Cost-benefit analysis of an early childhood nutrition intervention to prevent stunting in Haiti

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Abstract

We conduct a cost-benefit analysis of a package of nutrition interventions targeting pregnant women and children that can reduce the prevalence of stunting in Haiti. Results indicate that if this package can reach 90% of a given birth cohort, it will prevent 10,350 cases of stunting, save 474 lives and avoid 412,000 episodes of illness over five years. For those children who avoid being stunted it will deliver consumption benefits equivalent to eight times GDP per capita in present value terms, at a 5% discount rate. The paper tests the effects of various methodological choices on the valuation of avoided mortality, avoided morbidity and lifetime productivity. In the base case scenario, the net benefits of the intervention are 17,921 HTG per child reached, and the benefit-cost ratio is 2.4. The various valuation approaches create significant variation in the results, with a high to low range 51% as large as the central estimate. However, this is smaller than the variation resulting from other sources of uncertainty such as the choice of discount rate, and the inherent impact of the intervention on stunting, health and lifetime productivity outcomes. These sources of uncertainty generate a range of net benefits estimates which span up to 167% of the central estimate.

Note to reader: This first draft was completed in parallel with methods papers in the BCA Reference Case series and may not have incorporated the latest recommendations from those papers. Results of this case study could change significantly depending on the recommendations arising from final drafts of these methods papers.

1. Introduction

Haiti has the poorest health and education outcomes in the Western Hemisphere. The infant mortality rate (51 deaths per 1000 live births in 2016) is three times higher than the Latin America and Carribean (LAC) average, while the maternal mortality rate (359 per 100,000 live births) is five times higher than the regional benchmark. A Haitian child born today is expected to live for 63 years, about 10 years less than a child born in the neighboring Dominican Republic (World Bank, 2017). In terms of education, the adult literacy rate in 2015 was 61% while the Caribbean average was 92%. The literacy rate for youth aged 15-24 is better at 82%, but still very low compared to its neighbors. For a country hunting for sources of economic growth, the future economic development of the country will require an improved human capital base. One-third of the population is under the age of 15. If these children do not achieve reach higher standards of health and education, their prospects and the prospects of their country are bleak. That would be the assessment even if the country had not also experienced crippling earthquakes and hurricanes.

At the same time, the available resources to solve Haiti's myriad problems are not particularly large. In 2016 the government had expenditures of $1.9bn USD (CIA Factbook, 2016) while donors spent roughly $1bn (aidflows.org) for total public resources of only $270 USD per capita. Cost-benefit analysis is one useful tool to determine effective uses of Haiti's limited funds. It is against this backdrop that this paper undertakes a cost-benefit analysis of an intervention that addresses both health and education challenges of Haiti, and has the potential to be an effective use of funds: the provision of a package of nutrition and micronutrients to reduce stunting.

An analysis of this package is motivated by the fact that the intervention has been assessed as one of the most effective use of development funds globally[1] but a cost-benefit analysis has not been previously undertaken in the Haitian context to the best of our knowledge. Additionally,

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[1] This package of interventions, or variations of it, has been ranked highly in previous Copenhagen Consensus exercises. It was the top ranked intervention in the 2008 Copenahgen Consensus II (Horton, Alderman and Rivera, 2008) and 2012 Copenhagen Consensus III exercises (Hoddinott, Rosegrant and Torero, 2012) and the third ranked intervention in Bangladesh Priorities project in 2016 (Rose and Zaman, 2016). In the Post-2015 Consensus, the intervention was partial justification for assigning 'Reduce stunting by 40%' as one of the top 19 targets that the world should focus on over the 15-year period from 2016-2030 (Horton and Hoddinott, 2014).

undertaking a cost-benefit anlaysis of this intervention is useful for the purposes of the Gates BCA Reference Case exercise, as it includes three types of benefits – avoided mortality, avoided morbidity and lifetime productivity – as well as immediate and longer term benefits. This allows us to test the effects of various valuation methods and discounting assumptions on the results.

In our base case scenario, results indicate that the provision of this package is an effective use of development money, with net benefits of 17,921 HTG ($283 USD)[2] per child and a benefit-cost ratio of 2.4. Assuming 234,000 children or 90% of a given birth cohort can be reached, the intervention will prevent 10,350 cases of stunting, save 474 lives and avoid 412,000 episodes of illness over five years. The package would reduce stunting from 22% to 17.4% if implemented nationally over multiple years. For those children who avoid being stunted the estimated life-long consumption benefits are very large, equaling eight times GDP per capita in net present value terms (at 5% discount rate). Fifty two percent of the benefits are due to improvements in lifetime productivity, 45% due to avoided mortality and the remainder are avoided morbidity. Despite these impressive benefits, the package is not as effective as other uses of development money, and is not likely to be the most effective nutrition, health or education intervention in the Haitian context.

Additional analyses indicate that the results are sensitive to the choice of valuation methods adopted. In this study, we estimate the Haitian VSL using benefit transfer approach suggested by the methods paper, using a default estimate of 170x GNI per capita PPP and a low-end estimate of 80x GNI per capita PPP. These correspond to a Haitian VSL of 7.6m HTG and 3.6m HTG. We also assess the effects of valuing years of life lost (YLLs) rather than lives saved. For valuing mordbidity we adopt a benefit transfer approach using a willingness-to-pay study conducted in rural China (Guh et al., 2008) as well as a standardized value per year lost to disability (YLD), adjusting for costs borne by third parties. At the 5% discount rate, adopting the valuation methods that maximize health benefits leads to net benefits of 19,828 HTG ($313 USD) while adopting valuation methods that minimize health benefits results in net benefits of 10,714 HTG ($169 USD). This high to low range of 9,114 HTG ($144 USD) is 51% as large as the central estimate.

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[2] Throughout this study we use the following 2016 exchange rates sourced from the online World Bank database: 1 USD = 63.34 HTG and 1 HTG = 25.03 Int$. Unless otherwise stated all currency figures are in 2016 dollars, gourdes or international dollars.

