COST-BENEFIT ANALYSIS OF INTERVENTIONS TO IMPROVE NUTRITION AND HEALTH OVER THE FIRST 1000 DAYS: A CASE STUDY FROM GHANA

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Cost-benefit analyses of interventions to improve nutrition and health over the first 1000 days: a case study from Ghana

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Academic Abstract

This paper reports the outcome of cost-benefit analyses of four interventions designed to improve nutrition and health outcomes over the first 1000 days of Ghanaian children's lives, from conception to age two years. These interventions are multiple micronutrients and calcium supplementation in pregnancy, breastfeeding promotion, complementary feeding promotion, and an integrated community-based nutrition-focused agricultural livelihoods package (nutrition-sensitive agriculture). Our analysis indicates that all interventions have the potential to deliver large improvements in health and nutrition outcomes. If all women who currently attend a minimum of four ANC visits while pregnant switch from taking iron and folic acid to Multiple Micronutrients (MMN) and Ca supplementation, the intervention will avoid 109,637 cases of anemia, 24,162 pre-term births, 4,210 infant deaths, 82 maternal deaths, and 887 still births, each year. For the remaining interventions, if 20 percent of a given birth cohort could be reached (roughly 174,000 women-child pairs), then breastfeeding promotion would lead to an additional 43,325 women exclusively breastfeeding; complementary feeding promotion to 4,352 children avoiding stunting, and nutrition-sensitive agriculture to 8,782 children avoiding stunting. Overall, our cost-benefit analyses indicate that complementary feeding promotion has the highest Benefit Cost Ratio (BCR) of 36 while nutrition-sensitive agriculture has the lowest BCR in the range of 1.3 to 1.6. MMN Ca supplementation has a BCR of 18 and breastfeeding promotion has a BCR of 24. Our results suggest that the government of Ghana could prioritize the scale up of complementary feeding promotion. MMN and Ca supplementation and breastfeeding promotion are also worthy investments, although the quality of the evidence for impacts is weaker, particularly for breastfeeding promotion.

Key Words: Supplementation, stunting, exclusive breastfeeding, nutrition-sensitive agricultur

Policy Abstract

The Problem

Ghana is considered one of the few success stories on the African continent regarding child nutrition. The rates of child growth faltering (indicated as stunting, wasting, and underweight) has declined steadily at the national level (GSS et. al., 2014). Trend data from the Demographic and Health Survey (DHS) and multiple Indicator Cluster Survey (MICS) demonstrate that the rate of stunting (indicating chronic undernutrition) among children below five years has declined significantly from 35% in 2003 to 19% in 2017, at the national level (GSS et. al., 2014; MICS, 2018). The rate of wasting (indicating acute undernutrition) has declined, almost by half, from 8% to 5% in the same period. The number of underweight children (indicating low weight compared to normal weight children of similar age) also has declined from 18% in 2003 to 11% (GSS et. al., 2014; GMHS, 2018).

It is, however, important to note that the rates of undernutrition in young children in Ghana remains unacceptably high, especially when compared to other countries at a similar developmental stage. Further, although the national prevalence of these undernutrition indicators has declined, there are wide differences across rural and urban settings, regions, income levels, and education levels that are yet to be addressed. Another important aspect of child nutrition is the prenatal stage. The proportion of children born with a low birth weight (<2500g) has remained around 10% (GSS et. al., 2014).

Intervention 1: Multiple Micronutrients and Calcium in Pregnancy

Overview

Avoidable maternal deaths are unacceptably high in Ghana. An estimated 310 women die per 100,000 live births, annually (GSS et. al., 2017). Between 10% and 20% of maternal deaths in Ghana are due to hypertensive disorders, particularly pre-eclampsia and eclampsia (Asamoah et. al., 2011; Der EM et. al., 2013). There is indication that calcium status of pregnant women in Ghana may be lower than non-pregnant counterparts (Djagbletey et. al., 2018). Additionally, anemia among pregnant women is an important health and nutrition challenge in Ghana; an estimated 42% of women are anemic (IGSS et. al., 2014; Ghana Micronutrient Survey, 2017).

Implementation Considerations

The intervention analyzed calls for the provision of multiple micronutrient (MMN) and calcium (Ca) supplements at routine antenatal care (ANC) visits. Currently, MMN and Ca supplementation is not a routine public health policy in Ghana. However, based on WHO recommendation, Ghana has been implementing iron and folate (IFA) supplementation, and there is experience in the Ghana Health Service for delivering IFA supplements through the health system with significant success. Currently, 89% of pregnant women undertake at least four ANC visits and 93% of pregnant women take IFA supplements during pregnancy (GSS et. al., 2014). Given that MMN and Ca represent a similar type of product as IFA delivered in a setting with high patronage by pregnant women (ANC visits), the basis for a successful intervention is strong. Based on this, we anticipate that the intervention coverage will range from 64% to 98% of pregnant women, with a base case estimate of 89%. After accounting for still-births, we estimate that a total of 850,573 pregnant women will be reached by the intervention (i.e. will be given the supplements) out of which 791,033 (93%) will actually take them.

Costs and Benefits

Costs

We estimate the monthly tablet cost for MMN and Ca respectively as 0.5 and 28.16 GH¢ in 2018 prices. Applying this cost to all 850,573 women estimated to have been reached by the intervention and assuming an 8-month course, the total ongoing costs for the intervention is estimated at GH¢ 203 million, representing over 96% of the total costs of this intervention

Benefits

The analysis indicates a range of substantial benefits from the intervention including 109,637 cases of avoided anemia, 24,162 cases of avoided pre-term birth, and 82 avoided maternal deaths. Further, in total, the intervention is expected to avoid 3,951 infant deaths, 82 maternal deaths and 887 still births.

Intervention 2: Breastfeeding Promotion

Overview

Early initiation (within first hour of birth) and exclusive breastfeeding during first six months is recommended for infant survival and optimal development. However, rates of both early initiation and exclusive breastfeeding have stagnated. A recent assessment of the barriers to scaling-up breastfeeding in Ghana identified a number of challenges including insufficient funding and capacity to sustain breastfeeding promotion all year-round, and inadequate human resource capacity to deliver effective services (Aryeetey et. al., 2018).

Implementation Considerations

This intervention focuses on breastfeeding counseling delivered in facility- and community-based settings, and improving the competence (knowledge and skills) of health care providers to counsel caregivers and their significant others on breastfeeding. This will be achieved through training and providing job aids such as counseling cards, guidance protocols, plus monitoring and evaluation. In addition, the intervention aims to increase the coverage of baby-friendly hospitals which were initiated in Ghana in 1993 to improve optimal breastfeeding (UNICEF, 2017). However, implementation of the initiative in Ghana is suboptimal (Aryeetey et. al., 2013).

Costs and Benefits

Costs

Direct costs of breastfeeding promotion include i) training of health workers, ii) community support, iii) training in breastfeeding code implementation and iv) baby friendly hospitals. The total cost for these four components is $26.75 (2015 Int$) per live birth, which corresponds to GH¢ 60 in 2018 prices. 56% of the unit cost is for baby friendly hospital implementation, 37% for community support and 7% for the remaining two components. This cost is applied to all 173,764 women who receive the intervention. The total direct cost of promotion is therefore GH¢ 10.4 million.

The time cost of breastfeeding promotion factors in six consultations of 30 minutes from each mother over the course of pre- and post-pregnancy, with most of the consultations occurring after birth. The value of women's time is based on Ghana Priorities' standard assumptions of half of relevant wage and is equal to GH¢ 3.25 / hour. This time cost is applied against all women who receive the intervention and totals GH¢ 1.4 million. Further a time cost of one hour per day is assumed for women who exclusively breastfeed because of the intervention and would have otherwise not breastfed or partially breastfed.

Benefits

The analysis indicates that 745 child deaths would be avoided from the intervention over two years, based on a target population of approximately 174,000 women with 43,300 women adhering to exclusive breastfeeding, and 20,600 continuing to breastfeed until 2 years. Further, the analysis indicates that the intervention will avoid 158,370 cases of diarrhea over two years with most of the cases avoided, coming from upper respiratory infections. The results indicate that benefits are equal to approximately GH¢ 622M with 98% of benefits coming from mortality avoided.

Intervention 3: Complementary Feeding Promotion

Overview

Optimal complementary feeding involves providing young children with sufficient quantities of quality diets at sufficient frequency, appropriate to age (Dewey et. al., 2008). This is achieved through providing diets which are sufficiently diverse (that is varied) food groups and at optimal frequency, based on child age. Dietary counseling for young infants assumes that caregivers are food secure and that the deficits in child feeding is dependent on improving caregiver competence on optimal foods and feeding methods. For those who are food insecure, complementary feeding promotion is not effective without combining dietary counseling with a food provisioning strategy (WHO, 2003), and will not be considered in this analysis.

Implementation Considerations

This intervention provides information about complementary feeding to caregivers through child welfare clinics in Ghana through one-on-one dietary counseling. Although the intervention targets all children attending child welfare clinics, those whose growth pattern trails behind the growth standard, are more likely to benefit from dietary counseling. Scaling up complementary feeding promotion requires multiple actions including training of care providers on how to use existing counseling cards, and on counseling skills. Complementary feeding intervention also requires increasing supply of job aids for dietary counseling. The intervention targets 173,764 children (in households which are food secure), representing a 20% increase in the coverage of the intervention.

Costs and Benefits

Costs

Based on Ghana Priorities' assumptions, we calculate the cost of reaching a child as GH¢ 28 (at 2018 prices). We also include the cost of mother's time and following Penny et al. (2005), Saleem et al. (2014) and Zhang et al. (2013), assume about 7 counseling sessions of one hour duration per mother. We also used personnel time per counseling session of 0.17 hour (or 10 minutes) following Bhutta et al. (2013). The cost of maternal time is also valued at Ghana Priorities standard assumptions and equals GH¢ 2.7 per hour. The total cost of the intervention is GH¢ 4.9m of which GH¢ 4.6m represents direct promotion costs and the remainder maternal time costs.

Benefits

The results of the analysis indicate that the intervention will avoid 65 deaths, with 27 deaths avoided in the period between 6-11 months, and the remaining deaths over the next four years. Diarrhea disease and lower respiratory infections represent the causes with the greatest deaths avoided. The central estimate of benefits from the intervention is GH¢ 178m with 73% of the benefits from increased productivity, and 27% from improved health benefits.

Intervention 4: Nutrition Sensitive Agriculture

Overview

Globally, sub-optimal diets, and malnutrition in all its forms are common and linked with disease and impaired health outcomes. A critical aspect of improving the food and nutrition system is to better understand the important role agriculture plays in supplying adequate amounts of quality food in a sustainable fashion across different contexts. Agricultural strategies that address malnutrition (nutrition-sensitive agriculture) are considered critical to address malnutrition.

Implementation Considerations

The intervention is a community-based integrated health and nutrition-sensitive agriculture intervention targeting households. The agriculture component of the intervention involves providing inputs to eligible households (those with young children under one year old). The households receive thirty to forty chickens at point of lay that will be raised for their eggs. Along with the chickens, they also receive technical assistance for constructing chicken coop, maintaining health, hygiene, and reducing mortality of the chickens, harvesting, storing and marketing the eggs. Beneficiary households also receive support for identifying a sustainable source of feed as well as increasing/replacing their chicken stock, when needed. The intervention also included a substantial home gardening component to provide households with nutritious vegetable-based foods.

