SHORT CHANGED: The Human and Economic Cost of Child Undernutrition in Papua New Guinea

Save the Children

frontier economics

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Cover photo: Photo of child from East Sepik, Papua New Guinea.

Photo credits: all photos in this report were taken by Majella Hurney in Papua New Guinea for Save the Children Australia. Photos of children were taken with the fully-informed consent of parents or guardians.

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We save children's lives. We fight for their rights.
We help them fulfil their potential.

This report was written by Majella Hurney for Save the Children Australia.

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EXECUTIVE SUMMARY

Papua New Guinea (PNG) is facing a nutrition crisis. Alarmingly, almost one in two children in PNG have stunted growth due to chronic malnutrition.[1] PNG has the fourth highest child stunting rate in the world[2] – a rate that is more than double the global average and higher than some of the most impoverished countries in Africa and Asia.[3]

Not only does malnutrition pose a threat to the survival and development of over half a million children, it also poses a major threat to sustainable economic growth in PNG. This is because the human and economic costs of malnutrition are inextricably linked.

Evidence shows that a child will suffer cognitive and physical impairments if they are undernourished in the first 1000 days of life, from pregnancy to their second birthday. Tragically, these impairments are permanent and irreversible.

If stunted, a child's brain and body will never fully develop. These impairments limit a child's education and employment prospects. Reduced individual earning capacity translates into reduced household level incomes and economic productivity at the national level. This is how undernutrition can trap children into an intergenerational cycle of poverty.

Undernutrition robs children of their growth, education and employment prospects. It also threatens their very survival. According to national data in PNG, approximately 33% of all hospital deaths of children under five are either directly or indirectly caused by malnutrition.[4] However, Frontier Economics estimates that malnutrition could be the underlying cause of up to 76% of total deaths of children under five across community and health facilities combined.[5] This figure is staggering, and significantly higher than the global estimate of deaths of children under five associated with malnutrition at 45%.[6] Undernutrition weakens a child's immunity and causes them to suffer more frequent and severe episodes of disease. This often causes a child to become further malnourished, leading to a potentially lethal cycle. Evidence also suggests that childhood undernutrition can increase mortality risks later in life, with stunted children more susceptible to obesity, coronary heart disease and type 2 diabetes.

This report reveals, for the first time, the enormous human and economic costs of child undernutrition in PNG.

Frontier Economics estimates that child undernutrition cost the PNG economy the equivalent of $USD 508 million in the financial year 2015-16 (2.81% of its annual GDP) through three main pathways:

1. Losses in productivity from a reduction in labour force due to increased childhood mortality, estimated at $USD 46 million (0.26% of GDP);
2. Losses in potential income and productivity from poor physical status and reduced cognitive function, estimated at $USD 459 million (2.54% of GDP); and
3. Losses from increased health care expenditure in treating diseases associated with childhood undernutrition, estimated at $USD3 million (0.02% of GDP).

The estimated cost of child undernutrition significantly exceeds PNG's projected health sector and education sector budgets for 2017 ($USD 385 million and $USD 366 million respectively).[7]

The estimated cost of 2.81% of GDP is regarded as conservative, reflecting the methodology and assumptions described in Section 4 of this report. **Frontier Economics estimates the economic cost of child undernutrition could be as high as 8.45% of GDP ($USD1.5 billion per annum) using alternative assumptions,** as detailed in Section 4. Despite the shocking impact of child undernutrition, PNG has struggled to make progress in tackling this challenge over the past two decades, as acknowledged in the National Nutrition Policy 2016-2026.[8]

It has been widely assumed that economic growth alone should drive a reduction in child undernutrition. The World Bank, for example, had estimated that a 5.0% per year GDP growth rate would predict a reduction in national stunting prevalence of around 0.9 percentage points per year.[9] However, this has not proven to be true for PNG. Indeed, the stunting rate may have increased against a backdrop of strong economic growth and increased overseas aid. PNG had an average of 6.85% GDP growth from 2005 to 2010, reaching 8% in 2014.[10] Despite such growth, estimates indicate that the stunting rate for children under five rose from 43.5% in 2005[11] to 49.5% in 2015.[12] This points to the urgent need to make targeted investments to improve child nutrition outcomes in PNG, rather than assuming economic growth will drive a reduction in stunting and other forms of undernutrition.

PNG has received over $USD 5 billion in overseas development assistance from bilateral and multilateral donors over the past decade.[13] However, investments in nutrition have been extremely limited. For example, the Australian Government is the largest bilateral donor to PNG, yet only 0.1% of its official development assistance to PNG was allocated to nutrition in the years 2010 and 2012 (latest data publicly available).[14] Instead, successive Australian Governments have prioritised other aid investments with the stated aim of promoting economic development without adequately addressing child nutrition as a foundation for sustainable and inclusive growth.

It is not possible to promote inclusive and sustainable economic development in the long term in PNG if around half of the population of working age continues to suffer reduced productivity from childhood undernutrition. Indeed, child undernutrition will likely impede the potential impact of other aid investments that bilateral and multilateral donors make for the purpose of promoting economic growth.

This report shows there is an urgent need for targeted investments to improve child nutrition in PNG. It also highlights there are proven, cost-effective solutions for reducing child undernutrition, with high economic and social returns on investment. Indeed, the Copenhagen Consensus found there is a median return of $USD 16 for every $USD 1 invested in nutrition-specific interventions to reduce stunting, but the returns may be even higher as detailed in Section 5 of this report.

However, nutrition-specific interventions alone will not combat child undernutrition in PNG. It is also critical to complement these with nutrition-sensitive investments across a range of sectors to address the underlying causes of child-undernutrition, particularly those relating to food security, access to health services, family planning, access to education (particularly for girls), and lack of safe drinking water, good sanitation and hygiene.

Never before has there been a more opportune time to invest in nutrition in PNG. The country has just become a member of the Scaling Up Nutrition Network and has revised its National Nutrition Policy to accelerate progress towards ending all forms of malnutrition by 2030.