However, this is smaller than the variation resulting from other methodological, statistical and epistemtic sources of uncertainty such as the choice of discount rate, and the inherent impact of the intervention on stunting, and the likely impact of stunting on health and lifetime productivity outcomes. These sources of uncertainty generate a range of net benefit estimates that span up to 167% of the base case estimate.

[note to reader: in future drafts we will conduct analysis of distribution of costs and benefits].

The rest of this case study is structured as follows: in the next section we outline the nutrition status of Haiti, and review the impacts of stunting on health and productivity. Section 3 describes the nutrition package and its effect on stunting. In Section 4 we undertake the cost-benefit analysis, including sensitivy analyses. Section 5 concludes and discusses uncertainties in the valuation approaches.

2. Stunting

2.1 Stunting in Haiti

Stunting is assessed by measuring the height for age of a child and comparing that metric to WHO Child Growth Standards to construct a z-score. A child is considered mildly stunted if she has a height for age z-score (HAZ) between -2 and and -1, moderately stunted if her HAZ is between -2 and -3, and severely stunted if her HAZ < -3. About 22% of children under the age of five years in Haiti were moderately or severely stunted in 2012. This compares to 7% in neighboring Dominican Republic in 2013 and 11% in the Latin American and the Caribbean region in 2014 (World Bank, 2017). In addition, 27% of children under 5 in Haiti were mildly stunted in 2012. Prevalence of moderate and severe stunting among rural children was substantially higher than among urban children, and children from the poorest quintile of households were nearly 5 times more likely to be stunted than children from the richest quintile of households (Table 1).

Table 1. Prevalence of stunting among children under five years in Haiti, 2012

	Moderate and Severe	Moderate	Severe
National	21.9%	14.1%	7.8%
Urban	15.8%	10.3%	5.5%
Rural	24.7%	15.8%	8.9%
Poorest Quintile	31.0%	18.1%	12.9%
Richest Quintile	6.6%	4.5%	2.1%

Source: Haiti EMMUS-V 2012.

2.2 The effects of stunting on health

Child undernutrition has long been associated with increased risk of child mortality (Fishman et al., 2004; Black et al., 2008; Olofin et al, 2013; Forouzanfar et al., 2016). Estimates of increased risk of all-cause and cause-specific mortality in children under five years of age with mild, moderate and severe stunting are presented in Table 2 based on Olofin et al (2013)[3].

The evidence indicates that severely stunted children are over 5-6 times more likely to die in early childhood from all-cause mortality and diarrheal disease and acute lower respiratory infection (major causes of mortality among children under five) than non-stunted children. Even moderately stunted children are 46-67% more likely to die from these causes than non-stunted children.

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[3] The interested reader can consult Olofin et al (2013) and the references in that paper for a more detailed description of the evidence behind these relative risk estimates.

Table 2. Relative risk of mortality from stunting in children under five years of age

	Severe	Moderate	Mild	None
All-cause mortality	5.48	2.28	1.46	1.00
Diarrhea	6.33	2.38	1.67	1.00
ALRI	6.39	2.18	1.55	1.00
Measles	6.01	2.79	1.25	1.00
Malaria	1.92	1.06	0.74	1.00
Other infectious diseases	3.01	1.86	0.95	1.00

Source: Olofin et al (2013). ALRI is acute lower respiratory infections. Other infectious diseases include septicemia, febrile illness, tuberculosis, cellulitis, hepatitis and meningitis. Severe stunting refers to a HAZ less than -3. Moderate stunting refers to a HAZ between -2 and -3. Mild stunting refers to a HAZ between -1 and -2. Relative risks are in relation to stunting according to the WHO Child Growth Standards.

In terms of morbidity several studies across a range of environments have demonstrated an association between stunting and increased diarrheal incidence and duration. Tomkins (1981) shows that stunting leads to a 37% increase in diarrheal duration for pre-school children in rural Nigeria. Schorling et al. (1990) show that worsened nutritional outcomes, as measured by weight and height for age scores, predict increase diarrheal disease among children in an urban Brazilian slum. The results of El Samani et al. (1988) indicate that stunting increases odds of diarrheal incidence by 40% in rural Sudan. A recent systematic review suggests that malnutrition weakens the immune system, which is the likely cause of increased mortality and morbidity risk when exposed to childhood diseases (Rytter et al. 2014). Over the long-term, stunted children also experience increased risk of metabolic diseases in later life, particularly in cases where stunting is followed by over-consumption of calories in adulthood as has occurred in many countries that have moved rapidly up the development ladder such as in India (Prendergast and Humphrey, 2014).

2.3 The effects of stunting on cognitive development and lifetime productivity

There is a wealth of evidence that stunting detrimentally affects cognitive and phsyical development in childhood (Prendergast and Humphrey, 2014; Bhutta et al, 2013). Iannotti et al. (2016) provide Haitian specific evidence of this effect. They follow 583 Haitian 6-11 month old children from an urban slum in Cap-Hatien for one year and find that linear growth is predictive of faster achievement of motor and language skills, even after controlling for a range of maternal and child characteristics.

Due to the long period of time that must elapse between provision of nutrition in childhood and their adolescence and adulthood, only a handful of studies have been able to robustly estimate the long-term consequences of not being stunted on schooling and lifetime productivity (see McGovern et al., 2017 for a recent, thorough review of the evidence). The seminal studies in this genre are by Hoddinott et al (2008) and Hoddinott et al (2011). Both studies concern a group of Guatemalen children who were provided with protein supplementation (atole) in 1969-1977 and were tracked down and identified in 2002-2004. Compared to a control group that were provided only with no protein (fresco), the treatment cohort had 25-percentage points (45% versus 20%) lower prevalence of *severe* stunting. The 2008 study indicates that non-stunted men had 46% higher wages than stunted men, while there was no difference in wages for women. The 2011 study shows that men have 20% higher hourly earnings for each 1 S.D. increase in HAZ scores, while for women the increase is 7.2% but it is not statistically significant.

However consumption, not wages are the primary indicator of welfare. Given that the benefit of linear growth in childhood might not show up in the labour market but the marriage market (particularly for women) the authors also estimate per capita consumption between treatment and control groups. Those who were stunted as children had 66% lower per capita consumption 35 years later compared to their non-stunted peers.

