



CHAPTER 6

Early Life Nutrition and Subsequent Education, Health, Wage, and Intergenerational Effects

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Three articles in a prominent 2007 series in *Lancet* summarize much of what is known about early childhood development in developing countries, including nutritional aspects. Grantham-McGregor and others (2007) claim that more than 200 million children under five in developing countries fail to reach their developmental potential because of risk factors associated with poverty. Walker and others (2007) argue that these risk factors include stunting, inadequate cognitive stimulation, iodine deficiencies, and iron deficiency anemia; they also claim that evidence is sufficient “to warrant interventions for malaria, intrauterine growth restriction, maternal depression, exposure to violence, and exposure to heavy metals” (Walker and

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others 2007: 145). Engle and others (2007: 229) conclude that “governments and civil society should consider expanding high-quality, cost-effective early child development programmes” because there are potentially considerable gains from doing so in developing countries. Engle and others (2007) also note that in recent years developing countries and international development organizations have shown increased interest in early childhood development programs.¹

In an even more recent *Lancet* series on the implications of infant and maternal undernutrition for outcomes over the life cycle, Victora and others (2008) review the associations among undernutrition, human capital, and risk of adult diseases in developing countries. The authors consider 14 adult outcomes: height; school attendance and educational performance; income and assets; birth weight of offspring; body mass index, body composition, and obesity; blood lipids; insulin resistance and type 2 diabetes; blood pressure; cardiovascular disease; lung function; immune function; cancers; bone mass, fracture risk, and osteoporosis; and mental illness. They also consider exposure variables measured during pregnancy (maternal height and weight before pregnancy, weight gain, micronutrient status, and diet), at birth (weight, length, ponderal index, and intrauterine growth restriction), and at two years of age (stunting, wasting, and underweight).

Victora and others (2008) also contribute new analysis of data from five long-standing prospective cohort studies from Brazil, Guatemala, India, the Philippines, and South Africa. They report that indexes of maternal and child undernutrition (maternal height; infant birth weight and intrauterine growth restriction; and weight, height, and body mass index at two years, using new standards from the World Health Organization) are related to several adult outcomes (height, schooling, income and assets, offspring birth weight, body mass index, glucose concentrations, and blood pressure).

The authors also identify 28 relevant published articles.² Based on this review, they report that undernutrition is strongly associated with shorter adult height, less schooling, reduced economic productivity, and lower offspring birth weight (the last for women only). They also report that associations with adult disease indicators are ambiguous. Increased size at birth and

1 “Awareness of child development is increasing in developing countries. The health sector has advocated for early child development programmes for children with low birth weight, [with] developmental delays, and from low-income disadvantaged environments. Child development information is often incorporated into growth monitoring charts. Government-supported pre-school programmes for children are increasing; in the past 15 years, at least 13 developing countries have instituted compulsory preschool or pre-primary programmes. By 2005, the World Bank had financed loans to 52 developing countries for child development programmes, for a total of US\$1,680 million, at least 30 developing countries had policies on early child development, and UNICEF [United Nations Children’s Fund] was assisting governments in supporting parenting programmes in 60 countries” (Engle and others 2007: 229–30).

2 They searched in the Medline, Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL), EconLit, Psychinfo, and PsychArticles databases, with all possible combinations of exposures and outcomes, and identified more than 15,000 original articles and 700 reviews. The search was then limited to articles on developing countries where outcomes had been measured in adulthood or late adolescence, excluding studies with low statistical power or poor methodological quality, and identified 28 relevant articles.

in childhood is positively associated with adult body mass index and, to a lesser extent, blood pressure values, but not with blood glucose concentrations. In their new analyses and in the published work they review, low birth weight and undernutrition in childhood are risk factors for high glucose concentrations, high blood pressure, and harmful lipid profiles once adult body mass index and height are controlled for, suggesting that rapid postnatal weight gains, especially after infancy, are linked to these conditions.

The authors' review of published studies indicates that there is insufficient information about long-term changes in immune function, blood lipids, or osteoporosis indicators. Birth weight is positively associated with lung function and the incidence of some cancers, and undernutrition may be associated with mental illness. The authors note that height at two years is the best predictor of human capital and that undernutrition is associated with lower human capital.

