This paper first summarizes recent research in developing countries that is surveyed in prominent *Lancet* articles and that reports, albeit based on relatively few systematic studies, substantial associations between early life nutrition and subsequent education, health, wage and intergenerational outcomes. The rest of the paper summarizes further evidence. The next section summarizes some of the strongest micro-level evidence available based on panel data over 35 years from Guatemala on causal effects of early life nutritional improvements on adult cognitive skills and wage rates and offspring anthropometric outcomes. The subsequent section summarizes some benefit-cost analyses for early life nutritional interventions that led to such interventions being ranked highly among interventions of all types, largely on the basis of benefit-cost ratios by prominent economists in the 2004 Copenhagen Consensus. The studies reviewed in this paper 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.

**Jere R. Behrman, William R. Kenan Jr. Professor of Economics, University of Pennsylvania**
Early Life Nutrition and Subsequent Education, Health, Wage, and Intergenerational Effects

Jere R. Behrman
About the Series

The Commission on Growth and Development led by Nobel Laureate Mike Spence was established in April 2006 as a response to two insights. First, poverty cannot be reduced in isolation from economic growth—an observation that has been overlooked in the thinking and strategies of many practitioners. Second, there is growing awareness that knowledge about economic growth is much less definitive than commonly thought. Consequently, the Commission’s mandate is to “take stock of the state of theoretical and empirical knowledge on economic growth with a view to drawing implications for policy for the current and next generation of policy makers.”

To help explore the state of knowledge, the Commission invited leading academics and policy makers from developing and industrialized countries to explore and discuss economic issues it thought relevant for growth and development, including controversial ideas. Thematic papers assessed knowledge and highlighted ongoing debates in areas such as monetary and fiscal policies, climate change, and equity and growth. Additionally, 25 country case studies were commissioned to explore the dynamics of growth and change in the context of specific countries.

Working papers in this series were presented and reviewed at Commission workshops, which were held in 2007–08 in Washington, D.C., New York City, and New Haven, Connecticut. Each paper benefited from comments by workshop participants, including academics, policy makers, development practitioners, representatives of bilateral and multilateral institutions, and Commission members.

The working papers, and all thematic papers and case studies written as contributions to the work of the Commission, were made possible by support from the Australian Agency for International Development (AusAID), the Dutch Ministry of Foreign Affairs, the Swedish International Development Cooperation Agency (SIDA), the U.K. Department of International Development (DFID), the William and Flora Hewlett Foundation, and the World Bank Group.

The working paper series was produced under the general guidance of Mike Spence and Danny Leipziger, Chair and Vice Chair of the Commission, and the Commission’s Secretariat, which is based in the Poverty Reduction and Economic Management Network of the World Bank. Papers in this series represent the independent view of the authors.
Acknowledgments

The author thanks participants at the Health and Growth Workshop sponsored by the Commission on Growth and Development on October 16, 2007 at the World Bank in Washington, D.C. for useful comments. The author also thanks the coauthors of the various studies summarized here for their collaboration on the work that underlies this paper, particularly Harold Alderman, Maria Cecilia Calderon, Suzanne Duryea, John Hoddinott, John Maluccio, Reynaldo Martorell, Agnes Quisumbing, Sam Preston, and Aryeh Stein. The research summarized in the second section was supported by National Institutes of Health grants TW-05598 on “Early Nutrition, Human Capital and Economic Productivity,” HD-046125 on “Education and Health across the Life Course in Guatemala,” and HD045627-01 on “Resource Flows among Three Generations in Guatemala,” as well as National Science Foundation/Economics grants SES 0136616 and SES 0211404 on “Collaborative Research: Nutritional Investments in Children, Adult Human Capital, and Adult Productivities.”
Abstract

This paper first summarizes recent research in developing countries that is surveyed in prominent *Lancet* articles and that reports, albeit based on relatively few systematic studies, substantial *associations* between early life nutrition and subsequent education, health, wage and intergenerational outcomes. The rest of the paper summarizes further evidence. The next section summarizes some of the strongest micro-level evidence available based on panel data over 35 years from Guatemala on *causal* effects of early life nutritional improvements on adult cognitive skills and wage rates and offspring anthropometric outcomes. The subsequent section summarizes some benefit-cost analyses for early life nutritional interventions that led to such interventions being ranked highly among interventions of all types, largely on the basis of benefit-cost ratios by prominent economists in the 2004 Copenhagen Consensus. The studies reviewed in this paper 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.
Contents