Victora et al (2008) summarise the available findings (at that time) from longditudinal cohort studies in Brazil (Victora et al, 2003), Guatemela (Martorell et al, 2005; Grajeda et al 2005) and India (Sachev et al. 2005; Bhargava et al, 2005) of childhood HAZ on future income and assets. They note that a 1-point HAZ increase at age two is associated with 8% higher wages in Brazil, 8-25% higher wages in Guatemela and 18-27% more assets in India at adulthood.

Interestingly the results of Gertler et al (2015) provide evidence that the effects of stunting may be completely or partially reversible through early childhood pyscho-social stimulation. The results of that study suggest that stunting in Jamaica was associated with a 25%-35% decrease in wages.

Several studies have shown that reduction in stunting leads to higher education attainment, which is a strong indicator of future wages. Nandi et al (2016) show that children in villages near the city of Hyderabad provided with a supplementary feeding program were 7.8% more likely to be enrolled in school and completed 0.84 more years of schooling 16 years later compared to control villages. Victora et al (2008) using the aforementioned studies from Brazil, Guatemela and India and also including cohort studies from Phillipines and South Africa show that an increase in 1 S.D. HAZ at age two leads to 0.5 years of extra schooling. In the Haitian context 0.5 to 0.84 years of schooling would correspond to 4-7% increase in wages, according to the latest wage data (ECVMAS, 2012).

There is ample evidence that stunting reduces lifetime schooling, earning capacity and consumption. The most econometrically robust evidence comes from Hoddinott et al. 2011, which indicates a 66% consumption boost from not being stunted.

3. Intervention description

Bhutta et al (2013) describe a package of ten evidence-based interventions to address various forms of undernutrition, some elements targeted at pregnant women / women of reproductive age, others targeted at children aged 0-2 and one, salt iodization, targeted at the entire population. The authors estimate that scaling up this package of interventions to 90% coverage rates of the target population in 34 countries will result in 20.3% reduction in stunting as well as avoiding 1,000,000 under 5 deaths. The interventions, target population and total cost in 2010 Int$ are summarized in Table 4.

Table 4 – Package of interventions to improve maternal and child nutrition, target and beneficiary populations and estimated costs to scale up to 90% coverage in 34 countries

Intervention	**Intervention population**	**Beneficiary population**	**Cost, 2010 Int$, millions**
Salt iodization	Whole population	Whole population	$68
Multiple micronutrient supplementation in pregnancy, including iron folate	Pregnant women	Pregnant women and children in utero	$472
Calcium supplementation in pregnancy	Pregnant women	Pregnant women and children in utero	$1914
Energy protein supplementation in pregnancy	Pregnant women	Pregnant women and children in utero	$972
Vitamin A supplementation in childhood	Children 6-59 months	Children 6-59 months	$106
Zinc supplementation in childhood	Children 12-59 months	Children 12-59 months	$1182
Breastfeeding promotion	Mothers of children aged 6-23 months	Children aged 6-23 months	$653
Complementary feeding education	Mothers of children aged 6-23 months	Children aged 6-23 months	$269
Complementary food supplementation	Mothers of children aged 6-23 months	Children aged 6-23 months	$1359
SAM Management	Children 6-23 months severely wasted	Children aged 6-23 months	$2563
TOTAL			$9559

Source: Adapated from Bhutta et al (2013).

Bhutta et al (2013) summarise the evidence for the components of the intervention on various health outcomes including low birth weight, linear growth, stunting, wasting and others. Epiodeomological modeling in that paper suggests a reduction in stunting of 20.3% from the package. However only three components out of the ten have an evidence base that allowed for an estimation of impact on stunting: complementary food supplementation, complementary feeding education and zinc supplementation. Table 5 belows shows the odds ratios used by Bhutta et al (2013) to estimate the reduction in stunting from the package.

Table 5 – Odds ratio of stunting for selected sub-interventions and costs

Intervention	**Odds ratio** (95% confidence interval)	**Cost, 2010 Int$, millions**
Zinc supplementation in childhood	0.90 (0.83 - 0.96)	$1182
Complementary feeding education for food secure	0.70 (0.49 – 1.01)	$269
Complementary food supplementation and education for food insecure	0.33 (0.11 – 1.00)	$1359
TOTAL for these three components		$2810

Adapated from the online appendix to Bhutta et al (2013)

The greatest reduction in odds of stunting occurs when food insecure households are provided with complementary feeding supplementation and education. In Haiti 38% of the population is food insecure. Among 6-23 month old children, only 14% receive the Infant and Young Child Feeding (IYCF) recommended amount of nutrition, 29% have sufficiently diversified diets and 44% receive an IYCF recommended amount of meals per day (Ministry of Public Health and Population, 2013). Iannotti et al. (2014) showed that a lipid-based nutrient supplement (LNS[4]) with zinc and other vitamins provided to Haitian children for 6 months increased linear growth

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[4] While not technically part of the Bhutta et al (2013) package, LNS is sometimes considered a means to enhance complementary feeding

relative to a control group who received no LNS and a set of children who only received the LNS for 3 months.

However, evidence is emerging that approach and context matters greatly when assessing the ability of these interventions to reduce stunting. In Haiti, targeting all children from 6-23 months with a feeding and education intervention had greater impact on stunting than the same intervention targeted at underweight children presenting between 6-59 months (Ruel et al., 2008). The results from Hirvonen and Hoddinott (2016) indicate that access to food markets is critical for complementary feeding promotion to be effective in diversifying diets and reducing stunting. Homestead food production of animal source foods can aid in providing the dietery diversification that reduces stunting risk (Hoddinott, Headey and Dereje, 2015; Hirvonen and Headey, 2016). However, the strategy may not be effective when animals and children share the same living space (Headey and Hirvonen, 2016). Additional evidence from Malawi indicates that LNS did not reduce stunting in that setting (Maleta et al, 2015) and were only mildly effective in increasing height in a similar trial in Ghana (Adu-Afarwuah et al, 2015). In interpreting the results, the authors speculate that the causes of stunting are multi-faceted and they may not be easily reduced by singular interventions.