The PNG government and donors should seize this opportunity to scale up investments to combat child undernutrition in PNG. We recommend they:

1. Commit sufficient financial and technical resources to support the implementation of the PNG National Nutrition Policy 2016-2026, including multi-year funding to finance:
    a. Nutrition-specific interventions targeting the first 1000 days of a child's life, with a focus on promoting optimal maternal nutrition, infant and young child feeding practices, and access to health services to prevent and treat diseases that contribute to undernutrition.
    b. Nutrition-sensitive interventions addressing the underlying causes of undernutrition, with a focus on improving food security (including diversification and fortification of staple foods), increasing access to quality education (especially for girls), family planning, and improving access to clean drinking water, and good sanitation and hygiene.
2. Establish national and provincial multi-sectoral coordination mechanisms to provide leadership, oversight and accountability for the implementation of the National Nutrition Policy 2016-2026. It is critical to ensure nutrition interventions are costed, and adequately resourced and evaluated from the national to the district level and below.
3. Declare and implement interim targets to support the achievement of the Sustainable Development Goal on nutrition, particularly for the reduction of low birthweight, stunting and wasting.
4. Establish a national monitoring and evaluation framework to track nutrition funding, outcomes and impacts. This should include establishing reliable baseline data, and the publication of progress updates on a biennial basis to ensure transparency and accountability for the achievement of targets.

Now is the time for donors to support the PNG Government in scaling up efforts to improve child nutrition. Now is the time for action.

We cannot afford to ignore child undernutrition in PNG any longer. It not only threatens the lives of millions of children, but also threatens the long-term economic growth of the nation.

A national crisis: Almost one in two children in Papua New Guinea have stunted growth from undernutrition – a rate that is more than double the global average.

The cognitive and physical impairments from stunting are largely permanent and irreversible.

This is why child undernutrition can be a life sentence.

GLOSSARY

Malnutrition encompasses both undernutrition and overnutrition.

Nutrition-sensitive interventions are those that address the underlying determinants of child nutrition and are delivered through sectors other than health such as the agriculture, education, and water, sanitation, and hygiene sectors. Examples include diversification and fortification of food crops, conditional cash transfers, and water and sanitation infrastructure improvements.

Nutrition-specific interventions are those that address the immediate determinants of child nutrition, such as food and nutrition intake, feeding and caregiving practices, and treating disease. Examples include promotion of exclusive breastfeeding and optimal infant and young child feeding practices, micronutrient supplementation, and deworming.

Overnutrition is caused by excessive energy intake and is often measured as excessive weight-for-height (overweight and obesity) using growth reference standards for children and body mass index measurements (weight-for-height squared, or kg/m^2) for adults.

Stunting is defined as the percentage of children aged 0 to 59 months whose height for age is below minus two standard deviations (moderate and severe stunting) and minus three standard deviations (severe stunting) from the median of the WHO Child Growth Standards. It reflects chronic undernutrition during the most critical periods of growth and development in the first 1000 days of life.

Undernutrition is caused by consuming insufficient and inadequate nutrients, or excreting them more rapidly than what can be replaced. It is commonly measured by inadequate height-for-age (stunting), by inadequate weight-for-height (wasting), or by deficiencies in micronutrients such as vitamin A, iodine, zinc, and iron.

Wasting is defined as the percentage of children aged 0 to 59 months whose weight for height is below minus two standard deviations (moderate and severe wasting) and minus three standard deviations (severe wasting) from the median of the WHO Child Growth Standards. It reflects acute undernutrition, often seen in humanitarian crises where there are severe food shortages.

This mother in East Sepik said she only has 1-2 meals per day and felt hungry for most of her pregnancy. She feared she would not have enough breastmilk to feed her baby, so she started feeding her baby 'fish soup' 4 days after his birth.

1. CRISIS POINT: CHILD UNDERNUTRITION IN PAPUA NEW GUINEA

PNG is facing a child nutrition crisis. According to recent estimates, it has the fourth highest child stunting rate in the world[16] – higher than the most impoverished countries in Africa and Asia.

Alarmingly, almost one in two children in PNG is stunted (48.2% in 2016[17]) – a rate that is more than double the global average (23.8% in 2016[18]).

This means that over half a million children in PNG will never reach their full growth potential. Their cognitive and physical development will be permanently impaired. This will impact on their ability to learn, grown and gain an education. Which in turn will limit the extent to which they can gain employment, contribute productively to society and support their nation's growth. Their immunity will be compromised and they will be more vulnerable to disease, thereby increasing health care costs and contributing to higher child mortality rates. The consequences of stunting are irreversible, as described in detail in the next section.

Despite the shocking impact of child undernutrition, there has been insufficient progress in tackling this challenge to date. Indeed, the child stunting rate has worsened against a backdrop of strong economic growth.

Until relatively recently, it was widely assumed that economic growth alone would drive a reduction in stunting. The World Bank, for example, had estimated that a 5.0% per year GDP growth rate would predict a reduction in national stunting prevalence of around 0.9 percentage points per year.[19] However, rapid economic growth in PNG has not led to improved child nutrition outcomes. Indeed, the situation has become worse.

As a result of a mining resources boom, PNG enjoyed 14 years of consecutive growth.[20] It had an average of 6.85% GDP growth from 2005 to 2010, reaching 8% in 2014.[21] Despite such growth, it is estimated that the stunting rate for children under five may have worsened from 43.5% in 2005[22] to 49.5% in 2015.[23]

This finding is consistent with research which shows that rapid economic growth in several countries has produced little or no reduction in child undernutrition in the absence of targeted interventions to improve child nutrition.[24] However, there is compelling evidence to show that economic growth can drive a reduction in child undernutrition where there are macroeconomic policy initiatives to address the determinants of child nutrition.[25] An extensive cross-country econometric analysis found that macroeconomic development drives improvements in child nutrition when it leads to increased food production, reduced poverty, increased female educational attainment, improved access to health services and reduced fertility rates.[26] This has been clearly displayed in China[27] and Thailand,[28] where economic development has led to rapid improvements in child nutrition status due to targeted policy interventions specifically designed to address undernutrition.

