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The economic rationale for investing in stunting reduction

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Abstract:

This paper outlines the economic rationale for investments that reduce stunting. We present a framework that illustrates the functional consequences of stunting in the 1000 days after conception throughout the life cycle: from childhood through to old age. We summarize the key empirical literature around each of the links in the life cycle, highlighting gaps in knowledge where they exist. We construct credible estimates of benefit-cost ratios for a plausible set of nutritional interventions to reduce stunting. There are considerable challenges in doing so that we document. We assume an uplift in income of 11 percent due to the prevention of one fifth of stunting and a 5% discount rate of future benefit streams. Our estimates of the country-specific benefit: cost ratios for investments that reduce stunting in 17 high-burden countries range from 3.6 (DRC) to 48 (Indonesia) with a median value of 18(Bangladesh). Mindful that these results hinge on a number of assumptions, they compare favourably with other investments for which public funds compete.

Key words: stunting, economic productivity, benefit: cost ratios

1. Introduction

Stunting, defined as having a height-for-age Z-score (HAZ) that is more than two standard deviations below the age-sex median for a well-nourished reference population, remains widespread in low and middle income countries. Black et al estimate that in 2011, 165 million children in low and middle income countries were stunted. There has been a dramatic reduction in the prevalence of stunting in Asia, from 49 percent in 1990 to 28 percent in 2010, nearly halving the number of stunted children from 190 million to 100 million. Nevertheless the majority of those stunted remain in Asia. The stunting prevalence in Africa has stagnated at about 40 percent since 1990 and accounts for the second largest regional share of world stunting, a share which is increasing (de Onis et al. 2010).[1]

Undernutrition has been described as "a scourge in our world" (DFID 2011). But in a world characterized by limited public resources and many global scourges, while there is a clear intrinsic rationale for investing in reducing stunting, the rationale for public investments that reduce stunting is strengthened if it can be shown that these have substantive economic returns.[2] This paper, building on our earlier work (Behrman et al. 2004, Horton et al. 2010; Hoddinott et al. in press), seeks to do so. The rest of this paper is organized as follows. Section 2 presents a framework for understanding the economic rationale for investments to reduce stunting. Section 3 discusses the pathways through which stunting might have economic losses. Section 4 presents and discusses estimates of the benefits and costs of investments in stunting reduction. Section 5 presents and discusses benefit: cost ratios for investments to reduce stunting in high-burden countries. Section 6 presents discussion and conclusions.

2. A framework for understanding the economic rationale for investments to reduce stunting

Although they use somewhat different language, nutritionists and economists share a common understanding of the causes of stunting in early life. In the widely-used UNICEF Conceptual framework, for example, early life child undernutrition is directly caused by disease or inadequate dietary intake. In turn, these reflect four underlying causes, household food insecurity, inadequate care, unhealthy conditions and absence of access to health services (UNICEF 1990). To understand the economic rationale for investments that reduce stunting, a

[1] Although beyond the scope of this paper, we note that overweight/obesity among children has become an increasing problem. Global prevalence of childhood overweight and obesity has increased from 4.2% in 1990 to 6.7% in 2010 and is expected to reach 9.1% or 60 million in 2020 (de Onis et al. 2010).

[2] Examples include major policy initiatives related to undernutrition among children that appeal to these economic considerations include the 1000 days initiative (http://www.thousanddays.org/), Scaling Up Nutrition: http://www.scalingupnutrition.org/) and Grand Challenges Canada's program on "Economic Impacts of Poverty-Related Risk Factors During the First 1000 Days for Cognitive Development and Human Capital."

life-cycle framework is important because investments to reduce stunting in early life may have impacts in terms of adult productivities and chronic diseases decades later.[3]

We consider such a framework with six life-cycle stages: (1) the First 1000 Days[4], (2) subsequent early childhood (i.e., from the end of the First 1000 Days of life to the normal school-entry age ~ 5 or 6 years), (3) late childhood, (4) adolescence, (5) adulthood (including fertility and parenting and therefore intergenerational effects) and (6) old age. Children start life with a given set of genetic and environmental endowments. Conditional on these endowments, stunting and other dimensions of early childhood development are affected by investments that mitigate four risk factors: inadequate food intake in terms of both macro and micro-nutrients; infection; complications during pregnancy and birth and inadequate stimulation and nurturing. These investments emanate from two sources: familial or private sources such as family-provided food and care; and public investments (public in the sense that their supplies are results of policy decisions) such as the accessibility and quality of health care, publicly-provided sanitation and the public provision of macro and micronutrients. An important feature of this framework is that, in contrast to the UNICEF conceptual framework, it explicitly separates the underlying causes of stunting into those that reflect private/familial decisions and those that reflect public policy decisions to undertake, or not undertake, investments that mitigate the risk factors for stunting described above.