To the extent that poor infrastructure limits access to markets, risky animal husbandry practices increase pathogen transmission between animals and children, and general poverty reduces the ability of families to adequately feed their children, the effects of the intervention may be diminished in the Haitian context. To account for this, we also present results using the low and high end of the Bhutta et al (2013) estimate in sensitivity analyses.

4. Cost-benefit analysis

4.1 Discount rates

[Note to reader: this section will be updated with any recommendations arising from the methods papers]. In this study we use discount rates of 3%, 5% and 12% Three percent is used since it is a common value adopted in health economics papers. Five percent is used since it is also common, and used in other cost-benefit analyses of this intervention (Hoddinott et al. 2013, Horton and Hoddinott, 2014). The use of a 12% discount rate is based on the advice of a counsel of senior Haitian economists who suggested this value as an appropriate social discount rate for the country. This counsel was gathered for the *Haiti Priorise*[5] exercise conducted by the Copenhagen Consensus.

4.2 Costs

In previous analyses, the cost of this intervention for a range of developing countries has been estimated at around $100 per child for a two-year program in 2010 Int$ (Bhutta et al., 2013; Hoddinott et al., 2013; Horton and Hoddinott, 2014). Several factors, such as poor infrastructure, a fragmented health landscape consisting of private, public and NGO facilities working in isolation and limited government administrative capacity, mean that costs are likely to be higher for Haiti.

We use studies in the *Haiti Priorise* series to calibrate costs of this package. Engle-Stone et al. (2017) perform a cost-benefit analysis of micronutrient provision to pregnant women and find a cost of 2660 HTG to deliver micronutrients *and* calcium supplementation. That paper also identifies a cost of 320 HTG per child provided with multiple micronutrients, including Vitamin A. Costs in that paper were estimated using an 'ingredients approach': identifying and modeling the individual components – transport, packaging, storage, supplements, health workers to deliver the interventions at scale – and verifying costs with organizations working 'on-the-ground' in Haiti. We use the costs from this paper, for the elements in the Bhutta et al. (2013) package that are the same.

We do not have costs for the other parts of the package, so we use these two unit cost figures as reference points with which to estimate the full intervention cost in the Haitian context. Bhutta et al. (2013) present unit cost estimates for each of the components in an appendix (page 31) and adjust these costs based on the proportional delta suggested by the *Haiti Priorise* studies. For the purposes of this exercise we take Bhutta et al.'s AFRO D region costs to be the relevant comparator for Haiti.

For those components where the intervention is delivered directly to mothers, we compare the unit cost of that component to the $6.15 + $18.89 = $25.04 (2010 Int$) required for

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[5] *Haiti Priorise* is a research and advocacy project conducted by the *Copenhagen Consensus* over the period 2015 to 2017. The project commissioned 42 cost-benefit analyses papers across 18 topic areas covering key Haitian policy questions. For more information see www.haitipriorise.com

micronutrient and calcium provision to pregnant women as indicated in Bhutta et al (2013). That fraction is then multiplied by 2660 HTG unit cost for micronutrient + calcium provision estimated in Engle-Stone et al (2017) to estimate the unit cost of other components directed at mothers in Haiti. For example, breastfeeding promotion has a unit cost of $14.32 (2010 Int$) in Bhutta et al., which is 57% of the unit cost of providing micronutrients and calcium. So we assume in Haiti that breastfeeding promotion has a unit cost of 57% * 2660 HTG = 1521 HTG per pregnant woman. The same approach is applied to components directed at *children* using the 320 HTG for micronutrient supplementation as the reference unit cost for Vitamin A supplementation.

Lastly, community management of severe acute malnutrition (SAM) and salt iodization represent unique cases that need to be considered differently. Since management of SAM is a treatment as opposed to a preventative intervention costs are adjusted as per Hoddinott et al., 2013 by multiplying the cost of SAM treatment by twice the prevalence rate in Haiti. Another *Haiti Priorise* paper, Vosti and Adams (2017) estimate a cost of treatment for SAM at 6334 HTG per wasted child and we multiply this by twice the prevelance rate of 1.3% for a unit cost of 165 HTG. In effect, this amortizes the high unit cost of SAM treatment over a wider universe of children who will receive the preventative regime. For salt iodization we assume a cost equal to 2 HTG per child treated. This is the unit cost identified in Hoddinott et al. 2013, adjusted for inflation and converted to gourdes at market rates.

The estimated unit costs for the intervention are 13,795 HTG per child, or $218 USD presented in Table 5.

Table 6 – Estimated costs per child

Intervention	**Unit Cost, Bhutta et al (2013) AFRO D region 2010 Int$**	**Estimated unit cost for Haiti, 2016 HTG**	**Estimated unit cost for Haiti, 2016 USD**	**Basis for estimation**
Salt iodization	$0.06	2.00	$0.03	Following Hoddinott et al, 2013 adjusted for inflation
Multiple micronutrient	$6.15	2660	$42.00	Estimated in Engle Stone et al.

supplementation in pregnancy, including iron folate				(2017)
Calcium supplementation in pregnancy	$18.89	Incl. above	Incl. above	Estimated in Engle Stone et al. (2017)
Energy protein supplementation in pregnancy	$25.0	2,656	$41.93	Proportional increase based on 2660 HTG to deliver MMN and Ca to pregnant women in Haiti
Vitamin A supplementation in childhood	$2.85	320	$5.05	Estimated in Engle Stone et al. (2017)
Zinc supplementation in childhood	$5.90	600	$9.47	Proportional increase based on 320 HTG to deliver Vitamin A to children in Haiti
Breastfeeding promotion	$14.32	1,521	$24.02	Proportional increase based on 2660 HTG to deliver MMN and Ca to pregnant women in Haiti
Complementary feeding education	$5.27	560	$8.84	Proportional increase based on 2660 HTG to deliver MMN and Ca to pregnant women in Haiti
Complementary food supplementation	$50	5,312	$83.86	Proportional increase based on 2660 HTG to deliver MMN and Ca to pregnant women in Haiti
SAM Management	n/a	165	$ 2.60	6344 HTG per child treated estimated in Vosti and Adams (2017) multiplied by twice prevalence rate of 1.3% as per Hoddinott et al, 2013
TOTAL		13,795 HTG	$218	

For cost estimation purposes, we assume all pregnancy related interventions and salt iodisation occur in the year before the child is born, while the remaining cost is split across the first and second years of the child's life.