Costs and Benefits

Costs

The costs of the intervention are based on a recent analysis that estimated both financial and economic costs of the intervention delivered to 287 households. Total costs of the intervention are GH¢ 8,025 per household with 45% of the costs for education and training, 38% for poultry production, and the remainder for home gardens. Given a population of ~174,000 households the total costs of the intervention would equal GH¢ 1,394m

Benefits

The results of the analysis estimate three types of benefits –health and productivity benefits from avoided stunting, as well as an increase in income from the intervention. It would generate GH¢ 1,823m in income benefits. The intervention reduces the prevalence of stunting in the beneficiary population by 5% leading to potential additional benefits for health (GH¢ 150m) and lifetime productivity (GH¢ 261m). We do not know how much of the extra income was used to generate the stunting reduction, and therefore we estimate a range of benefits between GH¢ 1,823m and GH¢ 2,174.

BCR Summary Table

Interventions	Total benefits (GH¢ m)	Total costs (GH¢ m)	BCR	Quality of Evidence
MMN and CA supplementation in pregnancy	3,703	203	18	Medium
Breastfeeding promotion	623	26	24	Limited
Complementary feeding promotion	178	4.9	36	Strong
Nutrition sensitive agriculture	1,823 to 2,174	1,394	1.3 to 1.6	Very Strong

Notes: All figures assume an 8% discount rate

1. Introduction

Ghana is considered one of the few success stories on the African continent regarding child nutrition. The rates of child growth faltering (indicated as stunting, wasting, and underweight) has declined steadily at the national level (GSS et. al., 2014). Trend data from the Demographic and Health Survey (DHS) and multiple Indicator Cluster Survey (MICS) demonstrate that the rate of stunting (indicating chronic undernutrition) among children below five years has declined significantly from 35% in 2003 to 19% in 2017, at the national level (GSS et. al., 2014; MICS, 2018). The rate of wasting (indicating acute undernutrition) has declined, almost by half, from 8% to 5% in the same period. The number of underweight children (indicating low weight compared to normal weight children of similar age) also has declined from 18% in 2003 to 11% (GSS et. al., 2014; GMHS, 2018).

It is, however, important to note that the rates of undernutrition in young children in Ghana still remains unacceptably high, especially when compared to other countries at a similar developmental stage. Further, although the national prevalence of these undernutrition indicators have declined, there are wide differences across rural and urban settings, regions, income levels, and education levels that are yet to be addressed. Another important aspect of child nutrition is the prenatal stage. The proportion of children born with a low birth weight (<2500g) has remained around 10% (IGSS et. al., 2014). Low birth weight is a critical indicator of sub-optimal pregnancy outcome. Children born with weight below 2500g have high risk of growth faltering, high risk of infectious morbidity, and are less likely to survive beyond the age of five years (Black et. al., 2013).

Poor growth in children in Ghana is attributable to several factors, including high rates of infectious diseases (including malaria, respiratory infections, and diarrheal diseases), and suboptimal diets (Darteh et. al., 2014; Aheto et. al., 2015). The unacceptably high infection rates are driven by exposure to unclean environments, limited access to sanitation and toilet facilities, suboptimal diets, poor access to sufficient amounts of potable water on a sustainable basis, and limited physical and economic access to health care services (Amugsi et. al., 2015; Denno et. al., 1994; Kanmiki et. al., 2014; Aheto J, 2019). Consumption of poor diets is driven by multiple factors, including high rates of household food insecurity, misperceptions and limited knowledge about optimal diets for young children, maternal undernutrition, and poor child care practices (Issaka et. al., 2015; Agbadi et. al., 2017).

Maternal and child anemia is perhaps the most intractable indicator of undernutrition in Ghana (SPRING, 2016). Although anemia has multiple determinants, it is estimated that suboptimal diets explain almost half of the risk of anemia (WHO, 2011). Young children in Ghana have the highest risk of anemia; 66% of children under five years were considered anemic, as reported in the 2014 DHS. In 2003, the rate of childhood anemia was 76%, indicating a decline of only 10 percentage points in a decade. The decline in child anemia rates is more pronounced in the least vulnerable children (i.e. children from households with higher levels of wealth, and maternal education). In Ghana, child anemia remains highest in the three Northern regions, the Central, and Volta regions (SPRING, 2016). A similar story can be told regarding maternal anemia. More than 40% of Ghanaian women in reproductive age are anemic with only a three percentage point change since 2003. In both women and children, the rate of anemia exceeds the threshold of a serious public health problem.

Appropriate breastfeeding of infants and young children is considered an important public health outcome to limit child mortality and promote maternal and child wellbeing, especially in infection-prone settings like Ghana. The national target for exclusive breastfeeding (giving only breast milk to infants during the first six months of life) is 80%. However, currently, only 43% of Ghanaian infants are exclusively breastfed (GSS et. al., 2014). The trend of exclusive breastfeeding in the past decade demonstrates a lack of progress towards meeting the national target. The highest rate of exclusive breastfeeding was attained in 2008 when it reached 63% (GSS et. al., 2008). Thereafter, exclusive breastfeeding rates have remained low, around 50% or lower. A recent assessment of the barriers to scaling-up breastfeeding identified four priority gaps including insufficient funding and capacity to sustain breastfeeding advocacy and promotion all year-round, inadequate human resource capacity to deliver effective services, revision and enforcement of regulations that support optimal breastfeeding, weak system of coordination of breastfeeding services and stakeholders in the landscape (Aryeetey et. al., 2018).

Nutrition interventions in Ghana are implemented across multiple agencies (both government and non-government) and coordinated by the Ghana Health Service Nutrition Department. In 2016, the Ministry of Health launched a National Nutrition Policy that aims to prioritize nutrition as a human development issue, and thereby promote cross-sectoral harmonized actions to address malnutrition (National Nutrition Policy, 2016). Ghana also signed up to the Scaling Up Nutrition (SUN) Movement in 2011, with a commitment to scale up effective interventions that address malnutrition in all its forms (SUN, 2014). As part of the commitments to SUN, stunting reduction was prioritized as a key outcome to be addressed through multi-sectoral programming.

The main interventions being implemented to address child and maternal nutrition outcomes include behavior change communication regarding infant and young child feeding, iron folate supplementation for adolescent girls and pregnant women, vitamin A supplementation for infants and lactating mothers, and disease control. Complementary interventions are implemented by other sectors agencies outside of the health ministry including the Livelihood Empowerment Against Poverty (LEAP) - a social safety net program, water and sanitation improvement interventions, agriculture and foods security, early childhood development, and school health and nutrition interventions. A key challenge in the implementation of these challenges is limited government investment to scale up coverage of effective intervention strategies.

Against this backdrop, this paper undertakes a cost-benefit analyses of four interventions that seek to improve nutrition and health outcomes across the period between pregnancy up to age two – the so called first 1,000 days of a child's life. These interventions are i) multiple micronutrient (MMN) and calcium (Ca) supplementation in pregnancy, ii) breastfeeding promotion, iii) complementary feeding promotion, and iv) nutrition-sensitive agriculture. These intervention options were chosen based on a combination of factors including demonstrated high benefit-cost ratios (BCRs) in other settings (Joe, Kumar and Subramanian, 2018a; Joe, Kumar and Subramanian, 2018b; Engle-Stone et. al., 2019), policy priority in Ghana, and availability of high quality evidence of impact in country (Marquis et. al., 2018).

Our analysis indicates that all the interventions have the potential to deliver large improvements in health and nutrition outcomes. If all women who currently attend four ANC visits while pregnant switch from taking iron and folic acid to MMN and Ca supplementation, the intervention will avoid 109,637 cases of anemia, 24,162 pre-term births, 3,951 infant deaths, 82 maternal deaths and 887 still births. For the remaining interventions, if 20 % of a given birth cohort could be reached (roughly 174,000 women-child pairs) then breastfeeding promotion would lead to an additional 43,300 women exclusively breastfeeding, complementary feeding promotion to 4,352 children avoiding stunting and nutrition sensitive agriculture to 8,780 children avoiding stunting. These improvements in nutrition status would themselves result in 745 avoided child deaths for breastfeeding promotion, 65 avoided child deaths for complementary feeding promotion, and 120 avoided child deaths for nutrition-sensitive agriculture (Marquis et. al., 2018). Children that avoid stunting would receive lifetime productivity benefits worth roughly three times GDP per capita in present value terms at an 8% discount rate.

The unit costs of these interventions vary considerably, spanning three orders of magnitude. Nutrition-sensitive agriculture intervention (Marquis et. al., 2018) costs GH¢ 8,000 per beneficiary, MMN and Ca supplementation, GH¢ 238 per beneficiary, breastfeeding promotion, GH¢ 150 per beneficiary, and complementary feeding promotion, GH¢ 4.88 per beneficiary.

Overall, our cost-benefit analyses indicate that complementary feeding promotion has the highest BCR of 36 while nutrition sensitive agriculture has the lowest BCR in the range of 1.3 to 1.6. MMN and Ca supplementation has a BCR of 18 and breastfeeding promotion has a BCR of 24. From a policy perspective, our results suggest that the government of Ghana should prioritize the scale up of complementary feeding promotion. Not only does it have the highest BCR of the interventions, the overall quality of evidence for the costs and benefits is strong. A caveat is that the BCR is somewhat sensitive to reasonable variations in the unit costs of the intervention. MMN and Ca supplementation and breastfeeding promotion are also worthy investments, although the quality of the evidence for impacts is weaker, particularly for breastfeeding promotion. The nutrition-sensitive agriculture intervention described in this paper (Marquis et. al., 2018) has the lowest BCR, mostly due to its high cost. While the intervention has a large absolute impact on stunting, livelihoods and empowerment, there are likely to be other interventions that have higher benefits and can achieve these outcomes more cost-effectively.

2. Multiple Micronutrients and Calcium in Pregnancy

2.1 Intervention context

Avoidable maternal deaths are unacceptably high in Ghana. An estimated 310 women die per 100,000 live births, annually (GMHS, 2017). Between 10% and 20% of maternal deaths in Ghana are due to hypertensive disorders, particularly pre-eclampsia and eclampsia (Asamoah et. al., 2011; Der EM et. al., 2013). Suboptimal micronutrient status, particularly for vitamin A, folate, iron, iodine and calcium is common among pregnant women in developing countries, and often is the result of inadequate consumption of the nutrients from the diet. Deficiency of these micronutrients is associated with maternal anemia, night blindness, spontaneous abortion, and mortality. In addition, the deficiencies are also linked with adverse birth outcomes including low birth weight, premature delivery, and cognitive impairment. Low maternal calcium status is linked with increased risk of hypertensive disorders of pregnancy (WHO, 2018). Globally, 14% of maternal deaths are attributable to hypertensive disorders in pregnancy. There is indication that calcium status of pregnant women in Ghana may be lower than non-pregnant counterparts (Djagbletey et. al., 2018).

Multiple micronutrient supplementation (MMN) of pregnant women has been tested to yield beneficial outcomes for women and children. In a recent Cochrane review of 20 trials (19 in low- and middle-income country settings), MMN supplementation, compared to IFA, resulted in a slight but significant reduction in preterm births, small for gestational age, and low birth weight. In addition, the nutrients in the MMN are likely to have other benefits for child development. A trial in Indonesia has reported that when women received MMN during pregnancy, their children had better development across the first decade of life, compared to those who only took IFA during pregnancy (Prado et al, 2017).

