A Framework for Physical Growth and Child Development

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ABSTRACT

It is widely recognized that there is a continuum of physical growth and social-emotional and cognitive development across the life course, from the preconception health status of the mother through adulthood. This paper lays out a core economic model that illustrates the interrelationship of investments over the life cycle. It then shows how this framework can be used to the relative cost-effectiveness analysis and benefit-cost analysis of interventions during early childhood development with both physical growth and cognition as key outcomes.

Keywords: nutrition, human capital, child development
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1. INTRODUCTION

Worldwide patterns of growth faltering have been illustrated in a pair of influential articles analyzing cross sections of age cohorts from Demographic Health Surveys and Maternal Infant Child surveys conducted in a large number of low- and middle-income countries (Shrimpton et al. 2001; Victora et al. 2010). These studies revealed an early deterioration of nutritional status in children less than 6 months old in low- and middle-income countries in all developing regions of the world. Moreover, the decline, particularly with regard to height-for-age z scores (related to stunting) continued until about 24 months, after which it appeared to level off or be slightly reversed. This age pattern is supported by prospective cohort studies from the five Consortium of Health-orientated Research in Transitioning Societies (COHORTS) countries (Brazil, Guatemala, India, the Philippines, and South Africa) that show similar growth patterns (Stein et al. 2010; Prentice et al. 2013). In addition, analysis of these five cohorts indicated that low birth weight (LBW) or undernutrition at age two years, or both, were associated with shorter adult height, less schooling, and reduced economic productivity (Victora et al. 2008). These results were influential in prioritizing global efforts toward combating undernutrition in the first 1,000 days, from conception to a child’s second birthday.

This emphasis differs somewhat from the broader concern for child nutrition in the period up to age five, as reflected, for example, in the indicator of undernutrition in the Millennium Development Goal (MDG) of reducing poverty and hunger. The 1,000-day focus also contrasts with the MDG indicator in that the MDG indicator tracks the share of children who are underweight while the 2008 Lancet series on nutrition emphasized reducing stunting, arguing that height-for-age is a better predictor of adult human capital than other measures of nutrition (Victora et al. 2008). Similarly, both birth weight and linear growth in the first two years of life are associated with schooling and adult height with little risk of adverse outcomes in terms of increased obesity (Adair et al. 2013). In contrast, weight gain on small frames in subsequent years is associated with obesity and adult chronic disease (Monteiro and Victora 2005; Yajnik 2004, 2009).

While not disavowing the emphasis on the first 1,000 days, the 2013 Lancet series on nutrition acknowledged the need to address the dual problems of undernutrition and that of increased levels of obesity in low- and middle-income settings (Black et al. 2013), recognizing that there is, of course, often a causal link between these two concerns. That Lancet series also pointed out that the importance of prenatal nutrition necessitates a need to address the relative neglect of programs to improve the nutrition of adolescent girls (Bhutta et al. 2013). To some degree, then, the 1,000-day window for interventions can be viewed as a much longer window—even going back to the childhood of the mother—when preconception nutritional status is taken into consideration.

As with physical growth, the first years of a child’s life are an important period for overall cognitive and socioemotional development, with both protective and risk factors for undernutrition having a similar role in broader emotional and cognitive development as they do in nutrition (Walker, Wachs, et al. 2011). These shared risk factors include deficiencies in protein, energy, and some micronutrients; intrauterine growth retardation; and social and economic conditions such as maternal depression and poverty. Developmental neuroscience also points to key phases of brain growth and development that encompass the first 1,000 days, the period of peak susceptibility to nutritional insults. The overlapping risk factors, the timing of peak vulnerability, and the possibility that early deficits have long-lasting impacts motivate interest in seeking interventions that integrate nutritional and other approaches to stimulating overall child development (Alderman et al. 2014).

To do so, however, it is necessary to fine-tune an understanding of the timing of individuals’ development as well as the malleability or response of individuals to external factors at different ages (Wachs et al. 2014). It is clear, for example, that different organs grow at different rates during the life cycle, with the growth of the brain reaching a far higher percentage of total growth during childhood than do muscles and bones (Prentice et al. 2013). Similarly, different cognitive functions and socioemotional skills develop at different ages. Elucidating such nuances not only assists us in understanding the
sensitivity of responses to interventions but helps us comprehend how events at one period of an individual’s life influence how the individual will respond to nutritional and educational programs in another period.

To elaborate, although the early years in a child’s life probably remain the best opportunity for preventing undernutrition, there remains debate about the potential to catch up should a child be stunted in his or her first two years of life, with several studies suggesting some significant catch-up (Behrman, Deolalikar, and Lavy 1994; Adair 1999; Mani 2012; Crookston et al. 2013; Lundeen et al. 2014a; Prentice et al. 2013; Schott et al. 2013). As with the pattern on the onset of stunting, a few longitudinal studies support the results that show some improvement beyond 24 months based on population averages derived from cross-sectional. Leroy et al. (2014) and Lundeen et al. (2014b) point out that while there is some improvement in population average height-for-age Z scores (HAZs) after 24 months, the absolute deficit (in centimeters) between reference heights and the average height of an age group continue to widen well past age two years into adulthood for the populations in their study.

There is not empirical evidence on which is more predictive of productivity or other outcomes of interest in adulthood, deficits in height or in HAZ. Indeed, as noted by Lundeen et al. (2014b), since HAZ is just a linear transformation of height for the age range of the reference population, and generally wide age ranges are used for adults, height deficits and HAZ for adults are perfectly correlated, so it is not possible to claim that one is better than the other for the purpose of measuring the impact of adult indicators of childhood malnutrition on adult outcomes of interest. But as Lundeen et al. (2014b) argue, what really may be of interest are the changes in height deficits and the changes in HAZ since early childhood and how they are related to outcomes of interest such as cognitive skills—for which we are aware of no currently published studies. In any case, this argument about what to measure opens up a wider debate as to the consequences of a nutritional deficit or, to rephrase the same issue, the benefits from improving nutrition and, thus, to a discussion of the role nutrition plays in the overall well-being of an individual.

The most obvious and definitive consequence of early-life malnutrition is child mortality. Combined, fetal growth restriction, suboptimal breast-feeding, stunting, wasting, and deficiencies in vitamin A and zinc were associated with 3.1 million deaths in children younger than five years in 2011 (Black et al. 2013). This is 45 percent of global deaths in this age group. While this comparative risk assessment has not been calculated by age brackets, since roughly three-quarters of child deaths before age five occur in the first year of life, addressing catch-up growth beyond the 1,000-day window is less about the risk of mortality of children than it is about the consequences in later life for the survivors.

Women’s achieved height does, however, influence the risk of complications in pregnancy (Toh-Adam, Srisupundit, and Tongsong 2012). Similarly, maternal stunting increases the risk of LBW children (Black et al. 2013), which, considering the association of size at birth with subsequent child undernutrition (Christian et al. 2013), brings the discussion full circle. Height is also associated with aerobic capacity (Haas et al. 1995) and thus the potential for many forms of work. Nevertheless, in many settings physical strength likely has a smaller effect on productivity than do cognitive and other skills for which height is largely a proxy.

As with malnutrition, cognitive delays often occur early in life, with measurable differences across socioeconomic groups apparent in the first few years of a child’s life (Paxson and Schady 2007; Schady et al. 2015). Similarly, early-life stress—often deemed toxic if it is extreme—can lead to lifetime consequences that are difficult to reverse (Shonkoff and Garner 2012), and to complete the parallel, there is debate as to how responsive an individual is to interventions that are implemented after initial developmental insults.