4.3 Benefits from avoided mortality

The intervention is targeted at pregnant mothers in 2016, and the subsequent cohort of children born in 2017. It is assumed to reduce the likelihood of mild, moderate and severe stunting by 20.3% based on Bhuttta et al (2013) resulting in lowering of stunting prevalence for that cohort (Table 7).

Table 7. Pre-and post-intervention prevalence of stunting among children under five in Haiti

	Pre-intervention prevalence of stunting	Intervention effectiveness	Post- intervention prevalence of stunting
Severe	7.8%	-20.3%	6.22%
Moderate	14.1%	-20.3%	11.24%
Mild	26.6%	-20.3%	21.20%
None	51.5%		61.3%

Source: Pre-intervention prevalence is from Haiti EMMUS V 2012. Post-intervention prevalence is calculated based on intervention effectiveness.

The potential impact fraction (PIF) is applied to estimate the change in mortality from a change in the stunting prevalence distribution:

$$PIF_j = \frac{\sum_{i=1}^{n} P_i RR_{ji} - \sum_{i=1}^{n} P_i^{'} RR_{ji}}{\sum_{i=1}^{n} P_i RR_{ji}} \qquad (1)$$

where RR_{ji} is relative risk of mortality from cause, *j*, for children in each of the stunting categories, *i*, in table 2; and P_i and P'_i are the pre- and post-intervention prevalence rate of stunting in Table 7.

Change in mortality (M), or annual deaths avoided from the intervention is then:

$$M = \sum_{j=1}^{j=m} PIF_j D_j \qquad (2)$$

where D_j is baseline annual deaths from cause, *j*, among the cohort at a given age. D_j is taken from the Global Burden of Disease 2016 (GBD 2016) for Haiti. We analyse the baseline annual deaths for the first year of life separately to ages 1-4. Since we only have data aggregated for the entire 1-4 cohort, we assume that deaths, DALYs and YLDs are split equally across these years. While Olofin et al. (2013) present cause specific risk reductions for malaria and measles, these diseases are almost non-existent in Haiti for children under 5, according to GBD 2016. Benefits from their reduction are not presented in the tables that follow because the values are trivially small. Table 8 presents the deaths avoided for every 1000 children reached by the intervention. The results suggest the package would avoid about 2 deaths per 1000 before the recipients' fifth birthdays, with most of the benefit occurring in the first year of life. More than 80% of the benefit comes from avoided diarrheal and respiratory related deaths.

Table 8. Deaths avoided per 1000 children in 2017 birth cohort reached by the intervention

Year	Diarrhea	ALRI	Other infectious diseases	Total per year
2017	0.63	0.64	0.23	1.49
2018	0.06	0.05	0.03	0.14
2019	0.06	0.05	0.03	0.14
2020	0.06	0.05	0.03	0.14
2021	0.06	0.05	0.03	0.14
Total per cause	0.86	0.83	0.34	**2.03**

Source: Estimates by the authors. ALRI = acute lower respiratory infections. Other infectious diseases include septicemia, febrile illness, tuberculosis, cellulitis, hepatitis and meningitis. Results are for an intervention targeted at the 2017 Haitian birth cohort.

Mortality benefits are valued using the approaches suggested by the methods paper (Robinson Hammitt and O'Keffe 2017). To the best of our knowledge there are no stated or revealed preference studies conducted in Haiti that would elucidate the willingness to pay for a reduction in mortality risk for diarrhea, lower respiratory infection or any other disease. Therefore, we apply three alternative approaches to value avoided mortality benefits.

Approach 1: Apply the 'default value' suggested by the methods paper, namely 170x GNI per capita, PPP. This approach, after conversion from international dollars, suggests a Haiti VSL of

7.6m HTG or 120,000 USD in 2016 values. The use of 170x as a multiplier is based on transfering a VSL from the USA of $9m, using an income elasticity of 1.0. The Haitian VSL value is multiplied by the lives saved by the intervention to estimate the monetary value of the benefit.

Approach 2: Apply a lower value of 80x GNI per capita PPP, which generates a VSL of 3.6m HTG or 56,600 USD. The use of 80x as a multiplier is based on transfering a VSL from the USA of $4.2m, using an income elasticity of 1.0. This value is multiplied by the lives saved by the intervention to estimate the monetary value of the benefit.

Approach 3: A constant VSLY is calculated by dividing the VSL from the approaches above by the discounted average age of an adult Haitian (26 years). Avoided deaths from the intervention are converted to avoided YLL by applying Haiti life tables. YLL are then discounted at rates 3, 5, and 12% and multiplied by the constant VSLY.

The VSLY values from this approach at 3%, 5% and 12% discount rates are 304,000 HTG, 424,000 HTG and 918,000 HTG respectively when the higher VSL is used, and 143,000 HTG, 199,000 HTG and 432,000 HTG when the lower VSL is used. It should be noted that a higher discount rate generates a significantly higher VSLY but this is offset by greater discounting of the YLLs.

The results of each of these approaches to valuation are presented in Table 9.

Table 9. Avoided mortality benefit per child based on three approaches

Discount rate	Mortality avoided benefit per child reached Approach 1: All deaths avoided valued at 7.6m HTG	Mortality avoided benefit per child reached Approach 2: All deaths avoided valued at 3.6m HTG	Mortality avoided benefit per child reached Approach 3a: All YLLs valued at constant VSLY derived from VSL of 7.6m HTG	Mortality avoided benefit per child reached Approach 3b: All YLLs valued at constant VSLY derived from VSL of 3.6m HTG
3%	14,314	6,736	16,222	7,634
5%	13,613	6,406	14,486	6,817
12%	11,545	5,433	11,593	5,456

Source: Estimates by the authors.