It is clear there is an urgent need for targeted investments to improve child nutrition in PNG. Despite this, nutrition has not been prioritised by PNG's largest multilateral and bilateral donors to date. For example, Australia is PNG's largest bilateral donor, but its investment in nutrition has been extremely limited. According to a review conducted for Australia's Office of Development Effectiveness, only 0.1% of Australia's official development assistance to PNG was allocated to nutrition in the years 2010 and 2012 (latest available data).[29]

The stated purpose of Australia's aid to PNG is to promote human and economic development.[30] However, it is questionable whether Australia's aid investments will achieve this purpose in the longer term if around half of the country's population of working age continues to suffer reduced productivity from childhood undernutrition. Indeed, child undernutrition will likely impede the potential impact of other aid investments that Australia and other donors make for the purpose of promoting economic growth. Unless the Australian government and other bilateral and multilateral donors reallocate aid to prioritise investments in child nutrition, there is little prospect of donor support leading to broad-based, sustainable economic development.

There is a clear need for targeted investments in PNG to improve child nutrition across the whole nation as stunting is not just a problem for the poor or specific regions. The stunting rate is high across all regions (as shown in Figure 1 below). The Highlands Region[31] has an extremely high rate of 61.5%, while the New Guinea Islands Region[32] has the lowest at 38.1%, which is still markedly higher than the average global rate of 23.8% in 2009-10.[33]

FIGURE 1: SEVERE STUNTING, WASTING AND UNDERWEIGHT RATES FOR CHILDREN UNDER FIVE IN PNG

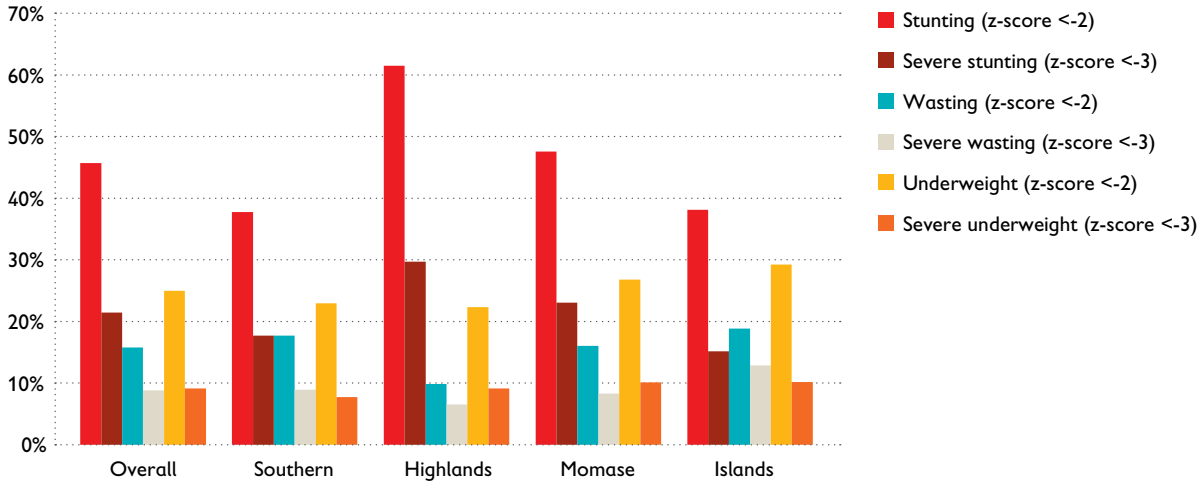


Table World Bank (2015) Data source: HIES 2009-2010

Although, globally, household wealth is a significant indicator for child stunting status, it is surprising to note that stunting is high across all wealth quintiles in PNG. As shown in Figure 2 below, the poorest wealth quintile has the highest stunting rate at 55%.[34] However, the stunting rate among the richest quintile is still very high at 36%, and similarly high among the third and fourth quintiles.[35] This evidence indicates the need for further inquiry into the factors causing such high child stunting rates, even among higher wealth quintiles. These are discussed in more detail in the following section.