Anemia among pregnant women is an important health and nutrition challenge in Ghana; an estimated 42% of women are anemic (GSS et. al., 2014. Supplementation with multiple micronutrients may alleviate some of this burden while also having additional health benefits such as reducing still births and babies born with low birth weight (Pena-Rosas, 2015, Haider et al., 2017). Regarding maternal anemia, the Cochrane review reported that among anemic women receiving MMN, the likelihood of low birthweight, small for gestational age, and infant mortality was reduced.

Further, interventions that improve calcium intake, such as calcium supplementation during pregnancy have been linked with significant improvement in calcium intake as well as reduced risk of hypertensive disorders in pregnancy. A Cochrane review of 14 clinical trials testing the effect of calcium supplementation in non-hypertensive women demonstrated positive effect of daily high dose calcium intake (>1g) to reduce risk of hypertensive disorders and morbidity among pregnant women (Hofmeyr et. al., 2018). Women who consume high dose of calcium are less likely to deliver preterm babies. Thus in populations with low dietary intake, daily oral calcium supplementation (1.2-1.5g) is recommended during pregnancy (WHO, 2016; Omotayo et al., 2016).

The intervention analyzed in this section calls for the provision of multiple micronutrient (MMN) and calcium (Ca) supplements at routine antenatal care (ANC) visits. Currently, MMN and Ca supplementation is not a routine public health policy in Ghana. However, there is experience in the Ghana Health Service of delivering iron and folic acid (IFA) supplements through the health system with significant success. Currently, 89% of pregnant women undertake at least four ANC visits and 93% of pregnant women take IFA supplements during pregnancy (GSS et. al., 2014). Given that MMN and Ca represent a similar type of product as IFA delivered in a setting with high patronage by pregnant women (ANC visits), the basis for a successful intervention is strong. Nevertheless, initiating MMN and Ca supplementation will require actions including procurement of supplements, development of a sustainable procurement system, training of health workers, and a system for assuring quality along the value chain for delivering this service (WHO, 2016; 2018)

2.2 Calculation of Costs and Benefits

2.2.1 General parameters

The base year for the analysis is 2018, and follows a cohort of new pregnant women within a year after exposure to the intervention. Based on data from the International Institute for Applied Systems and Analysis (IIASA), the population of Ghana in 2018 is 28,960,614. With an estimated 2018 population of nearly 29 million people and the crude birth rate of 30 births per 1000 (projections based on World Bank data), we estimate the total number of births at 868,818 per annum. Since MMN and Ca supplementation during ANC visits is not public health policy in Ghana, we do not have data on the number of pregnant women currently on MMN and Ca supplementation. According to the Maternal Health Survey 2017, 98% of pregnant women accessed ANC from a skilled provider (GMHS, 2017); 64% received ANC in the first trimester of pregnancy while 89% made at least four ANC visits. Based on this, we anticipate that the intervention coverage will range from 64% to 98% of pregnant women, with a base case estimate of 89%. After accounting for still-births, we estimate that a total of 850,573 pregnant women will be reached by the intervention (i.e. will be given the supplements) out of which 791,033 will actually take them. This is based on findings that 93% of pregnant women in Ghana take IFA tablets (IDHS, 2014) and we assume the same adherence rate for MMN and CA.

2.2.2 Costs

Ongoing costs of MMN and Ca supplementation

The ongoing costs of switching from IFA to MMN supplementation are derived from Engle-Stone et al. (2019) a cost-effectiveness exercise undertaken for Burkina Faso and Bangladesh. That study estimates an incremental switching cost of 2018 USD 0.004878 per tablet based only on the change in the cost of micronutrients. The incremental cost per pregnancy – GH¢ 4 – is small because the remaining cost categories (shipping, in-country transportation, storage) are assumed to be the same across the two products.

For calcium supplementation, which requires a separate tablet, we adopt the figures from WHO (2011) which note a cost of 2011 USD 4 per month. Adopting these unit cost figures and applying necessary adjustments (i.e. using the GDP inflation index in the IIASA database), we estimate the monthly tablet cost for MMN and Ca respectively as 0.5 and 28.16 GH¢ in 2018 prices. Applying this cost to all 850,573 women estimated to have been reached by the intervention and assuming an 8-month course, the total ongoing costs for the intervention is estimated at GH¢ 194.1 million (Table 1). This represents 96% of the total costs of this intervention.

Scale up and administrative costs

We estimate scale up and administrative costs associated with the intervention including training, planning and coordination, and activities aimed at achieving behavior change in women. Adopting unit cost figures from a breastfeeding promotion costing initiative as a reference (Holla-Bhar et al, 2015), and adjust costs downwards by 1/3 to account for the relatively simpler nature of the intervention. We estimate these items together constitute about 4% of the total cost of the intervention. Table 1 shows specific levels of the various cost items.

Table 1. Cost estimates for MMN and Ca supplementation in Ghana for 850,573 women

Description	**Cost (in millions of 2018 GH¢)**
Tablets	194.1
Training	3.02
Planning and coordination	1.07
Behavior change communication	3.41
Total	202.6

There is the need to make a few observations about the costs. First, cost of creating the institutions or overhead and capital costs for health services delivery systems are excluded from the estimates with the assumption that the health system already possesses the basic capacity to deliver (Holla-Bhar et al, 2015). It is further assumed that the public health sector is already endowed with the necessary human resources and logistics to ensure effective delivery of the intervention. These assumptions seem reasonable in light of the fact that the Ghana Health Service already delivers IFA to pregnant women with high efficacy.

2.2.3 Benefits

Effects of MMN and Ca supplementation on health outcomes

The benefits of multiple micronutrients (MMN) and calcium (Ca) supplementation are many. These supplements are associated with reductions in anemia, pre-eclampsia, maternal mortality and morbidity, and infant mortality and morbidity (Keats et al, 2019; Bourassa et al. 2019; Haider & Bhutta 2017). To assess the health benefits of MMN and Ca supplementation, we rely on studies reporting associations between MMN and maternal anemia (Peña-Rosas et al, 2015), still-births and low birth weights (Haider & Bhutta 2017); and a study linking Ca supplementation to reductions in maternal deaths and pre-term births (Hofmeyr et al, 2018). Relative risk ratios, pre- and post-intervention incidence and absolute number of cases avoided are shown in Table 2.

Table 2. Relative risk of various health events compared to no supplementation

Cause	**Relative risk compared to IFA or no supplementation**	**Baseline incidence in beneficiary population**	**Post- intervention incidence in beneficiary population**	**Absolute number avoided**
Iron deficiency anemia (MMN vs IFA)	0.34	21 pp	7 pp	109,637
Still births (MMN vs IFA)	0.92	14 per 1000 pregnancies	13 per 1000 pregnancies	887
Low birth weight (MMN vs IFA)	0.88	95 per 1000 live births	84 per 1000 live births	8,198
Maternal death from hypertensive disorders (Ca)	0.8	52 per 100,000 live births	42 per 100,000 live births	82
Pre-term birth (Ca)	0.76	140 per 1000 live births	106 per 1000 live births	24,162

Source: Estimates by the authors. Notes: Women reached by intervention and number of new births are 850,573 and 868,818 respectively. Relative risk values are from various meta-analyses: iron deficiency anemia (Peña-Rosas et al 2015), still births and low birth weights (Haider & Bhutta, 2015), maternal death from hypertensive disorders and preterm birth (Hofmeyr et al, 2018). Baseline incidence values are from Ghana Micronutrient Survey

2017 (iron deficiency anemia), Demographic and Health Survey 2014 (still births, low birth weight), Global Burden of Disease (maternal deaths from hypertensive disorders) and UNICEF (pre-term birth rate).

The analysis indicates a range of substantial benefits from the intervention including 109,637 cases of avoided anemia, 24,162 cases of avoided pre-term birth, and 82 avoided maternal deaths. Besides these first order benefits, there are additional mortality benefits from avoided poor birth outcomes. Katz et al, (2013) conduct a meta-analysis of studies covering more than 2 million live births in lower middle income countries (LMICs) and identify that the relative risk of neonatal mortality and post-neonatal mortality from being pre-term is 6.82 and 2.50 respectively. Equivalent relative risk values for low-birth weight are 1.83 and 1.90. We apply these relative risks and estimate that MMN supplementation leads to avoidable death cases of 170 neonatal and 89 post-neonatal whilst Ca supplementation leads to 3,516 avoided neonatal and 435 post-neonatal deaths.

In total, the intervention is expected to avoid 4,210 infant deaths, 82 maternal deaths, and 887 still births.

Valuation of mortality, morbidity, still birth and productivity benefits

Mortality avoided is valued by initially converting each avoided death into years of life lost (YLL) avoided using Ghana-specific life tables. A value of statistical life year (VSLY) is subsequently applied to each YLL avoided following standard *Ghana Priorities* assumptions (Wong & Dubosse 2019), leading to the value per life year in 2018 as GH¢ 12,854.[1] We apply this valuation to the 6,843 infant deaths avoided and 82 maternal deaths avoided, noting YLLs per avoided death are equal to 63 and 46 respectively. The total value of infant mortality avoided is GH¢ 3,445m and maternal mortality is GH¢ 49m.

For morbidity avoided, benefits were estimated using assumptions from Horton and Ross (2003) and Ershler et al, (2005). The value of morbidity benefit avoided for mild, moderate and severe cases of anemia from the analysis are GH¢ 23, GH¢ 88 and GH¢ 153, respectively, while the number of mild, moderate and severe anemia cases averted are respectively 48,815, 26,034 and 558. Anemia also increases the severity of illness in six disease states (i.e. cancer, chronic kidney disease, chronic obstructive pulmonary disease, congestive heart failure, inflammatory bowel disease, and rheumatoid arthritis). Following, Ershler et al. (2005) we

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[1] This is equivalent to 1.2 ×*per capita GDP*.

estimate the avoided cost per woman at 2005 USD 111 which equals 2018 GH¢ 1,359 after making necessary exchange and inflation adjustments, with the number of women avoiding the condition at 10,964.

There is significant uncertainty around the appropriate method to estimate the welfare benefit from avoided stillbirths. As a conservative estimate, we value the avoided direct healthcare costs, burial costs avoided and loss of productivity for two caregivers associated with an avoided stillbirth. Direct healthcare costs are assumed to be GH¢ 2800, on the basis that stillbirths cost 40% more than live births (Heazell et al. 2016) and the average cost of a hospital live birth is GH¢ 2000. Burial costs are assumed to be GH¢ 10,000[2], while caregiver productivity losses are GH¢ 333. Total benefits per avoided stillbirth are therefore GH¢ 13,333 for a total benefit of GH¢ 12m.

Lastly, we estimate the value of improved lifetime productivity from avoided low birth weight. Behrman and Alderman (2004) indicate that avoided birth weight leads to a reduction in lifetime earnings of 7.5%. We apply this parameter to the stream of future income estimated under the Ghana Priorities standardized assumptions (Wong and Dubosse, 2019), assuming a working age of 15 to 60 years.