About the Series ............................................................................................................. iii
Acknowledgments ..........................................................................................................iv
Abstract ....................................................................................................................... v
Prevalence of Early Life Nutritional Shortfalls  and Associations with
   Outcomes over the Life Cycle and across Generations ............................................. 1
Evidence from Guatemala on Impacts of Early Life Nutrition and Other
   Aspects of Early Childhood Development over the Life Cycle ................................. 4
Benefit-Cost Estimates of Improving Early Life Nutrition in Poorly
   Nourished Populations........................................................................................... 10
References ..................................................................................................................... 17
Early Life Nutrition and Subsequent Education, Health, Wage, and Intergenerational Effects

Jere R. Behrman

Prevalence of Early Life Nutritional Shortfalls and Associations with Outcomes over the Life Cycle and across Generations

Three articles in a prominent 2007 series in The 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” (p. 145). Engle and others (2007, p. 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 Jere R. Behrman is the William R. Kenan, Jr. Professor of Economics and research associate in the Population Studies Center at the University of Pennsylvania.
2 “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, developmental delays, and from low-income disadvantaged environments. Child development information is often incorporated into growth monitoring charts. Government-supported preschool 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 was assisting governments in supporting parenting programmes in 60 countries” (Engle and others 2007, pp. 229–230).
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. 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 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 and 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

---

3 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.
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 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. 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 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 being determined by behavioral choices in the presence of intergenerationally correlated endowments. The estimates suggest some strong associations over the life cycle and across generations between early life nutrition and a range of adult outcomes.

Based on their review of the literature and the estimates in table 1, Victora and others (2008) conclude that:

- 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.

### Table 1: Selected Associations between Maternal and Infant Anthropometric Measures and Adult Outcomes

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

*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.*

---

4 The income estimates are based only on data from Brazil and Guatemala, the latter of which is discussed in the second section of this paper.

5 Though there are exceptions—as in the Guatemalan case discussed in the second section.
Thus these *Lancet* studies provide a limited, qualified, but still strong suggestion that better early life nutrition and health appear to 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 paper 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 third section summarizes some benefit-cost analyses for early life nutritional interventions. The studies reviewed in this paper 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, 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; and 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 under the next heading are based on that project and initially were collected for children age 0–7 years during 1969–77 in four villages in eastern Guatemala. In addition, follow-up data have

---

6 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
repeatedly been collected for the same individuals, also described below. 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 0–15 years when the project ended. Accordingly, the length and timing of children’s exposure to the nutritional interventions (described below) 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, forthcoming; Martorell, Habicht, and Rivera 1995; and Martorell and others 2005 and the references therein). Recent estimates summarized under the next heading 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 2008; Hoddinott and others 2008; Maluccio and others, forthcoming).

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, noted above, 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, but had a sweet taste.

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 intakes 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 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).

7 This population has been studied intensively, with particular emphasis on impacts of the nutritional intervention (Martorell and others 2005 provide references to many of these studies).
Espíritu 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. For the studies summarized under the next heading, a critical question is to what extent 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 that 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, figure 4). Micronutrient intakes from the supplements were also larger in Atole than in Fresco villages.

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 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

---

8 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.

9 To assess whether total caloric intake by these children increased, Islam and Hoddinott (forthcoming) estimate an ordinary least squares (OLS) 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 one if the child resided in one of the two villages where Atole was provided, providing 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 those in Atole villages. Thus the intervention improved nutritional intakes in general—rather than only protein, as originally envisioned in 1969.
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 the 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 paper, 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 2002–04 sample members ranged from 25–42 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—most 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 paper) 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 provides 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 the following criteria:

- was interviewed in the Human Capital Study and successfully completed the education, marriage, and income history interviews
- was 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 is referred to as the Intergenerational Transfers Study area\textsuperscript{10}.

- 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.\textsuperscript{11} 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 above (or had a spouse or partner who did),\textsuperscript{12} and 1,463 children of original sample members.

Estimates of Direct and Indirect Impacts of Early Childhood Nutrition

INCAP’s datasets 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 datasets. 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 first section of this paper.

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

\textsuperscript{10} 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.