Figure 1 presents a simplified overview of such a framework. The four risk factors are indicated in the box to the upper left. They affect outcomes in the First 1000 Days such as (a) physical (health and nutritional) status but also (b) cognitive skills, (c) socio-emotional skills and (d) executive function/self-regulation (in the box at the upper right), which in turn affect outcomes in the subsequent sequential life-cycle stages. Stunting is the most common measure of the long-run nutritional status component of the physical status outcome. Familial investments and public investments, in the center left of the figure in the box, may moderate not only the four risk factors and their impacts on outcomes such as stunting in the First 1000 Days of life but also how the outcomes of the First 1000 Days have impacts over the life cycle. As noted in the box, these investments occur within a particular context and have resource costs associated with them. Across contexts, the effects of these investments and their resource costs are likely to vary.

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[3] An online appendix to this paper provides a formal exposition of these ideas.

[4] Our identification of the first stage being the first 1000 days (conception through to 24 months) follows from analysis by Victora et al. Using the World Health Organization (WHO) Global Database on Child Growth and Malnutrition, comprising data from national anthropometric surveys from 54 countries, with sample sizes ranging from 1000 to 47,000 children, they report that length/height for age starts at birth close to the WHO standard and falters dramatically until 24 months and then increases slightly after 24 months. They conclude that their comparison of child growth patterns with WHO standards shows that growth faltering in early childhood is more pronounced than earlier analyses based on the United States' National Center for Health Statistics reference (Victora et al. 2010). See also the paper by Stewart et al. for a discussion of the contextual and causal factors leading to stunted growth and development (Stewart et al. (in preparation))

Within this framework, parents make decisions that affect child developmental outcomes, including stunting, during the First 1000 Days. Outcomes in the next (preschool) life-cycle stage reflect the outcomes of the First 1000 Days, familial and public investments at the preschool life-cycle stage and random factors such as variations in the disease/nutrition/cognitive and socio-emotional stimulation environment in which the family lives. Note that the outcomes at the end of the First 1000 Days stage may complement or substitute investments in the next preschool life-cycle stage. Familial and public investments also may compensate or reinforce each other. To illustrate, public investments that reduce the occurrence of dehydration stemming from diarrhea may lead parents to provide children with more cognitive and socio-emotional stimulation (complementarity). For another example, when the quality of public day care services is low, parents may spend more resources on private alternatives (substitution). The outcomes of the pre-school ages (stage 2), thus, are produced by the outcomes of the First 1000 Days (stage 1) plus familial and public investments in the second life-cycle stage and by a random term. Similarly the outcomes of the late childhood ages (stage 3) are produced by the outcomes of the preschool ages (stage 2) plus familial and public investments in the third life-cycle stage and by a random term – and so on through the six life-cycle stages.

The outcomes for the adult and old-age life stages include not only the four noted above, but also outcomes such as labor force participation, wage earnings, marriage market outcomes, involvement in crime and violence, adult health and nutritional status, and fertility and parenting of the next generation. Therefore it is possible to examine the impact on outcomes through the life cycle of whether a child experienced the four risk factors of interest and of polices and other behaviors that mitigate the impact of the risk factors on outcomes such as stunting in the First 1000 Days. In the context of Figure 1, we can think of there being direct arrows from one of the top two boxes for the First 1000 Days to the box for adult outcomes with the sequence of factors exogenous to the household, including public investments during the intervening period, modifying those arrows. An example of this approach is Maluccio et al. who assess the impact of publicly-provided supplementary feeding during the First 1000 Days on cognitive skills in adulthood (Maluccio et al. 2009).

3. Understanding the pathways through which stunting generates economic losses

This framework points to a number of potential positive impacts over the life cycle of investments that reduce stunting. We now review the evidence on some of these pathways that are thought to be central.

Loss of physical growth potential

Stein et al draw on the COHORTS data from five countries (Brazil, Guatemala, India, the Philippines, South Africa) and show that growth failure in the first 24 months of life is associated with reduced stature in adulthood (Stein et al. 2010). Using different methods, Coly et al. and Alderman, Hoddinott and Kinsey obtain similar findings in Senegal and Zimbabwe (Coly et al. 2006, Alderman et al. 2006). The magnitudes of this loss of growth are large. For example, in their Senegalese study, Coly et al. find that the age-adjusted height deficit between stunted and non-stunted children was 6.6 cm for women and 9.0 cm for men (Coly et al. 2006).

There is a body of evidence that shows associations between height and outcomes in the labor market in developing countries (Immink & Viteri 1981, Deolalikar 1988, Behrman & Deolalikar 1989, Haddad & Bouis 1991, Strauss & Thomas 1996, Thomas & Strauss 1997, Schultz 2002, Schultz 2003). For example, Thomas and Strauss find that in Brazil, a 1.0% increase in height leads to a 2.4% increase in adult male earnings in a regression of log hourly wages on height and completed grades of schooling, controlling for selectivity into employment (Thomas & Strauss 1997). Moreover, height is also associated with increased earnings in developed economies (Persico et al. 2004, Case & Paxson 2008) where for the vast majority of occupations, there is no obvious link between physical stature and productivity. Consequently, interpretation of observed correlations has focused on possible dimensions of human capital for which attained height might be a proxy measure, such as social skills attained in adolescence (Persico et al. 2004), cognitive ability (Case & Paxson 2008), social class (Steckel 2009) or general healthiness (Lundborg et al. 2009).