There is some evidence that the accumulation of skills may be far more plastic than physical growth, with noncognitive or socioemotional development on a different time path than more conventional cognitive abilities (Borghans et al. 2008). Still, there is relatively little known about the time paths of interventions to address nutritional, cognitive, and socioemotional development. Considerations of priorities for interventions should be based as much on when as on which type of growth—linear (height), weight gain, cognitive, or socioemotional—is being addressed. The evidence base for
elucidating the most cost-effective timing of interventions is limited. Moreover, even though the maxim that prevention is more cost-effective than cure likely holds within a range of deficiencies, it is unlikely that all resources ever invested in children should be concentrated in the first 1,000 days, and it is important to determine what second-chance interventions later in life reduce the consequences of early malnutrition or cognitive delay should efforts at prevention fall short.
To look at child and adolescent development from a life cycle perspective it is useful to have a framework that distinguishes the time dimension of different outcomes and different determinants. Figure 2.1 presents such a framework in which there are three formative stages during childhood and adolescence as well as a stage of maturity. We define life cycle stage 1 as the period from conception to school age, life cycle stage 2 as the years of primary and early middle school, and life cycle stage 3 as late adolescence. The individuals who survive each stage continue on to the next stage, as indicated by the red arrows in the figure. The individuals who survive late adolescence enter into life cycle stage 4, adulthood. This paper presents evidence of opportunities for interventions in the preschool, school age, and late adolescence life cycle stages, including any evidence about costs, returns on investment, and implications for trade-offs.

One could, of course, divide the life cycle into more periods, or fewer, but the pattern by which actions in one period influence outcomes both in that period and in subsequent periods, either directly or indirectly, is generalizable. Moreover, the timing of exit from one period and entry into the subsequent one is itself partially dependent on earlier outcomes and concurrent decisions; for example, entry into school depends in part on nutritional status (Glewwe and Jacoby 1995; Alderman et al. 2001; Glewwe, Jacoby, and King 2001), and entry into the labor force depends both on physical stature and schooling achievement (Yamauchi 2008; Pitt, Rosenzweig, and Hasan 2012). Even transitions that are biological such as menarche and the beginning—as well as the duration—of the adolescent growth spurt are partially dependent on earlier health outcomes and on behavioral responses to the contexts in which they occur.

Broadly speaking, the outcomes in each life cycle stage can be classified into three categories: physical growth, cognitive development, and socioemotional development (including executive function). However, the components of these categories vary at different stages. For example, the risk of early mortality is particularly relevant in the first stage, while school attainment is most relevant in the second and third stages, and employment in the third and fourth stages. Mortality has a unique status among the outcomes since there is no debate about the degree of reversibility or catch-up. Moreover, establishing priorities for investment or integrating mortality with other outcomes such as improved development for survivors is particularly problematic without a common metric. While most other outcomes can be assessed in terms of their financial value or cost, there is no consensus as to how to make such an assessment for mortality. To be sure, a wide range of estimates of the value of averted mortality has been proposed. These estimates, however, range from the cost of the cheapest alternative for averting mortality (for example, on the order of magnitude of $1,000 for vaccinations in Pakistan; Summers 1992) to what compensating differentials individuals require to assume more risk (for example, based on wage tradeoffs, on the order of magnitude of $10,000,000 for the United States; Viscusi and Aldy 2003).

A particular conceptual value of a life cycle model is that it can illustrate how inputs in one period influence outcomes in later stages. For example, it can indicate situations in which higher stocks of health (skills) in one period create even higher health (skills) later. This is termed “self-productivity” by Cunha and Heckman (2007). Similarly, it can highlight cross-productivities in which better health in one period increases cognitive skills in the same or subsequent periods, or vice versa. Cross-productivities may also occur if cognitive skills in one period enhance socioemotional skills in another (Helmers and Patnam 2011). The model also elucidates what Cunha and Heckman (2007) call “dynamic complementarities,” by which higher health or skills in one period lead to greater returns to investments in subsequent periods.
Figure 2.1 Physical growth and other developmental outcomes within a life cycle framework

Exogenous Proximate Determinants for Life Cycle Stage 1
1. Individual characteristics (genetics)
2. Household characteristics (income, parental education, parental time use, home environment)
3. Community characteristics (health and nutritional services, environment, water and sanitation, markets)

1. Outcomes in First 1,000 Days after Conception and through Preschool Ages
   a. Physical (health, nutritional status, survival)
   b. Cognitive
   c. Socioemotional
   d. Executive function

Exogenous Proximate Determinants for Life Cycle Stage 2
1–3 again

2. Outcomes for School Age Children
   a–d again, school attainment, and so forth

Exogenous Proximate Determinants for Life Cycle Stage 3
1–3 again

3. Outcomes in Later Adolescence
   a–d again, labor market, partnering, parenting, household production

Exogenous Proximate Determinants for Life Cycle Stage 4
1–3 again

4. Outcomes in Adulthood
   a–d again, labor market, health, partnering, parenting, grandparenting, household production, chronic diseases, mortality

Source: Drawn by the authors.
An important inference of dynamic complementarities is that from an economic efficiency perspective more investments should be targeted to those with better initial health and greater skills, although this would widen disparities in the population as children age. This is not only a possible outcome of decisions by governments; it may also pertain to households’ investments in siblings. Given dynamic complementarities, do households choose an efficient strategy and invest more in more productive children, or do they seek more equity and compensate less productive children? It is, however, an empirical issue whether dynamic complementarities predominate—there may be dynamic substitution if investments in one period have a greater return when provided to children with worse outcomes in the earlier period. It is also an empirical question as to whether either governments or households prefer strategies that reinforce earlier differentials or whether they invest in equity and seek to compensate for disparity. At the household level there are examples of greater investments in schooling for children with higher cognitive abilities or skills (Behrman, Rosenzweig, and Taubman 1994; Akresh et al. 2012) as well as investments that are apparently intended to compensate for differences (Behrman 1988).

This framework also helps understanding of how short-term health shocks may affect future outcomes. If dynamic complementarities are strong, then moderately sized shocks to children’s health in early life may lead to major differences in schooling outcomes and in other outcomes thereafter if nothing is done to compensate for these shocks. Similarly, self-productivity is consistent with long-term impacts of early life nutritional deficits, morbidity, inadequate stimulation, toxic stress that is defined as severe, and uncontrollable and chronic adversity (National Scientific Council on the Developing Child 2014).

To quantify the links in the framework illustrated in Figure 2.1 it is necessary to address the challenge imposed by the fact that there are likely to be a number of proximate determinants of the outcomes of interest in each of the life cycle stages. Therefore, with the rare exception of randomized controlled trials or natural experiments that alter one of these determinants only in a single life cycle stage, these determinants are likely to be highly correlated across different life cycle stages. Thus, the causal effect of growth in one period on outcomes in subsequent stages may be overstated because it attributes to the prior stage the effects not only of growth in that stage on subsequent growth (the red arrow) but also the effects of correlated determinants across stages (the blue arrows).

In addition, it is difficult to separate the different dimensions of growth—physical, cognitive, and socioemotional—during the life cycle. For example, in order to examine the impact of an investment in physical growth per se, either the investment has to affect only physical growth or else other dimensions of child development need to be controlled. Randomized controlled trials or natural experiments directed only at physical growth with impacts measured during the four life cycle phases might permit such an assessment under the former condition, but such studies are rare (for example, the 1969–1976 Institute of Nutrition of Central America and Panama Guatemalan nutritional supplementation trial analyzed inter alia in Hoddinott, Behrman, et al. (2013). If, instead, observational data are used, and channels for the impacts of investment other than physical growth are not controlled for in the analysis, the impacts of physical growth are likely to be misrepresented (probably in the direction of an overstatement). This is because physical growth will likely be positively correlated with impacts through other channels. Since one of those channels is cognitive development, for example, there is a challenge to identify the impacts of physical growth as distinct from the impacts of cognitive development.

