce household resources more, but mothers' deaths may reduce the share of resources going to children more. However, because mothers tend to spend more time with young children, mothers' deaths are likely to have larger impacts on children's skill development. Mothers' deaths may have gender-specific impacts on children if daughters substitute for mothers in home production. Higher maternal mortality risks also may lower human capital investments in girls relative to boys because they shorten expected horizons over which returns to investments in girls flow. Male mortality risks, higher on average than female mortality risks, for the same reason lower the incentives for human capital investments in boys.

The rest of this section reviews some empirical evidence on impacts of maternal and reproductive health interventions on later-life outcomes of children.

Prenatal Interventions

Field, Robles, and Torero (2009) evaluate the effects of iodine supplementation during pregnancy in Tanzania. Iodine deficiency is widespread in many developing countries. Compelling evidence indicates that iodine matters most during fetal brain development, and iodine deficiencies have adverse effects on children's cognitive abilities. In the early 1970s, 40 percent of the Tanzanian population lived in iodine-deficient areas and 25 percent had iodine-deficiency disorders. Tanzania subsequently launched a large and intensive early iodine supplementation program, which ultimately reached nearly a quarter of the population for an average of four years. Field, Robles, and Torero (2009) assess whether children who benefited from supplements in utero exhibited higher grade progression rates 10–15 years later. They also compare those exposed to the sporadic iodization efforts with unexposed siblings, thereby controlling for selective uptake by families.

They find large and robust impacts. Children protected from iodine deficiency during their first trimester in utero attain an average of 0.3 schooling grades more than siblings and older and younger children in their district who were not protected, confirming that first trimesters are critical for cognitive development. The effects are substantially larger for girls, indicating potentially important roles of micronutrient deficiencies in explaining gender differences in schooling attainment.

To verify their findings, Field, Robles, and Torero (2009) present cross-country regressions of school participation on baseline iodine-deficiency disorders and fractions of populations consuming adequately iodized salt. The results show a negative correlation between baseline iodine-deficiency disorders and female secondary schooling and a positive correlation between early salt iodization and female primary schooling attainment. Given the low cost of iodine supplementation and the persistence of iodine deficiency in poor countries, Field, Robles, and Torero (2009) conclude that prenatal supplementation offers an efficient, cost-effective means of improving human capital. Studies of introduction of iodized salt in Sweden and the United States similarly show that it raised schooling attainment (especially for women) and cognitive performance, respectively (Feyrer, Politi, and Weil 2013; Politi 2011).

Recent studies estimate substantial economic benefits of micronutrient supplementation. Five of the top 10 most cost-effective solutions for addressing the world's 10 biggest challenges, according to the Copenhagen Consensus Expert Panel (2008), were micronutrient-related early childhood interventions (table 27.1). The 2012 Copenhagen Consensus Expert Panel also ranked micronutrient supplementation and fortification as the top priority, but the micronutrient-related interventions were combined as "Bundled Interventions to Reduce Undernutrition in PreSchoolers" (Lomborg 2014). Updating the estimates in

Table 27.1 Top Priorities for Addressing the World's 10 Biggest Challenges, Ranked by the Expert Panel of the Copenhagen Consensus, 2008

	Solution	Challenge
1	Micronutrient supplements for children (vitamin A and zinc)	Malnutrition
2	The Doha Development Agenda	Trade
3	Micronutrient fortification (iron and salt iodization)	Malnutrition
4	Expanded immunization coverage for children	Diseases
5	Biofortification	Malnutrition
6	Deworming and other nutrition programs at school	Malnutrition and education
7	Lowering the price of schooling	Education
8	Increase and improve girls' schooling	Women
9	Community-based nutrition promotion	Malnutrition
10	Provide support for women's reproductive role	Women
11	Heart attack acute management	Diseases
12	Malaria prevention and treatment	Diseases
13	Tuberculosis case finding and treatment	Diseases
14	R&D in low-carbon energy technologies	Global warming
15	Bio-sand filters for household water treatment	Water
16	Rural water supply	Water
17	Conditional cash transfers	Education
18	Peacekeeping in postconflict situations	Conflicts
19	HIV combination prevention	Diseases
20	Total sanitation campaign	Water
21	Improving surgical capacity at district hospital level	Diseases
22	Microfinance	Women
23	Improved stove intervention	Air pollution
24	Large, multipurpose dam in Africa	Water
25	Inspection and maintenance of diesel vehicles	Air pollution
26	Low sulfur diesel for urban road vehicles	Air pollution
27	Diesel vehicle particulate control technology	Air pollution
28	Tobacco tax	Diseases
29	R&D and mitigation	Global warming
30	Mitigation only	Global warming

Source: Copenhagen Consensus Expert Panel 2008.
Note: HIV = human immunodeficiency virus; R&D = research and development.

Behrman, Alderman, and Hoddinott (2004) and Horton, Alderman, and Rivera (2009), Hoddinott, Rosegrant, and Torero (2013) report benefit-cost ratios (BCRs) for iodized salt (BCR=81), iron supplements for mothers and children ages 6–24 months (BCR=24), vitamin A supplementation (BCR=13), and zinc supplements for children (BCR=3). The evidence thus suggests that micronutrient supplementation and fortification have very high economic returns relative to costs.