Cognitive impairments

Chronic undernutrition has neurological consequences that lead to cognitive impairments. In a review of early evidence, Levitsky and Strupp noted that the prefrontal cortex may be especially vulnerable to undernutrition (Levitsky & Strupp 1995). Evidence that undernourished children score poorly on tests of attention, fluency and working memory are consistent with this (Kar et al. 2008). Undernutrition adversely affects the hippocampus by reducing dendrite density (Blatt et al. 1994, Mazer et al. 1997, Ranade et al. 2008) and by damaging the chemical processes associated with spatial navigation, memory formation (Huang et al. 2003), and memory consolidation (Valadares & de Sousa Almeida 2005). Chronic undernutrition results in reduced myelination of axon fibers, thus reducing the speed at which signals are transmitted (Levitsky & Strupp 1995). Chronic undernutrition damages the occipital lobe and the motor cortex (Benítez-Bribiesca et al. 1999) leading to delays in the evolution of locomotor skills (Barros et al. 2006). Brown and Pollitt posit that these damaging effects are exacerbated by the interactions that occur, or do not occur, between children and their caregivers

(Brown & Pollitt 1996). For example, delayed development of motor skills such as crawling and walking, together with lethargy and increased incidence of illness in undernourished infants, reduces their interactions with adults and with their environment.

Cognitive impairments experienced in early life have long-term consequences (Victora et al. 2008). Kar, Rao and Chandramouli find that in Indian children 5-7y and 8-10y, stunting affects the development of higher cognitive processes such as tests of attention, working memory, learning and memory and visuospatial ability (Kar et al. 2008). Victora et al. (2008) summarizing evidence found in the Philippines (Mendez & Adair 1999), Guatemala (Maluccio et al. 2009) and Zimbabwe (Alderman et al. 2006) show that stunting or other measures of lost growth potential is associated with reduced grade attainment (Victora et al. 2008). Hoddinott et al. show that Guatemalan adults who had been stunted at age 36 months had lower scores on tests of vocabulary and non-verbal cognitive ability than comparable individuals who had not been stunted (Hoddinott et al. 2011).

There are numerous studies that examine the relationship between schooling, cognitive skills and earnings and income in adulthood. A summary by Hanushek and Woessman (Hanushek & Woessman 2008) indicates that across a range of countries, being literate raises earnings by 10 percent and that an additional grade of schooling, controlling for literacy, raises earnings by an addition five percent. Hanushek and Woessman, however, stress that learning, not years of schooling, is the driving force for this increase in productivity. In Guatemala, Behrman et al. find that an additional grade of schooling raises wages by nine percent and that an increase of one standard deviation in tests of reading and vocabulary raises wages by 35 percent (Behrman et al. 2010).

Increased risk of chronic disease

Separating the concept of malnutrition into under- and over- nutrition is a false dichotomy; early malnutrition may be a risk factor for obesity as well as some types of chronic diseases in adults.

In a seminal paper, Barker and Osmond traced adult illness in England and Wales to birth-weight records and from this developed the fetal origins hypothesis (Barker & Osmond 1986). While the so-called Barker hypothesis remains controversial, the evidence for it is stronger than when originally proposed.

One source of evidence on the links between early life undernutrition has been famine survivors. For example, given the short duration of the Dutch Famine and the rapid return to relative food abundance, this event has facilitated a nuanced assessment of critical periods during pregnancy. As the children born during and immediately after the Dutch famine enter into their middle age, it is apparent that they have increased risk of some chronic diseases and mental illnesses. For example, glucose metabolism is impaired in adults who were *in utero* at any time during the famine. However, only those adults whose mothers were in their first trimester were found to be at increased risk of obesity and heart disease as well as breast cancer.[5] Similarly, children born in the disastrous Chinese Great Leap in the 1950s (Huang et al. 2010) and in the Biafra famine of 1967-1970 have increased risk of chronic disease as adults. In the latter example, Hult et al. report increased risk of diabetes and hypertension among children with fetal exposure to the famine compared to the cohorts immediately preceding and immediately following the famine (Hult et al. 2010).

While famines are extreme events, the patterns identified by these temporally circumscribed events are reinforced by cohort studies. For example, a longitudinal study of a cohort of births in New Delhi followed up to age 32 found that those children who were thinner in infancy (with a body mass index [BMI] less than 15) had an accelerated increase of BMI until adulthood. Although none were classified as obese by age 12, those with the greatest increase in BMI by this age had impaired glucose tolerance or diabetes by the age of 32 (Bhargava et al. 2004). In their multi-country study using the COHORTS data (Brazil, Guatemala, India, Philippines, South Africa) Victora et al. report that lower birth weight and greater undernutrition in childhood were risk factors for high glucose concentrations, blood pressure, and harmful lipid profiles after controlling for body-mass index and height (Victora et al. 2008).