Total benefits are presented in Table 3 and results indicate total benefits of GH¢ 5,733 million (8% discount rate). Approximately 97% of the total benefits are from avoided infant mortality. The discount rate only affects the productivity benefit, since the remaining interventions are incurred in the same year as the intervention. Since productivity is a relatively small share of the benefits, the overall benefits are somewhat insensitive to the discount rate.

[2] Ghana is well known for having very costly funerals (de Witte, 2003). One anthropometric study documented an average cost of USD 1800 in 1998 – equivalent to around 2018 GH¢ 23,100. GH¢ 10,000 is assumed as a conservative estimate for stillborn children.

Table 3. Total benefits (in GH¢ millions) from MMN and Ca supplementation

Description	Discount Rate		
	5%	8%	14%
Morbidity avoided from maternal anemia	4	4	4
Avoided maternal mortality	49	49	49
Productivity benefit from LBW avoided	192	74	16
Avoided still births	12	12	12
Avoided infant mortality	3,445	3,445	3,445
Total	3,703	3,572	3,527

2.2.4 Summary of results

Costs and benefits of MMN and Ca supplementation are summarized in Table 4. The results show the intervention while costing GH¢ 203 million, results in a total benefit of GH¢ 3,585 million. The benefits thus outweigh the costs leading to a BCR of 18 (8% discount rate).

Table 4: Summary of costs and benefits from MMN and Ca supplementation

	Total costs (2018 GH¢ millions)	**Total benefits (2018 GH¢ millions)**	**BCR**
5%	203	3,703	18
8%	203	3,585	18
14%	203	3,527	17

2.2.5 Sensitivity analysis

To test the sensitivity of results to assumptions we vary several key parameters: i) the cost of calcium tablets, ii) the value placed on avoided still births, iii) the effects of MMN on infant mortality, iv) the effects of calcium on pre-term birth, and v) the effects of pre-term birth on infant mortality. The results are reported in Table 5 below, and here we consider only the effects on the BCR estimate at an 8% discount rate i.e. BCR = 18.

The cost of calcium tablets can vary considerably due the different formulations of the tablets and also because shortages can drive up the price (Hoddinott, personal communication). We therefore vary the price of calcium tablets by +/-25% to test the effects of this phenomenon. Results indicate that an increase in calcium tablet costs by 25% leads to a BCR of 14, while a reduction by 25% leads to a BCR of 23.

There is unclear evidence on the welfare gain associated with avoided stillbirths (Robinson et al. 2019). In the preceding analysis we used a plausible lower bound estimate on the avoided costs of health and burial, plus avoided lost caregiver time. A plausible upper bound estimate is the value placed on avoided infant deaths. Utilizing this approach, yields a BCR of 21.

In the main analysis, the effects of MMN on infant mortality are estimated by first adopting the effect of MMN on low birth weight (Haider and Bhutta, 2015) and then the effect of low birth weight on infant mortality (Katz et al. 2013). However, this approach stands in tension with a recent Cochrane review, which found no direct impact on infant mortality from MMN supplementation (Keats et al. 2019). Therefore, we remove any infant mortality benefits attributed to the MMN portion of the intervention. The result is a minor deviation to a BCR of 17.

Lastly, we vary the two key parameters that are responsible for the largest benefit category – the effects of calcium on pre-term birth, and the effects of pre-term birth on neonatal and post-neonatal infant mortality. For each we adopt the lower and upper bound of the 95% confidence interval from the respective studies ((Hofmeyr et al. 2018; Katz et al. 2013). The results indicate that using the lower (upper) bound estimate for the relative risk on pre-term birth from calcium results in a BCR of 28 (4). Adopting the lower (upper) bound estimates for the relative risk of mortality from pre-term birth result in a BCR of 35 (9). Unsurprisingly, varying these parameters has the largest effect on the BCR.

Table 5: Sensitivity Analysis for MMN and CA supplementation in pregnancy

Scenario	**BCR**
Central estimate	18
Increase calcium costs by 25%	14
Decrease calcium costs by 25%	23
Welfare gain from avoided stillbirth equal to welfare gain from avoided infant death	21
No infant mortality benefits from MMN supplementation	17
Relative risk of preterm birth from calcium = 0.6	28
Relative risk of preterm birth from calcium = 0.97	4
Relative risk of neonatal mortality = 13.07 and post-neonatal mortality = 4.22 from preterm birth	35
Relative risk of neonatal mortality = 3.56 and post-neonatal mortality = 1.48 from preterm birth	9

2.3 Discussion

The analysis indicates that replacing IFA with MMN and Ca for ~850,000 pregnant women that utilize ANC services at least four times, visits annually will cost GH¢ 203m per year, 96% from the costs of the tablets. It will lead to a variety of benefits including avoiding 4,210 infant deaths, 82 maternal deaths and reducing maternal anemia by 14%. The value of these benefits is GH¢ 3,585m per year, leading to a BCR of 18 at an 8% discount rate.

The analysis is predicated on the fact that the Ghana Health Service is already successfully delivering IFA to 93% of pregnant women. We make the reasonable assumption that the system could deliver a different set of tablets to the same women. The intervention requires minimal behavior change, since 89% of women are already going to at least four ANC visits and we have not factored in anticipated increase in ANC visits into our calculations.

The benefits of the intervention draw from numerous studies, but by far the largest benefit comes from avoided infant mortality arising out of avoided pre-term births. This benefit relies on two meta-analyses of studies in developing countries, the first documenting the effect between calcium provision and pre-term birth (Hofmeyr et al, 2018), and the effects of pre-term birth on mortality (Katz et al, 2013). The quality of evidence for the pre-term birth effect is rated as low by Hofmeyr et al, (2018) as the authors indicated the possibility of small sample size and publication bias. In the case of Katz et al, (2013), the effect size was drawn from a mixture of RCTs and observational studies with large variance in the underlying mortality risk of target populations. This relationship appears more robust although the authors do not rule out possible confounding. In contrast, the impacts from MMN are more or less consistent across two recent meta-analyses (Keats et al. 2019; Bourassa et al. 2019). Overall we, therefore, rate the quality of evidence for this intervention as moderate.

3. Breastfeeding promotion

3.1 Intervention context

Existing evidence shows that breastfeeding promotion is an important public health action (Global Breastfeeding Collective, 2019). Optimal breastfeeding reduces risk of infectious morbidity and mortality among young children. It is also linked with improved human capital through its effects on cognitive development, and reduced risk of non-communicable disease of in the breastfeeding mother and during the adult life of the breastfed child (Rollins et. al., 2016; Victora et. al., 2016. Diverse strategies exist for promoting breastfeeding and here we focus on breastfeeding counseling delivered in facility- and community-based settings. A recent assessment of the barriers to scaling-up breastfeeding in Ghana identified a number of challenges including insufficient funding and capacity to sustain breastfeeding promotion all year-round and inadequate human resource capacity to deliver effective services (Aryeetey et. al., 2018).

This intervention seeks to address these gaps by improving the competence (knowledge and skills) of health care providers to counsel caregivers and their significant others on breastfeeding. This will be achieved through training and providing job aids such as counseling cards, guidance protocols, plus monitoring and evaluation. In addition, the intervention aims to increase the coverage of baby-friendly hospitals. Baby friendly hospitals initiative was initiated in Ghana in 1993 to improve optimal breastfeeding (UNICEF, 2017). However, implementation of the initiative in Ghana is suboptimal (Aryeetey et al., 2013).

In Ghana, prenatal, maternity, and postnatal health services serve as the main platforms for breastfeeding counseling. Antenatal clinics (ANCs) are available throughout Ghana and can be accessed through health facilities (health centers and hospitals) as well as in communities (satellite ANCs and CHPS compounds). Caregivers attending postnatal and child welfare clinics, delivered through facilities and community service points, have the opportunity to receive information on optimal breastfeeding. The Baby Friendly Hospitals initiative is implemented in Ghana as an important mechanism for communicating breastfeeding prior to, during, and after delivery (UNICEF, 2017).

3.2 Calculation of Costs and Benefits

3.2.1 General parameters

The base year for the analysis is 2018 and follows a cohort of new mothers over two years after exposure to the intervention. Based on data from the International Institute for Applied Systems and Analysis (IIASA), the population in Ghana in 2018 is 28,960,614. With an estimated 2018 population of nearly 29m people and the crude birth rate of 30 births per 1000 (projections based on World Bank data), we estimate the total number of births at 868,818 per annum. There is limited data on the coverage of breastfeeding promotion nationwide, though it is likely to be far from universal. The coverage of baby friendly hospitals is only 33% and attendance at post-natal clinics ranges between 50% and 90% depending on the region. Only 21% of health workers in facilities are properly trained in lactation management (Yawson et. al., 2017). For this analysis we assess the costs and benefits of a 20% increase in coverage due to the intervention, for example from 40% to 60% of all newborns.[3] A 20 % increase in coverage implies 173,764 [4] new births reached by the intervention.

3.2.2 Effect of intervention on exclusive and continued breastfeeding

To estimate current rates of exclusive breastfeeding, we conduct a simple linear trend analysis on 20 years of survey data in Ghana. This analysis suggests rates of exclusive breastfeeding at 51% albeit with some noise (95% CI: 34%, 67%). We then estimate the percentage of predominant, partial and non-breastfed children assuming that the relative share between these three states remains the same as depicted in the 2014 DHS. For baseline rates of continued breastfeeding between 6-23 months, we adopt a value of 50% drawing upon the 2014 DHS.

Table 6: Estimated rates of breastfeeding on the target population with and without the intervention

	Without intervention prevalence of breastfeeding	**With intervention prevalence of breastfeeding**
0-5 months		
Exclusive	51%	76%
Predominant	18%	9%
Partial	30%	15%
None	1%	>1%
6-23 months		
Continued	50%	62%
Not continued	50%	38%

Source: Estimates by the authors. Baseline prevalence of breastfeeding estimated from trend analysis of 20 years of data. Intervention prevalence estimated using odds ratios from Sinha et. al., (2017).

Effects of the intervention on exclusive and continued breastfeeding are drawn from a recent meta-analysis of various breastfeeding promotion strategies in LMICs (Sinha et. al., 2017).

[3] This choice of increase is somewhat arbitrary insofar as a slightly smaller (say 10pp) or slightly larger (say 30pp) increase would have a sufficiently similar BCR across the range of plausible coverage changes. We would expect higher costs as coverage approaches 100% due to the difficulties in accessing the remotest parts of Ghana.

[4] That is obtained by $[20\% \times 868{,}818] = 173{,}764$

That study reports an odds ratio for counseling in the home or community environment on exclusive breastfeeding in children aged 1-5 months of 3.02 (95% CI: 2.19, 4.18). We apply this value as the effect from the intervention, noting that similar results are reported for interventions in the health system environment, for overall breastfeeding promotion and for children 0-1 months. This parameter value is directionally consistent with a small randomized trial conducted in Accra, Ghana in 2002 which promoted exclusive breastfeeding to 87 women, demonstrating increase in exclusive breastfeeding rates of 55% to 100% depending on the intervention design, relative to a control (Aidam et. al., 2005).

Sinha et. al., (2017) also report an increase in the odds of continued breastfeeding of 1.62 (95% C.I: 1.16, 2.27), a value which we adopt for the effects between 6 and 23 months. The computed relative risks for exclusive and continued breastfeeding based on these odds ratios are 1.49 and 1.24 respectively.