Prioritization of interventions involves an understanding of these causal impacts and the costs of these interventions as well. The costs of interventions include the total resource costs of changes in the boxes on the left side of Figure 2.1, where resource costs means the use of resources for this intervention that have value in other uses. Many interventions, probably most interventions, have resource costs for public-sector providers and for private individuals. For example, if mothers have to take their children to health clinics to receive interventions, there are resource costs in the form of transportation costs and the costs of the mothers’ time in addition to the public resource costs of the clinic. In addition there are likely to be distortion costs from raising funds to finance public expenditures; these have been estimated to be approximately 25 percent of public expenditures (Devarajan, Squire, and Suthiwart-Narueput 1997). If only the service provider costs are incorporated into the analysis, therefore, the total resource costs are likely to be understated.
A further consideration related to costs may be the “budget envelope,” the short-term constraint on available revenue (or the line item for a sector). Policymakers may perceive that the budget envelope constrains their choices so that, for example, if they increase public-sector expenditures on one item such as preschool programs it must come at the expense of other items such as primary school teacher salaries even if the benefit-cost ratios of both options are considerably greater than one. That is, the budgetary process imposes a constraint on their choices that from their perspective is an additional cost component. The impact of the budget envelope is likely to hit particularly new initiatives because of “endowment effects” and vested interests, which make it particularly difficult to reduce public-sector expenditures on items that were purchased in the past. For instance, it may be difficult to reduce long-standing primary teacher salary payments to introduce a new preschool program even if the true benefit-cost ratio is relatively low—perhaps even less than one—for teacher’s salaries at the margin and the true benefit-cost ratio is relatively high and much greater than one at the margin for preschool programs. It is important to note that the budget envelope does not represent real resource costs, but nevertheless it may be a real constraint on public-sector choices, especially for new initiatives, if there are—as seems likely—endowment effects.

It is also important to note that if policymakers think that they are constrained by budget envelopes, they have incentives to offload as much as possible real program costs onto private entities. For example, if new services are provided and a choice is made between expenditure of public-sector funds to improve households’ access to those services and higher private transportation costs to be borne by those households, the constraint imposed by budget envelopes creates incentives to choose the latter even if those costs are borne by very poor people, such as poor women who have to travel considerable distances if they are to obtain access to those services. This last point is related to a more general distortion present in many policy discussions that wrongly equate public-sector expenditures with real resource costs, ignoring that important components of real resource costs may be private-sector costs and that components of public-sector expenditures such as transfers may not be real resource costs. Considerations such as budget envelopes and endowment effects are likely to be real constraints on many policy choices, but they should not be confused with real resource costs even though they may have implications for real resource costs.

Another consideration is that because of the interest in longer-run impacts, it is important to recognize that the timing of both impacts and costs matter if there is an advantage to obtaining returns earlier rather than later because the returns can be reinvested to generate further returns. This is particularly important if early-life interventions have impacts decades later through affecting adult productivities and chronic diseases. In this context, the intertemporal discount rate used may make a considerable difference. Hoddinott, Alderman, et al. (2013), for example, give an example in which the benefit-cost ratio for reducing stunting in Bangladesh is 17.9 with a 3 percent discount rate but is cut in half to 8.9 with a 5 percent discount rate and reduced to 3.3 with an 8 percent discount rate.

Finally, it should be apparent that the whole framework in Figure 2.1 is context dependent. Resources, environments, policies, cultures, and markets are likely to vary considerably across contexts. Therefore intervention and investment experiences that are promising in one context may be promising in another, but they may not be—careful assessment is needed. Analysts and policymakers would be naïve, perhaps with great costs in terms of scarce resources, to assume that what is best practice in one context necessarily should be adopted without careful monitoring and evaluation in another context.
As suggested above, to make informed decisions about interventions to mitigate inadequate child development versus other possible interventions, information about benefits and costs or equivalently, estimates of the internal rates of return, is needed. To provide more background for sections 4 through 6, here we first illustrate some dimensions of benefit-cost ratios with an example of interventions to mitigate inadequate physical growth very early in the preschool life cycle stage, in utero, and then present and discuss a well-known stylized characterization of relative rates of return to investments during the life cycle.

**Benefit-Cost Ratios**

On the benefit side, it is critical to include all the important impacts (which means that different types of benefits need to be put into the same terms) and to account for the fact that some impacts may be realized only years, maybe even decades, after the intervention (and thus need to be discounted to the present to obtain present discounted values (PDVs). Table 3.1 gives an illustration for moving one child out of LBW status in a low-income country based on the best estimates of causal links during the life cycle in such contexts that the authors could find. Note several features of the estimates in this table. First, the major impacts in the table include the first three from the preschool life cycle stage and the last four from the adult life cycle stage, with the latter including productivity impacts that include intermediate effects through channels such as schooling. Second, all the impacts have been put into the same terms (in this case US dollars), with the most contestable value being that for averting mortality in the preschool life cycle stage, for which case the costs of the cheapest alternative means of averting mortality through vaccinations was used (Summers 1992). Third, the PDVs of total benefits vary a fair amount with the discount rates because of the gains from being able to reinvest returns that are realized sooner rather than later and are half as large with a 10 percent rather than a 5 percent discount rate and are 63 percent larger with a 3 percent rather than a 5 percent discount rate. Fourth, the estimated impacts are primarily from productivity gains with 3 percent and 5 percent discount rates (62 percent and 57 percent of the total benefits, respectively), and the productivity gains are a substantial part of the total (33 percent) even with the 10 percent discount rate. This is because the productivity gains are realized each year over the working lives of surviving adults. Thus, if these “economic” productivity gains were ignored by focusing only on direct health impacts, there would be a substantial underestimate of the overall benefits. Fifth, even though the early-life origins of chronic diseases have received increasing attention in recent decades, the estimated PDV of gains from this source are relatively small—5.9 percent of the total benefits with a 3 percent discount rate, 2.9 percent with a 5 percent discount rate, and 0.4 percent with a 10 percent discount rate—because the impacts (assumed equal to a decade of income) are obtained late in the life cycle, so they are discounted considerably to obtain their present values.
Table 3.1 Estimates of present discounted values in US dollars of seven major impacts of moving one infant out of low–birth weight status in a low-income developing country

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Annual discount rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>1. Reduced infant mortality</td>
<td>95</td>
</tr>
<tr>
<td>2. Reduced neonatal care</td>
<td>42</td>
</tr>
<tr>
<td>3. Reduced costs of infant and child illness</td>
<td>36</td>
</tr>
<tr>
<td>4. Productivity gain from reduced stunting</td>
<td>152</td>
</tr>
<tr>
<td>5. Productivity gain from increased cognitive ability</td>
<td>367</td>
</tr>
<tr>
<td>6. Reduced costs of chronic diseases</td>
<td>49</td>
</tr>
<tr>
<td>7. Intergenerational effects</td>
<td>92</td>
</tr>
<tr>
<td>Total benefits</td>
<td>832</td>
</tr>
</tbody>
</table>

Source: Constructed by authors based on Alderman and Behrman (2006).

The relevant costs include the intervention-provider resource costs, the private resource costs, and the distortion costs of raising any funds for public expenditures on the program (that estimates in Devarajan, Squire, and Suthiwart-Narueput 1997 suggest are likely to be on the order of magnitude of roughly 25 percent of public expenditures). Note that the total resource costs are not the same as public budget expenditures, which ignore private and distortion costs (and thus tend to be underestimates of the resource costs) but also sometimes include considerable transfers such as in cash transfer or conditional cash transfer programs (so for this reason might overstate resource costs).