FIGURE 2: THE STUNTING, WASTING AND UNDERWEIGHT RATES ACROSS WEALTH QUINTILES IN PNG

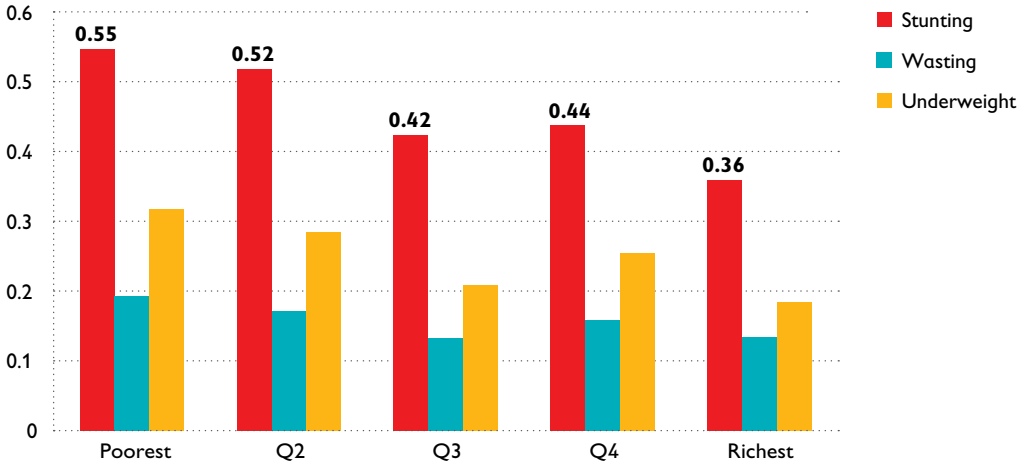
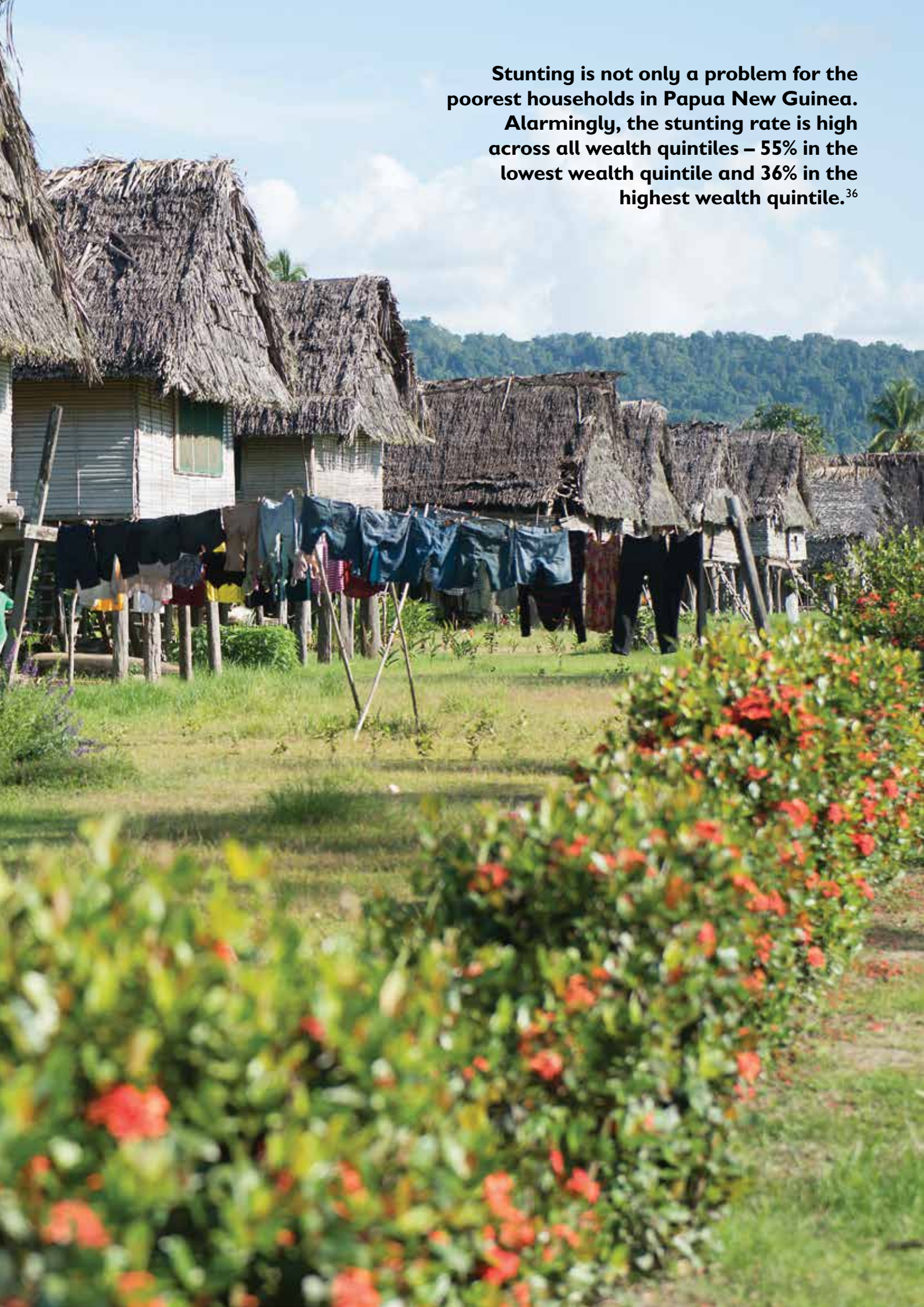


Table: World Bank (2015) Data source: HIES 2009-2010



Stunting is not only a problem for the poorest households in Papua New Guinea. Alarmingly, the stunting rate is high across all wealth quintiles – 55% in the lowest wealth quintile and 36% in the highest wealth quintile.[36]

2. CAUSES OF CHILD UNDERNUTRITION

2.1 General Causes of Child Undernutrition

To tackle the challenge of child undernutrition in PNG, we must first bust some myths about its causes. Despite common misconceptions, undernutrition is not just about food intake. That is why children can remain undernourished even when poverty decreases and access to affordable food increases. The prevalence of child undernutrition globally has declined at around half the rate of increases in GDP per capita and four times slower than the decline in poverty rates.[37]

According to UNICEF, there are two **immediate causes** of child undernutrition:[38]

1. inadequate intake of food; and
2. disease which increases energy requirements, impairs the absorption of nutrients and often reduces appetite.