Table 6 reports the changes in breastfeeding in the target population after applying these effects. The "with intervention" share of partial, predominant and no breastfeeding is estimated by assuming that any change in exclusive breastfeeding leads to a reduction in the three other states, weighted by the size of the share in the pre-intervention state. We estimate that the intervention will increase exclusive breastfeeding by 25% (51% to 76%) or 43,325 women from the target population, while continued breastfeeding will increase by 12% (50% to 62%) or 20,560 women in the target population.

3.2.3 Costs

Direct costs of breastfeeding promotion

The costs of the breastfeeding promotion intervention were drawn from a global breastfeeding intervention costing exercise (Holla-Bahr et. al., 2015). We adopt the unit cost figures of elements from that study that most closely correspond to the intervention envisaged here. These are i) training of health workers, ii) community support, iii) training in breastfeeding code implementation, and iv) baby friendly hospitals. The total cost for these four components is $26.75 (2015 Int$) per live birth, which corresponds to GH¢ 60 in 2018 prices after making the necessary exchange and inflation adjustments. 56% of the unit cost is for baby friendly hospital implementation, 37% for community support and 7% for the remaining two components. This cost is applied to all 173,764 women who receive the intervention. The total direct cost of promotion is therefore GH¢ 10.4 million.

Time cost of breastfeeding promotion

The intervention is expected to require six consultations of 30 min from each mother over the course of pre- and post-pregnancy, with most of the consultations occurring after birth. Since these consultations occur when the woman is already at the facility or in her home, travel costs are absent. The value of women's time is based on Ghana Priorities' standard assumptions of half of relevant wage and is equal to GH¢ 3.25 / hour. This time cost is applied against all women who receive the intervention and totals GH¢ 1.4 million.

Time commitment required for exclusive breastfeeding

Exclusive breastfeeding places a constraint on the mother since she is the only individual who can provide the child with a source of food. Numerous studies across a wide range of developing country contexts including Ghana, show that the likelihood of a mother exclusively breastfeeding is reduced by the existence of other time pressures such as the need to go to work (Tampah-Naah et. al., 2019; Colambara et. al., 2015; Marquis et. al., 1998) or to conduct household chores (Tampah-Naah et. al., 2019; Haider et. al., 1997). Presumably, this tension between breastfeeding and other commitments is why breastfeeding promotion strategies often include paid maternity leave as a key component (Holla Bahr et. al., 2015). Another study in Mexico estimates the per capita costs of work-related costs of breastfeeding in the form of maternity cash transfers for informally employed women (Vilar-Compte et. al., 2019).

The non-transferable commitment of exclusive breastfeeding might represent a cost and requires careful consideration in a social cost-benefit framework. At a minimum, there is the marginal increase in time required for exclusive breastfeeding compared to other methods of food provision (*EBF time cost*). This would represent a cost in a social cost-benefit framework if mothers were able to spend the extra time that generated more welfare than breastfeeding. Additionally, because a child needs to be fed on multiple occasions during the day at times that can only be partially predicted, women's time and choice of activities may also be constrained even when they are not breastfeeding (*EBF inconvenience cost*). From a societal perspective this represents a cost if the household cannot optimize caregiving responsibilities such that welfare is maximized (for example, leaving the infant with another caregiver who has a lower opportunity cost of time). On the other hand, feeding can be integrated with other leisure and non-leisure activities with uncertain implications on time use and its costs.

Data on the magnitude of the time commitment required from exclusive breastfeeding is scarce. To the best of our knowledge, only three studies have measured the marginal time requirement for exclusive breastfeeding relative to other methods of food preparation. A study in Honduras showed that women who exclusively breastfed spent significantly less time on food provision (64-73 min per day) than women who breastfed and provided solid foods (99-108 min per day) (Cohen et. al., 1995). This study suggests if anything, there is an *EBF time cost* saving of 4 hours per week from exclusive breastfeeding. However, almost half of the mothers in the group that provided solid foods indicated that breastfeeding interfered with other activities suggestive of a non-zero *inconvenience cost.*

Two studies from developed countries measure the extent of *direct time* costs from exclusive breastfeeding. Smith and Forrester (2013) show that women in Australia who exclusively breastfeed spend 7 hours more breastfeeding but 2 hours less preparing solid foods per week compared a group of mothers not exclusively breastfeeding. Pugh et. al., (2002) conduct a cost-benefit analysis of a randomized breastfeeding promotion strategy in the United States and ascertained that those in the intervention group spent 40 hours more over a 6-month period on average feeding their infants than in the control group. Note that this number is the intent-to-treat effect (i.e. the weighted average over exclusively breastfeeding and non-exclusively breastfeeding mothers in the intervention group) and does not represent the additional time spent only by exclusively breastfeeding mothers. In that study, the time cost was material and about twice the size of the promotion costs, and accounting for 67% of total costs.

Bearing all of this in mind, we apply a marginal time cost of one hour per day for women who exclusively breastfeed because of the intervention and would have otherwise not breastfed or partially breastfed (we do not apply this cost to women who would have otherwise predominantly breastfed). This one hour is meant to encompass both a *direct time cost* and an *inconvenience cost*. Because other caregivers are able to provide food to the child beyond 6 months we do not assess any marginal time and inconvenience cost beyond this period.

The value of this cost over six months is material and totals GH¢ 13.7m or about as much as the direct and time costs of promotion itself. This is approximately consistent with Pugh et. al. (2016) where breastfeeding time consisted of 66% of total costs in their cost-benefit analysis.

Summary of costs

Table 7 provides a summary of the costs of the intervention for a cohort of approximately 174,000 women. Total costs are GH¢ 25.6m. Since all the costs are incurred in the first year (2018), the discount rate has no bearing on the cost profile.

Table 7. Cost estimates for breastfeeding promotion in Ghana (millions 2018 GH¢) for 173,764 women

Description	**Discount Rate**		
	5%	8%	14%
Direct cost of promotion	10.43	10.43	10.43
Time cost of promotion	1.43	1.43	1.43
Breastfeeding time and inconvenience cost	13.7	13.7	13.7
Total	25.6	25.6	25.6

Several observations should be noted about the calculations. First, following Holla-Bhar et. al. (2015), overhead and capital costs for health services delivery systems are excluded from the estimates; the health system is assumed to already possess the basic delivery capacity. It is also assumed that the public health sector through its community health system is already equipped with the needed human resources and transport so that all that is required is additional training of the staff for effective delivery of antenatal care services. Finally, it is assumed that the public health sector and indeed the public will monitor implementation and compliance with maternity regulation.

3.2.3 Benefits

Optimal breastfeeding is associated with multiple beneficial outcomes for infants and their families. Optimal breastfeeding is associated with lower risks of avoidable child mortality and morbidity (Lamberti et. al., 2013; Sankar et. al., 2015). Breastfeeding saves costs for households (Walters et. al., 2019). Beyond that, it is an investment in human capital that yields benefits at the societal level. This is because breastfed children have better cognitive abilities and school performance, and less susceptible to infectious morbidity, particularly diarrhea and pneumonia (Rollins et. al., 2016).

For this analysis, we assess health benefits drawing upon meta-analyses that present associations between breastfeeding and reductions in diarrhea (Lamberti et. al., 2011), pneumonia (Lamberti et. al., 2013), and infection related disease (Sankar et. al., 2015). Relative risk ratios from these analyses are reported in Table 8.

Table 8: Relative risks of cause-specific mortality from various types of breastfeeding

	Relative risk of diarrhea mortality	Relative risk of pneumonia mortality	Relative risk of infection related mortality
0-5 months			
Exclusive	1.00	1.00	1.00
Predominant	2.28	1.66	1.70
Partial	4.62	2.50	4.56
None	10.52	14.97	8.66
6-23 months			
Continued	1.00	1.00	1.00
Not continued	2.18	1.92	2.09

Source: Lamberti et. al., 2011; Lamberti et. al., 2013; Sankar et. al., 2015

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

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

where RR_{ji} is relative risk of mortality from cause, *j*, for children in each of the breastfeeding categories, *i*, in Table 8; and P_i and $P^{'}_i$ are the pre- and post-intervention prevalence rate of breastfeeding in Table 6.

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

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

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 this analysis we apply diarrhea RRs to diarrheal diseases, pneumonia RRs to lower respiratory infections and infection RRs to a group of common infectious diseases in children: measles, malaria, tuberculosis, upper respiratory infections, meningitis, neonatal sepsis, and other infectious diseases. We also separate the analysis into the first five months, 6-11 months and 12-23 months since cause-specific probability of death differs during these time periods.

The results of the analysis are presented in Table 9.

Table 9: Estimated deaths avoided per cohort exposed to intervention (n=173,764) by cause and age

Cause	Deaths avoided 0-5 months	Deaths avoided 6-11 months	Deaths avoided 12-23 months	Total deaths avoided by cause
Neonatal sepsis	319	3	0	322
Diarrhea	72	17	6	96
Lower respiratory infections	74	12	4	90
Malaria	69	19	15	103
Other infectious diseases	100	24	9	134
Total by age group	634	76	35	745

The analysis indicates that 745 child deaths would be avoided from the intervention over two years, based on a target population of approximately 174,000 women with 43,300 women switching to exclusive breastfeeding and 20,600 switching to continued breastfeeding. The vast majority (85%) of deaths avoided occur in the first five months of life. Deaths avoided from neonatal sepsis represent the largest category by cause. We value mortality avoided by first converting each death avoided into years of life lost (YLL) avoided, using Ghana-specific life tables. We then apply a value of statistical life year (VSLY) to every year of life lost avoided (YLL) following standard *Ghana Priorities* assumptions (Wong and Dubosse 2019). The value per life year in 2018 is $1.2 \times GDP\ per\ capita$ or GH¢ 12,854.

For morbidity avoided, we conduct a similar analysis but focus on diarrheal diseases, lower respiratory infections and upper respiratory infections, using effect sizes from Lamberti et. al., (2011), Lamberti et. al., (2013) and Sankar et. al., (2015) respectively.[5]

[5] Morbidity effects are presented in Lamberti et. al., (2011) and Lamberti et. al., (2013). Sankar et. al., do not report morbidity, so we assume they are equal to the mortality risk ratios for infectious diseases.

Table 10: Incidence of diarrheal and respiratory diseases avoided by the intervention

Cause	**Cases avoided 0-5 months**	**Cases avoided 6-11 months**	**Cases avoided 12-23 months**	**Total cases avoided by cause**
Diarrhea	24,318	7,406	10,840	42,564
Lower respiratory infections	1,046	105	210	1,362
Upper respiratory infections	64,148	19,022	31,274	114,444
Total by age group	89,512	26,533	42,325	158,370

The analysis indicates that the intervention will avoid 158,370 cases of diarrhea over two years with most of the cases avoided coming from upper respiratory infections. The value of an avoided case of diarrheal disease is estimated at GH¢ 196, which assumes a small but high cost rate of hospitalization (Aikins et. al., 2010). Avoided cases of respiratory infections are valued at GH¢ 51 based on Walters et. al., (2019).

Total benefits are presented in Table 11 below. The results indicate that benefits are equal to approximately GH¢ 622M with 98% of benefits coming from mortality avoided (8% discount rate). The discount rate does not have a significant effect on the benefits which is unsurprising given the two-year timeframe of the model.