Chronic diseases have direct resource costs including the costs of medication and the costs associated with accessing and using health-care services. There also are costs associated with lost employment as a result of illness, medical treatment or premature death. Costs may also be incurred by other household or family members who forgo time spent working or at school in order to care for someone who is ill. Simulation estimates of the costs of chronic diseases suggest that these costs are high with one study reporting that cardiovascular disease, chronic respiratory disease, cancer, diabetes and mental health will generate a global output loss of US$ 47 trillion over the next twenty years (Bloom et al. 2011) with nearly half of this coming from cardiovascular disease. An alternative approach, estimating the value of a statistical life, produces a very wide range of estimates, US$6.7 to 43.4 trillion per year (Jha et al. 2012). More generally, the literature on the economic impact of chronic disease tends to be highly sensitive to assumptions made about lost labor productivity, the value of averted mortality and the costs of treatment with all these differing according to the medical system, markets, and policies of a country. However, given that these costs occur decades after the intervention to prevent low birth weight or stunting, they contribute very little to benefit: cost estimates due to discounting (Alderman 2013).

[5] Personal correspondence with T. J. Roseboom based on a presentation in Santiago Chile November, 2009, cited with permission.

4. Estimating the benefits and costs of investments in stunting reduction: General issues

Assessing the economic benefits and costs of investments in stunting reduction is far from straightforward. Guided by our framework, which links factors that affect child height in utero and during the first two years of life, we briefly outline a number of salient issues. Behrman, Alderman and Hoddinott (Behrman et al. 2004) and Alderman (Alderman 2010) discuss them in depth.

Benefits of interventions

Where stunting leads to illness or premature death, and if we aim to account for all economic benefits of reduced stunting, there is the non-trivial issue of how to value in monetary terms a human life. As Alderman notes, one common approach is to use the expected earnings over the individual's lifetime (Alderman 2010).[6] This approach implies that there will be higher economic benefits to reducing stunting in well-off countries than in low and middle income countries and within countries, to individuals expected to have the highest levels of earnings. Ranking the value of life as a function of wages within and across countries is ethically fraught. But alternative approaches, such as estimates based on the cheapest available alternative means of reducing mortality (e.g. Summers 1992) or estimates based on compensating differentials for risks in different occupations (Viscusi & Aldy 2003) are also problematic (Behrman et al. 2004).

Some impacts of reduced stunting in the First 1000 days happen fairly quickly, such as reduced infant and child morbidity in the first or second life-cycle stages of Figure 1. Others may happen only with considerable lags, such as the increased productivity in adulthood or reduced morbidity in old age in the fifth and sixth life-cycle stages in the Figure. To account for the timing of different impacts it is necessary to discount the economic costs and benefits to the same point of time. Calculations of economic benefits are highly sensitive to the discount rate used as is the share of benefits derived from different sources. For example, Alderman (2010) shows that the economic benefits from averting low birth weights is 357 percent higher when using a one percent rather than five percent discount rate. In his example, the reductions in costs associated with chronic diseases represent 20 percent of total economic benefits when the discount rate is one percent but less than one percent when the discount rate is set at 10 percent. Discounting also has implications for our treatment of the gains from reduced stunting that accrue to subsequent generations.

[6] Within standard models of economic behavior, labor market earnings equal marginal productivity and individuals who work in labor markets equate their marginal productivity or earning per last hour worked in the labor market and non-labor market activities, where the latter include home production of health and nutritional status, upbringing of children and care of those family members who are sick and aging, etc. Under these assumptions, thus, the use of labor market earnings per unit time for marginal productivity also captures marginal productivity in other activities.

While these gains may exist, the mechanics of discounting these back to the present imply that they are unlikely to play a major part in our benefit: cost calculations. As there is no consensus on discount rates, it is necessary that estimates of economic returns be explicit about the rate used and advisable to indicate sensitivity to reasonable alternatives.

Most of the resource costs for investments to reduce stunting in the First 1000 Days are likely to occur in the first life-cycle stage so neither discounting nor adjusting for survival is a big concern. However there are likely to be some resource costs that are incurred in later life-cycle stages as a result of reduced stunting. For example, if reduced stunting causes extended school attendance, additional real resource costs in the form of additional teaching, educational material and space may be incurred.

There is an important distinction between private and social benefits. Private benefits are those that accrue to individuals and possibly their households and families. But there may be societal benefits beyond the private benefits because of spillover effects. For example, Hanushek and Woessman note that there are studies that show that investments in schooling reduce crime and increase civic participation (Hanushek & Woessman 2008). Given that investments that reduce stunting increase schooling, this suggests an indirect link from stunting reduction to a societal benefit in terms of reduced crime and greater civic engagement. For another example, more educated workers may make their co-workers more productive though the empirical evidence supporting this is less clear-cut. Such spillover effects are not captured in estimates of private benefits from stunting reduction. Another social benefit that is difficult to quantify is the value that society places on equity achieved through increasing the earnings of children from poor households.