Table 6.1 summarizes numerical associations between maternal and infant-child anthropometric measures of nutritional status, on the one hand, and selected adult outcomes, on the other.³ The outcomes in the table only include one indicator of adult health outcomes—adult height, commonly considered an indicator of long-run nutritional status—because Victora and others (2008) do not provide such estimates for other adult health outcomes. The estimates are generally “adjusted” estimates, meaning that they include controls for other variables (which tends to lower the estimates). But other than those adjustments, these are estimates of associations without efforts to control for maternal and infant-child anthropometrics that are determined by behavioral choices in the presence of intergenerationally correlated endowments.⁴ The estimates suggest some strong associations over the life cycle and across generations between early life nutrition and a range of adult outcomes.

Table 6.1 Select Associations between Maternal and Infant Anthropometric Measures and Adult Outcomes

Outcome	Measure
Adult height	0.7–1.0 centimeter per centimeter at birth 3.2 centimeters per HAZ at age 2 0.5 centimeter per centimeter of maternal height
Education attainment	0.3 grade per kilogram at birth 0.5 grade per HAZ at age 2 0.5 grade per WAZ at age 2
Labor income	8 percent per HAZ at age 2 for males 8–25 percent per HAZ at age 2 for females
Birth weight of offspring	208 grams per kilogram for mother at birth 70–80 grams per HAZ or WAZ of mother

Source: Victora and others 2008.

Note: HAZ refers to height-for-age z scores (that is, the number of standard deviations in the international reference population). WAZ refers to weight-for-age z scores.

³ The income estimates are based only on data from Brazil and Guatemala.

⁴ Although there are exceptions, as in the Guatemalan case discussed below.

Based on their review of the literature and the estimates in table 6.1, Victora and others (2008) conclude the following:

- Damage suffered in early life leads to permanent impairment and might also affect future generations.
- Preventing such damage would probably generate major health, educational, and economic benefits.
- Chronic diseases are especially common in undernourished children who experience rapid weight gain after infancy.

Thus these *Lancet* studies provide a limited, qualified, but still strong suggestion that better early life nutrition and health have intrinsic benefits that increase later welfare. Moreover, for developing-country populations, better early nutrition and health are associated with and may have good outcomes over the life cycle and across generations.

The rest of this chapter summarizes further supporting evidence. The next section summarizes some of the strongest micro-level evidence available based on panel data over 35 years from Guatemala. The second section summarizes some benefit-cost analyses for early life nutritional interventions. The studies reviewed in this chapter indicate that improved early life nutrition in poorly nourished populations may have substantial causal effects on improving productivity and saving resources over the life cycle and into the next generation and may have benefits that substantially outweigh the costs. Thus, in addition to important direct intrinsic welfare benefits, better early life nutrition in such contexts should be a high priority in strategies for increasing growth and productivity.

Evidence from Guatemala on Impacts of Early Life Nutrition and Other Aspects of Early Childhood Development over the Life Cycle

Some of the richest available evidence on the long-term impacts of early life nutrition comes from a study covering 35 years on an experimental nutritional project initiated in four Guatemalan villages in 1969 and running through 1977. This section first describes the project and related data and then summarizes recent estimates of its long-term effects.

The Nutritional Intervention and Follow-Up Data

In the early and mid-1960s protein deficiency was considered the most important nutritional problem facing poor people in developing countries, and there was considerable concern that this deficiency affected children's ability to learn. The Institute of Nutrition for Central America and Panama (INCAP), based in Guatemala, became the locus of a series of preliminary studies on this subject in the second half of the 1960s (see Habicht and Martorell 1992; Martorell, Habicht, and Rivera 1995; Read and Habicht 1992). These studies informed the

development of a large-scale nutritional supplementation project that began in 1969.

The data used in the studies summarized in the following section are based on that project and initially were collected for children age birth to seven years during 1969–77 in four villages in eastern Guatemala.⁵ In addition, follow-up data have repeatedly been collected for the same individuals.⁶ Three of the villages—Conacaste, Santo Domingo, and San Juan—are in mountainous areas with shallow soils, while Espíritu Santo, located in a river valley, has somewhat higher agricultural potential. All four villages are located relatively near the Atlantic Highway, which connects Guatemala City to the country’s Caribbean coast, ranging from 36 to 102 kilometers from Guatemala City.

