Global Panel on Agriculture and Food Systems for Nutrition

Working Paper

The economics of reducing malnutrition in Sub-Saharan Africa[1]

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Summary

Reducing malnutrition in Africa has both intrinsic and instrumental value. Better nourished populations are more economically productive. Children better nourished during the first 1000 days (*in utero* and the first two years of life) will be more productive as adults, increasing country GDP. Malnutrition costs African economies between 3 and 16 percent of GDP annually. For an illustrative set of 15 African countries, meeting the 2025 World Health Assembly target for stunting will add 83 billion dollars to national incomes. Interventions that prevent malnutrition are excellent investments; for a typical African country, every dollar invested in reducing chronic undernutrition in children yields a $16 return. Reductions in malnutrition will occur most rapidly when countries undertake investments in both nutrition-specific and nutrition-sensitive interventions.

Background

Nutrition has always been important to development. Good nutrition allows for healthy growth and development of children, inadequate nutrition is a major contributing factor to child mortality and obesity leads to poor health and premature death. Put simply, improving nutrition is intrinsically valuable. A large and growing body of evidence now shows that good nutrition is also important for economic development

Malnutrition encompasses both undernutrition and overweight/obesity; see Box 1. While there have been improvements since 2000, undernutrition in sub-Saharan Africa remains pervasive. Across Africa, 56 million (36 percent) of children under the age of 5 are chronically undernourished and as of 2013, no country had a stunting prevalence of less than 19 percent. More than 13 million are acutely undernourished (8.5 percent). Micronutrient deficiencies in children under five are also widespread: 41 percent of children are Vitamin A deficient; 40 percent are iodine deficient; 20 percent suffer from iron deficient anemia; and 24 percent are zinc deficient (Black et al, 2013). Undernutrition is a direct consequence of diets lacking in sufficient quantities of high quality nutrients and of illness. Obesity is the consequence of excess caloric intake relative to energy use. While the prevalence of obesity across much of sub-Saharan Africa is low, there are places and groups (such as adult women in southern Africa) where it is rising rapidly (Ng et al, 2014)

Box 1: What do we mean by malnutrition?

Malnutrition has two dimensions: undernutrition and overweight/obesity.

Undernutrition reflects inadequate intake of nutrients: calories, proteins and micronutrients. There are two manifestations of undernutrition: anthropometry (height and weight); and micronutrient deficiency. The World Health Organization (WHO) has developed and validated anthropometric standards for children. One important measure pertains to chronic undernutrition. A child is considered chronically undernourished, or stunted, if - relative to WHO reference standards for healthy, well-nourished children - a child is too short given her age and sex. A second is acute undernutrition. A child is considered acutely undernourished, or wasted, if – again relative to WHO reference standards for healthy, well-nourished children – she is too thin given her height. The human body needs approximately 20 different micronutrients of which four – iodine, Vitamin A, iron and zinc – are especially important. Overweight/obesity occurs when there is an excess consumption of calories leading to the accumulation of body fat. For adults, individuals with a Body Mass Index greater than or equal to 25 are considered overweight and individuals with a Body Mass Index greater than or equal to 30 are considered obese.

It is well understood that Africa's future economic success lies in increasing human capital – schooling, knowledge and skills that will allow Africans to compete and thrive in a global economy. Human capital is an important determinants of labour productivity; raising labour productivity lies at the heart of raising incomes across Africa. In debates regarding African economic development strategies, it had long been assumed that increasing human capital comes about through investments in the formal education system but this is only partially true. Investments in nutrition – particularly in the nutrition of very young children – are equally important.

To understand the economic effects of malnutrition, it is helpful to begin with a specific form, chronic undernutrition in the first 1000 days (pregnancy and the first two years of life). There is abundant evidence that this has long term adverse consequences. One manifestation of these is attained stature in adulthood. Data from Brazil, Guatemala, India, the Philippines, Senegal, South Africa and Zimbabwe (Stein et al, 2010; Alderman et al, 2006) all show that growth failure in the first 24 months of life is associated with reduced stature in adulthood. The magnitudes of this loss of growth can be large. In Senegal, men who were stunted when they were two years old were 9.0 cm shorter in adulthood compared to men who were not stunted. The economic consequences are captured by evidence showing associations between height and outcomes in the labor market. A useful rule of thumb is that every loss of one percent of attained height in adulthood reduces adult earnings by 2.4%.