Benefit-cost ratios are the PDV of benefits relative to the PDV of costs. If they exceed 1.0, then the expected PDV of benefits exceeds the PDV of costs, and the intervention is warranted. An alternative means of summarizing such information is the internal rate of return, which is defined as the discount rate, which makes the PDV exactly equal to one.

Even though there are meta-analyses for many interventions of interest for health and child development discussion of PDV must acknowledge the potential heterogeneity of program response, the impact of many interventions depends on complementary inputs both at the health system level as well as within the household level. For example, sanitation programs may be more effective according to the education of the caregiver (Jalan and Ravallion 2003). Implementation costs, too, may vary by locale and other factors. Thus, ex ante, estimated benefit-cost ratios usually have a range of plausible values.

Relative Rates of Return to Human Capital Investments over the Life Cycle

A well-known example of relative rates of return to investments in skills formation over the life cycle is given in Heckman (2006). This presentation indicates declining rates of return to age-specific investments in human capital as a child’s age increases. Thus, investments prior to birth appear to have higher returns than investments in the first two years of life, which appear to have higher returns that preschool programs directed toward three- to five-year-olds. These, in turn, appear to have higher returns than additional years of schooling, which also have higher returns than postschooling job training. Although it is based on a body of evidence from the United States, the figure is, nevertheless, stylized. A key implication presumably is to concentrate interventions in early life—the earlier the better—where the highest overall returns are obtained. However, if, as seems plausible, there are diminishing marginal rates of return to such investments, they should be concentrated in early life until the interventions are sufficiently substantial to reduce the rates of return to very-early-life investments and, through the diversion of resources from later life investments to early life, to increase the rate of return to investments later in life. Therefore, current human capital investment levels may yield the declining rates of return shown in Figure 2.1, but optimal investments would yield equal returns for all age levels.
A reasonable interpretation of the age pattern of rates of return in Figure 2.1 is that more resources should be shifted to early-life investments, where the rates of return are highest, until the rates of return are equalized across ages. But why do the rates of return differ so much by age? If the private rates of return are so high, why do families not take immediate advantage of such high-return opportunities? Is it a lack of knowledge? Or is it credit market constraints? Why is it that very poor families often pass up such attractive investment opportunities? Of course it may be the case that the private rates of return are not as high as the social rates of return, which may be much higher than the private rates of return due to positive externalities. But that raises another set of questions: Why does public investment not follow? Is it lack of knowledge or high discount rates for policymakers because of political cycles? Or is it the combination of the budget envelope and endowment effects discussed above or a concern that the evidence is too thin or is based on studies from distant countries? Why are governments passing up these attractive alternatives? Again, understanding why the age pattern of rates of return exists, as well as clarifying the extent to which they differ from private and social perspectives, would be useful for informing good policy responses, such as whether emphasis should be placed on improving information, improving capital markets, subsidizing providers of services relevant to early-life development, increasing the direct public provision of services relevant to early childhood development, empowering mothers, or other possibilities.

Many presume that such age patterns of rates of return to investments in human skills prevail in many developing country contexts. There does seem to be some support for relatively high rates of return to investing in nutrition and stimulation during the first 1,000 days of life in some contexts (for example, Hoddinott et al. 2008; Hoddinott, Alderman, et al. 2013; Hoddinott, Behrman, et al. 2013; Gertler et al. 2014) as well as for investing in preschool programs across a number of countries for children three to five years of age from poorer countries (Engle et al. 2011). Nevertheless, the age pattern of rates of return is much less well documented for most low- and middle-income settings than for the United States. It would be desirable to be able to base policy recommendations for other developing countries, for example, on more extensive information than the available careful analysis of a few small special samples from Guatemala, Jamaica, and the United States or on analyses of cross-country data such as in Engle et al. (2011). Nor is the available evidence sufficient to indicate a wide range of possible heterogeneity of investments, such as complementarities of inputs and the possibility that the return to an investment in one period depends on investments in prior life cycle stages. The next three sections review the evidence on benefit-cost ratios for investments in prenatal and early childhood nutrition, preschool programs, and schooling, respectively.
4. BENEFIT-COST RATIOS FOR INVESTMENTS IN NUTRITION

We first document the recent prevalence of nutritional deficits to establish that these are major problems. We then turn to estimated benefit-cost ratios of interventions directed toward some of these deficits.

Prevalence of Early-Life Nutritional Deficits

Table 4.1 gives the prevalence, by major world regions, of key indicators of preschool malnutrition based on the most recent available data (last updated February 2013, which reflects data from 2005–2012) from UNICEF: LBW, whether exclusively breast-fed for the first six months of life, and for children younger than five years of age, moderate and severe underweight, severe underweight, wasting (defined in terms of weight-for-height), overweight/obese, and stunting. Though data on these indicators have improved considerably in recent decades, there remain substantial data problems that are discussed in the original sources. For example, China is not included in the East Asian/Pacific and World aggregates for the last five indicators (although we have included values for China when available), and coverage in some cases is otherwise limited; an example of the latter is that even in the early part of the 21st century, 58 percent of all infants in the developing world, including 74 percent for South Asia and 65 percent for Africa south of the Sahara, were not weighed at birth—see UNICEF and WHO (2004). Table 4.2 gives further estimates/projections, from 1990 to 2020 and by major world regions, of the prevalence—and millions of children affected—of overweight/obese and stunting among children younger than five years old.

Table 4.1 Children’s nutritional status in major world regions, most recent available data

<table>
<thead>
<tr>
<th>Region or subregion</th>
<th>Low birth weight (&lt; 2,500 grams, %)</th>
<th>Children’s first 6 months exclusive breast-feeding (%)</th>
<th>Children &lt; 5 years of age</th>
<th>Underweight (Moderate and Severe, %)</th>
<th>Underweight (Severe, %)</th>
<th>Wasting (Moderate and Severe, %)</th>
<th>Overweight/Obese (%)</th>
<th>Stunting (Moderate and Severe, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa south of the Sahara</td>
<td>15</td>
<td>—</td>
<td>21</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Eastern and Southern Africa</td>
<td>14</td>
<td>41</td>
<td>18</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>West and Central Africa</td>
<td>15</td>
<td>20</td>
<td>23</td>
<td>8</td>
<td>12</td>
<td>9</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>12</td>
<td>29</td>
<td>8</td>
<td>—</td>
<td>9</td>
<td>12</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td>27</td>
<td>38</td>
<td>33</td>
<td>14</td>
<td>16</td>
<td>3</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>East Asia and the Pacific</td>
<td>6</td>
<td>43</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>3</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>2</td>
<td>7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>9</td>
<td>—</td>
<td>3</td>
<td>—</td>
<td>2</td>
<td>7</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Central and Eastern Europe/Commonwealth of Independent States</td>
<td>6</td>
<td>22</td>
<td>2</td>
<td>—</td>
<td>1</td>
<td>16</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Industrialized countries</td>
<td>7</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>2</td>
<td>15</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Least-developed countries</td>
<td>17</td>
<td>—</td>
<td>23</td>
<td>7</td>
<td>10</td>
<td>4</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>14</td>
<td>—</td>
<td>16</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Sources: UNICEF (2006a) for exclusive breast-feeding; UNICEF (2006b; n.d.) for low birth weight; UNICEF (2013b) for all others.