Between January 1969 and February 1977, INCAP implemented a nutritional supplementation trial in these four villages and collected data on recipient children’s growth and development. Data collection focused on all village children under seven and all pregnant and lactating women. Data on cohorts of newborns were collected until September 1977. Data stopped being collected when children turned seven. Thus the birth years of the children included in the 1969–77 longitudinal data collection ranged from 1962 to 1977, so their ages ranged from 0 to 15 years when the project ended. Accordingly, the length and timing of children’s exposure to the nutritional interventions depended on their birth dates.

For example, only children born after January 1969 and before October 1974 were exposed to the nutritional interventions for the full first three years of their lives—considered a critical period for child growth (see Maluccio and others 2009; Martorell, Habicht, and Rivera 1995; Martorell and others 2005 and the references therein). Recent estimates summarized in the next section suggest that this is also a critical period for early life nutrition’s impact on education achievement, adult cognitive skills, and wage rates and intergenerational effects (Behrman and others 2009; Hoddinott and others 2008; Maluccio and others 2009).

Conacaste and San Juan were randomly assigned to receive a high-protein energy drink, *Atole*, as a dietary supplement. *Atole* contained incaparina (a vegetable-protein mixture developed by INCAP and still widely available in markets in Guatemala), dry skim milk, and sugar and had 163 calories and 11.5 grams of protein per 180 milliliter serving. This design reflected the prevailing view of the 1960s that protein was the critical missing nutrient in most developing countries. *Atole*, the Guatemalan name for hot maize gruel, was pale gray-green and slightly gritty, with a sweet taste.

5 Some 300 villages were screened to identify those of appropriate size, compactness (to facilitate access to feeding stations, health centers, and psychological testing sites), ethnicity, diet, schooling levels, demographic characteristics, nutritional status, and physical isolation. This screening identified two sets of village pairs similar in these characteristics: Conacaste and Santo Domingo (relatively populous villages) and Espíritu Santo and San Juan (less populous villages).

6 This population has been studied intensively, with particular emphasis on the impacts of the nutritional intervention (Martorell and others 2005 provide references to many of these studies).

In designing the data collection efforts, there was considerable concern that the social stimulation associated with attending feeding centers—such as the observation of children’s nutritional status, monitoring of their intake of *Atole*, and so on—might also affect children’s nutritional outcomes, confounding efforts to understand the impacts of the supplement alone. To address this concern, in Espiritu Santo and Santo Domingo a different drink, *Fresco*, was provided. *Fresco* was a cool, clear, fruit-flavored drink. It contained no protein and only sufficient sugar and flavoring for palatability. It also contained far fewer calories per serving (59 calories per 180 milliliters) than did *Atole*. Several micronutrients were added to *Atole* and *Fresco* in equal concentrations. These additions were made to sharpen the contrast between the drinks in protein. Although the energy content differed, this was not recognized as being of much importance at the time.

The two nutritional supplements were distributed in supplementation centers and were available daily, on a voluntary basis, to all community members at times convenient to mothers and children that did not interfere with usual meal times.⁷ For the studies summarized in the next section, a critical question is the extent to which the project’s design resulted in differences in access to calories, proteins, and other nutrients. Averaging over all children in the *Atole* villages (that is, both those who consumed the supplement and those who never consumed any), children under one consumed 40–60 calories a day, children age one consumed 60–100 calories a day, and children age two consumed 100–120 calories a day as supplement. By contrast, children in the *Fresco* villages consumed almost no *Fresco* for the first two years of their lives, averaging at most 20 calories a day, rising to about 30 calories a day by age three (Schroeder, Kaplowitz, and Martorell 1992: fig. 4). Micronutrient intakes from the supplements were also larger in *Atole* than in *Fresco* villages.⁸

Multidisciplinary research teams conducted several follow-up rounds of data collection on participants from the 1969–77 sample as well as their children. Data collection in 1987–88 targeted the same individuals born

7 A program of free primary medical care was provided throughout the period of data collection. Periodic preventive health services, such as immunization and deworming campaigns, were conducted in all villages.