Table 11: Total benefits from breastfeeding promotion

	Mortality avoided (2018 GH¢ millions)	Morbidity avoided (2018 GH¢ millions)	Total benefits (2018 GH¢ millions)
5%	608.6	15.0	623.5
8%	607.8	14.8	622.6
14%	606.3	14.6	620.9

3.2.4 Summary of results

Costs and benefits of the intervention are summarized below. The results indicate that the intervention will cost GH¢ 26M with about 45% in direct costs and the remainder in increased time and inconvenience of exclusively breastfeeding. The benefits of the intervention are much higher at 623m GH¢ for a BCR of 24. The result is insensitive to the choice of discount rate.

Table 12: Summary of costs and benefits from breastfeeding promotion

	Total costs (2018 GH¢ millions)	Total benefits (2018 GH¢ millions)	BCR
5%	26	624	24
8%	26	623	24
14%	26	621	24

3.2.5 Sensitivity analysis

Given that the BCR estimate is subject to substantial uncertainty on both the cost and the benefit sides, we performed sensitivity analyses to tests the robustness of the BCR estimate. The sensitivity analyses examine the impact of lower post-intervention coverage, lower time and inconvenience cost, reduced intervention size and variations in overall costs and benefits on the BCR, holding all other variables constant.

Breastfeeding promotion seeks to change the behavior of breastfeeding mothers in a positive direction. Due to the fact that behavioral changes are difficult to achieve, we performed a sensitivity analysis by lowering the post intervention coverage from 70% to 60%. The BCR increases from 24 to 37 using this scenario.

One might argue that the costing of time is too high; particularly for women living in rural areas. These women are likely to have only limited access to wage employment and their hourly earnings from agriculture or from operating non-agricultural businesses might be pretty low. Sensitivity analysis on how this time is costed (for example, applying a lower cost to time for women in rural areas) would be appropriate. Since 50% of the Ghanaian population is rural and urban wages are 40% higher than rural wages for females (GLSS 6 Labor force module), we applied a 40% lower cost of time for rural women. The resulting BCR is 30, which is higher than the baseline BCR of 24.

We also tested the impact of a reduction in the effect size (odds ratio) of exclusive breastfeeding from 3.02 to 1.5. The BCR increases from 24 to 29 in this case which appears counterintuitive. However, a decrease in the effect size for exclusive breastfeeding reduces the costs of maternal time required, which outweighs any loss in benefits. The next sensitivity test examined the impact of a 20% increase in the overall cost of the intervention on the BCR. Applying this new cost reduces the BCR from 24 to 20. Lastly, we tested the impact of an upward variation of total benefits by 20%. This causes the BCR to increase from 24 to 29. These sensitivity analyses imply that the BCR for breastfeeding promotion is robust to variations in costs and benefits.

Table 13: Sensitivity Analysis for Breastfeeding Promotion

Parameter	BCR at 8% Discount Rate
Post-intervention coverage @ 60%	37.0
Lower time and inconvenience cost	30.0
Reduced effect size of intervention (1.5)	29.0
20% Increase in total cost	20.0
20% Increase in total benefits	29.0

3.3 Discussion

Our analysis shows that a breastfeeding promotion intervention targeting approximately 174,000 women will lead to 43,300 extra women exclusively breastfeeding and 20,600 extra women continuing breastfeeding. The intervention costs 12m GH¢ to implement and would lead to an assumed 1 hour per day of time and inconvenience cost for 27,439 women who would have otherwise partially or not breastfed. We value this cost at 14m GH¢ for a total intervention cost of 26m GH¢. The intervention could lead to substantial health benefits with 745 child deaths and approximately 160,000 cases of child illness avoided before age two. These benefits are valued at 608m GH¢ for a BCR of 24.

It is worth mentioning that this estimate is subject to substantial uncertainty on both the cost and the benefit sides. Regarding costs, estimation of time and inconvenience of exclusive breastfeeding is extremely limited, with only three studies (to the best of our knowledge) assessing this parameter. These studies are inconsistent and have questionable external validity to Ghana.

The health benefits of breastfeeding come from several meta-analyses (Lamberti et. al., 2013; Sankar et. al., 2015). However, these effects are drawn from cohort and case-control studies and are subject to a significant risk of bias (i.e. there is high chance that an unobserved variable, such as maternal conscientiousness, is the factor that increases both breastfeeding and infant health). Nevertheless, we do not include other potential benefits such as health benefits to breastfeeding women, cognitive improvement in children (Horta, de Mola & Victora, 2015) and the intrinsic joy of breastfeeding.

4. Complementary feeding promotion

4.1 Intervention context

Optimal complementary feeding involves providing young children with sufficient quantities of quality diets at sufficient frequency, appropriate to age (Dewey et. al., 2008). This is achieved through providing diets which are sufficiently diverse (that is varied) food groups and at optimal frequency based on child age. Dietary counseling for young infants assumes that caregivers are food secure, and that the deficits in child feeding are dependent on improving caregiver competence on optimal foods and feeding methods. For those who are food insecure, complementary feeding promotion is not effective without combining dietary counseling with a food provisioning strategy (WHO, 2003).

Information about complementary feeding is typically provided to caregivers through child welfare clinics in Ghana through one-on-one dietary counseling. Although the intervention targets all children attending child welfare clinics, those whose growth pattern lags behind the growth standard, are more likely to benefit from dietary counseling. Scaling up complementary feeding promotion requires multiple actions including training of care providers on how to use existing counseling cards, and on counseling skills. Complementary feeding intervention also requires increasing supply of job aids for dietary counseling. Finally, increasing access to child welfare clinics will improve coverage of complementary feeding promotion. Community health worker led interventions where the workers go to houses with small children to provide counselling are also known to have a positive impact (Singh et. al., 2017). Complementary feeding improves nutrition outcomes, notably stunting (Panjwani and Heidkamp, 2017).

4.2 Calculation of Costs and Benefits

4.2.1 General parameters

As with the previous analysis the intervention targets 173,764 children, representing a 20% increase in the coverage of the intervention. The intervention is only suitable for children in households which are food secure. Darfour and Rosentrater (2016) indicate that 95% of households are food secure in Ghana. In the following analysis we assume that implementers cannot identify food secure households *ex-ante*. Therefore, costs are applied to the entirety of the target population but benefits only to the food secure proportion of that population.

4.2.2 Baseline and post-intervention prevalence of stunting

To estimate the prevalence of stunting in the general population we conduct a trend analysis on 30 years of survey data. Stunting in Ghana has fallen consistently over this time period with a rate of 42.6% in 1988 to 18.0% in 2017. The trend analysis indicates that the appropriate 2018 stunting prevalence is 17.3%.

However, this represents the value for the entire population, including both food secure and insecure. Given that the intervention only benefits food secure households, we estimate the stunting prevalence in this sub-group noting that being food insecure increases the odds of stunting by 2.46. The estimate of stunting prevalence in 2018 for food secure households in Ghana is therefore 17.0%.

For the purposes of subsequent calculations on stunting reduction and associated health benefits, we also estimate the prevalence of severe and mild stunting. We do this by recognizing that the distribution of HAZ scores is by definition, a Z-distribution with standard deviation of 1. The WHO reference distribution has a mean of zero, and stunting is defined by those whose HAZ falls below 2 standard deviations of this reference distribution. Therefore, we can identify the parameters of the z-distribution for the target population – i.e. where the probability density function includes 17.0% (the estimated prevalence of stunting) below the 2 sd cutoff, and estimate the prevalence of other types of stunting at < 3 sd (severe) and < 1 sd (mild) below the reference mean. The results are presented in Table 14 below.

Table 14: Estimated prevalence of under-5 stunting with and without the intervention

Stunting type	Without intervention	With intervention	Absolute number of avoided stunting for a target population of ~174,000 children
Mild stunting or worse (<1 s.d. below reference mean)	52%	47%	7,240
Moderate stunting or worse (<2 s.d. below reference mean)	17%	14%	4,352
Severe stunting (<3 s.d. below reference mean)	3%	2%	964

A recent meta-analysis indicates that complementary feeding promotion has a small but significant impact on child height, boosting mean HAZ by 0.11 (Panjwani and Heidkamp, 2017). We use this relationship to estimate the new rates of stunting by shifting the mean of the z-distribution by 0.11 to the right, and calculating how much of the new distribution falls below the cut-off levels. This information is presented in Table 14 above. The analysis indicates that the intervention will reduce severe stunting by 1% (3% ➔2%, 964 children), moderate stunting by 3% (17% ➔ 14%, 4,352 children) and mild stunting by 5% (51% ➔ 47%, 7,240 children).

4.2.2 Costs

Based on Ghana Priorities' assumptions, we calculate the cost of reaching a child as GH¢ 27 (at 2018 prices). We also include the cost of mother's time and following Penny et al. (2005), Saleem et al. (2014) and Zhang et al. (2013), assume about 7 counseling sessions of 15 min per mother, broadly following Bhutta et al. (2013). We also used personnel time per counseling session of 27 min which accounts for counseling time plus travel to the next household. The cost of maternal time is also valued at Ghana Priorities standard assumptions and equals GH¢ 2.7 per hour. The total cost of the intervention is GH¢ 4.9m of which GH¢ 4.63m represents direct promotion costs and the remainder maternal time costs.

4.2.3 Benefits

Child undernutrition has long been associated with increased risk of child mortality (Olofin et. al., 2013; Forouzanfar et. al., 2016). Additionally, there is evidence that stunting detrimentally affects cognitive and physical development in childhood (Bhutta et. al., 2013) and is associated with lower education attainment (Nandi et. al., 2015), lower asset accumulation (Victora et. al., 2008), and significantly lower consumption in adulthood (Hoddinott et. al., 2013).

Health benefits

Higher HAZ scores are associated with lower risks of mortality, primarily through the pathway of reduced infection (Olofin et. al., 2013). 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 15 based on Olofin et. al., (2013). 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 ALRI (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.

Table 15. 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
Acute lower respiratory infections (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 neonatal sepsis, tuberculosis, 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.

We estimate health benefits using the potential impact fraction approach (see Equations 1 and 2). In this case, because the intervention only affects children above age 6 months, we only assess risk reductions against baseline deaths from 6 months to 5 years. The results of the analysis indicate that the intervention will avoid 65 deaths, with 27 deaths avoided in the period between 6-11 months and the remaining deaths over the next four years (see Table 16). Diarrhea disease and lower respiratory infections represent the causes with the greatest deaths avoided.

Table 16: Estimated deaths avoided per cohort exposed to complementary feeding (n=173,764) by cause and age

Cause	Deaths avoided 6-11 months	Deaths avoided 1-4 years	Total deaths avoided by cause
Diarrhoea	11	15	26
Lower respiratory infections	8	11	19
Other infectious diseases	8	13	21
Total by age group	27	39	65

The value of these avoided deaths, using *Ghana Priorities* standardized assumptions, is GH¢ 48m at an 8% discount rate.

Productivity benefits

It is typical to assess the long-term benefits of stunting as an increase in lifetime productivity (Hoddinott et. al., 2013). Monetizing lifetime productivity benefits has been well explored in the returns to education literature (Psacharopolous and Patrinos, 2018). The 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. We adopt a similar approach, but instead of differing education levels we assess productivity premium associated with being stunted versus not being stunted.