Note: Dashes indicate not available.
### Table 4.2 Estimated prevalence and millions of children younger than five years of age overweight/obese and stunted in major regions, 1990–2020

<table>
<thead>
<tr>
<th>Region</th>
<th>Overweight/Obese</th>
<th>Stunted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prevalence (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>4.0</td>
<td>5.7</td>
</tr>
<tr>
<td>Asia</td>
<td>3.2</td>
<td>3.7</td>
</tr>
<tr>
<td>South-Central</td>
<td>2.3</td>
<td>2.9</td>
</tr>
<tr>
<td>LAC</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>All developing</td>
<td>3.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Global</td>
<td>4.2</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Millions of children &lt; 5 years old</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>4.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Asia</td>
<td>12.4</td>
<td>13.7</td>
</tr>
<tr>
<td>South-Central</td>
<td>4.2</td>
<td>5.4</td>
</tr>
<tr>
<td>LAC</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>All developing</td>
<td>20.7</td>
<td>25.0</td>
</tr>
<tr>
<td>Global</td>
<td>26.9</td>
<td>31.4</td>
</tr>
</tbody>
</table>

Sources: de Onis, Blössner, and Borghi (2010) for “overweight/obese” columns and de Onis, Blössner, and Borghi (2011) for “stunted” columns.

Note: LAC = Latin America and the Caribbean. Overweight/obese > 2 standard deviations from weight-for-height median; Stunted (< 2 standard deviations from height-for-age median.

LBW babies (< 2,500 grams) face a greater risk of dying in their early months and years and, if they survive, have greater risks of cognitive disabilities, impaired immune function, and diabetes and heart disease later in life (UNICEF 2006b, n.d.; UNICEF and WHO 2004). The prevalence of LBW varies considerably across world regions, with the rate of 27 percent for South Asia being almost twice the rate in Africa south of the Sahara, which is relatively high in comparison with other regions. There are about 19.5 million LBW babies born annually, half of whom are born in India (38 percent), Pakistan (7.7 percent), and Nigeria (3.9 percent) (UNICEF 2013a). Trend analysis is complicated by the lack of comparable estimates over time, both within and between countries. Trend data are insufficient for most regions, but a population-weighted average for available surveys shows that the incidence of LBW remained unchanged from the 1990s to 2010 for both Africa south of the Sahara and Asia (UNICEF 2013a).

Exclusive breast-feeding in the first six months of life stimulates babies’ immune systems and protects them from diarrhea and acute respiratory infections—two of the major causes of infant mortality in the developing world—and improves their responses to vaccination (UNICEF 2006a). Particularly in unhygienic conditions, breast milk substitutes carry high risks of infection that can be fatal in infants. Yet only slightly more than one-third of all infants in developing countries are exclusively breast-fed for the first six months of life. There is a fair amount of variation in the prevalence of breast-feeding, from 20 percent and 22 percent, respectively, in West and Central Africa and Central and Eastern Europe to 38–43 percent in South Asia, Eastern and Southern Africa, and East Asia and the Pacific. Trend data indicate increases in those rates for countries where the available data cover at least half of the births in the 1990–2004 period (UNICEF 2006a).
Globally, 15 percent of children younger than five are estimated to be moderately or severally underweight. The high prevalence of moderate and severe underweight of 33 percent (14 percent for severe) in South Asia stands out in comparison to other regions of the world. Africa south of the Sahara (with West and Central Africa a little higher) is next, with 21 percent. All other world regions have prevalence less than 10 percent, with the lowest being 2–3 percent for Latin America and the Caribbean and Central and Eastern Europe/Commonwealth of Independent States. Children who are suffering from wasting are at substantially increased risk of severe acute malnutrition and death. Globally, 8 percent of children are wasted, a much lower percentage than for moderate or severe underweight due to extensive stunting (discussed below), which also affects wasting but not underweight. For this reason, in South Asia, despite the highest prevalence of wasting (16 percent), that rate is less than half the prevalence of underweight (33 percent). A similar comment holds for Africa south of the Sahara, which has a 9 percent prevalence of wasting. Increasing trends in child overweight/obese have occurred in the past two decades in most world regions, not just developed countries. Globally, an estimated 42.8 million (7 percent) of children younger than five years of age were overweight/obese in 2010, a 59 percent increase from an estimated 26.9 million in 1990. Projections are for a further increase of 39 percent from 2010 to 59.4 million in 2020, of which 49.9 million are projected to be in developing countries. Among developing country regions, Latin America and the Caribbean had the highest prevalence in 1990, at 6.8 percent, which increased slowly to 6.9 percent in 2010 and is projected to be 7.2 percent in 2020. Other developing country regions had much more rapid increases in the past two decades, with Africa being notable because of the increase from 4 percent in 1990 to 8.5 percent in 2010, projected to be 12.7 percent in 2020, the latter two of which are substantially greater than global averages. Throughout 1990–2020, South Asia has the lowest prevalence, but with substantial increases from 4.2 million in 1990 to 8.0 million projected for 2020.

Globally more than one-quarter (26.7 percent) of children younger than five were stunted in 2010, which implies an estimated 171.4 million stunted children. Africa south of the Sahara and South Asia have particularly high prevalence rates, at about 36–38 percent. UNICEF (2013b) states that this “indicates an urgent need to accelerate integrated programs addressing nutrition during the mother’s pregnancy and before the child reaches two years of age, the period of children’s most rapid physical and mental growth and development.” Note, however, that although the prevalences in these two regions are similar for 2010, the trends are different. For Africa the prevalence of 40.3 percent in 1990 (44.9 million children) has declined slowly, to 38.2 percent in 2010, and is projected to be 37.1 percent by 2020 (64.1 million). In South Asia the prevalence in 1990 was much higher than in Africa, at 60.7 percent, which implies 110.1 million stunted children—yet the rate dropped to 36.4 percent (69 million) in 2010 and is projected to be 25.9 percent (68.4 million) in 2020.

**Benefit-Cost Estimates for Nutritional Interventions**

There is some consensus on the outcomes of specific nutrition interventions (Bhutta et al. 2013). Often employing meta-analyses of controlled trials, reviews such as Bhutta et al. (2013) indicate the expected changes in outcomes such as stunting or anemia for a given intervention. There is, similarly, a body of evidence on the costs to achieve such outcomes (Horton et al. 2010). These costs, as well as the expected outcomes, can be combined to get the relative cost-effectiveness of approaches to achieve a desired improvement in nutrition. However, as mentioned above, to estimate a benefit-cost ratio one needs to convert the multiple relevant outcomes into the same metric as the costs. As indicated in the example in Table 3.1, this usually involves summing over different outcomes. Some of these, such as a reduction in resources used to care for illness, can be directly assessed in monetary terms. Others, such as increased labor productivity, require estimates of the degree to which the change in nutritional status leads to an increase in earnings, as well as assumptions about the productivity of those not in wage jobs. The majority of such estimates are based on indirect inference—the changes in schooling or learning attributable to improved nutrition combined with the impact that such increases in learning will have on earnings, often derived from separate studies. One study (the Institute of Nutrition of Central America and
Panama Guatemalan study), however, has been able to track individuals from the time they participated in a community-randomized program of supplemental feeding when they were infants and toddlers to their adult years about 35 years later (Hoddinott et al. 2008; Hoddinott, Behrman, et al. 2013). This study found that men who had received better (protein-enriched) supplements prior to the age of 3 years earned on average 44 percent higher wage rates and thus confirmed that the body of indirect estimates of returns to nutrition programs based on changes in schooling or cognitive ability discussed below are in keeping with direct longitudinal evidence.