Even more importantly, chronic undernutrition has neurological consequences that lead to cognitive impairments – see Box 2. These cognitive impairments result in children starting school later, dropping out earlier and attaining fewer grades of schooling. Longitudinal studies that have followed individuals for several decades show that, in adulthood, those persons who were chronically undernourished as pre-schoolers scored poorly on tests of cognitive ability. They earned lower wages and, for women, had more children (Hoddinott et al, 2013).

These economic losses also occur if we consider micronutrient deficiencies. Both iodine deficiency and iron deficient anemia lead to cognitive damage. Iodine deficiency in childhood adversely affects psychomotor skill development (think movement, balance, fine motor skills) and there is some evidence linking it to slowed physical growth. A series of meta-analyses suggest that iodine deficiency results in a loss of 13-15 IQ points. Horton and Ross (2003) estimate that iron deficiencies cost African economies between 2.7 and 4.2 percent of GDP annually.

These links – poor nutrition to damaged cognitive abilities to poorer schooling outcomes to poor cognitive abilities in adulthood to lower economic productivity – are the economic rationale for investing in efforts to reduce malnutrition.

Box 2: How does chronic undernutrition affect cognitive abilities, schooling and wages?

Undernutrition in early life damages children’s brains. Early life malnutrition damages the hippocampus by reducing dentrite density (Dentrites are branch like structures, which receive signals sent along axons.) This adversely affects spatial navigation and memory formation. In severely malnourished children, dentrites in the occipital lobe (responsible for the processing of visual information) and in the motor cortex are shorter, having fewer spines and greater numbers of abnormalities; consequently, chronic malnutrition leads to delays in the evolution of locomotor skills. Malnutrition results in reduced myelination of axon fibers thus reducing the speed at which signals are transmitted. Lastly, early-life undernutrition decreases the number of neurons in the locus coeruleus which plays a role in signaling the need to inhibit the production of cortisol. Thus early-life malnutrition diminishes the ability to exhibit down regulation and handle stressful situations. The cognitive impairments experienced in early life have long-term consequences. Two studies – one in Guatemala and one in Zimbabwe – have traced children from infancy (when their nutritional status was first measured) to adulthood. In both countries, a one standard deviation increase in Height-for-Age z (HAZ) scores increases grade attainment by approximately 0.75 grades; in Zimbabwe, shifting a child from being stunted to being well-nourished would increase schooling by 1.25 grades. In Guatemala, a one standard deviation increase in HAZ increases *adult* test scores for reading and nonverbal cognitive skills by 0.28 and 0.25 SDs respectively. In Guatemala, 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. The economic consequences of these cognitive impairments arise because of the well-documented links between schooling, cognitive skills and earnings and income in adulthood.

Do economic benefits justify investments that reduce undernutrition?

Poor nutrition kills. But faced with multiple demands on limited resources, and the overarching need to raise economic growth rates, how strong is the economic case for investments that reduce undernutrition? There are three complementary ways of answering this question: Measuring the cost of doing nothing in terms of lost GDP; measuring the benefits of working towards the World Health Assembly targets for nutrition; and by calculating the benefit: cost ratios associated with investments in nutrition.

A number of African governments have attempted to estimate the costs of hunger and malnutrition in terms of lost GDP. Seven African countries participated in an exercise to quantify the impact of undernutrition across individuals of different ages. These were: ages 0-5 – economic costs associated with higher prevalence of illness and increased mortality; ages 6-18 – economic costs associated with higher rates of grade repetition and increased dropout; and ages 15-64 – economic costs associated with lower productivity arising from reduced physical capacity and lower levels of schooling (Government of Ethiopia, 2013). The median estimate is a loss of 7.7 percent of GDP (Table 1).

Table 1: Annual cost of undernutrition: National estimates

Country	Annual cost of undernutrition (% of GDP)
Ethiopia	16.5
Rwanda	11.5
Malawi	10.3
Burkina Faso	7.7
Ghana	6.3
Uganda	5.6
Swaziland	3.1

Source: www.costofhungerafrica.com

Assessing how much GDP will change if chronic undernutrition is reduced is an alternative way of thinking about the economic impact of reducing undernutrition. Suppose for example that African countries attained the 2025 World Health Assembly target of a 40 percent reduction in chronic undernutrition. How much would GDP change if this achievement, which forms part of Sustainable Development Goal 2, was reached?