\textsuperscript{11} 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 his or her parent and vice versa, and the child did not consider anyone else to be his or her parent. All such children under 12 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.

\textsuperscript{12} 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 either 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.
part—perhaps substantial part—parents’ interest in and capacity for investing in their children.

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 2 summarizes estimates of the direct impacts of the childhood nutritional interventions described in the previous section 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.

There are significant and substantial effects of exposure to the Atole intervention (relative to Fresco) for the first three years of life 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.

### Table 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

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Impact of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Later in individuals’ lives</strong></td>
<td></td>
</tr>
<tr>
<td>Female schooling attainment (grades)</td>
<td>1.17</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>2.13</td>
</tr>
<tr>
<td>Female and male reading comprehension</td>
<td>0.28</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>2.52</td>
</tr>
<tr>
<td>Female and male nonverbal skills</td>
<td>0.24</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>2.01</td>
</tr>
<tr>
<td>Male income (U.S. dollars per year)</td>
<td>870</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>1.59</td>
</tr>
<tr>
<td>Male wage rate (U.S. dollars per hour)</td>
<td>0.67</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>2.61</td>
</tr>
<tr>
<td>Male hours worked (hours per year)</td>
<td>−222</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>−1.25</td>
</tr>
<tr>
<td><strong>Across generations—women’s children</strong></td>
<td></td>
</tr>
<tr>
<td>Birth weight (grams)</td>
<td>179</td>
</tr>
<tr>
<td>(standard deviations)</td>
<td>1.87</td>
</tr>
<tr>
<td>Height-for-age Z score (0–12 years old)</td>
<td>0.34</td>
</tr>
<tr>
<td>(standard deviations in reference distribution)</td>
<td>2.21</td>
</tr>
<tr>
<td>Subscapular skinfold Z score (0–12 years old)</td>
<td>0.66</td>
</tr>
<tr>
<td>(standard deviations in reference distribution)</td>
<td>2.32</td>
</tr>
</tbody>
</table>

*Source: Behrman and others 2008, Hoddinott and others 2008, Maluccio and others, forthcoming.*

*Notes: Impacts are in bold; t-values in italics (t values > 1.65 indicate significance at the 0.10 level; t values > 1.96 indicate significance at the 0.05 level).*
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 179 grams, their children’s height by about a third, and their children’s subscapular skinfold by about two-thirds of standard deviations of international standards. 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 summarized above 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 make 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: “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 had been 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. Then 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.\textsuperscript{13} 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:

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

Moreover, adults who are better nourished in their early lives and childbearing years transmit the above 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, as suggested above, but few datasets provide information on people and their children over such long periods. Instead Behrman, Alderman and

\textsuperscript{13} 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 other malnutrition problems.
Hoddinott piece together as best as the literature permits information on various impacts and channels through which they occur.

Table 3 shows seven major benefits of moving a baby from below to above the standard low birth weight cutoff of 2,500 grams. 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.\textsuperscript{14} 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 later life—reducing chronic diseases through the so-called Barker (1998) effect. But under the assumptions underlying these estimates,\textsuperscript{15} 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.

### Table 3: Estimated Present Discounted Values of Seven Major Benefits of Moving One Infant from Low Birth Weight, at Different Discount Rates (U.S. dollars)

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Annual discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 percent</td>
</tr>
<tr>
<td>Reduced infant mortality</td>
<td></td>
</tr>
<tr>
<td>Reduced neonatal care</td>
<td>95</td>
</tr>
<tr>
<td>Reduced costs of infant and child illness</td>
<td>42</td>
</tr>
<tr>
<td>Productivity gain from reduced stunting</td>
<td>36</td>
</tr>
<tr>
<td>Productivity gain from increased cognitive ability</td>
<td>152</td>
</tr>
<tr>
<td>Reduced costs of chronic diseases</td>
<td>367</td>
</tr>
<tr>
<td>Intergenerational benefits</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>832</td>
</tr>
<tr>
<td>Share of total at 5 percent discount rate (percent)</td>
<td>163</td>
</tr>
</tbody>
</table>

\textbf{Source}: Alderman and Behrman 2006.

\textbf{Note}: The 5 percent discount rate is the base case estimate.

\textsuperscript{14} This is less than the $580 given in Behrman, Alderman, and Hoddinott (2004) because Alderman and Behrman (2006) estimates incorporate survival probabilities.