The results from the table indicate that the choice of US VSL from which one uses benefit transfer to estimate a Haiti VSL has the greatest effect on the result. Moving from Approach 1 to Approach 2 reduces benefits by 50%. The choice of discount rate has a modest effect on the benefits calculation, while the choice between a VSL-based versus a VSLY-based approach has the least effect on the results.

4.4 Benefits from avoided morbidity

Due to a lack of systematic review of the effects of stunting on childhood morbidity, we use the relative risk reductions for mortality as assessed in Olofin et al. 2013 to estimate the avoided morbidity benefits. Baseline estimates of morbidity are taken from the Global Burden of Disease 2016, and as previously, the benefits are assessed separately for <1 and 1 to 4 year olds. GBD 2016 provides data on baseline YLDs. Using incidence and prevalence data for each disease, we can calculate baseline cases. Results are presented in Table 10 and Table 11 below for YLDs and cases respectively. Avoided YLDs from diarrhea make up 90% of the avoided morbidity benefit. Indeed, due to the frequent nature of diarrhea cases in Haitian infants, each child reached by the intervention will avoid one case of diarrhea on average in the first year alone.

Table 10. Years lost to Disability (YLDs) avoided per 1000 children in 2017 birth cohort reached by the intervention

Year	Diarrhea	ALRI	Other infectious diseases	Total per year
2017	1.97	0.03	0.07	2.08
2018	0.25	0.04	0.00	0.29
2019	0.25	0.04	0.00	0.29
2020	0.25	0.04	0.00	0.29
2021	0.25	0.04	0.00	0.29
Total per cause	2.95	0.19	0.08	**3.24**

Source: Estimates by the authors. ALRI = acute lower respiratory infections. Other infectious diseases include septicemia, febrile illness, tuberculosis, cellulitis, hepatitis and meningitis. Results are for an intervention targeted at the 2017 Haitian birth cohort.

Table 11. Cases of illness avoided per 1000 children in 2017 birth cohort reached by the intervention

Year	Diarrhea	ALRI	Other infectious diseases	Total per year
2017	1,035	28	40	1,104
2018	130	33	2	165
2019	130	33	2	165
2020	130	33	2	165
2021	130	33	2	165
Total per cause	1,555	159	49	1,765

Source: Estimates by the authors. ALRI = acute lower respiratory infections. Other infectious diseases include septicemia, febrile illness, tuberculosis, cellulitis, hepatitis and meningitis. Results are for an intervention targeted at the 2017 Haitian birth cohort.

Morbidity avoided benefits are valued using the approaches suggested in the methods paper (Robinson and Hammitt, 2017). To the best of our knowledge there are no stated or revealed preference studies conducted in Haiti that would elucidate the willingness to pay for a reduction in morbidity risk for diarrhea, lower respiratory infection or any other disease. We therefore apply two alternative approaches:

Approach 1: We search the literature for high quality studies that estimate the WTP for avoiding diarrheal disease in developing countries. We focus on diarrhea since this makes up 90% of the avoided morbidity benefit. The only relevant study is Guh et al. (2008). The authors survey respondents from rural China to estimate the willingness to pay to avoid cases of shigellosis, a leading cause of diarrhea. Guh et al. report a variety of results across age and location. For the purposes of this case study, we focus on the willingness to pay for avoiding diarrhea in children under 5, which was generated from the responses of caregivers. Results indicate a willingness to pay to avoid a case of diarrhea for under 5s at $35.40 in 2002 PPP[6] which is 1.6% of annual per capita income of respondents. We transfer this to the Haitian context using 2016 GNI per capita PPP and an income elasticity of 1.0 to generate a value of avoided case of diarrhea of $28.60 Int$ / 715 HTG / $11.28 USD. We assume that the value of all other cases of avoided illness (for ALRI and other infections) have the same value.

Approach 2: The methods paper suggests a sensitivity analysis where each YLD is valued at a constant VSLY + costs borne by third parties. The approach for estimating VSLY is discussed in the previous section with values of 304,000 HTG, 424,000 HTG and 918,000 HTG when the higher VSL is used, and 143,000 HTG, 199,000 HTG and 432,000 HTG when the lower VSL is used for discount rates of 3%, 5% and 12% respectively.

We calculate three types of costs borne by third parties: i) outpatient costs ii) inpatient costs and iii) cost of caregiver time. In Haiti there is a mix of private, NGO and public health care facilities, so some portion of costs are borne by external parties. We include the cost of caregiver time because the VSLs / VSLYs are based on the WTP to reduce risks to one's self, and not to others.

The calculation of outpatient costs assumes:

- 38% of children with diarrhea are taken to health care facilities for treatment based on estimates of similar metric for lower respiratory infections (DHS 2012)
- Each outpatient visit in Haiti costs 487 HTG or $7.50 (McBain et al. 2017)

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[6] Guh et al. (2008), Table 4 reports WTP figures for 0-1 year olds and 2-5 year olds separately. Therefore, it is theoretically possible to assign different valuations for these different age groups. However, given the small sample size of the 0-1 year olds (12) we combine them to form one WTP for avoiding diarrhea in children under 5 generally.

- 65% of all costs are borne by public or NGO health facilities (World Development indicators, World Bank 2016)

The calculation of inpatient costs assumes:

- 8.2% of patients who seek care are referred to a hospital facility (Hutton, 2007)
- Each outpatient visit in Haiti costs 3900 HTG or $60.00 (Sklar, 2017)
- 65% of all costs are borne by public or NGO health facilities (World Development indicators, World Bank 2016)

The calculation of caregiver costs assumes:

- One adult is responsible for care giving across the entire duration of the illness
- The average, unskilled rural wage is 2600 HTG per month
- Cost of time is approximated by 50% of rural wage as per the methods paper by Whittington and Cook, 2017
- The average duration of an episode of diarrhea is calculated at 6.0 days, of ALRI is 8.9 days and of other infections it is 91 days by dividing prevalence by daily incidence of each disease (GBD 2016)

The results of the two valuation approaches are presented in Table 12.