Table 4.3 gives some estimated benefit-cost ratios for nutritional interventions for preschool children based on Behrman, Alderman, and Hoddinott (2004). The benefits are calculated along the lines of those in Table 3.1. Details, including the cost assumptions, are given in the original source as are some sensitivity analyses (including varying the discount rate between 3 percent and 5 percent), resulting in a range of estimates. These interventions can be divided into three groups according to whether the aim is to (1) reduce LBW, (2) directly improve infant and child nutrition, or (3) reduce micronutrient deficiencies. For each group, there are estimates for three interventions. Some points to note concerning this table are that (1) the benefit-cost ratios are sensitive to the underlying assumptions on program costs as well as discount rates, so some of the ranges are large; (2) the benefit-cost ratios vary a fair amount within each group, for example, 0.58 to 35.20 for reducing LBW; and (3) many of these benefit-cost estimates are substantially greater than 1.0, suggesting that even if there is some further discounting (for example, a discount rate greater than 5 percent) to account for uncertainty in such estimates, a number of these interventions merit serious consideration in contexts in which the nutritional deficiencies they are intended to address are prevalent. Table 4.4 provides similar results using different discount rates.

Table 4.3 Benefit-cost estimates for nutritional interventions for preschool children with discount rates of 3–5 percent

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Benefit-cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reducing LBW for pregnancies with high probabilities of LBW</td>
<td></td>
</tr>
<tr>
<td>1a. Treatments for women with asymptomatic bacterial infections</td>
<td>0.58–4.93</td>
</tr>
<tr>
<td>1b. Treatment for women with presumptive sexually transmitted diseases</td>
<td>1.26–10.71</td>
</tr>
<tr>
<td>1c. Drugs for pregnant women with poor obstetric history</td>
<td>4.14–35.20</td>
</tr>
<tr>
<td>2. Improving infant and child nutrition in populations with high prevalence of child malnutrition</td>
<td></td>
</tr>
<tr>
<td>2a. Breast-feeding promotion in hospitals in which norm has been promotion of use of infant formula</td>
<td>5.60–67.1</td>
</tr>
<tr>
<td>2b. Integrated child care programs</td>
<td>9.40–16.20</td>
</tr>
<tr>
<td>2c. Intensive preschool program with considerable nutrition for poor families</td>
<td>1.40–2.9</td>
</tr>
<tr>
<td>3. Reducing micronutrient deficiencies</td>
<td></td>
</tr>
<tr>
<td>3a. Iodine (per woman of childbearing age)</td>
<td>15–520</td>
</tr>
<tr>
<td>3b. Vitamin A (per child younger than six years)</td>
<td>4.3–43.0</td>
</tr>
<tr>
<td>3c. Iron (pregnant women)</td>
<td>6.1–14.0</td>
</tr>
</tbody>
</table>

Source: Constructed by authors based on Behrman, Alderman, and Hoddinott (2004).
Note: LBW = low birth weight.
Table 4.4 Sensitivity of benefit-cost ratios for nutritional interventions to different discount rates and DALY values

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Discount rate 3%</th>
<th>Discount rate 6%</th>
<th>Discount rate 3%</th>
<th>Discount rate 6%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value of DALY $1,000</td>
<td>Value of DALY $1,000</td>
<td>Value of DALY $5,000</td>
<td>Value of DALY $5,000</td>
</tr>
<tr>
<td>Community nutrition education and promotion</td>
<td>12.5</td>
<td>7.5</td>
<td>62.5</td>
<td>37.5</td>
</tr>
<tr>
<td>Vitamin A and zinc supplementation</td>
<td>17.3</td>
<td>10.0</td>
<td>86.5</td>
<td>52.0</td>
</tr>
<tr>
<td>Salt iodization</td>
<td>30.0</td>
<td>12.0</td>
<td>30.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Iron fortification</td>
<td>8.0</td>
<td>7.0</td>
<td>8.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Anthelmintic treatment in preschool</td>
<td>6.0</td>
<td>2.4</td>
<td>6.0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Source: Adapted by authors from Horton, Alderman and Rivera (2009).
Note: DALY = Disability-Adjusted Life Year

Additional estimates of benefit-cost ratios for nutrition interventions that increase preschool linear growth (height) in the first 1,000 days are provided in Table 4.5. These are based on recent estimates by Hoddinott, Alderman, et al. (2013). On the cost side, Hoddinott, Alderman, et al. (2013) provide two sets of estimates of budgetary costs per child—as opposed to costs compiled from ingredients or inputs—for ten interventions (for example, universal salt iodization, vitamin A supplementation, deworming) to reduce stunting and micronutrient deficiencies in children in their first two years of life. One set of estimates is based on Bhutta et al. (2008) and Horton et al. (2010), and the other is based on Bhutta et al. (2013), with the latter providing information for four different country groups. For all but 1 of the 17 selected high-burden countries considered, the latter leads to higher cost estimates. On the benefit side, Hoddinott, Alderman, et al. (2013) multiplied the point estimate of the increase in per capita permanent income (consumption) from reducing stunting from Hoddinott, Behrman, et al. (2013) by 0.20 in recognition of Bhutta et al.’s (2013) estimate that this package of interventions will reduce stunting by 20 percent and, to be conservative, assume that only 90 percent of these income gains are realized.

The third column in Table 4.5 reproduces the resulting benefit-to-budgetary-costs ratios using the generally higher costs estimates based on Bhutta et al. (2013). However, the procedures in this particular approach seem to underestimate benefits because they include only income or consumption benefits (and not, for example, benefits from averting mortality and resource costs saved due to reduced morbidity) and underestimate resource costs because they do not include private costs and market distortion costs, in particular the cost of raising revenue to finance the intervention. They also do not exclude the transfer component of public expenditures, which means that they may overstate public-sector resource costs; however, for the interventions considered these transfer components would seem to be relatively small. Therefore, the fourth column includes adjustments to benefits, an increase of 20 percent to represent social benefits beyond increases in income, and an increase in costs of 50 percent to represent private costs and of 25 percent to represent distortion costs. The resulting benefit-cost ratios make interventions to reduce stunting still appear to be an attractive investment with all the estimates greater than 1.0, all but the one for the Democratic Republic of the Congo greater than 6.0, and a median of 12.4 (Bangladesh). The range of estimates also is considerable, from 2.4 for the Democratic Republic of the Congo to 33.1 for Indonesia, suggesting that contexts are important for evaluating such interventions.
Table 4.5 Benefit-cost ratios for moving child from stunting at 24 months to not stunted in 17 selected heavily burdened countries

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Income benefit/budgetary cost from Hoddinott et al. (2013a)</th>
<th>Adjusted benefit-cost ratio&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa south of the Sahara</td>
<td>Democratic Republic of the Congo</td>
<td>3.5</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Madagascar</td>
<td>9.8</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Ethiopia</td>
<td>10.6</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>Uganda</td>
<td>13.0</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>Tanzania</td>
<td>14.6</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>Kenya</td>
<td>15.2</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>Sudan</td>
<td>23.0</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>Nigeria</td>
<td>24.4</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>Yemen</td>
<td>28.6</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>Nepal</td>
<td>12.9</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>Burma</td>
<td>17.2</td>
<td>11.9</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>Bangladesh</td>
<td>17.9</td>
<td>12.4</td>
</tr>
<tr>
<td>South Asia</td>
<td>Pakistan</td>
<td>28.9</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>38.6</td>
<td>26.8</td>
</tr>
<tr>
<td></td>
<td>Vietnam</td>
<td>35.3</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
<td>43.8</td>
<td>30.4</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
<td>47.7</td>
<td>33.1</td>
</tr>
</tbody>
</table>

Source: Constructed by authors based on Hoddinott et al. (2013a) estimates with Bhutta et al. (2013) cost and intervention data.