Horton and Ross (2003, 51) review evidence for causal relationships between iron deficiency and a variety of "functional consequences with economic implications (motor and mental impairment in children and low work productivity in adults)." Using plausible impact estimates, they simulate annual physical and cognitive productivity losses due to iron deficiency for 10 developing countries and obtain a median value of 4 percent of GDP, with a range of 2.4 percent (Arab Republic of Egypt) to 7.9 percent (Bangladesh).

A few studies have examined the association between interventions that address acute undernutrition and future health, educational, and economic outcomes. A study by the Institute of Nutrition of Central America and Panama (INCAP) provided a protein-rich nutritional supplement to 2,392 children under age seven years starting in 1969. The intervention was later found to be associated with higher schooling grades of women, improved cognitive outcomes of men and women, and higher male wages (Hoddinott, Behrman, and others 2013; Maluccio and others 2006, 2009). The Andhra Pradesh Children and Parents Study is a similar trial of nutritional supplementation provided to pregnant women and young children in 29 villages of southern India from 1987 through 1990. Adolescent children born during the trial period in intervention areas were taller and had better cardiovascular health and educational outcomes (Kinra and others 2008; Nandi and others 2016).

Canning and others (2011) analyze effects of antenatal maternal vaccination against tetanus, which is expected to prevent children from acquiring tetanus at birth through blood infection and to thereby reduce infant mortality. They follow up a randomized controlled trial of maternal tetanus toxoid immunization conducted in 1974 in Bangladesh, looking at schooling outcomes for children born in 1975–79. They find, in cases in which parents had no schooling, that tetanus toxoid vaccination of mothers reduced the probability of no schooling for children by 4.5 percent and increased the probability of children completing one to seven grades of schooling by 1.5 percent and of children completing eight or more schooling grades by 3 percent. On average, schooling attainment increases by about 0.25 grades. They do not correct for the fact that about one-fourth of children had died by the year of follow up, arguing that the relevant parameter for policy purposes is the impact of maternal tetanus on child education conditional on survival. Driessen and others (2011) show that an intensive measles vaccination program in Bangladesh was associated with an increase in the probability that a boy has enrolled in school of 9.5 percentage points, while having no effect on girls' enrollment.

Breastfeeding Interventions

Numerous studies indicate positive short- and long-term associations of breastfeeding of newborn babies, in particular exclusive breastfeeding, with desirable outcomes (Horta and Victora 2013; Ip and others 2007; Kramer and Kakuma 2012; Victora 2000). The relationship is especially pronounced in LMICs. Anderson, Johnstone, and Remley (1999); Horta and Victora (2013); and Victora and others (2015) conclude that breastfeeding may significantly improve children's cognitive performance and reduce future risk factors and cardiovascular disease incidence.

There is a growing literature on breastfeeding promotion across the world. Renfrew and others (2009) provide a systematic review of nine types of breastfeeding promotion interventions in 48 studies, 65 percent of which are randomized controlled trials: increased mother and baby contact (kangaroo mother care [KMC], advocated by the World Health Organization [2003] and Conde-Agudelo, Diaz-Rossello, and Belizan [2003]), variation in feeding methods (cup feeding, gavage feeding, bottle feeding), methods of expressing breastmilk (use of pumps), increasing breastmilk production (use of galactagogues and relaxation techniques), supporting optimal nutritional intake from breastmilk, breastfeeding education and peer support, training of health care staff, early hospital discharge with home support, and better organization of care. They conclude that KMC and breastfeeding education and peer support are the two most effective methods of increasing breastfeeding uptake and adherence rates. Home-based education and peer support for breastfeeding for mothers of LBW babies is estimated to more than double breastfeeding rates up to 24 weeks and increase exclusive breastfeeding rates by even more in low-income settings. Support programs that are jointly based at home and in facilities also have similar effectiveness in increasing breastfeeding rates up to 12 weeks. Renfrew and others (2009) report evidence that short periods of KMC skin-to-skin contact significantly increase the duration of any breastfeeding at up to one month after hospital discharge in developed country settings and that daily contact between mothers and babies, which results in increased breastfeeding rates, is estimated to improve child health outcomes at two months and six months across the world.

Jolly and others (2012) conduct a systematic review and meta-regression analysis of peer-support breastfeeding programs. They find that peer support reduces risks of no breastfeeding by 30 percent in LMICs and 7 percent in high-income countries. Peer support also reduces risks of nonexclusive breastfeeding by 37 percent in developing countries.

Some methodological concerns about the causal relationship between breastfeeding and future outcomes need to be mentioned. Most available studies generally are associative and do not control for selection into breastfeeding on the basis of child characteristics such as innate health or expected survival chances or family characteristics such as socioeconomic status (Colen and Ramey 2014; Drane and Logemann 2000; Jain, Concato, and Leventhal 2002).