8 To assess whether total caloric intake by these children increased, Islam and Hoddinott (2009) estimate an ordinary least squares relation in which the dependent variable is the sum of calories consumed at home plus calories from supplements. In addition to controlling for maternal and paternal characteristics (age and completed grades of schooling) and household characteristics (a wealth index and distance from the feeding center), they include a dummy variable of 1 if the child resided in one of the two villages where *Atole* was provided, yielding a crude measure of the intent-to-treat effect of the intervention on intakes. For children age one to three years, the coefficient on *Atole* is positive and statistically significant, indicating that total caloric consumption for children exposed to *Atole* increased by 18 percent and total protein intake by 45 percent. Thus the intervention increased energy and protein intakes for young children in *Atole* villages relative to *Fresco* villages. In addition, for children under three the volume of *Atole* consumed was higher than the volume of *Fresco* consumed, implying that intakes of micronutrients were also greater for children in *Atole* villages. Thus the intervention improved nutritional intakes in general, rather than only protein intakes, as originally envisioned in 1969.

between 1962 and 1977 who had participated in the INCAP longitudinal data collection and were 11–26 years old in 1988, including those who remained in the original villages and those who had migrated to Guatemala City and to the provincial capital of the study area. Between 1991 and 1996, investigators studied the offspring of the original sample members in the original villages (migrants were not studied). In 1996, data collection was expanded to include surveillance of pregnancies and collect longitudinal data on these offspring. Between 1996 and 1999, information was collected on all children born between 1996 and 1999 and children born before this study's launch who were under three in 1996.

Next, a multidisciplinary team of investigators, including the author of this chapter, collected follow-up data in 2002–04 on all participants in the 1969–77 project through the Human Capital Study, the main source for the data on long-term outcomes in individuals' lives summarized below. In the 2002–04 sample, members ranged from 25 to 42 years old. By 2004, 1,855 (78 percent of the original sample) were found to be alive and living in Guatemala (11 percent had died, mostly due to infectious diseases in early childhood, 7 percent had migrated abroad, and 4 percent were not traceable). Of these 1,855 individuals, 1,113 lived in the original villages, 155 in nearby villages, 419 in or near Guatemala City, and 168 elsewhere in Guatemala. Of this sample, 1,051 (57 percent) had finished the complete battery of applicable interviews and measurements, and 1,571 (85 percent) completed at least one interview during the 2002–04 follow-up survey. For two-thirds of the 284 (15 percent) who completed no interviews, current addresses could not be obtained, and so contact could not be established. But the refusal rate for at least partial participation among those contacted was just 5 percent (Grajeda and others 2005).

Finally, an almost identical multidisciplinary team of investigators (again including the author of this chapter) conducted an additional survey between January 2006 and August 2007 of the original sample members, their children, and their aging parents, with an emphasis on intergenerational interactions—which is why this survey was called the Intergenerational Transfers Study (Melgar and others 2008 provide details). The data from this study are the source of the measures of intergenerational effects on children's anthropometric outcomes summarized below.

The sample frame for the Intergenerational Transfers Study builds directly on the original INCAP longitudinal study (1969–77), taking into account current information on residence status and information available for original respondents from later surveys, particularly the Human Capital Study (2002–04). The starting point was the sample of living individuals from the INCAP longitudinal study (hereafter referred to as original sample members) who met all of the following criteria:

- Were interviewed in the Human Capital Study and successfully completed the educational, marriage, and income history interviews
- Were living in one of the original study villages, another community in the department of El Progreso (where all the villages are located), or

Guatemala City or its suburbs, all of which are referred to as the Intergenerational Transfers Study area⁹

- Had a biological parent living in the Intergenerational Transfers Study area.

These criteria reflect a combination of cost considerations (such as tracing migrants to other parts of Guatemala) and study objectives (such as focusing on intergenerational interactions, particularly with the aging parents of the original sample members). Among other things, information was also collected on spouses or partners and children under 12 living in the same household as original sample members.¹⁰ There were 1,090 individuals (46 percent of the original sample and 54 percent of those alive in 2007) from the original sample who satisfied all three criteria (or had a spouse or partner who did)¹¹ and 1,463 children of original sample members.

Estimates of Direct and Indirect Impacts of Early Childhood Nutrition

INCAP's data sets permit more confident assessment of the magnitude of causal impacts of improved early life nutrition on long-term outcomes in a low-income country context than do almost any other existing data sets. First, this is because of the experimental design in which—beyond the control of the households involved—some children were exposed to better nutrition than others during critical windows of their development (such as the first three years of life). This makes it possible to move beyond the associations underlying much of what is summarized in the introduction to this chapter.

The problem with interpreting associations between, for example, early life indicators of nutritional status and later outcomes as causal effects is that parents who invest more in early life nutrition of their children may also invest more in other aspects of their children's development—such as education—because of their greater interest in or capacity for investing in their children. Thus associations between early life nutrition and later life outcomes may reflect not just the impact of early life nutritional status on subsequent outcomes, but also in part—perhaps substantial part—parents' interest in and capacity for investing in their children.