Calculating this entails a number of steps: (1) Making assumptions regarding how quickly countries will meet the WHA target; (2) Estimating the number of additional children would not be stunted if African governments and their partners undertook preventative actions that enabled them to meet the WHA target for 2025; (3) Calculating the increase in their incomes that would occur if they were not stunted from the time they enter the labour force to an end year; (4) applying a discount rate to calculate their net present value in 2016 US dollars. Results are shown in Table 2 for an illustrative set of 15 countries for which the needed data are available. Appendix 1 provides a detailed explanation of the methodology, including the criteria used to select the countries listed in Table 2.

Table 2: Cumulative additions to GDP associated with accelerating investments to meet the WHA 2025 target for stunting for 15 African countries: 2035 – 2060

Country	Cumulative addition to GDP (millions of 2016 USD)
Benin	1,571
Chad	3,718
Ethiopia	15,908
Lesotho	151
Madagascar	1,800
Malawi	1,513
Mali	2,814
Niger	5,553
Nigeria	29,274
Rwanda	1,028
Senegal	1,723
Togo	842
Uganda	7,464
United Republic of Tanzania	7,952
Zambia	2,513
TOTAL	83,824

Source: Author's calculations.

Table 2 indicates that there are large GDP gains to be had by meeting the WHA target. The magnitudes vary across countries because of population (countries with larger numbers of children will see larger increases), the existing prevalence of stunting (countries where current prevalences are low will see smaller increases) and median per capita incomes in 2016 (countries with higher per capita incomes will have larger increases in GDP). It is worth stressing that these numbers are conservative (see Appendix 1): a relatively high discount rate is used, it is assumed that individuals do not enter the labour force until they are 18, only benefits accrued until early middle age are counted and they do not take into account additional monetary benefits that certain components of the package generate. Mindful of this, across the 15 countries considered here, the cumulative addition to GDP is $83.8 billion. Calculations of this sort across African countries can be skewed by the presence or absence of countries like Nigeria, but even if Nigeria is excluded and small countries like Lesotho retained, the cumulative addition to GDP remains high at $54.5 billion.

Calculating the benefit: cost ratios associated with investments in nutrition requires:

- Identifying a set of interventions that have been demonstrated to reduce dimensions of undernutrition
- Costing these interventions
- Calculating the economic benefits derived from their implementation
- Comparing these benefits and costs through the calculation of Benefit: Cost ratios

Recent work by Bhutta et al (2013) that synthesizes a large body of empirical studies, has identified 10 interventions that will significantly reduce undernutrition. The logic behind these *nutrition-specific* interventions is that well-nourished children require well-nourished mothers and so measures to reduce undernutrition should focus primarily on these two groups. The 10 interventions they identify are:

1. Universal salt iodization
2. Multiple micronutrient supplementation during pregnancy
3. Calcium supplementation during pregnancy
4. Energy protein supplementation during pregnancy
5. Vitamin A supplementation during childhood
6. Zinc supplementation during childhood
7. Breastfeeding promotion
8. Complementary feeding education
9. Complementary food supplementation
10. Management of severe acute malnutrition

Bhutta et al (2013) estimate that scaled up at 90 percent coverage, these interventions would reduce severe acute undernutrition by 61 percent, stunting by 20 percent and, globally, would save nearly one million deaths per year.

The per-child cost of this package is currently estimated to be $118.[2] What about the economic benefits? Suppose we focus on chronic undernutrition. The best estimate of its malign economic impact comes from Hoddinott et al (2013b) who show that controlling for a wide range of confounding factors, in adulthood, per capita incomes of individuals who were not stunted at age 2y were 66 percent higher compared to individuals who were stunted at age 2y. This increase comes about through the impact of improved nutrition on income through higher schooling, better cognitive skills, greater height, reduced fertility and other channels (Hoddinott et al, 2013b). But this package of interventions only reduces stunting by 20 percent and coverage is estimated to be 90 percent. So, on average, implementing this package would raise incomes by 11.3 percent.