Some studies attempt to mitigate such biases. Doyle and Denny (2010) compare ordinary least squares and instrumental variables estimates and conclude that there is no significant selection into breastfeeding in their sample of British children. In view of evidence in other studies that less-educated women are less likely to breastfeed, this finding suggests context specificity in selection. Using sibling comparisons, Der, Batty, and Deary (2006) argue that cross-sectional relationships between breastfeeding and child cognitive outcomes are overestimates of causal effects and that family background explains most of the positive associations. Colen and Ramey (2014) find that perceived positive effects of breastfeeding on a series of child health, cognitive, and behavioral outcomes in the United States are completely nullified in sibling comparisons. However, Rees and Sabia (2009), using sibling fixed effects estimators, find positive breastfeeding effects on children's high school test scores and college attendance, and Rothstein (2013) and Belfield and Kelly (2012) use propensity score matching and find positive effects of breastfeeding on young American children's health and cognitive outcomes. Borra, Iacovou, and Sevilla (2012) also use propensity score matching and find that breastfeeding for four weeks improves cognitive test scores among British children. Kramer and others (2008), based on a large randomized controlled trial, find that longer and exclusive breastfeeding improves Belarussian children's IQs. Using hospital-level variation in coverage of the Baby-Friendly Hospital Initiative, a breastfeeding support program initiated in 1991 and led by the World Health Organization and the United Nations Children's Fund, Del Bono and Rabe (2012) find significantly positive impacts of breastfeeding on children's cognitive and emotional development but not on any indicators of their physical health. In addition, they find that breastfeeding has significantly positive effects on mothers' mental health. Using variation in breastfeeding generated by whether births occur on weekends when hospital staffing is more limited or on weekdays, Fitzsimons and Vera-Hernandez (2014) estimate large impacts of breastfeeding on cognitive development but no effects on noncognitive development or health in a sample of less-educated mothers in the United Kingdom.

Maternal Survival

Mothers' deaths can profoundly affect their children's emotional and educational well-being, thereby affecting their future schooling attainment and labor productivity. Ainsworth and Semali (2000) analyze effects that maternal deaths (from AIDS) have on Tanzanian children's schooling. They find that female adult deaths—irrespective of whether they were parents—are associated with delayed school enrollment among children ages 7–11 years and early dropout among children ages 15–19 years. In contrast, prime-age male deaths do not have significant effects on children's school enrollment. This finding is consistent with teenage children substituting for adult women's time in home-production activities. Impacts of adult deaths on child schooling are largest among poor households.

Ainsworth and Semali (2000) also find that children ages zero to five years who lost their mothers are much more likely to be stunted than children who lost their fathers or children with both parents living. The children whose nutritional status is most affected by mothers' deaths are those whose mothers had no schooling (and who were therefore likely to be from poor households). Similarly, Case and Ardington (2006), using longitudinal data from KwaZulu-Natal, South Africa, find that maternal orphans are significantly less likely to be enrolled in school and complete significantly fewer schooling grades than children whose mothers are alive, but no significant effects are observed for paternal orphans.

Using a large Indonesian panel dataset, Gertler, Levine, and Ames (2004) observe that recent parental death lowered children's school enrollment, with the largest effects for youth at transitions between primary and junior secondary and between junior secondary and secondary. Their results suggest that children in bereaved families drop out of school at roughly 50 percent higher rates than their classmates. They find no significant difference between effects on child schooling of maternal versus paternal deaths. The impact on human capital investment in girls of improvements in women's life expectancies from large concentrated reductions in Sri Lankan maternal mortality is analyzed in Jayachandran and Lleras-Muney (2009). They study district-level data for 1946–53, a period in which maternal mortality rates fell by 70 percent. The "treatment" group was individuals who were ages 2–11 years in 1946, just before the maternal mortality decline; the "control" group was individuals ages 18–37 years in 1946 whose schooling preceded the maternal mortality decline. Their results suggest that the maternal mortality rate decline increased female literacy by 2.5 percent, a 1 percentage point increase (relative to changes in male literacy), and raised completed schooling by about 0.2 grades or 4 percent.

ANTHROPOMETRIC AND COGNITIVE OUTCOMES OF EARLY-LIFE INTERVENTIONS

Interventions That Reduce Low Birth Weight

Alderman and Behrman (2006) estimate the economic benefits of reducing LBW in LMICs through seven pathways: reduced infant mortality, reduced neonatal care, reduced costs of infant and child illness, productivity gains from reduced stunting, productivity gains from increased cognitive ability, reductions in prevalence (and thereby costs) of chronic disease, and intergenerational benefits. Based on their review of relevant empirical studies, they estimate that economic benefits from reducing LBW in LMICs are fairly substantial, with a present discounted value of US$510 (using a 5 percent discount rate) for each infant moved from the LBW to the non-LBW category. They decompose the economic benefits of reducing LBW status into the seven individual components and calculate estimates for different discount rates (table 27.2). Their results suggest that the largest economic gains come from productivity increases due to increased cognitive ability (about 40 percent of the total with a 5 percent discount rate), followed by productivity increases from reduced stunting (17 percent) and reduced infant mortality (16 percent). The present discounted value of moving an infant from LBW to non-LBW status ranges from US$832 with a discount rate of 3 percent to US$257 at a discount rate of 10 percent. The implication of these results is that any intervention that costs less than these amounts per child moved from LBW to non-LBW status is worthwhile to undertake purely on the grounds of saving resources or increasing productivity.