9 This is in contrast to the Human Capital Study, for which original sample members anywhere in Guatemala were interviewed. This was not financially feasible for the Intergenerational Transfers Study, so about 10 percent of potential subjects were excluded under this criterion.

10 Spouses and partners include both formally married persons and cohabiting persons describing themselves as being in a union. Children include biological or adopted children of the original sample member or his or her spouse or partner. To be considered adopted, the child had to consider the original sample member to be his or her parent, and vice versa, and not consider anyone else to be his or her parent. All such children under 12 years of age who lived in the same household as the original sample member or his or her spouse or partner were included. In addition, children of original sample members who lived with a former spouse or partner who was not an original sample member were included in the target sample.

11 Among those who did not, 383 (16 percent) had died by the time of the survey and 624 (26 percent) were living outside the study area or could not be traced. The remaining 352 (15 percent) individuals were ineligible because they had not completed the relevant forms for the Human Capital Study, they did not have an eligible parent living in the study region, or both.

Table 6.2 Effects of Exposure in the First Three Years of Childhood to *Atole* Relative to *Fresco* Nutritional Supplements on Guatemalan Adults Age 25–42 and on Their Offspring

Dependent variable	Impact of exposure
<i>Later in individuals' lives</i>	
Female schooling attainment (grades)	1.17 (2.13)
Female and male reading comprehension	0.28 (2.52)
Female and male nonverbal skills	0.24 (2.01)
Male income (US\$ per year)	870 (1.59)
Male wage rate (US\$ per hour)	0.67 (2.61)
Male hours worked (hours per year)	-222 (-1.25)
<i>Across generations: women's children</i>	
Birth weight (grams)	275 (2.58)
Weight (kilograms, 0–12 years old)	1.91 (2.58)
Triceps skinfold thickness (millimeters), 0–12 years old	1.38 (2.81)

Sources: Behrman and others 2009; Hoddinott and others 2008; Maluccio and others 2009.

Note: Impacts are in bold; *t* values (standard deviations) are in parentheses (*t* values > 1.65 indicate significance at the 0.10 level; *t* values > 1.96 indicate significance at the 0.05 level).

Second, INCAP data are unusually rich in some ways, covering about 35 years from childhood to adulthood, with biomedical and socioeconomic information on the original participants, their children, and parents.

Table 6.2 summarizes estimates of the direct impacts of the childhood nutritional interventions described above on outcomes over individual life cycles and the next generation. These are estimates of the causal impact of being exposed to the better nutritional supplement (*Atole*) instead of the other (*Fresco*) during the critical first two or three years of life.

The exposure to the *Atole* intervention (relative to *Fresco*) for the first three years of life has significant and substantial effects on a series of education-related outcomes. Female schooling increased by more than a full grade, and scores on reading comprehension and nonverbal cognitive skills tests rose by about one-quarter of a standard deviation for both men and women. For men—who are more likely to enter the formal labor market, with more than 95 percent participating—exposure to the *Atole* intervention during the first two years of life led to insignificant but substantial increases in annual income (nearly \$900, compared with average income of about \$3,500) and significant increases in hourly wages of \$0.67, about a third of the average wage.

For women (there are no significant effects for men), exposure to the *Atole* intervention during the first three years of life increased their children's birth weight by 275 grams as well as indicators of fatness for children 0–12 years old. Thus early nutritional interventions can have substantial, long-lasting effects that are likely to enhance welfare, productivity, and growth, both over the life cycles of otherwise malnourished beneficiaries and across generations to their children.

Benefit-Cost Estimates of Improving Early Life Nutrition in Poorly Nourished Populations

The estimated outcomes suggest that, at least in contexts such as that in Guatemala, improving early life nutrition delivers considerable long-term gains. But these estimates by themselves do not indicate whether such gains are likely to be high relative to the costs or what priority such interventions might have among a larger set of possible interventions.

To provide some perspective on such matters, this section summarizes efforts by Behrman, Alderman, and Hoddinott (2004) to include such estimates as part of the “Copenhagen Consensus” (Lomborg 2004). The Copenhagen Consensus sought to set priorities among proposals for confronting 10 major global challenges (selected from a wider set of issues identified by the United Nations): civil conflicts, climate change, communicable diseases, inadequate education, financial instability, weak governance, hunger and malnutrition, migration, trade reform, and poor water and sanitation.