Note: *Adjustments include increasing benefits by 20 percent to represent nonincome/consumption benefits and increasing costs by 50 percent to represent private costs and by 25 percent to represent distortion costs.
5. BENEFIT-COST RATIOS FOR INVESTMENT IN EARLY CHILDHOOD COGNITIVE AND SOCIOEMOTIONAL DEVELOPMENT

The range of programs aimed at improving child cognitive development in low- and middle-income countries during the period between birth and the initiation of primary schooling is reviewed in Engle et al. (2007) and Engle et al. (2011). These include programs to promote better parenting and mother-child interaction through home visits by community health workers or by means of group sessions with mothers. A subset of this approach to enhancing child stimulation includes programs that also provide nutritional supplements, often targeted to children who were born with LBWs or are stunted. While such programs generally show improvements in cognitive outcomes and socioemotional development and sometimes achieve better nutritional outcomes as well, there is little evidence of synergy between stimulation and nutrition interventions in terms of outcomes (Grantham-McGregor et al. 2014). However, the literature also indicates that the combination of stimulation and direct nutritional interventions does not reduce the expected impact of either intervention if it were delivered independently. Therefore there may be synergies in terms of costs if there are economies of scope because some common infrastructure components can support both interventions.

There is an important and influential longitudinal study spanning 20 years from Kingston, Jamaica, that has tracked a cohort of 129 malnourished children initially 9 to 24 months of age with random assignment to four groups, three of which involved interventions that lasted for 2 years. The first group received weekly one-hour home visits from community health workers who taught parenting skills and encouraged mothers to interact and play with their children in ways that would develop their children's cognitive and socioemotional skills. The second group received weekly nutritional supplements of 1 kilogram of formula. The third group received both home visits and nutritional supplements, and the fourth group (the control group) received neither. Gertler et al. (2014) directly assess the impact of these interventions on young adult earnings. While the children in the home visit stimulation treatments were malnourished at the time of recruitment into the study, they were able to close the wage gap with a matched nonstunted comparison group. More specifically, the analysis attributed a 25 percent increase in earnings to the stimulation interventions; in contrast, the nutritional arm of the intervention did not close the earnings gap. The authors contend that this increase due to stimulation was larger than that reported in the few similar interventions from the United States. While the research design was not set up to assess the relative value of cognitive and socioemotional gains, measures on both of these dimensions of development were improved in the intervention. The intervention also reduced violent behavior (Walker, Chang, et al. 2011) and thus provided a social benefit in addition to the earnings benefit, one that is not often measured in rates of return.

Another long-term panel following an early child development intervention in Turkey is presented in Kaytaz (2005). This study looked at the beneficiaries of an intervention in which parents were provided training to improve the home learning environment for their children. The benefit-cost estimates reported in this study when parental training was center based were 4.25 and 6.37 using plausible discount rates of 10 percent and 6 percent, respectively. The benefit-cost estimates for the home-based parental training using the same discount rates of 10 percent and 6 percent were 5.91 and 8.74, respectively. These benefits are based on the increase in schooling (and reduced dropout rates) and the expected increase of earnings that can be inferred from these levels of schooling; the earnings of the beneficiaries were not collected. These estimates do not include any increased learning per year of school, and thus, as Kaytaz indicates, they are lower-bound estimates.

Behrman, Cheng, and Todd (2004) analyze the impacts of Bolivia’s Proyecto Integral de Desarrollo Infantil (PIDI). The program, which provided feeding as well as day care to groups of up to 15 children in the homes of women in low-income neighborhoods, achieved improvements in measures of language and auditory development, psychosocial skills, gross motor development, and fine motor development, but not height or weight. Using estimates of the expected increase of schooling that these improvements are assumed to translate into, as well as the returns to this additional schooling in the
country, the benefit-cost ratio ranges between 2.0 and 2.9 for children for whom the increase of schooling would be at the intermediate level for discount rates of 5 and 3 percent, respectively, and somewhat lower for children for whom the increase in schooling would be at the secondary level. The costs in this estimate include the direct program costs, the private opportunity costs of the time devoted to increased schooling, and the expected deadweight cost to the economy from raising the revenue to finance the program.

Colombia has been running a similar publicly funded day care program, Hogares Comunitarios de Bienestar (in fact, PIDI was modeled after this program). Bernal and Fernández (2013) report that children three years and older who have spent at least 15 months in the program show improvements in both cognitive development and socioemotional skills, although no gains in nutrition status were observed. The benefit-cost ratio was estimated between 1.0 and 2.7, using discount rates of 8 and 5 percent, respectively.

While both of these day care centers in Latin America reach children up to the age of 6 years, they are not structured preschool programs. Engle et al. (2011) provide an order of magnitude estimate of the benefit-cost ratio for such preschool programs at scale. This assessment was based on an estimate of the gap between the completed level of schooling for the wealthiest quintile in a given country and that of the poorest as a function of preschool enrollments in the previous 8 to 12 years. This estimate provided the basis for projecting the expected increase in schooling, and the concomitant increase in earnings, due to an increase in preschool participation, controlling for country effects. Using a discount rate of 3 percent, the assessment indicates that bringing the preschool enrollment rate in all low- and middle-income countries to 25 percent starting from each country’s base level would have a benefit-cost ratio of 14.3; bringing the enrollment rate to 50 percent would have a benefit-cost ratio of 17.6. Discounting future returns at a higher rate of 6 percent would lead to benefit-cost ratios of 6.4 and 7.8, respectively.

While these estimates have a wide range and are also sensitive to assumptions about the impact of schooling on wages as well estimates of the cost of providing this schooling, these results are similar to program-specific estimates in the literature. For example, Berlinski, Galiani, and Manacorda (2008) present evidence on schooling outcomes measured a decade after the expansion of preschool enrollments in Uruguay. Their data indicate that as the supply of preschool services increased between 1989 and 2000, participation in preschools increased by 12 percentage points so that more than 90 percent of all children attended preschool by the end of the period. From their results on the influence of preschool enrollment on school achievement as well as the cost of construction of classrooms along with local salaries for teachers, they estimate a benefit-cost ratio of 3.2 using a discount rate of 10 percent. If the discount of future earnings is 3 percent, the estimated benefit-cost ratio is 19.1.
6. RETURNS TO INVESTMENTS IN SCHOOLING

The vast majority of estimates of the returns to investments in schooling in developing countries are based on estimates of the impact of years of schooling on the earnings of wage workers. More specifically, if one assumes that the only cost of schooling is forgone wages and that the logarithm of wages is a linear function of years of schooling and other variables, then the coefficient on schooling from a regression of the log of wages on years of schooling and those other variables can be interpreted as the private return to schooling (see Glewwe 1996). Yet there are two problems with such estimates. The first is that they estimate only the private returns to schooling that result from increased wages, and thus they exclude both other private returns, such as improved health accruing to that person and his or her children, and social returns that accrue to other members of society. This implies that private returns may underestimate total returns. On the other hand, overestimation is also possible because there are also social costs, in particular the costs that governments incur by providing schooling opportunities at little or no cost to students and their families. The second problem is that these regressions yield private rates of return to investments in years of schooling only if the coefficient on years of schooling measures the causal impact of schooling on wages, and there are several reasons why such estimates may not reflect a causal relationship, as explained in the following paragraph.

The first reason why regressions of wages on years of schooling and other variables may not lead to accurate estimates of the causal impact of schooling on wage income is that random measurement error in years of schooling could lead to underestimates of that impact, and such measurement errors are particularly likely to be a problem in data gathered from developing countries. A second reason is that unobserved factors such as ability, motivation, and family connections could determine both schooling and earnings even after controlling for schooling and thus lead to overestimates in rates of return to schooling. Third, such estimates from developing countries are almost always for wage earners only, not for the self-employed, and there is a substantial amount of evidence that the return to education among the self-employed is lower than the return to wage earners, which implies that estimates based only on wage earners are likely to be overestimates in countries with large numbers of self-employed workers, which is the case in many developing countries. Fourth, even among wage earners, estimates should, in general, exclude government workers; yet in most cases such workers are included. The pay received by government workers with different levels of education mainly reflects governmental salary policies, not the productivity of different types of workers; indeed, Glewwe (1996) finds that separate regressions for private-sector and government workers in Ghana yield much larger impacts of schooling on the wages of the latter (relative to private-sector workers). Given these problems, it is not surprising that compilations of estimates in recent years often give very different results. For example, Psacharopoulos and Patrinos (2004) present compilations that indicate that the rate of return to an additional year of primary education in Africa south of the Sahara is 37.6 percent, but in a paper produced eight years later by Montenegro and Patrinos (2012) that rate of return was much smaller, only 13.4 percent.