Costs of interventions

Bhutta et al. (2008) and Bhutta et al. (2013) provide systematic reviews that identify interventions for which there is compelling evidence of their impact on stunting between birth and 36 months. They argue that there exists rigorous evidence to support the large-scale implementation of the following interventions:

– Interventions that improve the health and nutrition of mothers: universal salt iodization; micronutrient supplementation; and calcium supplementation. In Bhutta et al (2013), balanced energy protein supplementation was included in the list of interventions to be scaled up. Bhutta et al (2008, 2013) also noted that folate and iron fortification of staples, maternal iron-folic acid supplementation for mothers during pregnancy and interventions to reduce tobacco consumption conveyed important health and nutrition benefits

– Interventions aimed at improving care behaviors: community-based nutritional programs that provide information on breastfeeding and complementary feeding.

– Interventions that address health-related causes of undernutrition: therapeutic zinc supplementation and Vitamin A supplementation given its impacts on reducing mortality in children six to 59 months although there is limited evidence on a link to stunting reduction.

Interventions that improve the quantity and quality of a child's diet: community-based management of severe acute malnutrition and limited use of supplementary foods. Bhutta et al. (2013) construct a cohort model that assesses the cumulative impact of these interventions in 36 countries that collectively account for 90 percent of the moderately- or severely-stunted children worldwide. They find that these interventions in these 36 countries would reduce stunting at age 36 months by 20 percent.

Horton et al. and Bhutta et al. estimate the budgetary costs of scaling-up these nutritional interventions in these high-burden countries (Horton et al. 2010; Bhutta et al. 2013).[7] Horton et al. base the costs on program experience, and Bhutta et al extend this by using the OneHealth costing approach (i.e. breaking costs into components such as labour costs, drugs, food, etc. The context from which these have been taken – whether they are part of outreach programs, stand-alone interventions or components of primary health services – is considered as is the collective packaging of these interventions. This approach is attractive because unlike other budgetary costing methods it takes into account the fact that interventions may well not operate at maximum efficiency. Results from Horton et al. have been used in previous work on estimating benefit: cost ratios (Hoddinott et al., in press) and so it is instructive to compare results from the Horton et al cost data with the newer data from Bhutta et al which incorporate regional differences in costs.[8] Per child costs of these interventions are given on Table 1.

5. Benefit: cost ratios for investments to reduce stunting in high burden countries

Section 4 considered the benefits and budgetary costs associated with stunting separately. In this section we bring these together in order to calculate benefit: cost ratios for investments to reduce stunting in selected high burden countries.[9, 10] In earlier work, we did so by calculating the economic benefits associated with

[7] It is important to be clear about what we mean by budgetary costs. These are the financial costs of intervention providers in terms of time, material and transfers to provide an intervention. They exclude private costs (e.g., time of mothers that is necessary for an intervention, private transportation costs for the intervention) and the distortion costs of raising funds for public expenditures (Harberger 1997). They include transfers, which are not a resource cost but just a redistribution of purchasing power.

[8] Note that these cost estimates exclude the cost of calcium and energy-protein supplements for mothers.

[9] These are found in sub-Saharan Africa (Democratic Republic of Congo, Ethiopia, Kenya, Madagascar, Nigeria, Sudan, Uganda, Tanzania), Middle East and North Africa (Yemen), South Asia (Bangladesh, India, Burma, Nepal, Pakistan) and East Asia (Indonesia, Vietnam, Philippines), (Bryce et al. 2008).

increased stature, improved cognitive outcomes, averted illness and inter-generational impacts, see Behrman, Alderman and Hoddinott (Behrman et al. 2004). Specifically, we used estimates of the impact of linear growth failure on attained height and monetized the impacts by applying estimates of the impact of height on earnings derived from wage regressions where height appears as an argument; and on grade attainment and cognitive skills, again monetizing this impact by applying estimates of the impact of schooling or cognitive skills on earnings derived from wage regressions where these education-related outcomes appear as arguments.

In this paper, we take a more direct approach. Hoddinott et al. provide direct estimates of the impact of stunting in early life on later life outcomes (Hoddinott et al. 2011). Specifically, they follow up on a group of approximately 1,450 individuals who participated in a nutritional supplementation trial in Guatemala in the late 1960s and early-mid 1970s. These persons were traced as adults aged somewhere between 25 and 42 years of age at the time of interview, and data obtained inter alia on their schooling, marriage and fertility histories, earnings, health and consumption levels. Treating stunting as endogenous, Hoddinott et al. find that an individual stunted at age 36 months was predicted, as an adult, to have 66 percent lower per capita consumption. This represents a direct measure of the economic cost of stunting.