The procedure followed was that a panel of what the Copenhagen Consensus characterized as “eight of the world's most distinguished economists” (including four Nobel laureates) met in Copenhagen in May 2004. The panel was asked to address the 10 challenges noted above and to answer the following question: What would be the best ways of advancing global welfare, and particularly the welfare of developing countries, supposing that an additional \$50 billion of resources were at governments' disposal? Before the meeting, 10 papers were commissioned from acknowledged experts to determine benefit-cost ratios for up to five proposals for each of the 10 challenge areas. The panel examined these proposals in detail. Each paper was discussed at length with the authors and with two other specialists who had been commissioned to write critical appraisals. The panel then met in private session and ranked the proposals.

Behrman, Alderman, and Hoddinott (2004) address the seventh challenge, hunger and malnutrition. The share of people in the developing world considered hungry fell from 20 percent in 1990–92 to 17 percent in 1999–2001, yet about 800 million people still do not consume enough food and nutrients to live healthy, productive lives. Most of these people live in Asia (505 million) or Sub-Saharan Africa (198 million). But while the prevalence of hunger has been falling in Asia, it has been rising in Africa. About half of the hungry live in farm households (often in high-risk production environments), with

about a fifth each in rural landless and poor urban households. Malnutrition is a challenge related to, but in some ways distinct from, hunger.¹² Important manifestations of malnutrition include the following:

- Low birth weight, with more than 12 million infants a year born with low birth weights
- Slowed skeletal (linear) growth, inadequate weight gain, or both—resulting in stunted or wasted children, with 162 million stunted children under five around the world
- Micronutrient deficiencies, particularly iodine (2 billion people), iron (3.5 billion, including 67 million pregnant women a year), and vitamin A (128 million preschool children).

Reducing hunger and malnutrition can readily be justified because of the potential direct gains in welfare. But reducing hunger and malnutrition also offers potential productivity gains and economic cost reductions. These benefits and how they compare with the costs of achieving them are the focus here. For example,

- reducing the incidence of low birth weights and vitamin A deficiencies lowers the costs of infant mortality.
- reducing the incidence of low birth weights, inadequate postnatal growth, and vitamin A deficiencies lowers the costs of neonatal care and infant and child illnesses.
- lowering the incidence of stunting increases physical productivity.
- reducing the incidence of low birth weights, stunting, and iodine and iron deficiencies increases cognitive abilities and raises schooling and adult productivity.
- reducing the incidence of low birth weights lowers the costs of chronic adult diseases.

Moreover, adults who are better nourished in their early lives and child-bearing years transmit these benefits to subsequent generations. The estimates in the preceding section show some of the available evidence, albeit from just Guatemala, of some of these benefits.

Behrman, Alderman, and Hoddinott (2004) systematically review estimates of the impact of reducing hunger and malnutrition from all over the world, focusing on studies from which inferences can be made more confidently based on the studies' data and estimation methods. Ascertaining these effects is challenging because the effects may be manifested over the life cycle and across generations, but few data sets provide information on people and their children over such long periods. Instead, Behrman, Alderman, and Hoddinott piece together as best as the literature permits information on various impacts and channels through which they occur.

12 For example, the rapid spread of obesity in many parts of the developing world is a growing malnutrition problem but is quite distinct from hunger. But information was not available at the time to assess obesity in the same way as some other malnutrition problems.

Table 6.3 Estimated Present Discounted Values of Seven Major Benefits of Moving One Infant from Low Birth Weight, at Different Discount Rates

US\$

Benefit	Annual discount rate		
	3 percent	5 percent	10 percent
Reduced infant mortality	95	99	89
Reduced neonatal care	42	42	42
Reduced costs of infant and child illness	36	35	34
Productivity gain from reduced stunting	152	85	25
Productivity gain from increased cognitive ability	367	205	60
Reduced costs of chronic diseases	49	15	1
Intergenerational benefits	92	35	6
Total	832	510	257
Share of total at 5% discount rate (%)	163	100	50

Source: Alderman and Behrman 2006.

Note: The 5 percent discount rate is the base-case estimate.