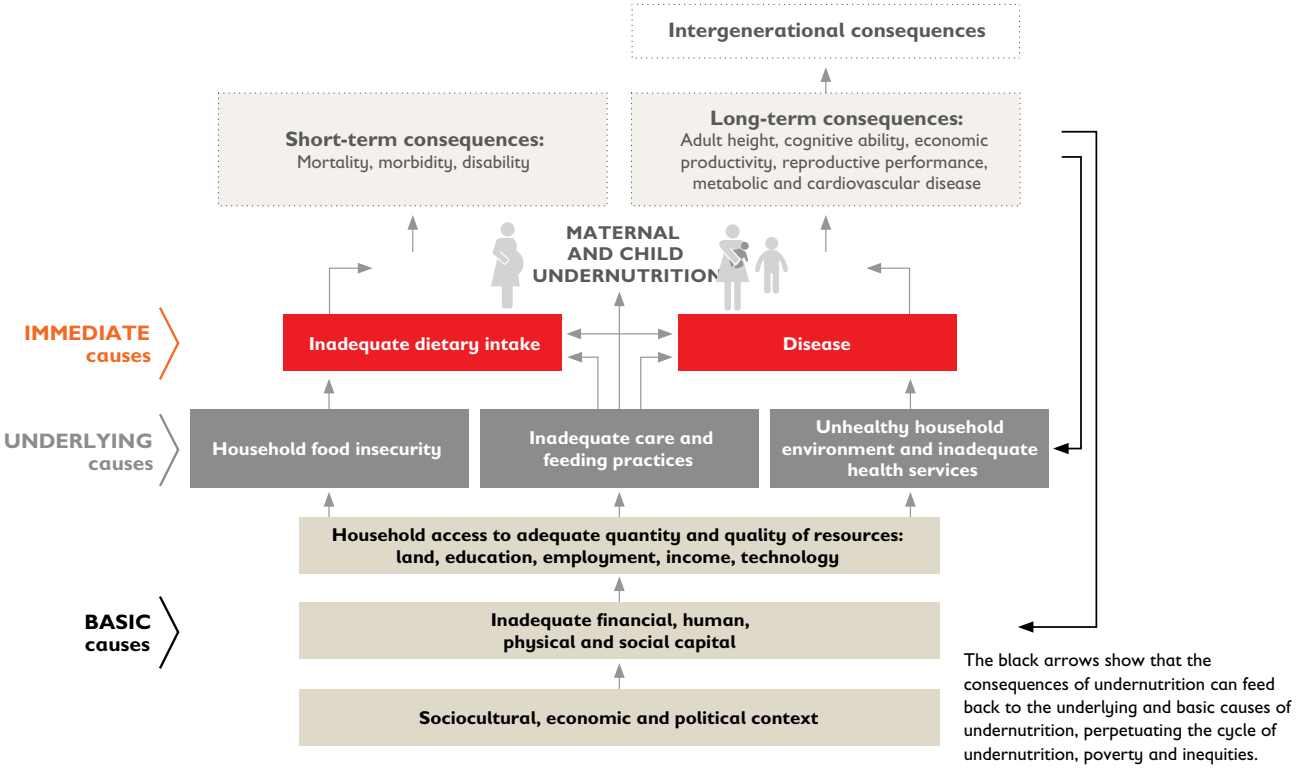
Therefore, a child may have adequate food intake, but may nonetheless be undernourished because disease impairs the absorption of nutrients.

There are a range of **underlying factors** that may result in the inadequate intake of food and/or disease in children, including:

- sub-optimal maternal and child feeding practices, most likely arising from lack of knowledge and education;
- poor health services;
- an unhealthy environment increasing the risk of disease, including lack of safe drinking water, and poor sanitation and hygiene.[39]

The interaction between these immediate and underlying factors is depicted in Figure 3 below:

FIGURE 3: THE UNICEF CONCEPTUAL FRAMEWORK OF UNDERNUTRITION



Source: UNICEF: Improving Child Nutrition: the achievable imperative for global progress. United Nations Fund 2013. p4

While the above causes impact child nutrition generally, we know that stunting specifically reflects a lack of adequate nutrition in the first 1000 days from pregnancy to a child's second birthday. During this critical period, a child has increased nutritional requirements to support rapid growth and development, and is more susceptible to infections.[40] A mother also has substantially increased nutritional requirements during pregnancy and lactation. As detailed in the next section, if a child is undernourished during this 1000 day period, the structural and functional development of the child's brain will be permanently impaired - directly affecting cognitive development. It will also affect the child's immune system and ability to fight off disease that may further compromise their nutrition status. For example, a child who is acutely malnourished is 9.5 times more likely to die from diarrhoea than a child who is not.[41]

Given that children are totally dependent on others for nutrition and care during this critical period, it is important to ensure attention is given to understanding maternal nutrition and infant and young child feeding practices in different contexts across PNG. Poor maternal nutrition – including deficiencies in protein, carbohydrates, vitamins and minerals – impairs foetal development and contributes to low birthweight, subsequent stunting and other forms of undernutrition.[42]

Inadequate maternal nutrition is often prevalent among adolescent mothers, particularly those who are uneducated and/or do not have access to adequate maternal health services. Undernourished girls have a greater risk of becoming undernourished mothers who in turn have a greater risk of giving birth to low birthweight babies, perpetuating an intergenerational cycle of undernutrition.[43]

After birth, a number of practices can directly lead to poor nutrition and growth. These include: not breastfeeding exclusively for the first six months; introducing complementary foods before or after six months that provide insufficient iron, Vitamin A and other micronutrients essential for growth and development; and/or unsanitary and unhygienic preparation of complementary foods, increasing the risk of infection.

Undernutrition can be exacerbated by diseases such as diarrhoea, malaria or intestinal worms, which increase energy requirements, impair the absorption of nutrients and often reduce appetite.[44] There is a growing body of evidence to suggest that repeated episodes of diarrhoea reduce the body's ability to absorb nutrients; and an undernourished child is at a high risk of suffering more frequent and severe episodes of diarrhoea.[45]

Recent evidence suggests that Environmental Enteric Dysfunction (EED) (also known as enteric enteropathy, or environmental enteropathy) is also a major cause of child under nutrition, with poor water, sanitation and hygiene being the main route through which EED causes stunting.[46] EED is an inflammatory condition of the gut that is caused by persistent infection as a result of poor sanitation and hygiene.[47] The use of nutrients to fight this ongoing infection diverts energy away from growth and may lead to stunting and impaired development, as well as oral vaccine failure, affecting children on a population level.[48] Infants and children living in conditions of poor sanitation and hygiene have chronic exposure to large quantities of faecal bacteria, resulting in physiological and anatomical changes to the gut without signs or symptoms.[49] Efforts to eliminate child undernutrition have historically focused on dietary solutions, such as complementary feeding, which have been insufficient to eliminate stunting. Failure to understand and address EED, and poor hygiene and sanitation practices may account for the current knowledge gap in the prevention and treatment of under nutrition, particularly stunting.[50]

Sustainable solutions to tackle child undernutrition must therefore address root causes – not just food intake. This requires an understanding of the causes in the given context. This is examined in more detail in the next section.