Now consider the following. Suppose a country, say Senegal, were to fully implement this package in 2016. We assume the beneficiaries of this package, children under the age of two, enter the labour force 18 years later, in 2034. Median per capita income in Senegal in 2034 is projected to be $2,592. (See Appendix 2 for full details on these calculations.) If this package were implemented, median incomes would be 11.3 percent higher, a gain of $293; in present value (2016) terms using a five percent discount rate, this is an increase of $134. Adding these up from 2034 to 2060 (ie until early middle age) yields an increase in income of $2,499. Given a cost of $118, the benefit cost ratio is 21.2.

Note that the calculation of this Benefit: Cost ratio is sensitive to the discount rate, the costing of the 10 interventions, assumptions regarding the magnitude of the impact on incomes and the duration over which benefits are calculated. Generally, these calculations are constructed so as to be conservative: the cost of the interventions has been raised relative to the data described in Bhutta et al, a relatively high discount rate is used and we only count these benefits until early middle age. These estimates do not take into account additional monetary benefits that certain components of the package generate. For example, universal salt iodization and iron supplementation have direct effects on economic productivity (through improved cognition and work effort respectively) which are not taken into account here. Further, no monetary value is ascribed to reduced morbidity or mortality that results from these interventions.

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[2] Bhutta et al (2013) report a cost of approximately $102 for most African countries. To be bring this up-to-date, I have assumed an inflation rate for these package of 15 percent.

Table 3 reports Benefit: Cost ratios associated with these interventions for 15 African countries.

Table 3: Benefit: Cost Ratios associated with reduction in stunting in 15 African countries

Country	Benefit: Cost ratio
Benin	16.2
Chad	21.6
Ethiopia	16.9
Lesotho	10.8
Madagascar	5.9
Malawi	7.0
Mali	14.2
Niger	17.1
Nigeria	16.8
Rwanda	11.5
Senegal	21.2
Togo	15.8
Uganda	17.4
United Republic of Tanzania	13.9
Zambia	12.6

Source: Author’s calculations.

Any investment with a benefit: cost ratio that exceeds one is a good investment. By this standard, the benefit: cost ratios reported in Table 3 indicate that investments to reduce chronic undernutrition are excellent investments. Even under fairly conservative assumptions –the benefit: cost ratios are high.[3] These economic benefits derive largely because averting chronic undernutrition gives children greater capacity to learn, learning is rewarded in the labour market with higher wages. Not only are they high in absolute terms, they are also high relative to other investments. When asked to rank alternative investments that would improve welfare and economic growth in developing countries four Nobel prize winning economists (Kydland, Mundell, Schelling and Smith) ranked investments in reducing undernutrition ahead of investments in schooling, health and family planning (Kydland et al, 2013).

Beyond nutrition-specific interventions to reduce malnutrition: Social protection and agriculture

It is important to recognize that nutrition-specific investments described above will not, by themselves, generate the reductions in undernutrition needed to meet the 2025 WHA targets. Black et al (2013) and Ruel and Alderman (2013) emphasize that these need to be complemented by

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[3] Note that these BCRs differ slightly from those found in Hoddinott et al (2013a) and in the Global Nutrition Report because of some technical changes in the assumptions used to generate them, most notably the switch to basing these on median (and not mean) per capita incomes.

nutrition-sensitive interventions that will accelerate reductions in undernutrition. Nutrition-sensitive interventions address the underlying determinants of child nutrition and incorporate specific nutrition goals. They can also serve as platforms for delivery of nutrition-specific interventions. Two are particularly relevant to Africa: social protection; and agriculture.