Table 6.3 shows seven major benefits of moving a baby from below to above the standard cutoff of 2,500 grams for low birth weight. Because the benefits occur over time, discounting is necessary to reflect the advantages in receiving benefits sooner rather than later, because the proceeds can be reinvested. With a 5 percent discount rate, the present discounted value of these benefits is \$510.¹³ But as the table shows, the present discounted value of benefits would be more than 60 percent higher with a discount rate of 3 percent—or just half as large with a discount rate of 10 percent.

The distribution of the components of the benefits among the seven categories is instructive. Much of the literature on the costs of low birth weight focuses either on early life or on later life—reducing chronic diseases through the so-called Barker (1998) effect. But under the assumptions underlying these estimates,¹⁴ with a 5 percent discount rate, more than half of the impact comes from increased adult productivity, primarily through increased cognitive development (40 percent) and secondarily through reduced stunting (16 percent). Thus, under these assumptions, the direct productivity gains over the life cycle are the most important part of the benefits.

So from the perspective of increasing growth and productivity, are investments in reducing low birth weight good investments? The evidence seems strong that they have a positive impact by raising productivity and lowering costs. But having a positive impact is only part of the information needed to answer this question. One also needs to know the present

¹³ This is less than the \$580 given in Behrman, Alderman, and Hoddinott (2004) because the estimates of Alderman and Behrman (2006) incorporate survival probabilities.

¹⁴ The most critical assumption is probably how to put a monetary value on averted mortality. Behrman, Alderman, and Hoddinott (2004) use the resource cost of the cheapest available alternative to averting mortality (infant inoculations, as in Summers 1994), but they present simulations to show how sensitive such estimates are to a range of alternatives.

discounted value of the costs of reducing low birth weight. If they are a lot less than \$510, then reducing the prevalence of low birth weight is likely to be a high-priority investment in terms of productivity and growth. But if the present discounted value of the costs of reducing the prevalence of low birth weight is greater than \$510, then in terms of productivity and growth such investments are not desirable, although they may be very desirable for intrinsic reasons.

Thus, Behrman, Alderman, and Hoddinott (2004) and Alderman and Behrman (2006) also try to obtain as good cost estimates as possible for reducing the prevalence of low birth weight in low-income countries. Many interventions have been proposed to address low birth weight problems (Alderman and Behrman 2006; Merialdi and others 2003; Steketee 2003), including antimicrobial treatments, antiparasitic treatments, insecticide-treated bed nets, maternal health records to track gestational weight gain, iron and folate supplements, targeted food supplements, and social awareness programs on birth spacing and timing of marriage.

Although some recommended interventions focus solely on low birth weight, some also address other goals, such as campaigns against smoking or the use of other drugs during pregnancy. To assess such interventions, one ideally would sum the expected present discounted value of all anticipated outcomes. Yet most lists of possible interventions provide little guidance on priorities, whether for using scarce public resources to alleviate problems related to low birth weight or for deciding which interventions have relatively high returns in which situations. This lack of clearly defined priorities likely reduces the influence of advocates of using scarce public resources to alleviate problems related to low birth weight. It also likely impedes agreement among advocates on how to use public resources to treat problems related to low birth weight.

Rouse (2003) provides a brief review of the cost-effectiveness of interventions to prevent adverse pregnancy outcomes, including low birth weight. He indicates, for example, that it costs \$46 per case of low birth weight averted with treatments for asymptomatic sexually transmitted bacterial infections where they are prevalent. Consider also an extensive field trial of iron and folate supplementation in a Nepalese community with high rates of both low birth weight and anemia. Christian and others (2003) find that 11 women would need to be reached with micronutrient supplements to prevent one case of low birth weight. Although no cost data are provided in that study, Parul Christian and Keith West said in personal communications with Harold Alderman that the cost of \$64 per pregnant woman reached in the experimental program could be reduced to \$13 in an ongoing program. With just one in 11 births benefiting directly in terms of a case of low birth weight averted, the initial cost does not represent an economically efficient intervention. But if just one-third of the estimated cost reduction for an ongoing program could be realized, the intervention would be economically efficient. Moreover, economies of scope would allow the provision of vitamin A supplementation at little marginal cost and thus might reduce both infant and maternal mortality.