This photo shows swamp water in East Sepik, in which humans and animals defecate. Tragically, the same swamp water is used to prepare sago and fish soup that is fed to infants shortly after birth.

Giving an infant food other than breast-milk before six months of age can be highly dangerous. Depending on the type of food given, there is a risk that the child will be deprived of the energy and nutrients required to support their growth and development. It also increases the risk of the child suffering more frequent and severe episodes of disease, which causes them to be further malnourished and vulnerable to other diseases.

This is how malnutrition and disease form part of a potentially lethal cycle.

2.2 Specific Determinants of Child Undernutrition in PNG

Despite having extremely high child stunting and wasting rates, limited research has been undertaken to identify the specific determinants of undernutrition in PNG and track changes in nutritional status over time. The discussion below is informed by a World Bank policy paper published in 2015 analysing the 2009-10 PNG Household Income and Expenditure Survey (HIES) and other national data.[51] Specifically, it examined the association between geography, household wealth, education levels, food intake and disease incidence on child nutritional outcomes The findings were consistent with earlier studies drawing on the 1982-3 National Nutrition Survey (NNS), 2005 NNS, and 1990 and 2000 Censuses

2.2.1 Household Wealth

Household wealth is a determinant of child nutrition outcomes in PNG, but not to the extent one might expect. Not surprisingly, the poorest wealth quintile in PNG has the highest stunting rate at 55% (see Figure 2). This is consistent with studies in other low income countries where household wealth is generally a predictor of food security, access to quality health services and educational attainment of the mother; factors which themselves are underlying causes of undernutrition.

However, what is interesting to note, is that the stunting rate among the richest wealth quintile is still very high at 36%, and similarly high among the third and fourth quintile (see Figure 2).[52]

The fact that the stunting rate is relatively high across all wealth quintiles suggests that undernutrition may persist even as household wealth increases. As recognised by the World Bank, this may be attributable to a lack of education and knowledge of optimal maternal nutrition, and infant and young child feeding practises, as detailed in sub-sections 2.2.2 and 2.2.3

Lack of awareness of, and access to information on, proper nutrition is likely to be an important factor contributing to high levels of child undernutrition in PNG, across all wealth quintiles.[53] This is especially the case in remote rural communities with limited access to education and low literacy rates.[54] In particular, studies in PNG have shown that mothers lack knowledge about optimal breastfeeding and complementary feeding for their children.[55]

Furthermore, past national capacity assessments have indicated that health workers, who are often a crucial source of child care information to families, themselves lack information on optimal maternal nutrition and infant and young child feeding practices.[56] This may be explained, in part, by health workers being in very remote areas and not able to access training to improve their knowledge.

2.2.2 Suboptimal Maternal Nutrition

The main window of opportunity to prevent child stunting and other forms of chronic undernutrition is the intra-uterine and postnatal periods from pregnancy until 24 months. During pregnancy and lactation, mothers have higher energy and nutrient needs to support foetal development and meet their own nutrition and energy requirements. As detailed in the next section, if a mother has a low body mass index and lacks essential nutrients such as iron during pregnancy, it will impact on the development of the baby in utero and lead to her delivering a low birthweight baby.[57] It can also lead to maternal depletion syndrome affecting the health of the woman and any future children. In 2005, an average of 7.9% of babies in PNG were born with low birth-weight (less than 2500 grams), with the highest rate in the Southern Region (22.8%).[58] The Southern region also had the highest rate of underweight non-pregnant women of reproductive age (11.2%),[59] followed by Momase (8%).[60] Sub-optimal maternal nutrition and malaria infection are known to increase the risk of low birthweight in PNG.[61]

Maternal nutrition is likely to be strongly influenced by household food security and geography. In particular, protein intake and geographic location are correlated. While food preferences and availability are changing in PNG, the majority of the population live in rural areas and typically consume diets that are low in either animal or vegetable-source protein. Typical rural diets mainly comprise of traditional root (tuber) crops of which sweet potato is the main food item, particularly in highland areas.[62]

Root vegetables contain less zinc than animal protein, which can impact on cellular growth processes for children in utero. Whereas, in coastal, riverine and swamp areas, the typical diet consists of fish and sago with limited vegetables. In contrast, the typical diet in urban areas contains more processed foods, including tinned meat and fish,[63] combined with rice, instant noodles and cereals staples.[64]

It is likely that maternal nutrition in PNG is also influenced by social and cultural norms, particularly in more remote areas. Among some cultural groups in PNG, food taboos and traditional customs in pregnancy and lactation are strongly adhered to. There is anecdotal evidence suggesting that in some locations women adhere to the erroneous belief that reducing protein intake during pregnancy can reduce the risk of having a large baby and experiencing complications during childbirth.[65]

Accordingly, there is a pressing need to ensure women of reproductive age and their family members in PNG are provided with information on optimal nutrition during pregnancy and lactation by health workers. However, given that less than 20% of the female population receive an education beyond primary school level[66] – particularly in rural areas – it is increasingly important to strengthen the nutritional education and counselling components of existing maternal and newborn child health services, to encourage optimal nutrition during and after pregnancy, and lactation.