Two of the problems cited in the previous paragraph can be resolved if valid “instrumental variables” can be found to predict years of schooling. In recent years, a few studies have attempted to use instrumental variable methods to obtain more accurate estimates of the impact of years of schooling on wages in developing countries. Duflo (2001) uses a sharp increase in the construction of primary schools to estimate the impact of years of schooling on wages in Indonesia. Her estimates indicate that an additional year of schooling increases wages in that country by 7–11 percent. She also notes that the instrumented results do not differ appreciably from the uninstrumented estimation, a result in keeping with Ashenfelter, Harmon, and Oosterbeek (1999). More recently, Behrman et al. (2013) estimate that a year of schooling increases wages by 9.8 percent in Guatemala, with the main identifying instruments

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1 More precisely, these estimates are in terms of grades completed, not years of schooling; the former does not include repeated grades, while the latter does.

being student-teacher ratios, mother’s height, and mother’s and father’s schooling. While more studies would be useful, these two studies suggest that private returns to education are approximately 10 percent in developing countries. On the other hand, even these studies can be criticized because they do not exclude government workers and they do not include the self-employed (both of which may lead to overestimation).

Whatever the value of an additional year of schooling on adult earnings, there remains the question of which investments may lead to an increase in schooling. School enrollment or years of schooling completed can be increased by demand-side interventions, such as transfer programs, or by increasing the supply and quality of schooling. The former category includes conditional transfers (Behrman, Parker, and Todd 2011) or school feeding programs (Adelman, Gilligan, and Lehrer 2008). The latter category is reviewed by Glewwe et al. (2013), who report that there are few unambiguous results regarding investments and schooling outcomes. While that literature goes far beyond the issues central to disease control priorities, a few salient points from that literature are worth discussing here.

First, while ability affects both years of schooling and what is learned in school, the latter is the stronger determinant of earnings (Hanushek and Woessmann 2008). Second, despite the regular pattern of increased earnings with increased schooling, the quality of education in many settings is discouraging. For example, 52.7 percent of standard 5 students in India could not read a standard 2–level text (ASER Centre 2014). Similar patterns are found in many Demographic and Health Surveys across the globe. While there are many reasons for this waste of resources that calls for reforms and improvements in school systems, it also can be the case that the students, or a subset of them, come to schools with huge disadvantages that could be offset through interventions in early childhood. Third, the impact of specific investments depends, in part, on the ability of students. For example, Glewwe, Kremer, and Moulin (2009) find that an increased supply of books in Kenya benefited the stronger students but had no measurable impact on the others. A different view of complementarity of inputs comes from Grantham-McGregor, Chang, and Walker (1998). This study found that feeding school children improved attention, but the impact on learning depended on the classroom structure, with stronger results found where the classes were more effectively organized. Fourth, education responds to health not only in regard to early-life nutrition but also in regard to health investments for school-age children. For example, Miguel and Kremer (2004) found deworming in Kenya to be more cost-effective at increasing school participation\(^3\) than supply-side interventions such as the provision of textbooks, and Bleakley (2007) noted that hookworm infections in the American South in the early 1900s reduced income in adulthood of infected children by 43 percent and that this was effectively corrected by a concerted program of control. Bleakley (2010) estimated a similar impact of malaria-control campaigns on incomes in the United States (circa 1920) and in Brazil, Colombia, and Mexico (circa 1955).

The possibility that healthier children will respond more to teaching inputs is an example of dynamic complementarity and is a major component of the returns to nutrition (Glewwe, Jacoby, and King 2001). However, in some circumstances, the interaction of health and schooling may show some dynamic substitution rather than complementarity. That is, there may be interventions that have higher impacts the lower the initial health conditions. For example, Bobonis, Miguel, and Sharma (2006) studied the provision of iron supplementation and deworming medicine to preschool children in India. Overall, children in the treatment group had less absenteeism, but children who were initially anemic at baseline had a larger response to the intervention. Similarly, iron supplementation costing less than $5 per child in primary schools in China during a seven-month period led to an improvement in hemoglobin as well as a significant improvement in math test scores (Luo et al. 2012), and it is noteworthy that the academic improvement was found only for children who were anemic prior to the program.

\(^3\) School participation combines enrollment with attendance; among two children who are enrolled in school, the one with higher attendance in a given year has higher participation, and any child not enrolled has a participation rate of zero.
7. CONCLUSIONS

Interventions to improve nutrition as well as to enhance cognitive and socioemotional development in each of the three life cycle stages considered in this review—preschool ages, schooling ages, and later adolescence—can achieve returns in later stages that greatly exceed their costs. Yet an empirical question remains: at what life cycle stage, and in what context, are the benefit-cost ratios (or rates of return) high enough to warrant investments? While the benefit-cost estimates from nutritional interventions in the first 1,000 days are based on extensive data and have been accumulated on a global basis, there is less evidence on benefits and costs for stimulation and early child development for programs at appreciable scale. For example, the majority of the published studies of the impact of home visits are efficacy trials and do not provide a reliable estimate of the costs of service provision on a programmatic level. Moreover, a review of the cost of programs at scale in Latin America indicates a wide—and at this time not fully understood—heterogeneity of costs (Araujo and López-Boo 2013). This knowledge gap hinders any generalizations.

Even if estimates of costs were confined to a narrow range in various environments, there is also a general dearth of results on the heterogeneity of impacts. A few studies show that programs may have a greater impact for children who enter these programs at an initial disadvantage. For example, the PIDI program had a greater impact for children whose initial weight-for-age was lower (Behrman, Cheng, and Todd, 2004). Similarly, Berlinski, Galiani, and Manacorda (2008) find that the impact of preschool attendance was largest for those children from households with less education, and Jung and Hasan (2014) find that block grants for preschool groups in Indonesia narrowed gaps in language and cognitive development. To the degree that such programs reduce gaps in development they have an additional social value in reducing the intergenerational transmission of poverty with possible gains in efficiency if such programs partially offset capital market failures that result in underinvestments in children. While a reduction in poverty is usually not translated into benefits that can be aggregated into benefit-cost ratios, the benefits are likely to be real and positive and could be incorporated by weighting outcomes for children from poorer families more heavily. As there is widespread evidence that gradients in cognitive ability by socioeconomic status appear early in a child’s life (Schady et al. 2015; Naudeau et al. 2011), the potential to prevent or reverse gaps implies that nutrition programs, the promotion of early stimulation, and preschool education may have social returns that are appreciably larger than commonly reported.

There are some who perceive that “prevention is better than cure” and that “an ounce of prevention is worth a pound of cure,” so that the earlier such interventions can be delivered, the better. But as discussed in section 3, there are likely to be diminishing marginal rates of return to such interventions, so even if under present circumstances the rates of return were highest to interventions to improve nutrition in the womb or very early in life, it does not follow that all resources should be moved to early in life from later in life. As more and more resources are moved from later to earlier life, most likely diminishing marginal rates of return will mean that the rates of return to the investments in early life will fall and those to investments in later life will increase. Indeed it would be socially optimal in an economic sense to move resources directed toward human development from older to younger ages until the social rates of return to the use of resources at all ages were equalized.
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