Behrman, Alderman, and Hoddinott (2004) estimate benefit-cost ratios for interventions to reduce hunger and malnutrition that lower the prevalence of low birth weight, improve infant and child nutrition, reduce micronutrient deficiencies (primarily for children and pregnant women), and invest in technological developments in low-income agriculture (which can improve nutrition by lowering prices for nutrients through more nutrient-rich foods and increasing incomes for poor farmers and farm workers; see table 6.4). The authors discuss a number of qualifications and caveats for these and other such estimates and explore the sensitivity of their estimates to some of the

Table 6.4 Estimated Global Benefit-Cost Ratios for Opportunities Related to Hunger and Malnutrition

Opportunities and targeted populations	Ratio of benefits to costs	Size of targeted population
<i>Reducing low birth weight for pregnancies with high probabilities of it (particularly in South Asia)</i>		12 million low birth weight births a year
Treatment for women with asymptomatic bacterial infections	0.6–4.9	
Treatment for women with presumptive sexually transmitted disease	1.3–10.7	
Drugs for pregnant women with poor obstetric history	4.1–35.2	
<i>Improving infant and child nutrition in populations with high prevalence of child malnutrition</i>		162 million stunted children under 5 years of age
Promotion of breastfeeding in hospitals where use of infant formula is the norm	4.8–7.4	
Integrated child care programs	9.4–16.2	
Intensive preschool programs, including meals and nutrition for poor families	1.4–2.9	
<i>Reducing micronutrient deficiencies in populations suffering from them</i>		
Iodine (per woman of child-bearing age)	15–520	2 billion people
Vitamin A (children under six)	4–43	128 million children
Iron (per capita)	176–200	3.5 billion people, including 67 million pregnant women
Iron (pregnant women)	6–14	
<i>Investing in technology to develop agriculture</i>		
Dissemination of new cultivars with higher yield potential	8.8–14.7	800 million undernourished who would benefit from price reductions, about 0.7 million of whom would benefit from any income increases due to productivity gains
Dissemination of iron- and zinc-dense rice and wheat	11.6–19.0	
Dissemination of vitamin A–dense “golden rice”	8.5–14.0	

Source: Behrman, Alderman, and Hoddinott 2004.

Table 6.5 Project Rankings in 2004 Copenhagen Consensus

Project rating	Ranking	Challenge	Opportunity
Very good	1	Diseases	Control HIV/AIDS
	2	Malnutrition	Provide micronutrients
	3	Subsidies and trade	Liberalize trade
	4	Diseases	Control malaria
Good	5	Malnutrition	Develop new agricultural technologies
	6	Water and sanitation	Develop small-scale water technology for livelihoods
	7	Water and sanitation	Provide community-managed water supply and sanitation
	8	Water and sanitation	Conduct research on water productivity in food production
	9	Government	Lower the costs of starting new businesses
Fair	10	Migration	Lower the barriers to migration for skilled workers
	11	Malnutrition	Improve infant and child nutrition
	12	Malnutrition	Reduce the prevalence of low birth weight
	13	Diseases	Scale up basic health services
Bad	14	Migration	Implement guest worker programs for the unskilled
	15	Climate	Impose optimal carbon taxes
	16	Climate	Adopt the Kyoto Protocol
	17	Climate	Impose a value-at-risk carbon tax

Source: Lomborg 2004.

most important assumptions.¹⁵ They conclude that these estimates suggest that there is considerable potential for enhancing growth and productivity by investing more in early life nutrition—both before and after birth.

Various options exist for which the expected present discounted value of benefits exceeds the expected present discounted value of costs, suggesting the potential for major gains in productivity. Moreover, the benefit-cost ratios are high relative to those for many other interventions. In fact, based in part on the patterns of benefit-cost ratios across more than 30 proposed projects in the 10 challenge areas defined above, the Copenhagen Consensus panel gave high rankings to projects for reducing hunger and malnutrition (see table 6.5).¹⁶

15 Some of the assumptions might bias some estimates up and others down. For example, if higher discount rates are used, estimated benefit-cost ratios fall because many benefits are due to productivity improvements when infants and children become adults. The opposite holds if lower discount rates are used or if most other methods common in the literature for valuing averted mortality are used.

16 The Copenhagen Consensus 2008 rankings that were released on May 30, 2008, also include nutritional interventions, primarily directed toward early life, very high in their rankings. In fact, nutritional interventions occupy four of their six top-ranked interventions, the other two in the top six being “the Doha development agenda” (number two) and “expanded immunization coverage for children” (number four). See Copenhagen Consensus Center (2008).

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