Expanding on work found in Hoddinott, Rosegrant and Torero (Hoddinott et al. 2013), we use this information as follows. Suppose starting in 2015, the full package of interventions described above is implemented for all children. This benefits a cohort of individuals born in 2015 whom we assume enters the labor market at age 21. We treat an increase in per capita consumption due to moving one of these individuals from being stunted to not-stunted as equivalent to an increase in per capita permanent income. We multiply the point estimate of the increase in per capita permanent income, 0.66, by 0.20 in recognition of Bhutta et al's (2013) estimate that this package of interventions will reduce stunting by 20 percent. Further, to be conservative, we assume that only 90% of these income gains are realized. We apply this predicted increase in income, 11.3 percent, to predicted per capita incomes of those stunted in infancy (based on current income levels and projected growth rates) in selected high-burden countries where stunting is widespread and that represent a range of income levels, for the period 2036 to 2050, that is the first fifteen years of their working lives.[11] Using a five percent discount rate, we construct the net present value of this increased consumption.[12]

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[10] We focus on stunting because the nutrition policy literature focuses heavily on the importance of reducing stunting as opposed to say increasing HAZ more generally. Also, the Bhutta et al (2013) cost estimates are framed in terms of reducing stunting, not HAZ.

[11] Alternatively, if we used Bhutta et al (2008)'s estimate that this package reduces stunting by 36 percent and assumed that half these income gains were realized, we would obtain a similar predicted increase in income.

[12] Under this approach we omit any monetary value associated with the intergenerational transmission of the benefits of reduced stunting.

The results are reported in Table 2 using both the Horton et al (2010) and Bhutta et al (2013) cost data.[13] Under these assumptions, the benefit: cost ratios are greater than one for all 17 countries. The median ratio (Bangladesh) is 18.4 using the Horton et al cost data and 17.9 using the Bhutta et al cost data. This means that in Bangladesh, every dollar invested in reducing stunting through programs is estimated to generate 17.9-18.4 dollars in economic returns. The benefit-cost ratios vary across countries because of differences in stunting rates, preexisting income levels and the cost of the package of interventions and because of different predicted growth rates. There does not, however, appear to be much difference in the benefit: cost ratios obtained from using the newer cost data found in Bhutta et al. (2013). As is the case with all calculations of benefit: cost ratios, these rise when we use a lower discount rate and fall when we assume a smaller percentage increase in income. Table 3 provides sensitivity analysis for our median country, Bangladesh, showing benefit: cost estimates for the interventions described in Bhutta et al (2013) under different assumptions of income growth and discount rates (Table 3). Even in cases where we are pessimistic about the effect of stunting reduction on incomes and where we assume a relatively high discount rate, 8%, we still obtain benefit: cost ratios that exceed one by a comfortable margin. Note that some of these interventions – such as salt iodization– convey benefits to all, not just pregnant women and young children. Also note that these estimates do not account for the reduction in child mortality, which we know to be substantial. As noted above, ascribing a monetary benefit to a lost life is difficult. Given these significant challenges, we do not calculate such a benefit stream. Set against these considerations – which suggest that our benefit: cost ratios are underestimates – are two additional points. First, these benefit: cost ratios capture public costs but not private costs associated with reducing stunting. So, for example, if caregivers must spend more time providing their children food more frequently, there is a cost to the caregiver that is not captured in our estimates. Second, the literature suggests that the marginal benefits of increased height diminish as height increases. The returns in Guatemala are very high - but Guatemala has a very low attained adult male height. The estimates for Guatemala may be informative for other parts of the world with similar high rates of stunting in which live hundreds of millions of children, primarily South Asia and parts of Sub-Saharan Africa. But the returns to reducing stunting are likely to be considerably lower in most of Latin American and in developed countries in which the prevalence of stunting is much lower.

[13] We do not report results for Guatemala. Our approach implicitly assumes that the benefit stream, in terms of income, is one where, on average, averting stunting increases mean incomes. For the countries we consider here, this is a reasonable assumption. For example, income in India is reasonably equally distributed (the Gini coefficient is around 0.38) and there are not massive differences in undernutrition across income quintiles. By contrast, income in Guatemala is highly unequally distributed and stunting is heavily concentrated in indigenous communities who have incomes well below mean income. That said, if we base our calculations on income levels of the poorest quintile of Guatemalan households and use a 5% discount rate, we obtain a benefit: cost ratio for Guatemala of 8.2.

6. Discussion and Conclusions

This paper has outlined the economic rationale for investments that reduce stunting. We have presented a framework that illustrates the functional consequences of stunting in the 1000 days after conception throughout the life cycle: from childhood through to old age. We have summarized the key empirical literature around each of the links in the life cycle, highlighting gaps where they exist.

Our overall goal in the paper was to generate credible estimates of benefit-cost ratios for a plausible set of nutritional interventions. The considerable challenges of doing have been outlined and our assumptions have been clearly presented and justified. Using assumptions on the uplift in income (11 percent) due to the prevention of one third of stunting and on the discount rate of future benefit streams (5 percent), we find average benefit: cost estimates of between 3.8 (DRC) and 34.1 (India). The median benefit: cost ratio is 18 (Bangladesh). While we stress that these results hinge on a number of assumptions, we note that they compare favourably with the other investments, such as schooling for which public funds will compete f(Lomborg,in press).

For the set of nutrition-specific interventions we have reviewed here, there is a consensus on their effectiveness and their costs. Countries that want to generate and sustain broad-based wealth are likely to find that scaling-up these nutritional interventions to be some of the best investments they can make. It is important to note that our arguments are based solely on economic calculations. We believe this is important because this is precisely the type of calculation that Ministry of Finance and Planning Commission officials make. The nutritional community needs to be similarly hard-headed and be prepared to discussion nutritional interventions in terms of the economic benefits and costs if it wants to convince these policymakers.