Nutritional Interventions That Reduce Stunting

Stunting reflects cumulative effects of chronic poverty, poor maternal health, inadequate nutrient consumption, and infections, among others (Bhalotra and Rawlings 2011, 2013; Martorell, Khan, and Schroeder 1994; Victora and others 2008). It has been claimed that growth faltering up to age two years is irreversible in its effects on an important set of adult outcomes, including not only stature but also education, health, and productivity (Bhutta and others 2008; Victora and others 2008; Victora and others 2010). Alderman, Hoddinott, and Kinsey (2006); Hoddinott, Alderman, and others (2013); Hoddinott, Behrman, and others (2013); and Hoddinott, Rosegrant, and Torero (2013) discuss the pathways through which stunting generates economic losses—loss

Table 27.2 Estimates of Present Discounted Value of Seven Major Classes of Benefits of Shifting One LBW Infant to Non-LBW Status

US dollars, except as noted

	Annual discount rate					
	1%	2%	3%	5%	10%	20%
1. Reduced infant mortality	97	96	95	93	89	81
2. Reduced neonatal care	42	42	42	42	42	42
3. Reduced costs of infant and child illness	40	40	39	38	36	33
4. Productivity gain from reduced stunting	350	250	180	100	29	4
5. Productivity gain from increased ability	850	600	434	240	70	10
6. Reduction in costs of chronic diseases	240	133	74	23	1.5	0
7. Intergenerational benefits	422	220	122	45	8	1
Sum of PDV of seven benefits	2,041	1,381	986	581	275.5	171
Sum as percentage of that for 5%	351%	238%	170%	100%	47%	30%

Source: Alderman and Behrman 2006.
Note: LBW = low birth weight; PDV = present discounted value.

of physical growth potential (and physical strength that is often needed to be productive in manual occupations), delayed enrollment in school, cognitive impairment, and increased risk of chronic diseases.

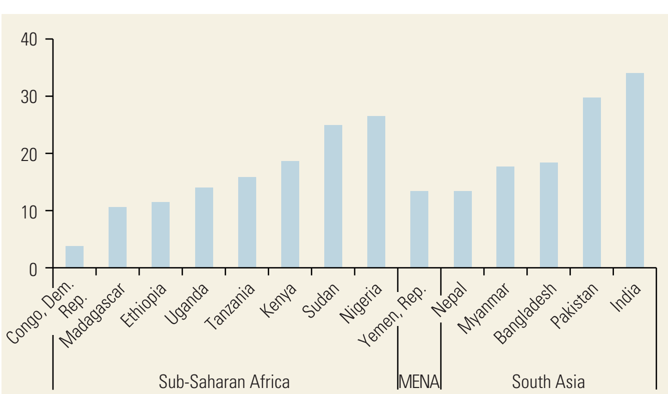
Recent studies, however, suggest the following:

- Although early-life nutritional status predicts significantly later child nutritional status, about half the variance in later child nutritional status is not predicted by early-life nutritional status.
- The unpredicted component of later child nutritional status is associated with parental and community characteristics and appears to be malleable and responsive to some possible interventions.
- The unpredicted growth in nutritional status between early and late childhood is significantly associated with late childhood cognitive skills (Crookston and others 2010; Crookston and others 2011; Crookston and others 2013; Prentice and others 2013; Schott and others 2013).

This revisionist literature raises questions about whether the conventional wisdom overemphasizes the first thousand days of life, at least with regard to irreversibility (though whether cost considerations may still imply that early-life interventions have relatively high rates of return remains a question). A bigger threat to conventional wisdom may be studies in process that find no evidence of significant causal impacts on late childhood schooling and cognitive skills if early-life household resources and the endogenous choices that lead to early-life nutritional status are controlled for (Georgiadis 2015).

Building on the work of three studies (Bhutta and others 2008; Hoddinott and others 2011; Horton and others 2010), two studies (Bhutta and others 2013; Hoddinott, Alderman, and others 2013) calculate average benefit-cost ratios for interventions that reduce stunting in 14 selected LMICs in Asia and Africa (figure 27.2). Among the interventions considered are universal salt iodization, iron fortification of staples, iron–folic acid supplementation, community-based nutrition programs, vitamin A supplementation, deworming, and therapeutic zinc supplementation. Figure 27.2 shows that the median benefit-cost ratio is 18.7 (Kenya), with a range from 3.8 (Democratic Republic of Congo) to 34.1 (India). The benefit-cost ratios for most countries, moreover, appear to be significantly greater than 1.0 under a range of more conservative assumptions than in the base simulations.

Figure 27.2 Average Benefit-Cost Ratios for Interventions to Reduce Stunting in Selected High-Burden Countries



Source: Hoddinott, Alderman, and others 2013.
Note: MENA = Middle East and North Africa.

Hoddinott, Behrman, and others (2013) use data from a randomized controlled trial in Guatemala to examine adult consequences at ages 25–42 years of growth faltering by age two years. The adults were participants in an INCAP food-supplementation trial in four Guatemalan villages when they were under age seven years in 1969–77. The trial was designed to test effects on physical and cognitive development of a nutritious protein-rich supplement, atole. The study uses instrumental variable methods to correct for estimation bias and control for potentially confounding factors. The authors find that growth failure had large significant effects on numerous adult outcomes, including schooling attainment, family formation, reproduction, cognitive skills, men's wage rates, and poverty avoidance. However, no impact was observed on female wage rates, possibly because most adult women were engaged in low-productivity activities such as agricultural production and processing. Also, no significant associations were observed between growth failure and several measures of adult health, including metabolic syndrome and cardiovascular disease risk factors. This paper suggests that interventions that improve childhood nutrition and promote linear growth from conception to age two years confer lifelong benefits to individuals as well as to their families. Indeed, Behrman and others (2009) provide evidence, using the same data, of intergenerational benefits in that women, but not men, in atole-supplied communities during their childhood, though not just up to age two years, three to four decades later had children with significantly greater birth weights and long-term nutritional status.