\textsuperscript{15} 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.
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 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 productivity and growth terms. But if the present discounted value of costs of reducing the prevalence of low birth weight is one, then in terms of productivity and growth such investments are not desirable—though 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 by one in low-income countries. Many interventions have been proposed to address low birth weight problems (Merialdi and others 2003; Steketee 2003; Alderman and Behrman 2006), including antimicrobial treatments, antiparasitic treatments, insecticide-treated bednets, 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.

Though some recommended interventions focus solely on low birth weight, some also address other goals—such as campaigns against smoking or consumption 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) found that 11 women would need to be reached with micronutrient supplements to prevent one case of low birth weight. Though no cost data were 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 1 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; table 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 most important
assumptions. They conclude that these estimates suggest there is considerable
potential for enhancing growth and productivity by investing more in early life
nutrition—both before and after birth.

A number of options appear available 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
(table 5).17

16 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.
17 The Copenhagen Consensus 2008 rankings that were released on May 30, 2008 also include
nutritional interventions, primarily directed towards 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).
Table 4: Estimated Global Benefit-Cost Ratios for Opportunities Related to Hunger and Malnutrition

<table>
<thead>
<tr>
<th>Opportunities and targeted populations</th>
<th>Benefits/costs</th>
<th>Size of targeted populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing low birth weight for pregnancies with high probabilities of it (particularly in South Asia)</td>
<td></td>
<td>12 million low birth weight births a year</td>
</tr>
<tr>
<td>Treatments for women with asymptomatic bacterial infections</td>
<td>0.6–4.9</td>
<td></td>
</tr>
<tr>
<td>Treatment for women with presumptive sexually transmitted disease</td>
<td>1.3–10.7</td>
<td></td>
</tr>
<tr>
<td>Drugs for pregnant women with poor obstetric history</td>
<td>4.1–35.2</td>
<td></td>
</tr>
<tr>
<td>Improving infant and child nutrition in populations with high prevalence of child malnutrition</td>
<td></td>
<td>162 million stunted children under five years of age</td>
</tr>
<tr>
<td>Promoting breastfeeding in hospitals where use of infant formula is the norm</td>
<td>4.8–7.4</td>
<td>0–5 years old</td>
</tr>
<tr>
<td>Integrated child care programs</td>
<td>9.4–16.2</td>
<td></td>
</tr>
<tr>
<td>Intensive preschool programs, including meals and nutrition for poor families</td>
<td>1.4–2.9</td>
<td></td>
</tr>
<tr>
<td>Reducing micronutrient deficiencies in populations suffering from them</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iodine (per woman of child=bearing age)</td>
<td>15–520</td>
<td>2 billion people</td>
</tr>
<tr>
<td>Vitamin A (children under six)</td>
<td>4–43</td>
<td>128 million children</td>
</tr>
<tr>
<td>Iron (per capita)</td>
<td>176–200</td>
<td>3.5 billion people, including 67 million pregnant women</td>
</tr>
<tr>
<td>Iron (pregnant women)</td>
<td>6–14</td>
<td></td>
</tr>
<tr>
<td>Investing in technology to develop agriculture</td>
<td></td>
<td>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</td>
</tr>
<tr>
<td>Dissemination of new cultivars with higher yield potential</td>
<td>8.8–14.7</td>
<td></td>
</tr>
<tr>
<td>Dissemination of iron- and zinc-dense rice and wheat</td>
<td>11.6–19.0</td>
<td></td>
</tr>
<tr>
<td>Dissemination of vitamin A–dense “golden rice”</td>
<td>8.5–14.0</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5: Project Rankings in 2004 Copenhagen Consensus