The rapid expansion of social protection interventions, particularly social safety nets - publicly funded, non-contributory transfer programmes targeted to the poor - across Africa represents a major opportunity for nutrition-sensitive programming. There is considerable evidence that these interventions improve household food security – across Africa, the average social safety net programme increases caloric acquisition by 13 percent (Hidrobo et al, 2015). However, there is weak evidence that safety nets, alone, improve nutritional status as measured by chronic or acute undernutrition in young children. This is true if one looks across the entire sub-continent (Manley, Gitter and Slavchevska, 2013) or at specific countries. For example, while Ethiopia's Productive Safety Net Programme (PSNP) – a safety net programme utilizing a mix of public works and unconditional transfers - has been effective at reducing food insecurity, it has had no impact on stunting or wasting (Berhane, Hoddinott and Kumar, 2016). In light of these findings, the Government of Ethiopia have revamped the PSNP to make it nutrition-sensitive. A nutrition goal – improving the quality of diets of children aged 6-24 months (as discussed above, this is an input needed for improving children's nutritional status) has been incorporated as a programme goal and the PSNP has been redesigned to be more nutrition sensitive. For example, starting in January 2016, attendance by men and women at training days run by health and nutrition workers now counts towards households' public work requirements and pregnant and lactating women are exempt from work requirements (Government of Ethiopia, 2014). While it is too early to learn whether such changes will have an impact on child diets or nutritional status, it is instructive in terms of how social protection can be made more nutrition sensitive.

Efforts to revitalize African agriculture are represent an opportunity to extend efforts aimed at improving nutrition. Agriculture can play three interlinked roles in improving nutrition outcomes: it is a source of nutritious foods; it is a source of income that can be used to buy nutritious foods and health care; and where agricultural interventions are undertaken in a gender sensitive fashion, can also be a mechanism for empowering women.

Within African agriculture, the last ten years has seen a resurgence of interest in increasing yields of staples. There are strong economic reasons for doing so – this represents a mechanism for increasing rural incomes and reducing food insecurity. But while these investments are necessary, they are not sufficient to reduce undernutrition. First, a narrow focus solely on yields will have little impact on micronutrient deficiencies. There now exist a range of biofortified staple crops that have been field tested in Africa (iron beans, Vitamin A cassava, Vitamin A maize, Vitamin A sweet potato). These have the potential to reduce micronutrient deficiencies but this potential will only be realized if the dissemination of these crops can be scaled up. Second, there is a growing body of evidence showing that consumption of animal source proteins (eggs, dairy, meat) is needed in order to reduce chronic undernutrition (Semba et al, 2016). Children with access to dairy products, either through home production or through local markets are less likely to be stunted (Hoddinott, Headey and Dereje, 2015). A systematic review by the UN's Food and Agriculture Organization shows that dairy production interventions such as strategies to introduce small livestock and improved breeds of cattle can improve children's nutritional status but that these are more effective when they are targeted to women and include awareness-raising on the nutritional value of milk (FAO, 2013). This emphasis on improving the dietary quality of African agriculture may also be relevant to rising concerns regarding obesity in Africa. While the prevalence of obesity is low in many parts of the sub-continent, it is of concern in southern Africa. These low prevalences, however, should not be a source of complacency as countries in other low and middle income regions have seen rapid increases in obesity over relatively short periods of time. While the causes of this rise are contested, diets that are too high in staples and oils and too low in fruits and vegetables are seen as contributing to obesity. Investments in improving dietary quality may have the benefit of addressing multiple nutritional issues.

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Appendix 1:

Estimating the economic impact of meeting the 2025 WHA target for stunting

Sustainable Development Goal 2 includes the following, “By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age.” This internationally agreed target is the World Health Assembly (WHA) target of a 40 percent reduction in stunting and wasting by 2025. Calculating the economic impact of meeting this goal requires the following information and assumptions:

- How many children would be lifted out of stunting if the WHA target was achieved?
- By what percent does it increase income?
- What are counterfactual incomes?
- What discount rate is used?
- How much does this increase GDP? Over what time frame?

How many children would be lifted out of stunting if the WHA target was achieved?

I begin with the data on stunting prevalence found in the Global Nutrition Report 2015 Country Profiles. I restrict my sample to countries where there is a recent (2010 or later) estimate of the prevalence of stunting. I then calculate how fast stunting would need to fall in order to meet the WHA target. Using UNPD (2015) population projections, I calculate the number of children aged 0-5 projected to be living in each year between 2016 and 2025 and the number of children who would be lifted out of stunting if the WHA target was achieved.