2.2.3 Suboptimal Infant and Child Feeding Practices

The way children are fed – particularly up to the age of 2 years – can have a profound impact on their health and development. The World Health Organization recommends exclusive breastfeeding for the first six months of life as the healthiest and safest feeding practice for infants.[67] Exclusive breastfeeding guarantees infants a food source that is uniquely adapted to their needs and contains nutrients in a form they can easily absorb, while also being safe, clean, health and accessible.[68] Breastfeeding also keeps infants safe from unhygienic environments and contaminants in foods that can cause disease and lead to nutrient loss.[69] Breastmilk also contains antibodies from a mother's immune system, helping prevent infection and disease. There is overwhelming evidence to suggest that breastfeeding protects against pneumonia and diarrhoea – the two leading killers of children under five. Indeed, in low-middle income countries research has shown that infants who were not breastfed exclusively for the first 6 months were 2.8 times more likely to die than those who were exclusively breastfed.[70] The risk of dying was highest among those not breastfed at all; these infants were 14 times more likely to die than those infants who were exclusively breastfed.[71]

Despite policies in PNG promoting exclusive breastfeeding for the first six months, the average rate of exclusive breastfeeding drops from 56% at birth[72], to only 20.1% by 6-7 months – less than half the global rate.[73] Also of great concern is the introduction of complementary foods too early, with 10% of newborns and almost 27% of infants given semi-solid or solid food before 4 months of age.[74] Similarly, mothers in East Sepik reported to Save the Children that they introduced complementary food from as early as two days after birth either because they feared they did not have enough breast milk or they had believed that introducing food such as fish soup or sago would 'make the baby strong'. Even more alarming is that we observed infants being given complementary food prepared using water containing human and animal faeces. As explained above, such practices are likely to directly expose infants with underdeveloped immune systems to pathogens, increasing risks of acute and chronic infection and undernutrition.

This highlights the need to train and support health workers in how to promote exclusive breastfeeding, optimal infant and child feeding practices, and hygiene practices. There is also a need to tackle social and cultural myths about infant and young child feeding practices. A survey on 1822 mothers, in 1998, showed that 29% of the mothers did not give colostrum, and about half of those surveyed introduced solids before the baby was four months old.[75]

According to this study, it is taboo for some tribes and clans to give colostrum, which is considered to be 'dirty' milk.[76] There are also myths about the value of introducing complementary food before six months. This type of information can be very dangerous for the health and development of infants, particularly given the poor nutritional value of many staple foods, combined with lack of safe drinking water and the risk of complementary food being prepared in unhygienic conditions.

2.2.4 Impact of Disease

There is a strong body of evidence to show that disease, particularly malaria and diarrhoea, contributes to stunting through causing loss of appetite, malabsorption of nutrients and increasing energy requirements to combat the disease. In PNG, children with malaria were significantly more likely to be underweight and stunted.[77] A causal relationship is not established through this research and the malaria-nutrition association is a complex one.[78] Explanations may include that the malfunction of malaria-infected cells after the incidence of malaria affects a child's ability to absorb nutrients and has a negative effect on height and weight. However, stunted children may also be at higher risk of getting malaria due to exposure to common living conditions, such as poor water and sanitation, that leads to both malaria and undernutrition (in addition to malaria infection of pregnant women that leads to intrauterine growth restriction and pre-disposure of her child to undernutrition).

Although its relative contribution to stunting is unclear, diarrhoea and undernutrition are part of a potentially lethal cycle. It is well documented that repeated episodes of diarrhoea reduce the body's ability to absorb nutrients, and an undernourished child is at a high risk of suffering more frequent and severe episodes of diarrhoea.[79] In PNG, diarrhoea is amongst the top reasons for hospitalisation of children, and most common causes of child death.[80] Improved sanitation practices and safe water sources are critical to limiting the spread of water-borne diseases. However, in PNG, 81% of the population do not have access to improved sanitation and at least 61% of people do not have sustainable access to improved water sources.[81] Although there is limited reliable evidence of a direct correlation between diarrhoea and stunting in PNG, diarrhoea is a well-established cause of growth faltering and is a widely recognised contributor to child stunting.[82] It is likely that inaccessibility to clean water sources and adequate sanitation would cause recurrent episodes of diarrhoea which would contribute to child stunting.

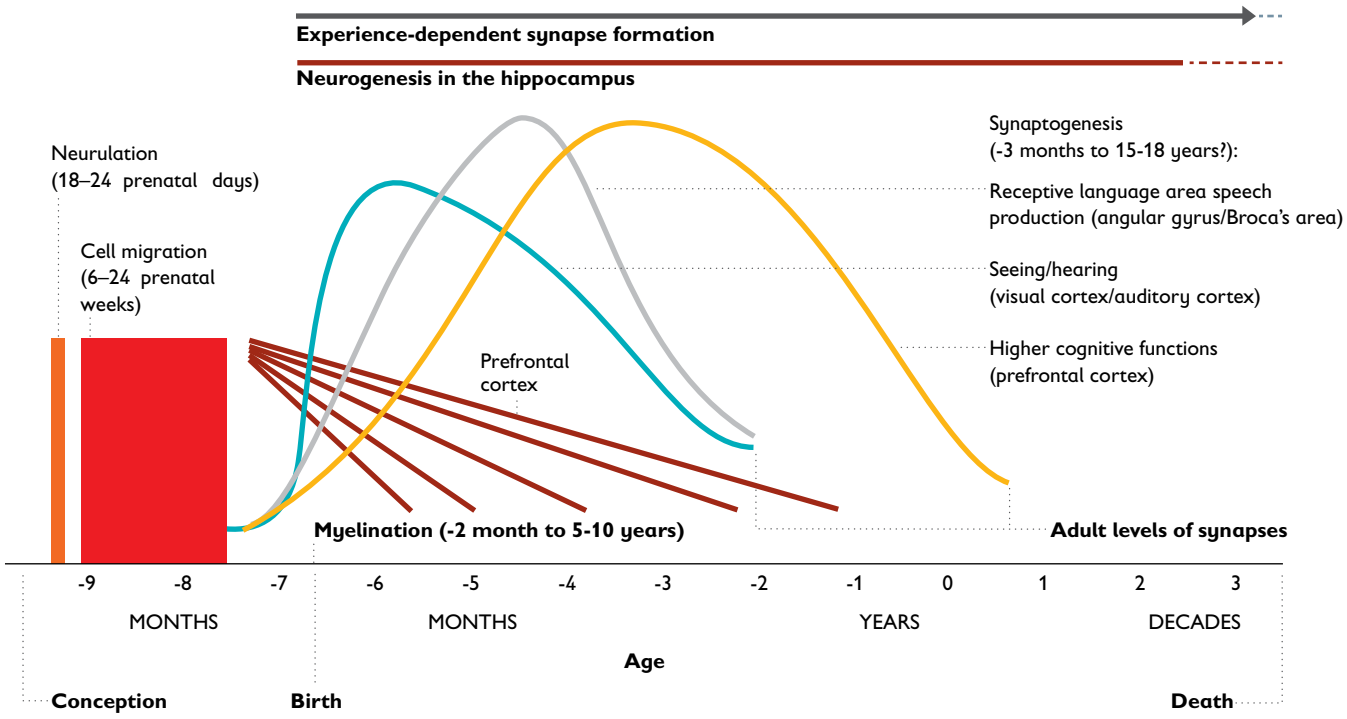
This baby in an urban settlement in Port Moresby was fed sweetened, chocolate milk from the age of 3 months because the mother believed this would help 'her baby grow healthy and strong'.