Nutritional Interventions That Improve Cognitive Development

Early childhood is critical for cognitive skill formation (Cunha and Heckman 2007; Grantham-McGregor and others 2007; Heckman, Stixrud, and Urzua 2006), as illustrated by analysis of how the preschool environment, for example, the U.S. Perry Preschool Program, influences adult test scores and other attainments (Schweinhart and others 2005). In fact, the early childhood health and nutritional environment also influences cognitive performance because nutritional deficiency or infection (which reduces net nutrition by consuming metabolic resources) may impair neurological development (Eppig, Fincher, and Thornhill 2010; Fischer Walker and others 2013). If investments in human capital through childhood and adolescence reinforce cognitive investments in early life, then the longer-term cognitive gains from early-life nutritional interventions may be even larger than might appear from short-term cognitive gains.

Numerous studies using quasi-experimental or experimental design provide evidence of the positive impacts on cognitive function or test scores. Almond, Mazumder, and Van Ewijk (2015) show that Muslim British children who are in utero during Ramadan have lower test scores. Majid (2015) shows that Muslim Indonesian children who are in utero during Ramadan have lower birth weights; study fewer hours during elementary school; do more child labor; score lower on cognitive and math tests; and as adults, work fewer hours and are more likely to be self-employed. Maluccio and others (2009) and Stein and others (2005) show that the INCAP early-life nutritional supplement resulted in higher cognitive attainments. Barham (2012) shows impacts from a health and family planning program in the Matlab area of Bangladesh. Venkataramani (2012) shows impacts from malaria eradication in Mexico. Almond, Edlund, and Palme (2009) identify cognitive deficits associated with exposure to radioactive fallout. Bhalotra and Venkataramani (2013) show that a Mexican clean water reform that led to sharp drops in diarrhea led to better cognitive performance. Bharadwaj, Loken, and Neilson (2013) show that the assignment of neonatal care facilities to babies who fall just below the LBW threshold resulted in their having better test scores relative to babies who fall just above the LBW threshold.

BENEFIT-COST RATIOS

Most studies that evaluate interventions provide estimates of impacts of early-life nutritional interventions on later-life education, health, and earnings. In this section, we construct somewhat generic benefit-cost estimates incorporating both immediate and longer-term impacts and costs of early-life nutritional interventions. However crude, such estimates are useful in assessing the viability of specific investments in maternal and early child health that compete with one another and with other interventions. Estimating benefit-cost ratios is challenging because of the paucity of information on longer-term benefits that can be causally associated with specific interventions and on relevant costs, all of which tend to vary by context. We provide illustrative estimates (table 27.3) based on evidence available from international experience and explore how sensitive our estimates are to key assumptions.

Benefits

We assume that the primary economic benefit for children treated by the intervention arises from increasing lifetime productivity and therefore earnings through increasing schooling, health, or both (Almond 2006; Behrman, Alderman, and Hoddinott 2004; Bhalotra and Venkataramani 2011; Engle and others 2011; Hoddinott, Alderman, and others 2013; Hoddinott, Rosegrant, and Torero 2013). The estimates we use to obtain the benefits depend on (1) the relationship between interventions and human capital (schooling attainment, health) and (2) the relationship between human capital and earnings or productivity. Some recent studies combine (1) and (2) by estimating direct effects of early-life interventions on adult earnings using approaches that also incorporate any externalities and general equilibrium effects (for example, Baird and others 2016; Bhalotra and Venkataramani 2011; Bleakley 2007). The illustrative simulations presented here isolate earnings impacts that flow from schooling increases generated by an early-life health intervention.

For the base case simulations in table 27.3, we use 0.5 additional schooling grades, as estimated in Field, Robles, and Torero (2009). For simulation, as shown in column 2 in table 27.3, we assume that schooling rates of return in labor markets equal schooling rates of return in other activities (for example, household production), as implied by models in which people allocate their time between wage activities and other activities so that at the margin, rates of return are equalized among all activities. This is a more plausible assumption for many developing economies where most of the working population is engaged in small- and medium-scale agricultural and other informal activities with less rigidities in work and pay schedules than those that dominate in, say, Western Europe. We assume workers live through age 64 years (but see later discussion on survival rates). We use as our base estimates for rates of return to schooling attainment in developing countries those summarized by Orazem, Glewwe, and Patrinos (2009): 7.5 percent for rural areas. Given the dominance of rural areas in South Asia and Sub-Saharan Africa, where

Table 27.3 Illustrative Simulations of Benefit-Cost Ratios of Early-Life Nutritional Interventions