For example, GNR (2015) reports that the prevalence of stunting in Tanzania was 35 percent in 2014; I assume that this had fallen to 34.5 percent by 2015. (Across all African countries, stunting fell by 0.5 percent per year between 2000 and 2012; 35 – 0.5 = 34.5). The WHA target for Tanzania is a fall of 40 percent between 2015 and 2025. In percentage point terms, this is a reduction of 13.8 percentage points (34.5 percent *x* 40 percent). Over the time frame being considered, this requires that stunting falls by 1.38 percentage points per year to meet the 2025 WHA target for Tanzania, a stunting prevalence of 20.5 percent.

Using United Nations Population Division population projections (UNPD, 2015), I calculate the number of children aged 0-5 projected to be living in Tanzania in each year between 2016 and 2025. This is shown in column (2) in Table A2.1 below. I then calculate the baseline number of children projected to be stunted if Tanzania were on track to reach the 2025 WHA goal. For example, in 2016, UNPD projects that there will be 9,652,125 children aged 0-5y in Tanzania. The stunting prevalence if Tanzania were on target to reach the WHA goal is 33.1 percent (column (3)). The difference between the 2015 and 2016 stunting prevalences is 1.4 percentage points (=34.5 - 33.1). Multiplying this by the number of children implies that the number of children aged 0-5y who would be lifted out of stunting in 2016 is 133,199 (column (3)). As Black et al (2013) and Bhutta et al (2013) note, actions that prevent children from becoming stunted must occur *in utero* or in the first two years of life. The literature does not provide guidance on exactly when this occurs within these 1000 days; we assume that 2/3rds of the prevented stunting occurs in children born in 2016 (Cohort 1) and the remaining 1/3rd to children born in 2015 (Cohort 0). This means that 45,288 children in Cohort 0 are not stunted and 87,192 children in Cohort 1.

When we repeat this exercise for 2017, we find that the projected number of children not stunted is 273,146. This number is based on a set of children age 0-5y. Some of the children who are now not stunted are those who had been shifted out of stunting in 2016 but are still in the age range 0-5y. So the number of *new* children not stunted is the projected number of children stunted (column 4) less the number of children switched out of stunting in the previous year, 2016. We again assume that these new children who are not stunted are a mix of children aged 1-2 years in 2017 (Cohort 1, - these are the children born in 2016) and children born in 2017 (Cohort 2) using the same proportions used for 2016. This means that an additional 47,581 children in Cohort 1 are not stunted and 92,365 children in Cohort 2. In 2016 and 2017, a total of 135,493 children in Cohort 1 (87,192 + 47,581 = 135,493) are not stunted as a consequence of efforts to work towards the WHA target. We repeat this exercise for each year until 2025, taking into account the fact that as we move forward in years, some of the earlier cohorts begin to drop out; see column (5). Table A2.2 shows the number of children not stunted by cohort.

Table A2.1: Number of children projected to be not stunted by year, Tanzania

(1)	(2)	(3)	(4)	(5)
Year	Projected Number of children, 0-5y	Projected prevalence of stunting	Projected number of children not stunted under progress toward WHA 2025 *by year*	Cohort for whom stunting has been averted
2015	-	0.345	-	0
2016	9,652,125	0.331	133,199	1, 0
2017	9,896,598	0.317	273,146	2, 1, 0
2018	10,085,392	0.304	417,535	3, 2, 1, 0
2019	10,273,440	0.290	567,094	4, 3, 2, 1, 0
2020	10,460,856	0.276	721,799	5, 4, 3, 2, 1
2021	10,647,074	0.262	881,578	6, 5, 4, 3, 2
2022	10,832,036	0.248	1,046,375	7, 6, 5, 4, 3
2023	11,016,000	0.235	1,216,166	8, 7, 6, 5, 4
2024	11,198,880	0.221	1,390,901	9, 8, 7, 6, 5
2025	11,525,120	0.207	1,590,467	10, 9, 8, 7, 6

Source: Author’s calculations.

Table A2.2: Number of children projected to be not stunted by cohort, Tanzania

(1) Cohort	(2) Projected number of children not stunted under progress toward WHA 2025 *by cohort*
0	45,288
1	135,493
2	141,157
3	146,147
4	166,706
5	232,388
6	299,006
7	309,547
8	324,609
9	372,215
10	285,089

Source: Author's calculations.

By what percent does it increase income?