Table 12. Avoided morbidity benefit per child based on two valuation approaches

Discount rate	Morbidity avoided benefit per child reached Approach 1: Benefit transfer from Guh et al. (2008)	Mortality avoided benefit per child reached Approach 2a: Each YLD valued at constant VSLY (from 7.6m HTG VSL) + costs borne by third parties	Mortality avoided benefit per child reached Approach 2b: Each YLD valued at constant VSLY (from 3.6m HTG VSL) + costs borne by third parties
3%	1,192	1,897	1,402
5%	1,150	2,185	1,521
12%	1,025	3,261	1,975

Source: Estimates by the authors.

The results indicate that across all approaches, almost all the estimates of avoided morbidity benefit are between 1000 and 2000 HTG per child reached, though the results from our preferred method (approach 1) are on the lower side of this range.

Two observations arise when applying these valuation approaches. First, the use of constant VSLY for valuing morbidity benefits generates the uunintive result of *increasing* benefits for *higher* discount rates. This occurs because VSLY is calculated by dividing VSL by the *discounted* age of the average adult. Higher discount rates generate a smaller denominator and thus higher VSLY values. The calculation of the benefit is (VSLY * *discounted* YLDs) + (costs borne by third parties). Since most of the avoided YLDs occur in the second year of the intervention the dampening effect of discounting on YLDs is not as large as the amplifying effect of a higher discount rate on the VSLY. This suggests an approach that monetizes YLDs independent of the discount rate may be preffered.

The second observation is that use of the central estimate VSLY values (approach 2a) generates results significantly larger than benefit transfer from a developing country (approach 1). This is suggestive (though by no means conclusive) of the fact that transferring benefits using US VSL of $9m and an income elasticity of 1.0 to the developing world may overstate the benefits of avoided morbidity and mortality.

4.5. Lifetime productivity benefits

[Note to reader: this section will be expanded and updated upon, using directions provided in the relevant methods paper]

Section 2.3 suggests that avoiding stunting in childhood has significant impacts on future productivity as an adult. Monetizing lifetime productivity benefits has been well explored in the returns to education literature (see for example, Psacharopolous 1973; Psacharopolous and Patrinos, 2010). The typical approach has been to calculate age-earnings profile (i.e. how much individuals earn at particular ages) for each level of education, and to compare differences between these profiles to assess the benefit of jumps between education levels or increases in years of education attained. This approach has focused on formal wages, without accounting for non-wage benefits, unemployment, mortality and benefits outside of education.

We broadly follow the approach of Hoddinott et al. (2013) and Horton and Hoddinott (2014) in calculating the lifetime productivity benefits of the nutrition intervention. Key features of the calculation:

- The baseline population rate of stunting is 22% as per 2012 DHS survey and the intervention will reduce stunting by 20.3% as per Bhutta et al. (2013)
- Avoiding stunting prevents a 66% per capita consumption reduction in adulthood as per Hoddinott et al. (2011)
- Consumption is assumed equivalent to income
- The intervention starts in 2016 with pregnant women and results in increased consumption in adulthood beginning at age 16 until 55.
- The average wage of a Haitian adult in 2016 is 51,324 HTG and is assumed to grow by 2.7% per year in real terms. The wage rate is calculated by the equation wage = GDP per capita * labour force participation / labour share of income. GDP per capita is 44,652 HTG (World Bank, 2016), labor force participation rate is 43.5% and the labour share of income is assumed to be 50%.

The results of this calculation are presented below in Table 13.

Table 13. Lifetime productivity benefit per child in 2017 reached by the intervention

Discount rate	Benefit (HTG, 2016)
3%	31,084
5%	15,728
12%	2,168

Clearly the discount rate has a pronounced effect on the benefits. This is unsurprising given the long-lived nature of the benefits (up to 72 years after the intervention) and the fact the benefits of increased productivity only start 16 years after the intervention commences. Even moving from 3% to 5% rate would halve the benefits. Choosing a 12% discount rate diminishes the benefits significantly and shifts the relative importance of the intervention firmly towards avoided mortality and morbidity.

5. Summary and Discussion

Table 14 summarizes the 'base case' results of the previous sections. The base case includes avoided mortality benefits using a VSL of 7.6m HTG, morbidity effects using benefit transfer from Guh et al. (2008) and productivity benefits. The provision of nutrition and micronutrients is likely to be beneficial in the Haitian context. Assuming 234,000 children or 90% of a given birth cohort can be reached, the intervention will prevent 10,350 cases of stunting, save 474 lives and avoid 412,000 episodes of illness over five years. The package would reduce stunting from 22% to 17.4% if implemented nationally over multiple years. However, the costs of the intervention are high, at 12,571 HTG ($198 USD) per child. At this rate, it would cost 280,000 HTG ($4,415 USD) to avoid one case of stunting through this package. The benefit cost ratio is 2.4 at the 5% level. Other studies focusing on health, nutrition and education interventions in the *Haiti Priorise* series suggest there are more effective use of funds to build an improved human capital base in Haiti for example wheat flour fortification which has a BCR of 24, early childhood development with a BCR of 17 and immunization of children with a BCR of 13 (all figures at 5% discount rate).

Table 14. Summary of costs and benefits of nutrition intervention to reduce stunting – base case results

Discount	Mortality avoided benefit	Morbidity avoided benefit	Productiv-ity benefit	Benefit per child, HTG	Cost per child, HTG	Benefit to Cost Ratio	Net benefit per child
3%	14,314	1,192	31,084	46,590	13,037	3.6	33,553
5%	13,613	1,150	15,728	30,492	12,571	2.4	17,921
12%	11,545	1,025	2,168	14,738	11,144	1.3	3,594

5.1 Why is the benefit cost ratio of the intervention relatively small in the Haitian context compared to estimates from previous exercises?