		Base case except					Higher discount rate	
	Base case	Higher intervention impact on schooling	Higher rate of return to schooling attainment	Lower costs	Higher positive externalities	Base case with changes in columns (2)–(5)	Base case except discount rate = 6%	Case in column (6) except discount rate = 6%
Assumptions	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Impact of intervention on schooling attainment (Grades)	0.5	1	0.5	0.5	0.5	1	0.5	1
Rate of return to increased schooling attainment (%)	7.5	7.5	11.5	7.5	7.5	11.5	7.5	11.5
Direct cost of intervention (% of annual basic wage)	4.0	4.0	4.0	2.0	4.0	2.0	4.0	4.0
Direct cost of additional grade of school (% of basic wage)	15.0	15.0	15.0	10.0	15.0	10.0	15.0	10.0
Opportunity cost of additional year of school (% of basic wage)	75.0	75.0	75.0	50.0	75.0	50.0	75.0	50.0
Discount rate (%)	3.0	3.0	3.0	3.0	3.0	3.0	6.0	6.0
Externality as percentage of labor market rate of return	10.0	10.0	10.0	10.0	25.0	25.0	10.0	25.0
Benefit-cost ratio	**2.3**	**2.4**	**3.5**	**3.6**	**2.6**	**6.9**	**1.4**	**4.2**
PDV of benefits (US$)	1,000	2,100	1,600	1,000	1,000	3,800	640	2,350
PDV of costs (US$)	450	870	450	300	450	550	440	560
Annual basic wage (US$)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Note: PDV = present discounted value.

undernutrition prevalence is highest, we assume 7.5 percent for our base case. We explore the robustness of our results to increasing this rate of return to 11.5 percent in simulation, as shown in column 3 of table 27.3.

Costs

In many relevant interventions, one primary cost is the time cost of program implementers and, for interventions that extend schooling, opportunity costs of time of school-age students and school teachers. We characterize time costs relative to wages of adults with basic schooling levels, which we label "basic wages." We assume a basic wage of US$1,000 per year, roughly the threshold per capita income used by the World Bank to define low-income countries. Changing this basic wage would not change the benefit-cost ratios presented in table 27.3 if beneficiaries and service providers receive comparable wages because it would change benefits and costs in the same proportions. If service providers are paid more than beneficiaries, the benefit-cost ratios in table 27.3 would be smaller.

We consider three components of resource costs:

- *Direct costs per child of interventions.* The primary emphasis in the literature is on supplier costs of providing interventions, which include time of individuals engaged in the interventions, costs of micronutrients and other materials that may vary with program scale, and fixed costs such as program-related infrastructure. There may also be important private costs, such as the financial and time costs that families (usually mothers) incur to ensure that their children benefit from interventions. In addition, there may be distortion costs of raising funds for public sector expenditures on interventions that have been estimated to be a quarter or more of public expenditures (Harberger 1997). For our basic simulations, we assume that all these costs for interventions for an additional child, such as in Field, Robles, and

Torero (2009), total 4 percent of the basic wage (that is, US$40 if the basic wage is US$1,000). We explore the sensitivity of our estimates to reducing this to 2 percent in simulation (4).

- *Direct costs of one additional year of schooling for one child.* We assume that early-life nutritional interventions raise children's final schooling attainment. The added direct cost of extending schooling again includes time costs of additional teachers, but also variable costs such as books and other materials and fixed costs related to school buildings. Private costs include families' costs for transportation and school materials. There may be distortion costs associated with taxation. For our basic simulations, we assume that all these costs for an additional child per school year total 15 percent of the basic wage, but we explore the sensitivity to a reduction to 10 percent in simulation (4). We assume that these costs are incurred when children are about age 14 years, the margin of completing basic schooling in most low-income countries.
- *Opportunity costs of time of extending schooling for children.* If schooling attainment is extended because of interventions, not only are there additional direct schooling costs, there are also opportunity costs of children being in school instead of engaged in other activities, including work. For our basic simulations, we assume that these costs for an additional child per school year are 75 percent of the basic wage, but we explore the sensitivity of our estimates to 50 percent in simulation (4). Again, we assume that these costs are incurred when children are about age 14 years.

Often relatively little attention is paid to costs, particularly private costs, even though private and public resource costs are as important as impacts in assessing the priority of particular interventions. There is often confusion between budgetary costs of suppliers, such as governmental entities, and real resource costs, private and public. Although policy makers need to be cognizant of budgetary constraints, allocation of public resources should be based on the present discounted value of benefits (perhaps weighted to reflect desired distributional goals, such as poverty alleviation) relative to the present discounted value of real resource costs. Those real resource costs include opportunity costs of alternative uses of public *and* private resources and any distortion costs of raising public funds. Public transfers should not be included in real resource costs although they are part of governmental outlays, a matter that has caused some confusion in assessing, for example, benefit-cost ratios of conditional and unconditional transfer programs.

Other Central Assumptions

Discount Rates

Most benefits of preschool programs accrue, and some costs are incurred, years after the interventions. For instance, if maternal health programs increase the adult productivity of the children of the targeted women attaining higher schooling, these benefits may flow one to six decades after the interventions. To account for this delay, future costs and benefits are discounted to the present. Evaluations of commercial projects often involve discount rates of 10 percent or 12 percent, but discount rates of 3 percent and 6 percent are often used in social sectors (Engle and others 2011). We therefore produce estimates using 3 percent and 6 percent.