Hoddinott et al (2013b) report that switching someone from being stunted at age 24 months to being not stunted at age 24 months raises their per capita consumption in adulthood (consumption is a proxy for income; it is less susceptible to measurement error and is a less volatile measure) by 66 percent. This increase comes about through the impact of improved nutrition on income through higher schooling, better cognitive skills, greater height, reduced fertility and other channels (Hoddinott et al, 2013b). Assume that in practice, the increase in income is much less, say only one-third of this. This is roughly equivalent to African estimates of the gain in incomes through the schooling channel alone (1.25 grades; see Alderman, Hoddinott and Kinsey, 2006) multiplied by the current estimates of returns to schooling in Africa (13.4 percent, see Montenegro and Patrinos, 2013).

What are counterfactual incomes?

We begin with a current estimate of per capita incomes, specifically median per capita incomes reported in PPP dollars as calculated by Diofasi and Birdsall (2016) for countries where current estimates (2010 or later) are available. Earlier, related, work (see Hoddinott et al, 2013a) used mean per capita incomes but this is problematic for countries with significant levels of inequality as it overstated the benefit streams from investing in nutrition. The median tells us how much the "typical" African earns (or consumes) in a year. These data are reported in PPP dollars; the PPP conversion factors reported in the World Bank development indicators database to convert the median per capita incomes to nominal US dollars.

Individuals are assumed to enter the labor force when they turn 18. This means that the children in cohort 1 enter the labor force in 2034, children in cohort 2 enter the labor force in 2035 and so on. What will their incomes be in that year in the absence of these interventions? I take these median per capita incomes and apply the projected economic growth rates for Africa for the period 2015-2060. This growth rate, calculated by the IMF and World Bank (and used on other projection exercises such as those associated with climate change projections), is 3.5 percent per year. As an example, for Tanzania, estimated per capita median income in 2034 will be (in nominal US dollars), $1,705.

What would their incomes be in that year if these interventions were implemented? Based on the assumption that wages are raised by 22 percent, for Cohort 1 in Tanzania, per capita median income in 2034 would be ($1,705 + ($1,705 x 22%)) $2,080. The increase in income is $375. For Cohort 1, this increased income is calculated for every year from 2034 to 2060; for Cohort 2, it is calculated for every year from 2035 to 2060, and so on.

What discount rate is used?

Because benefits accrue in the future, what discount rate should be used to estimate the present value of these benefits? The answer depends heavily on the extent to which the welfare of future generations is taken into account when making investment decisions – such as investments in the reduction of stunting – today. Based on this logic, the discount rate set for investments in climate change reduction use a low discount rate, 1.5% (Sunstein and Weisbach, 2008). Alternatively, a "cost of capital" approach would argue that the discount rate should be set at the interest rate at which the public sector can borrow on capital markets (Koyhama, 2006). For development partners such as the United States, this implies a discount rate of 3%. Finally, if the public sector investment is perceived to displace private investment, then it is argued that a higher interest rate be used with 5.5% and 7% being rates suggested in the extant literature (Koyhama, 2006; Sunstein and Weisbach, 2008). While there is a strong case for using either 1.5% or 3% (as there is unlikely to be significant displacement of private sector investment), to be conservative the discount rate is set at 5%. Discounting is done back to 2016 so all monetary figures are expressed in 2016 US dollars.

How much does this increase GDP? Over what time frame?

For these 11 cohorts, I calculate the increase to GDP from the year they enter the labour force to 2060. So for example, Cohort 1 enters the labour force in 2034. In this year, the increase in income is $375 (see above); in present value (2016) terms, this is $172. There are 135,493 children in this cohort (these are the children who are not stunted because of preventative actions that occurred when they between 0 and 2 years of age) see Table A2.1, column (6)) so the increase in income for this cohort in 2034 is 135,130 *x* $172 = $23,223,226. For Cohort 1, I undertake this calculation for every year from 2034 to 2060. For Cohort 2, who enter the labour force a year later, in 2035, I undertake this calculation for every year from 2035 to 2060 and so on. I then add up these increases in income across years and cohorts.

Which countries can this increase be calculated for?