In previous analyses, including those conducted by the Copenhagen Consensus Center (Hoddinott et. al., 2013; Joe, Kumar and Subramanian, 2018a; Joe, Kumar and Subramanian 2018b; Wong and Radin, 2019) the approach has been to use the results from a long term follow up to a single randomized controlled trial conducted in Guatemala in the 1960s. That analysis indicates that those who are stunted as children have 66% lower consumption than those who are not stunted (Hoddinott et. al., 2011). This, or slight discounts to this value, have typically been applied as the measure of the productivity improvement from avoided stunting.

However, there are reasons to believe that this might overstate the productivity improvement of avoided stunting in current situations in LMICs, including Ghana. First, the baseline prevalence of stunting in Guatemala in the 1960s was significantly worse than Ghana today. During the original experiment the prevalence of *severe* stunting at baseline was 45%, and the intervention was able to reduce this to 20% (Hoddinott et. al., 2008). In contrast, our estimates from Table 14 suggest rates of severe stunting are 2% in Ghana today. In the context of 1960s Guatemala, avoiding stunting meant rising from a significantly lower baseline, and a larger shift in the mean of the HAZ distribution.

Second, the Guatemala study, while a seminal piece in the literature of nutrition economics, is only one study with a relatively small sample size. There is growing recognition amongst both detractors and supporters of randomized controlled trials of the need to account for threats to external validity (Muralidharan et al, 2018). One solution is to conduct randomized trials at scale, ideally with government involvement (Muralidharan and Neihaus, 2017). However, this type of analysis including long term follow up is unavailable for the impact we hope to measure, and may not be available for some time.

To address these challenges, we draw from two strands of literature that may be more representative of situations in LMICs today (albeit still imperfect), and includes evidence from a larger sample of individuals than the INCAP study in Guatemala. One strand of literature examines the long-term effects of child stunting on adult height, while the second strand of literature examines the association between adult height and adult wages. Bringing these two bodies of work together can illuminate the relationship between child stunting and adult wages. This approach draws inspiration from recently completed work in the development of the World Bank's Human Capital Index (Kraay, 2019).

Gallaso and Wagstaff (2016) survey nine longitudinal studies of stunted children from LMICs including the well-known COHORTS study from five countries (Victora et. al., 2011), and identify that avoiding stunting is associated with a 6cm increase in height in adulthood or adolescence. McGovern et. al., (2017) review thirteen country studies that identify the relationship between adult height and wages (and control for unobserved confounding), noting that 1cm of height is associated with 4% increase in wages for men, and 6% increase in wages for women. This result is derived from evidence in developed and developing countries. However, one included study from Ghana demonstrates effects directionally consistent with these overall figures (5.6% for men, 7.6% for women; Schultz 2003).

Therefore, if avoided stunting implies 6cm of increased height in adulthood, and 1cm of height is associated with 5% wage increase, equally averaged between men and women, then a simple multiplication implies avoided stunting leads to a 6cm * 5% = 30% increase in wages.

We apply this value to the stream of future income projected under the *Ghana Priorities* standardized assumptions, assuming individuals work from age 15 to age 60 (Wong and Dubosse, 2019). Results indicate that at an 8% discount rate, the present value of future income attributable to avoided stunting is approximately GH¢ 30,000 or almost 3x GDP per capita in 2018. This is multiplied by the number of avoided stunting cases, 4,352 children resulting in a productivity benefit of GH¢ 130m at an 8% discount rate. This is likely to be an underestimate of the productivity benefit since we do not assess benefits from avoided mild stunting, nor include a premium above the 30% variable for avoided severe stunting.

Summary of benefits

The benefits of the intervention are summarized in Table 17 below across the three discount rates. The central estimate of benefits from the intervention is GH¢ 178m with 73% of the benefits from increased productivity and 27% from improved health benefits. Reducing (increasing) the discount rate increases (reduces) the value of productivity benefits, which is unsurprising given that these benefits are realized at 15 to 75 years after the intervention starts.

Table 17: Summary of benefits from complementary feeding

Discount rate	Mortality avoided benefits (GH¢, millions)	Productivity benefits (GH¢, millions)	Total benefits (GH¢, millions)
5%	52	337	389
8%	48	130	178
14%	43	28	71

4.2.4 Summary

A summary of costs and benefits is presented in Table 18 below. The results indicate that the intervention will cost 4.9m GH¢ with most of this representing direct costs of promotion and the remainder the cost of maternal time. The benefits of the intervention are significantly higher at 178m GH¢ for a BCR of 36. The result is sensitive to the choice of discount rate because a significant proportion of the benefits are due to improved productivity from avoided stunting, which only manifest 15 to 75 years after the intervention.

Table 18: Summary of costs and benefits from complementary feeding promotion

Discount Rate	Total cost (2018 GH¢ millions)	Total benefits (2018 GH¢ millions)	BCR
5%	4.9	389	79
8%	4.9	178	36
14%	4.9	71	14

4.2.5 Sensitivity analysis

To test the sensitivity of results to assumptions we vary several key parameters: i) higher stunting prevalence, ii) change in HAZ, iii) further improved and reduced boosts to productivity from avoided stunting, and iv) a 25% reduction and increase in unit costs. The results are reported in Table 19 below, and here we consider only the effects on the BCR estimate at an 8% discount rate.

Given that the national prevalence of stunting at 18% masks considerable variation across regions in Ghana, a sensitivity analysis with the stunting prevalence rate in northern Ghana (a region with much higher stunting prevalence - at 33%) was done. The BCR significantly improves from 36 to 53. Increasing the unit cost of the intervention by 25% reduces the BCR from 36 to 29, whereas reducing it by 25% causes the BCR to improve to 49.

Different boosts to productivity from avoided stunting were factored into the analysis. A 66% boost (Hoddinott et al, 2011) which is slightly more than double as compared to the 30% increase used in the analysis gives an improved BCR of 56 as compared to 36. Further, analyzing a slightly lower impact at a 15% productivity boost results in a reduced BCR of 25.

We next use the lower and upper bounds of 95% CI from Panjwani and Heidkamp (2017) to analyze the impact of change in stunting on the BCR. Using the lower bound of 0.01 sharply reduces the BCR to only 6 whereas factoring in the upper bound impact at 0.22 significantly improves the BCR to 66.

Table 19: Sensitivity Analysis of complementary feeding promotion

Parameter	**BCR at 8% Discount Rate**
Stunting rate of northern Ghana @ 33%	53
Increased unit cost of intervention by 25%	29
Decreased unit cost of intervention by 25%	49
Improved boost to productivity (66%)	56
Reduced boost to productivity (15%)	25
Change in HAZ (0.01)	6
Change in HAZ (0.22)	66

4.3 Discussion

Expanding complementary feeding promotion in Ghana is likely to be a very cost-effective intervention, with the cost-benefit analysis estimating a central BCR of 36. Providing ~174,000 women with education about appropriate feeding after 6 months via community health workers would only cost 4.9m GH¢. It is expected to lead to 4,352 cases of avoided stunting. These individuals would experience lifetime productivity benefits equivalent to 3x GDP per capita at an 8% discount rate. Additionally, this improvement in nutritional status would lead to 65 avoided deaths over five years.

The evidence for the effect on nutrition counseling on HAZ is high quality, having been derived from five RCT analyses (Panjwani and Heidkamp, 2017; Figure 2). None of these studies come from Ghana or Africa. However, there is evidence that knowledge of infant young child feeding practices and exposure to complementary feeding interventions is associated with optimal child feeding in Ghana (Agbozo, Colecraft and Ellahi, 2016; Gyampoh, Otoo and Aryeetey, 2014), suggestive that these interventions would be directionally consistent with the meta-analysis finding. One cluster-randomized control trial from the Upper Manya Krobo district of Ghana (n=367, from 2012) did not find any improvement in child feeding practices from complementary feeding promotion intervention (Cofie, 2012). However, in that experiment almost half of the enrolled mothers did not attend any education classes.

The expected cost of the intervention, based on an ingredients approach, is from Bhutta et. al., (2013) and compares reasonably well with programmatic costs under the Scaling Up Nutrition program.

Overall the body of evidence behind this intervention is assessed as strong with more uncertainty on the cost side. However, even if costs were to double, the intervention would still have a high BCR. On the basis of this analysis, scaling up of complementary feeding promotion appears to be one of the most cost-effective interventions not only within nutrition, but across all sectors in Ghana.

5. Nutrition sensitive agriculture

5.1 Intervention context

Globally, sub-optimal diets, and malnutrition in all its forms are common and linked with disease and impaired health outcomes. There is global commitment to ‘enhance sustainable food systems …that meets people’s nutrition needs and promote safe and diversified healthy diets.’ (Food and Agriculture Organization (FAO) and World Health Organization (WHO) 2014). A critical aspect of improving the food and nutrition system is to better understand the important role agriculture plays in supplying adequate amounts of quality food in a sustainable fashion across different contexts. Agricultural strategies that address malnutrition (nutrition-sensitive agriculture) are considered critical to address malnutrition. However, there are only a few examples demonstrating how such interventions work. The current analysis investigates the scale up a community-based integrated health and nutrition-sensitive agriculture intervention targeting households whose effects were studied under a randomized controlled trial framework and documented in Marquis et. al., (2018).

The agriculture component of the intervention involves providing inputs to eligible households (those with young children under one year old). The households receive thirty to forty chickens at point of lay that will be raised for their eggs. Along with the chickens, they also receive technical assistance for constructing chicken coop, maintaining health, hygiene, and reducing mortality of the chickens, harvesting, storing and marketing the eggs. Beneficiary households also receive support for identifying a sustainable source of feed as well as increasing/replacing their chicken stock, when needed. The intervention also included a substantial home gardening component to provide households with nutritious vegetable-based foods.

The health and nutrition component of the intervention involves linking eligible households to the health system so that they can access information on how frequently, and in what ways to feed their children with food prepared using eggs. This opportunity is also used to train caregivers about improving their capacity to stimulate mental development of their children through play, and other forms of interaction.

5.2 Calculation of Costs and Benefits

5.2.1 General parameters

As with the previous promotion interventions, this intervention targets ~174,000 households with young children. Studies indicate that nutrition education and complementary feeding are able to reduce stunting regardless of whether the target household is food secure or otherwise (Bhutta et. al., 2013; Panjwani and Heidkamp, 2017). As described in section 4.2.1 the prevalence of stunting is assumed to be 17.3% across the beneficiary population.

5.2.2 Costs

Costs are based on a recent analysis that estimated both financial and economic costs of the intervention delivered to 287 households (Owusu, 2019). Financial costs were obtained from implementation project managers and included the costs of activities (such as training of

Community Health Nurses on child health and nutrition, training of mothers on poultry egg production and vegetable home gardening activities) as well as materials and assets (chicken for mothers, materials for the construction of chicken coop, vehicle, transportation, stationery, and communication). Total direct costs are estimated at approximately GH¢ 1m or per household cost of GH¢ 3530. About half the costs were for poultry, 22% of costs for home gardening with the remainder for training and education.

The intervention was time intensive with significant assistance provided by volunteers, and community workers. The analysis thus requires a careful estimate of additional economic costs including time. Owusu (2019) estimates these indirect costs including time of implementation, time of training and travel costs incurred by households. For instance, mothers were trained on vegetable home gardening activities such as beds preparation, spacing when planting, pests and disease control, etc. Similarly, food demonstration sessions were organized to help mothers develop nutritional combinations that are ideal for their infants, and young children. The analysis indicates total economic costs of GH¢1.3m, using rural wage rates for the opportunity cost of time. This translates to a per household cost of GH¢ 4,495.