<table>
<thead>
<tr>
<th>Project rating</th>
<th>Challenge</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>1 Diseases</td>
<td>Control of HIV/AIDS</td>
</tr>
<tr>
<td></td>
<td>2 Malnutrition</td>
<td>Providing micronutrients</td>
</tr>
<tr>
<td></td>
<td>3 Subsidies and trade</td>
<td>Trade liberalization</td>
</tr>
<tr>
<td></td>
<td>4 Diseases</td>
<td>Control of malaria</td>
</tr>
<tr>
<td>Good</td>
<td>5 Malnutrition</td>
<td>Development of new agricultural technologies</td>
</tr>
<tr>
<td></td>
<td>6 Water and sanitation</td>
<td>Small-scale water technology for livelihoods</td>
</tr>
<tr>
<td></td>
<td>7 Water and sanitation</td>
<td>Community-managed water supply and sanitation</td>
</tr>
<tr>
<td></td>
<td>8 Water and sanitation</td>
<td>Research on water productivity in food production</td>
</tr>
<tr>
<td></td>
<td>9 Government</td>
<td>Lowering the costs of starting new businesses</td>
</tr>
<tr>
<td>Fair</td>
<td>10 Migration</td>
<td>Lowering the barriers to migration for skilled workers</td>
</tr>
<tr>
<td></td>
<td>11 Malnutrition</td>
<td>Improving infant and child nutrition</td>
</tr>
<tr>
<td></td>
<td>12 Malnutrition</td>
<td>Reducing the prevalence of low birth weight</td>
</tr>
<tr>
<td></td>
<td>13 Diseases</td>
<td>Scaled-up basic health services</td>
</tr>
<tr>
<td>Bad</td>
<td>14 Migration</td>
<td>Guest worker programs for the unskilled</td>
</tr>
<tr>
<td></td>
<td>15 Climate</td>
<td>Optimal carbon taxes</td>
</tr>
<tr>
<td></td>
<td>16 Climate</td>
<td>The Kyoto Protocol</td>
</tr>
<tr>
<td></td>
<td>17 Climate</td>
<td>Value-at-risk carbon tax</td>
</tr>
</tbody>
</table>

*Source: Lomborg 2004.*
References


Eco-Audit

Environmental Benefits Statement

The Commission on Growth and Development is committed to preserving endangered forests and natural resources. The World Bank’s Office of the Publisher has chosen to print these Working Papers on 100 percent postconsumer recycled paper, processed chlorine free, in accordance with the recommended standards for paper usage set by Green Press Initiative—a nonprofit program supporting publishers in using fiber that is not sourced from endangered forests. For more information, visit www.greenpressinitiative.org.

The printing of all the Working Papers in this Series on recycled paper saved the following:

<table>
<thead>
<tr>
<th>Trees*</th>
<th>Solid Waste</th>
<th>Water</th>
<th>Net Greenhouse Gases</th>
<th>Total Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>2,247</td>
<td>17,500</td>
<td>4,216</td>
<td>33 mil.</td>
</tr>
<tr>
<td>*40 inches in height and 6–8 inches in diameter</td>
<td>Pounds</td>
<td>Gallons</td>
<td>Pounds CO₂ Equivalent</td>
<td>BTUs</td>
</tr>
</tbody>
</table>

*40 inches in height and 6–8 inches in diameter
The Commission on Growth and Development
Working Paper Series

29. The Automotive Industry in the Slovak Republic: Recent Developments and Impact on Growth, by Malgorzata Jakubiak and Peter Kolesar, June 2008
30. Crime and Growth in Colombia, by Mauricio Cardenas, June 2008
31. Chilean Growth Through East Asian Eyes, Homi Kharas, Danny Leipziger, and Thillainathan Ramasamy, June 2008

Forthcoming Papers in the Series:
International Finance and Growth in Developing Countries: What Have We Learned, by Maurice Obstfeld (August 2008)
Policy and Institutional Dynamics of Sustained Development in Botswana, by Gervase Maipose (August 2008)

Electronic copies of the working papers in this series are available online at www.growthcommission.org. They can also be requested by sending an e-mail to contactinfo@growthcommission.org.
This paper first summarizes recent research in developing countries that is surveyed in prominent Lancet articles and that reports, albeit based on relatively few systematic studies, substantial associations between early life nutrition and subsequent education, health, wage and intergenerational outcomes. The rest of the paper summarizes further evidence. The next section summarizes some of the strongest micro-level evidence available based on panel data over 35 years from Guatemala on causal effects of early life nutritional improvements on adult cognitive skills and wage rates and offspring anthropometric outcomes. The subsequent section summarizes some benefit-cost analyses for early life nutritional interventions that led to such interventions being ranked highly among interventions of all types, largely on the basis of benefit-cost ratios by prominent economists in the 2004 Copenhagen Consensus. The studies reviewed in this paper 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.

Jere R. Behrman, William R. Kenan Jr. Professor of Economics, University of Pennsylvania