These calculations require data on median per capita consumption dated 2010 or later, data on population size and projected population growth and data on the prevalence of stunting dated 2010 or later. Twenty countries meet these criteria. However, for several countries there are reasons to expect that these median incomes are not a good guide either because of subsequent health crises (Ebola in Guinea), civil unrest (Democratic Republic of Congo; Guinea-Bissau) or because the economy is heavily reliant on mining (South Africa, Namibia). This leaves the following countries: Benin; Chad;

Ethiopia; Lesotho; Madagascar; Malawi; Mali; Niger; Nigeria; Rwanda; Senegal; Togo; Uganda; United Republic of Tanzania; and Zambia.

Appendix 2:

Estimating Benefit: Cost Ratios associated with reduction in stunting:

These benefit: cost ratios (BCRs) focus on the economic benefits associated with the reduction of stunting created by investing in nutrition-specific interventions. Calculating these requires the following information and assumptions:

- What is the time frame over which these calculations are made?
- How much does the intervention cost?
- What percent of the population will it reach?
- How effective is the intervention?
- By what percent does it increase income?
- What is the counterfactual – what would incomes be in the absence of this intervention?
- Because benefits accrue in the future, what discount rate is used to estimate the present value of these benefits?

What is the time frame over which these calculations are made?

These calculations are based on a cohort of individuals born in the year 2018. It is assumed that they enter the workforce at age 18 (ie in 2036). I calculate benefits based on their first 17 years of employment in the labour force, that is benefits obtained until age 42 (ie in 2060). Allowing benefits to accrue over a longer period of time will increase the BCRs; reducing the time period would reduce them.

How much does the intervention cost?

The 10-item intervention package described in Bhutta et al (2013) is estimated to cost on a per child basis, for African countries, $102.50 in 2013. It is reasonable to assume that because of inflation, the cost of this has risen; it is (somewhat arbitrarily) assumed that in 2018 (when it is first implemented – see time frame above), because of inflation this cost would increase by 15%, ie to $117.88.

What percent of the population will it reach?

In the work by Bhutta et al (2013), they assume that these interventions, scaled up, would reach 90 percent of children.

How effective is the intervention?

Bhutta et al (2013) estimate that this package of interventions would reduce stunting by 20 percent.

By what percent does it increase income?

Hoddinott et al (2013b, *AJCN*) show that switching someone from being stunted at age 24 months to being not stunted at age 24 months raises their per capita consumption in adulthood (consumption is a proxy for income; it is less susceptible to measurement error and is a less volatile measure) by 66 percent. But recall that the implementation of this intervention package reduces the prevalence of stunting by only 20 percent and that coverage in practice is estimated to be 90 percent. So on average, the implementation of this package raises incomes by (66% x 0.20 x 0.90) = 11.8%.

What are counterfactual incomes?

We begin with a current estimate of per capita incomes, specifically median per capita incomes reported in PPP dollars as calculated by Diofasi and Birdsall (2016). Earlier estimates of these BCRs used mean per capita incomes but this was problematic for countries with significant levels of inequality as it overstated the benefit streams from investing in nutrition. The median tells us how much the "typical" African earns (or consumes) in a year. These data are reported in PPP dollars; our cost data are in nominal US dollars. I use the PPP conversion factors reported in the World Bank development indicators database to convert the median per capita incomes to nominal US dollars.

Next, recall that the individuals benefitting from these interventions do not start working until the year 2036. What will their incomes be in that year in the absence of these interventions? I begin by taking these median per capita incomes and applying the projected economic growth rates for Africa for the period 2015-2050. This growth rate, calculated by the IMF and World Bank (and used on other projection exercises such as those associated with climate change projections), is 3.5 percent per year. Using this growth rate, I estimate per capita median income in 2036. As an example, for Senegal I estimate that per capita median income in 2038 will be (in nominal US dollars), $2,975.

What would their incomes be in that year if these interventions were implemented? Based on the estimated impact of investing in this package of interventions, they raise incomes by 11.8 percent. So if these interventions in Senegal took place, per capita median income in 2038 would be ($2,975 + ($2,975 x 11.8%)) $3,311. The increase in income is $336. I calculate this increase in income for every year from 2036 to 2060.

What discount rate is used?

For reasons given in Appendix 1, a five percent discount rate is used. Note that a higher discount rate would lower BCRs; a lower discount rate will increase BCRs.

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