Total costs of the intervention are therefore GH¢ 8,025 per household with overall 45% of the costs for education and training, 38% for poultry production, and the remainder for home gardens.

Table 20: Unit costs of the nutrition sensitive agriculture intervention (GH¢)

	Home Garden	**Poultry production**	**Education and training**	**Total**
Direct cost	792	1,668	1,070	3,530
Indirect cost	573	1,397	2,524	4,495
Total	1,365	3,065	3,594	8,025

Given a population of ~174,000 households the total costs of the intervention would equal GH¢ 1,394m.

5.2.3 Benefits

Here we estimate three types of benefits –health and productivity benefits from avoided stunting, as well as an increase in income from the intervention.

Health and productivity benefits from avoided stunting

Marquis et. al., (2018) indicate that exposure to the intervention leads to an increase in HAZ of 0.22. As with the complementary feeding promotion intervention we use this finding to estimate the pre- and post-intervention prevalence of stunting. Results are documented below and indicate that stunting would be reduced by 5% or 8,782 children.

Table 21: Pre- and post-intervention prevalence of stunting

Stunting type	Without intervention	With intervention	Absolute number of avoided stunting for a target population of 174,000 children
Mild stunting (<1 s.d. below reference group mean)	52%	44%	15,200
Moderate stunting (<2 s.d. below reference group mean)	17%	12%	8,782
Severe stunting (<3 s.d. below reference group mean)	3%	2%	1,874

Using this finding we calculate the flow effects to health outcomes (see complementary feeding section for methodology), and note that the intervention will avoid 120 deaths over the next five years. Using the valuation approach discussed previously, the health benefits of the intervention amount to GH¢ 89m at an 8% discount rate.

Table 22: Deaths avoided by cause by nutrition sensitive agriculture

Cause	Deaths avoided 6-11 months	Deaths avoided 1-4 years	Total deaths avoided by cause
Diarrhoea	21	30	52
Lower respiratory infections	17	21	38
Other infectious diseases	12	19	30
Total by age group	50	70	120

As discussed in Section 4, avoided stunting leads to a lifetime productivity benefit of 30%. Applying this to the number of cases of stunting avoided results in a benefit of GH¢ 261m.

Income benefits

Owusu (2019) indicates that women involved in the intervention experienced an increase in net income of GH¢ 339 per month, mostly from egg sales. We multiply this by the number of beneficiaries to estimate an increase of GH¢ 708m per year. We assume that the benefits of the intervention will last for three years, the average productive life of an egg-laying chicken. The income value is GH¢ 1,823m at an 8% discount rate.

However, it is likely that some proportion of this income was used to generate the health and productivity benefits documented previously. Owusu (2019) states that only 3% of the eggs generated by the intervention were actually consumed by the households (and not all of these by the children) suggesting that it was the additional purchases derived from the income that generated the additional health and productivity benefits. Summing up the benefits would probably represent double counting. Unfortunately, detailed expenditure data was not collected to ascertain, for example, the increase in food consumed post-intervention to make the appropriate adjustment.

Overall benefits

Due to the uncertainty around the extent of double counting, we generate a range of estimates where the minimum value represents just the income benefits, and the maximum value represents income plus health and productivity benefits. The minimum value represents the case where households spend income on foods and other goods to an extent that exactly equals the value of the nutrition benefits. The maximum value represents the case where households merely reallocated existing income to generate the nutrition benefits, and therefore the full amount of the increase in income is truly additional to other benefits.

The benefits of the intervention are noted below in Table 23.

Table 23: Summary of Benefits of Nutrition Sensitive Agriculture

Discount Rate	Income benefits (GH¢, millions)	Health benefits (GH¢, millions)	Productivity benefits (GH¢, millions)	Min total benefits (just income)	Max total benefits (income + health + productivity)
5%	1,927	161	680	1,927	2,703
8%	1,823	150	261	1,823	2,174
14%	1,643	132	57	1,643	1,778

Overall the intervention is expected to generate benefits of between GH¢ 1,823 and GH¢ 2,174. In the maximum case, roughly 85% of benefits come from income generation.

5.2.4 Summary of results

An intensive community-based nutrition-sensitive agriculture intervention that provides training in home gardening and poultry production - if expanded to 174,000 households, would cost GH¢ 1,394m. It would generate GH¢ 1,823m in income benefits. The intervention reduces the prevalence of stunting in the beneficiary population by 5% leading to potential additional benefits for health (GH¢ 150m), and lifetime productivity (GH¢ 261m). We do not know how much of the extra income was used to generate the stunting reduction, and therefore we estimate a range of benefits between GH¢ 1,823m and GH¢ 2,174. The BCR lies between 1.3 and 1.6, at an 8% discount rate.

Table 24: Summary of Costs and Benefits of Nutrition Sensitive Agriculture

Discount Rate	**Total cost (2018 GH¢ millions)**	**Total benefits (2018 GH¢ millions)**	**BCR**
5%	1,394	1,927 – 2,703	1.4 – 1.9
8%	1,394	1,823 – 2,174	1.3 – 1.6
14%	1,394	1,643 – 1,778	1.2 – 1.3

5.2.5. Sensitivity analysis

To test the validity of the BCRs and uncertainty, one-way sensitivity was analysis were performed with appropriate parameters. The sensitivity analysis describes the impact of variation in stunting rate, effect size of the intervention, costs of intervention, and increase in income earned as a result of the intervention while holding other variables constant on the BCR.

Given that the national prevalence of stunting at 18% masks considerable variation across regions in Ghana, a sensitivity analysis with the stunting prevalence rate in northern Ghana (a region with much higher stunting prevalence - at 33%) was done. The BCR increases very marginally from 1.6 to 1.7 in this case. Assuming that the costs for delivering the intervention could be higher than estimated, the sensitivity analysis was done with a higher cost figure (one and a half times the cost reported). The BCR drops from 1.6 to 1.0 in this case. The analysis next factored in a reduced effect size of the intervention – a 0.2 reduction in the prevalence of stunting instead of 0.22 was used to assess the robustness of the BCR. The lower rate of reduction in the prevalence of stunting was used with the assumption that eggs produced may not be used appropriately in the children's diet but instead sold for extra income. The BCR reduces marginally to 1.5. Further factoring in a 10% increase in extra income earned from the intervention, the BCR increases to 1.7.

Table 25: Sensitivity Analysis for Nutrition Sensitive Agriculture

Parameter	**BCR at 8% Discount Rate**
Stunting rate of northern Ghana @ 33%	1.7
Higher cost of intervention	1.0
Reduced effect size of intervention (0.2)	1.5
10% Increase in extra income earned	1.7

5.3 Discussion

The analysis in this section demonstrates that nutrition sensitive agriculture could generate significant benefits, particularly in increased income for the beneficiary population. The intervention also generates nutrition and health benefits. In a cost-benefit framework, we cannot ascertain the extent to which these benefits are double counted with income gains. We did not attempt to value empowerment benefits from the intervention. The quality of the evidence for this intervention is rated as very strong, since both costs and benefits come from the same randomized control trial in Ghana. The BCR range 1.3 - 1.6 also is consistent with BCRs from other livelihood interventions from across the world (Sulaiman et al., 2016).

Nevertheless, there is still uncertainty about the outcome of this intervention were it to be scaled up across other parts of the country. For example, providing poultry for 174,000 households would require the distribution of almost 7m chickens with uncertain implications for local animal and egg markets. The analysis strongly indicates that this intervention is likely to have the lowest BCR of all the interventions documented in this paper, and should not be prioritized over other nutrition programs if the aim is to maximize welfare per unit cost.

6. Conclusion

This paper undertook cost-benefit analyses of four achievable interventions designed to improve health and nutrition over the first 1,000 days of a child's life. A summary of each intervention is presented in the table below. The range of BCRs is large, spanning values from 1.3 to 36.

Table 26: Summary of Outcomes, Costs, Benefits and BCR of Interventions Analysed

Intervention	**Beneficiary population**	**Outcomes**	**Total costs (GH¢ m)**	**Total benefits (GH¢ m)**	**BCR**	**Quality of evidence**
MMN and Ca supplementation in pregnancy	850,573 pregnant women	• 109,637 cases of anemia avoided • 82 maternal deaths avoided • 24,162 pre-term births avoided • 887 Still births avoided • 4,210 infant deaths avoided	203	3,585	18	Medium
Breastfeeding promotion	174,000 mother-child pairs	• 43,300 more women exclusively breastfeeding • 20,600 more women continuing to breastfeed until 23 months • 745 child deaths avoided	26	623	24	Limited
Complementary feeding promotion	174,000 mother-child pairs	• 4,352 children avoiding stunting leading to lifetime productivity gain of 30% • 65 child deaths avoided	4.9	178	36	Strong
Nutrition sensitive agriculture	174,000 mother-child pairs and their households	• Boost to HH income of GH¢ 4,070 • 8,780 children avoiding stunting leading to lifetime productivity gain of 30% • 120 child deaths avoided	1,394	1,823 to 2,174	1.3 to 1.6	Very strong

Overall, the intervention with the highest BCR is complementary feeding promotion, and our analysis suggests that the Ghanaian government should prioritize the scale up of this intervention if the aim is to maximize welfare per unit cost. MMN and Ca supplementation is also a valuable investment, generating substantial benefits per cedi at 18, as well as largest absolute net benefits of the interventions analyzed (though this latter finding is mostly due to the larger scale of this intervention relative to the others). Breastfeeding promotion is also a worthy investment, although there is significant uncertainty on both the costs and benefits sides. The nutrition-sensitive agriculture intervention has the lowest BCR and should not be prioritized if government resources are constrained (i.e. the government cannot easily borrow or raise taxes to fund new investments), and the aim is to maximize welfare.

7. BCR Summary Table

Interventions	**Discount**	**Cost (GH¢ m)**	**Benefit (GH¢ m)**	**BCR**	**Quality of Evidence**
MMN and Ca supplementation in pregnancy	5%	203	3,703	18	Medium
	8%	203	3,585	18	
	14%	203	3,527	17	
Breastfeeding promotion	5%	26	624	24	Limited
	8%	26	623	24	
	14%	26	621	24	
Complementary feeding promotion	5%	4.9	389	79	Strong
	8%	4.9	178	36	
	14%	4.9	71	14	
Nutrition sensitive agriculture	5%	1,394	1,927 – 2,703	1.4 – 1.9	Very Strong
	8%	1,394	1,823 – 2,174	1.3 – 1.6	
	14%	1,394	1,643 – 1,778	1.2 – 1.3	

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GHANA PRIORITIES

The Ghanaian economy has been growing swiftly, with remarkable GDP growth higher than five per cent for two years running. This robust growth means added pressure from special interest groups who demand more public spending on certain projects. But like every country, Ghana lacks the money to do everything that citizens would like. It has to prioritise between many worthy opportunities. What if economic science and data could cut through the noise from interest groups, and help the allocation of additional money, to improve the budgeting process and ensure that each cedi can do even more for Ghana? With limited resources and time, it is crucial that focus is informed by what will do the most good for each cedi spent. The Ghana Priorities project will work with stakeholders across the country to find, analyze, rank and disseminate the best solutions for the country.

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