The benefit-cost ratio is relatively small compared to cost-benefit analyses of a similar intervention in the global context. The review by McGovern et al. 2017 suggests the median benefit to cost ratio of the intervention amongst selected studies is 17.9 to 1. The median value is for Bangladesh and it might be useful to compare the two countries to understand the difference in results. First, Haiti is a more costly country in which to operate development projects. This intervention appears to cost roughly twice as much as in other countries. That said, even if it were approximately as costly to undertake this intervention in Haiti as shown in Hoddinott et al. 2013, the BCR would still be relatively modest at $5 for every dollar spent. The second factor is the low level of wages in Haiti. According to our assumptions, annual wages of non-stunted individuals are 51,000 HTG ($800) in the year the intervention is started, compared to roughly 125% more ($1800) in the Bangladesh analysis. Given the benefits of stunting are estimated as a fixed percentage of current wages, any wage effect from avoided stunting will be lower in Haiti. Third, the current level of stunting in Haiti is ‘only’ about 22% while Bangladesh has a 36% stunting rate. This means that any blanket coverage of the intervention will prevent about 50% more children from being stunted in Bangladesh relative to Haiti. Lastly, while possessing a far from perfect business and governance environment, Bangladesh has much greater prospects forgrowth. The last 12 years have seen growth of 6% per anum. In contrast, historical growth rates in Haiti have been sluggish. We assume a 2.7% growth rate for Haiti, less than half that in Bangladesh. It is therefore unsurprising that Bangladesh - which has a well developed health infrastructure for a developing country, higher wages, high rates of stunting and high growth prospects – would reveal a high benefit cost ratio for this intervention.

5.2 To what extent do valuation choices affect the results?

As demonstrated in the previous sections, the choice of valuation approaches can significantly alter the results. Howevever, it is important to compare this source of variation with other forms of uncertainty to understand relative importance of methods choices on policy implications. To assess this we compare results from the base case scenario at 5% discount rate – i.e. where net benefits equal 17,921 HTG in Table 14 – with other sources of uncertainty. The first source of uncertainty is the discount rate, which is a source of uncertainty for all papers in economics, not just papers undertaking cost-benefit analysis. Second, we recalculate the results using the high and low end of the 95% confidence interval of the effect of the Bhutta et al. (2013) intervention package on stunting[7]. Third, results are recalculated using the ends of the 95% confidence

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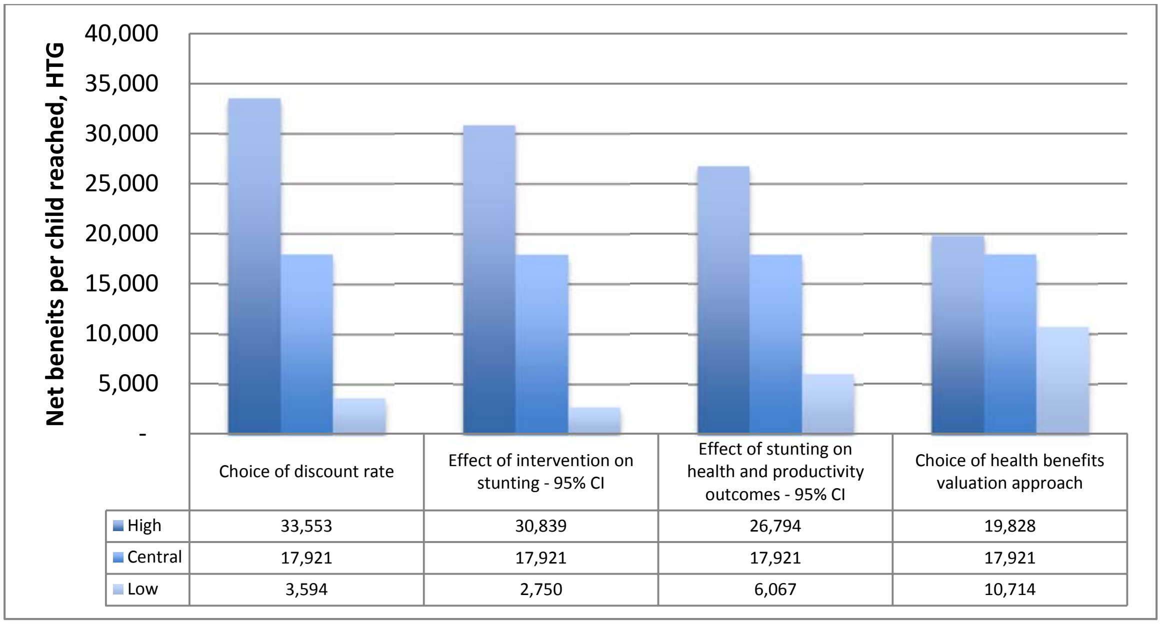
[7] These effect sizes are 10.3% reduction in stunting at the low end, and a 28.9% reduction in stunting at the high end.

intervals of the effect of stunting of future adult consumption from Hoddinott et al. 2011[8], and the effect of stunting on health outcomes from Olofin et al. 2013[9]. Lastly, we compare the various methodological combinations of health valuation approaches and present the combination of choices that maximize the benefits (high end VSL, use of VSLY for valuing mortality and morbidity), against the choices that minimize the benefits (low VSL, benefit transfer for morbidity). The results of these tests are presented in Figure 1 below. **[note to reader: the choice of valuation approaches will be updated in future drafts and include the effects of different choices for health and productivity outcomes from methods papers]**

Figure 1 – Effect of uncertainty on net benefits



	Choice of discount rate	Effect of intervention on stunting - 95% CI	Effect of stunting on health and productivity outcomes - 95% CI	Choice of health benefits valuation approach
■ High	33,553	30,839	26,794	19,828
■ Central	17,921	17,921	17,921	17,921
■ Low	3,594	2,750	6,067	10,714

The greatest variation in results comes from the choice of discount rate and the impact of the intervention on stunting. The high-to-low range resulting from various discounting choices is 167% of the central value. The inherent uncertainty in the intervention's effect on stunting creates a range 157% of the central value. The uncertainty in the effects of stunting on health and productivy create a range 116% of the central value. The choice of valuation methods, at least for

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[8] The 95% confidence interval is constructed by multiplying the standard error of the parameter estimate (0.21) by 1.96 and adding/subtracting that to the point estimate of the effect size from being stunted -0.66 – see Table 4.7a of Hoddinott et al. (2011).

[9] See Table 5 from Olofin et al. (2013) for confidence interval hazard ratios

the health component, appears to create less variation in results with a high to low range of only 51% of the central estimate. **To be updated**

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