But we know that the value of preventing stunting goes far beyond what can be captured in economic statistics. The value of preventing pain, emotional suffering and loss is very difficult to estimate but possibly very large. Such potential gains go beyond the economic benefits and costs presented above. Politicians and policy-makers who want to promote broad-based growth and prevent human suffering should place investments in scaling-up nutrition-specific interventions among their top priorities.

Key Messages

1. There are significant, life-long economic benefits from averting stunting.
2. For the set of nutrition-specific interventions that we consider, there is a consensus on their effectiveness and their costs.

3. The benefit: cost ratios associated with implementing these interventions exceed one in all countries considered in our study. They are larger than many other development interventions.
4. Thus, countries that want to generate and sustain broad-based wealth are likely to find that scaling-up these nutritional interventions to be some of the best investments they can make.

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On-Line Appendix : Technical Details for Framework in Section 2

Within the framework in Section 2 that is summarized in the Figure there, parents make decisions that affect child development outcomes, including stunting, during the First 1000 Days. Then the inputs into the outcomes in the next life-cycle stage (Y_S) are the four outcomes at the previous life-cycle stage (Y_{S-1}). The human development "production function" represents this relation:

$$Y_s = T_s(Y_{s-1}, F_s, P_s, U_s) \qquad (1)$$

Where F_S is familial investments in life-cycle stage *s*, P_S is public investments in life-cycle stage *s*, and U_s is a stochastic term that captures, among other terms, variations in the disease/nutrition/cognitive and socio-emotional stimulation environment in which the family lives. Production functions indicate how outcomes at the end of each life-cycle stage are produced by inputs in that stage of life and development from previous stages (i.e., the production function in relation (1) allows for the human development at the end of the previous stage to complement or substitute investments in the current stage). The production function also allows for familial and public investments to compensate or reinforce each other, examples of which are given in Section 2.

Parents (or other caregivers) make investment decisions in part based on the child's development at the end of the previous stage (Y_{s-1}) and the public investments that they face (P_S), as well as family resources and the distribution among family members of control over those resources (R_s), market characteristics such as credit constraints and prices for investment inputs (M_s), the motives that they have for investing in their children (including altruism and expected possible future benefits, such as old-age support from the children, W_s) and the parameters of the production function (T_S). Because these motives are likely to be forward-looking, the expected impacts of these decisions on outcomes over the child's life and the expected future school, work and other conditions that may affect the value of these impacts all enter into the parental decisions about investment in children in the *s*th life-cycle stage, which we denote by E_s. We then have a dynamic decision rule for familial investments:

$$F_s = T_s(Y_{s-1}, P_s, R_s, M_s, W_s, T_s, E_s) \qquad (2)$$

The outcomes for the adult and old-age life stages include not only the four noted for the child life-cycle stages, but also labor force participation, wage earnings, marriage market outcomes, involvement in crime and violence, and parenting of the next generation. The benefits should include all the private effects on the child being considered and, from a social perspective, any broader "spillover" external effects. We denote these adult outcomes by H_s. These outcomes depend partially on the vector Y_4, that is, the outcomes at the end of the adolescent stage of life, but also on other observable (X_s) and unobservable (V_s) determinants. This approach generates estimating equations:

$$H_s = Q(X_s, Y_4, V_s) \qquad (3)$$

The partial derivative of relation (3) with respect to the component of Y_1 (Y_4, which appears explicitly in equation (3), depends on Y_1) that refers to whether a child experienced the four risk factors of interest, for example, gives the impact of that policy component working through the risk factors on outcomes in the *s*th life-cycle stage (with possible interactions among those risk factors).

This modeling also allows for a related, but different approach now explained. Given the production function (1), it is possible to substitute into the relations for Y_4 all the links back to the First 1000 Days life-cycle stage that are transmitted across stages by the inputs into any particular stage being the outcomes of the previous stage. These substitutions permit explicit expression of how the outcomes in each later life-cycle stage relate to the child outcomes in the First 1000 Days Y_1 (or, by further substitution, the determinants of Y_1) and the subsequent sequences of public investments and other variables that influence familial investments:

$$H_s = Q\left(X_s, Y_1, \{R_j, M_j, W_j, T_j, E_j\}_{j=2}^{4}, \{P_j\}_{j=2}^{4}, \{U_j\}_{j=2}^{4}, V_s\right) \quad (4)$$

Estimates of relation (4) yield the direct impact of the four child outcomes (Y_1) in the First 1000 Days OR, by substituting in the production functions for Y_1, the underlying risk factors in the First 1000 Days of life on the economic outcomes of interest. Note that relation (4) implicitly allows for $F_j, j = 2,3,4$ to adjust in response to changes in Y_1 (as implied by the dynamics of the developmental process). In terms of the Figure, thus, this quasi-reduced form gives the impacts, for example, of the four risk factors or four child outcomes in the First 1000 Days on adult outcomes by substituting out or collapsing all the boxes between the First 1000 Days and the adult outcomes and the related induced familial investments; therefore for this case the Figure is simplified to having direct arrows from one of the top two boxes for the First 1000 Days to the box for adult outcomes with the sequence of exogenous factors including public investments during the intervening period modifying those arrows.