Survival Rates

Another reason that timing may be important is that not all children will survive to be productive adults through age 64 years. Therefore, our estimates of future benefits and costs (but primarily benefits given that they may flow for long periods or only be realized many years after interventions) are adjusted for survival probabilities based on World Health Organization Life Tables for Uganda for 2009 (as representative of a Sub-Saharan African country).[5] This adjustment reduces benefits from earnings for intervention-treated children at ages 45–49 years by about 10 percent and at ages 55–59 years by about 15 percent. For countries with longer life expectancies, these adjustments will be smaller, and vice versa.

Externalities

Schooling is perceived to have positive externalities—benefits to others in society beyond the person schooled—by, for example, reducing crime or increasing political participation, though systematic empirical evidence on such externalities remains fairly limited. To illustrate impacts of possible externalities, we assume that social rates of return to schooling increases induced by interventions are 10 percent higher than private rates of return (we also investigate the sensitivity of our estimates to an assumed 25 percent higher rate).

General Equilibrium Effects

If the programs we consider were scaled up, resulting schooling expansions may be substantial, and this outward shift in supply of educated adults may, all else equal, reduce schooling rates of return. This tendency may, however, be limited by outward shifts in demand for more-schooled adults because of productivity increases or, for instance, because more-schooled consumers consume more schooling-intensive goods and services. Because the outcome is ambiguous, we do not directly adjust for it, but it is effectively allowed for when we vary rates of return to schooling.

Benefit-Cost Estimates

Table 27.3 summarizes benefit-cost ratios for interventions such as iodine provision in pregnancy studied in Field, Robles, and Torero (2009) under the assumptions just discussed. Because the ratios attempt to include all benefits and costs, including externalities, these are social benefit-cost ratios. Private benefits are assumed to be smaller because they do not include externalities, but private costs also may be smaller if any of the costs are covered by public subsidies, as is likely. Therefore, private benefit-cost ratios may be larger or smaller than the public benefit-cost ratios in the table.

The first column presents base estimates, with somewhat conservative assumptions regarding key parameters. The base-case social benefit-cost ratio is 2.3, implying that benefits are 130 percent greater than costs. The next four columns vary the assumed parameters underlying the base case by making them less conservative and, as expected, benefit-cost ratios increase. The increase is relatively small, to 2.4, for simulation (2), which allows larger impacts of the intervention on schooling attainment. This is because the increase of 100 percent in impacts of interventions on schooling attainment not only increases benefits due to greater schooling attainment, but also increases costs, raising both direct and opportunity costs of schooling. For the next two cases, the benefit-cost ratios rise to 3.5–3.6, which implies that benefits are more than triple the costs. These two variations highlight different channels through which benefit-cost ratios might be higher: higher program impacts (in the second case perhaps through improved school quality) and reduced costs. The increase in simulation (5), for which assumed positive externalities cause social rates of return to schooling to be 25 percent rather than 10 percent greater than private rates of return, is to 2.6, about the same as for simulation (2). Simulation (6) gives benefit-cost ratios that would be obtained if all of the changes from the base simulation were implemented together and if their impacts were additive. Under this combined set of more optimistic assumptions, the benefit-cost ratio is 6.9, suggesting that early-life nutritional investments are definitely attractive.

The estimates, however, are sensitive to discount rates. The penultimate column makes the base-case assumptions but uses the more conservative assumption of a 6 percent discount rate. The estimated benefit-cost ratio is 1.4, that is, benefits are slightly greater than costs. The last column makes all the assumptions in column 6 except that the discount rate is assumed to be 6 percent instead of 3 percent. This change reduces the estimated benefit-cost ratio to 4.2. The substantial reduction reflects the importance of the appropriate discount rate. Even with this reduction, the benefit-cost ratio implies that benefits are more than four times as large as costs.

These estimates are based on a number of assumptions and illustrate substantial sensitivity to some assumptions, such as the appropriate discount rate. But all in all, they suggest the possibility of fairly large potential gains in children's lifetime productivity from interventions that improve maternal health, as in Field, Robles, and Torero (2009), with possibly very satisfactory benefit-cost ratios.

We must note that our analysis of iodine supplementation is an illustrative example and we are not advocating it over any other nutritional intervention. There is a large body of knowledge on the benefits of other micronutrient interventions including food fortification. In two clinical trials, Andersson and others (2008) and Haas and others (2014) find that double fortification of salt is associated with higher levels of hemoglobin and other body iron measures among Indian children and women. Horton, Wesley, and Mannar (2011) evaluate the effect of double fortification of salt using iron and iodine on hemoglobin levels in India to find a benefit-cost ratio ranging from 2.4 to 5.0. There are several systematic reviews and meta-analyses of the relationship between fortification and child health outcomes across the world (Aaron, Dror, and Yang 2015; Das and others 2013; De-Regil and others 2011; Ojukwu and others 2009; Pachón and others 2015). Farebrother and others (2015) provide a summary of these systematic reviews.

POLICY DESIGN: MECHANISMS AND SCALE UP

Rapid growth in randomized controlled trials and other systematic studies has expanded the evidence base, documenting the way in which cost-effective local or small-scale childhood interventions have led to improvements in health and educational capital and later-life productivity. However, two major challenges arise in using this evidence as the basis for policy. First, although there are notable exceptions, many trials identify intervention impacts without identifying the mechanisms driving the impact, and, in many cases, multiple mechanisms are plausible (Deaton 2010). This is important because external validity or transferability of interventions may depend upon understanding the mechanisms and relevant contextual dimensions (Cartwright and Hardie 2012).

The second, related, issue is that an intervention that is scaled up may not have the same impact as it does on a small scale, for instance, because of general equilibrium effects, endogenous political reactions, or heterogeneity across beneficiaries and implementers (Allcott and Mullainathan 2012). A vivid illustration is Bold and others (2013), who analyze provision of contract teachers to Kenyan schools. They find that pupils in schools in which a nongovernmental organization managed interventions experienced test score improvements, but there were no test score gains when the same interventions were implemented by the Ministry of Education. Their findings caution against assuming that the evidence gathered from good field trials can be used to guide policy as suggested, for instance, by Banerjee and He (2008).

Probably the most-studied social program with an important health and nutritional component in the developing world is the Mexican Oportunidades (originally PROGRESA) conditional cash transfer program, introduced in 1997 (Behrman 2007, 2010; Levy 2006; Levy and Rodriguez 2004). This program provided transfers conditional on various behaviors, including attending health clinics regularly and, among others, obtaining micronutrients for infants and young children. An important program component was the establishment of an evaluation strategy from the very start, with baseline data and periodic household surveys collected from about 25,000 families (both program eligible and noneligible) with about 125,000 individuals living in 508 small, poor, rural communities (population less than 2,500) to which the initial program was directed, 320 of which were randomly selected to receive the program initially with the remainder enrolled after about 18 months. The initial program results were instrumental in evaluations that resulted not only in program modifications but also in ensuring the political support necessary for scaling up the program to cover about 30 million Mexicans and to continue the program with changes in the government, including the first change in the governing party in more than seven decades.

With respect to impacts of the child nutrition component of the program, Behrman and Hoddinott's (2005) preferred estimates (child fixed effects estimates that control for unobserved heterogeneity correlated with access to the supplement) indicate significantly positive and fairly substantial program effects on children ages 12–36 months. The findings imply an increase of about one-sixth in mean growth per year for these children and a lower probability of stunting. The authors estimate that the long-term consequences of these improvements are nontrivial; the impact working through adult height alone could result in a 2.9 percent increase in lifetime earnings.

CONCLUSIONS

Evidence is accumulating that early-life health and nutritional interventions, including those that act to improve the health and nutritional status of potential mothers and pregnant women and those that directly treat children in early life, have significant impacts on schooling, earnings, and productivity over the lifecycle in LMICs. Our estimates of benefit-cost ratios for such interventions, obtained under a range of plausible parameters, consistently exceed one, suggesting that the present discounted value of gains exceeds costs. These results motivate the case for placing early-life health and nutrition high on the policy agenda. Causal estimates of impacts of early-life nutritional interventions mostly stem from small-scale local interventions; therefore, these estimates are likely to be sensitive to population heterogeneity (social, economic, and cultural differences), differences in program implementation (administrative capacity and trust), and differences in the wider political economy of reform. As a result, available impact estimates may have limited external validity. In addition, estimation of benefit-cost ratios using these impact estimates is, as we have illustrated, sensitive to choices of rates of return and discount rates applied in evaluating estimated future impacts against costs.

If, in fact, benefit-cost ratios associated with early-life health interventions are as attractive as some estimates in the literature and our simulations indicate, then it is natural to ask why governments have not implemented them at scale. Benefits may not scale up, and even if there are scale economies in costs, the benefit-cost ratio for nationwide implementation may be lower. Other possibilities are that governments are not sufficiently aware of the benefits of the studied interventions and, indeed, perusal of documents that guide national and international policy suggests that the tendency is to evaluate immediate reductions in morbidity, growth retardation, or mortality, and that the dynamic socioeconomic benefits of health interventions are often ignored. A third possibility is that even where governments recognize the net benefits of early-life interventions, they face budgetary constraints or conflicting political priorities in policy choices that are difficult to adjust given strong vested interests in existing programs.

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NOTES

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2013:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  a) lower-middle-income = US$1,046 to US$4,125
  b) upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

1. See the Millennium Development Goals Factsheet No. 290 (http://www.who.int/mediacentre/factsheets/fs290/en/).
2. The estimate of Grantham-McGregor and others (2007) of the number of children at risk of not reaching their development potential relies primarily on the prevalence of stunting.
3. Reviews of the economic benefits of early childhood stimulation and education include Behrman, Fernald, and Engle (2014); Behrman and Urzúa (2013); Engle and others (2007); and Engle and others (2011). Hoddinott, Rosegrant, and Torero (2013) review agricultural interventions and information and communications technology investments that have impacts on child nutrition.
4. The association between LBW and worse health, cognitive, and economic outcomes is, however, not free from criticism. Other indicators of the birth endowment are preterm birth, the Apgar score, and neonatal mortality. See review by Wilcox (2001) who finds that the literature on birth weight and health outcomes often reports a noncausal or biased positive relationship. The author proposes several modifications to the basic birth weight indicator along with alternative measures of fetal growth.
5. Global Health Observatory data repository, Life Tables, Uganda (http://apps.who.int/gho/data/view.main.61730?lang=en; accessed April 28, 2015).

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