There are some econometric issues that make estimation of relationships (1), (3), and (4) difficult. (i) ECD investments are behavioral decisions that parents or other caregivers make in response to a number of factors, of which some important ones are likely not to be observed by analysts, such as innate abilities, innate health, and current or expected future prices that directly or indirectly affect the risk factors of interest and child development. (ii) To obtain estimates of the benefits of public investments to reduce risk factors in the First 1000 Days life-cycle stage on outcomes, there must be control for endogenous program placement, which may cause biases in either direction depending on the nature of the placement (Rosenzweig & Wolpin 1986). (iii) The effects of investments to reduce the four risk factors of interest in the First 1000 Days life-cycle stage may be heterogeneous depending on characteristics of market, cultural and policy contexts, individual children and their families (see term sequence of shocks $\{U_j\}_{j=2}^{4}$ in equation 4) (Heckman et al. 2006).

Table 1: Per child costs of interventions to reduce stunting in children under 24 months

Intervention based on Bhutta et al (2008) and Horton et al (2010)	Cost per child		Intervention based on Bhutta et al 2013	Cost per child by country			
				Madagascar, Nigeria	DRC, Ethiopia, Uganda, Tanzania, Kenya, Sudan,	Bangladesh, Burma, India, Nepal, Pakistan, Yemen	Indonesia Philippines Vietnam
Universal salt iodization	$0.05		**Universal salt iodization**	$0.06	$0.06	$0.06	$0.06
Iron fortification of staples	$0.80						
Iron-folic acid supplementation for mothers during pregnancy	$2.00		**Multiple micro-nutrient supplements**	$6.15	$6.13	$5.84	$6.15
Community based nutrition programs providing information on breastfeeding, complementary feeding, handwashing; distribution of micronutrient powders, iron-folate supplements	$15.00		**Community based nutrition programs that provide information on breastfeeding ($14.32); complementary feeding education ($5.27)**	$19.59	$19.40	$17.03	$19.59
Providing complementary foods	$50.00[1]		**Provision of complementary foods**	$50.00[2]	$50.00[2]	$50.00[2]	$50.00[2]
Community based management of severe acute malnutrition	$8.13		**Community based management of severe acute malnutrition**	$10.46[3]	$10.23[3]	$9.99[3]	$10.46[3]
Vitamin A supplementation	$4.80		**Vitamin A supplementation**	$2.85	$2.82	$1.58	$2.85
Multiple micronutrient powders	$10.80		**Multiple micronutrients**	$7.98	$7.98	$7.98	$7.98
Therapeutic zinc supplementation for management of diarrhea	$4.00		**Zinc supplementation**	$5.90	$5.88	$4.63	$5.90
Deworming	$1.00						
TOTAL	$96.58		**TOTAL**	$102.99	$102.50	$97.11	$102.99

[1]We conservatively assume that all children receive this; however Horton et al (2010) only apply to 80% of households in South Asia, 50% of children in Africa and East Asia, and 10% elsewhere. [2] We conservatively assume that all children receive this; however Bhutta et al (2013) only apply to children in households with per capita income below $1 per day. [3]This is calculated by taking the per-child cost of community management of severe acute malnutrition and multiplying it by twice the prevalence of severe acute malnutrition. Source. Authors' calculations based on Bhutta et al (2008, 2013) and Horton et al (2010).

Table 2: Benefit: cost ratios for investments to reduce stunting in selected high burden countries

		Benefit: cost ratios calculated using interventions and cost data from	
Region	Country	Bhutta et al (2008) and Horton et al (2010)	Bhutta et al (2013)
Sub-Saharan Africa	Democratic Republic of Congo	3.8	3.5
	Madagascar	10.7	9.8
	Ethiopia	11.5	10.6
	Uganda	14.1	13.0
	Tanzania	15.9	14.6
	Kenya	18.7	15.2
	Sudan	25.0	23.0
	Nigeria	26.6	24.4
Middle East and North Africa	Yemen	13.4	28.6
South Asia	Nepal	13.3	12.9
	Burma	17.7	17.2
	Bangladesh	18.4	17.9
	Pakistan	29.8	28.9
	India	34.1	38.6
East Asia	Vietnam	35.5	35.3
	Philippines	43.9	43.8
	Indonesia	47.9	47.7

Source: Authors' calculations

Table 3: Sensitivity of benefit: cost ratio estimates to assumption of impact of stunting reduction on income growth and on the discount rate used, Bangladesh

	Discount rate		
Income growth due to reductions in stunting	3%	5%	8%
11.3%	35.1	17.9	6.7
8.5%	26.4	13.4	5.0
5.75%	17.5	8.9	3.3

Source: Authors' calculations

Figure 1: A lifecycle approach to investments in the First 1000 days