3. HUMAN COST OF CHILD UNDERNUTRITION

3.1 Impairments to Cognitive and Physical Development

Undernutrition in childhood can cause structural damage to the brain, impairing a child's growth and development.[83] The most crucial time to meet a child's nutritional requirements is the first 1000 days, from pregnancy to their second birthday. During pregnancy and lactation, mothers have higher energy and nutrient needs to support foetal development while maintaining their own energy and nutrient stores. After birth, a child has increased nutritional needs to support brain and muscular skeletal development, which is largely complete by their second birthday.[84] The timing, severity and duration of nutritional deficiencies during this period affect brain development in different ways based on the brain's need for a given nutrient at a specific time.[85] The diagram below depicts the rapid period of brain development which occurs from conception to a child's second birthday, with the capacity for speech production, seeing, hearing and higher cognitive functions in the prefrontal cortex being largely developed over this period.

FIGURE: 4 THE DEVELOPMENTAL COURSE OF HUMAN BRAIN DEVELOPMENT



Source: Thomson, Nelson (2001) Development Science and the Media

A lack of protein, energy and essential nutrients (e.g. iron, iodine, zinc, folate and vitamin B12) during the first 1000 days affects the structural and functional development of the brain. Even mild, sub-clinical maternal iodine deficiency during pregnancy impairs the motor and mental development of the foetus and increases the risk of miscarriage and foetal growth restrictions.[86]

Studies of young children with protein-energy malnutrition show brain atrophy – a shrinking of brain cells due to lack of nutrients.[87] Undernutrition during this critical period can also affect the brain functions required for memory, speech production, learning and motor skills, it can also impact on the nervous system.[88]

3.2 Permanent and Irreversible Damage

Tragically, the growth impairments resulting from undernutrition in the first 1000 days are permanent and irreversible. There is a strong body of evidence to show that it is not possible to recover from these impairments despite improvements in nutrition after age two. Longitudinal studies among children from five countries (Brazil, Guatemala, India, the Philippines and South Africa) confirmed that weight gain after the age of two did not lead to improvements in cognitive function and schooling.[89] Earlier studies of malnourished Korean orphans adopted into American families showed that those adopted after age two had significantly lower cognitive scores than those adopted earlier.[90] A series of longitudinal studies in South Africa confirmed that children who had experienced chronic undernutrition before age two suffered from irreversible intellectual impairment.[91]

3.3 Reduced Learning Capacity and Lifetime Earnings

It is well established that cognitive impairments from undernutrition impact on a child's ability to learn and gain an education. Undernourished children are more likely to drop out of school and are less likely to benefit from schooling, with even mildly or moderately undernourished children scoring poorly on tests of cognitive function and fine motor skills.[92] Children who are undernourished early in life also score worse on tests of psychomotor function, and have reduced attention spans and lower activity levels.[93] With lower activity levels, they interact less frequently with other people and their environment and thus fail to acquire physical and intellectual skills at normal rates.

A range of evidence links iron deficiency anaemia in young children to cognitive and developmental delays, with iron deficiency anaemia found to consistently reduce performance levels on tests of mental abilities, including IQ.[94]

Studies have shown that these cognitive deficits from undernutrition can affect a child's capacity to gain an education, with a direct effect on earnings.[95] The World Bank estimates that undernutrition in childhood results in 10% lower life-time earnings, while other studies that model the impact of under nutrition in the first five years of life place this figure at 20%.[96]

3.4 Increased Vulnerability to Disease and Death in Childhood

Undernutrition threatens a child's survival through weakening their immune system and increasing their vulnerability to disease; such as diarrhoea, acute respiratory infections, malaria and measles.[97] Undernourished children are therefore more likely to become ill, and are also more likely to have longer and more severe bouts of illness.

A child suffering severe wasting is nine times more likely to die than a well-nourished child.[98] A child suffering severe stunting is four times more likely to die than a child with adequate nutrition.[99] Specific nutritional deficiencies such as vitamin A, iron or zinc deficiency also increase the risk of disease and death.[100]

While undernutrition is rarely listed as the cause of death, it is estimated to be the underlying cause of 45% of death of children under the age of five worldwide.[101] Estimates suggest that stunting, severe wasting and intrauterine growth restrictions were together responsible for 2.2 million deaths and 21% of disability-adjusted life-years (DALYs) for children younger than five years, accounting for the largest percentage for any risk factor in this age group.[102] According to national data in PNG, approximately 33% of all hospital deaths of children under five related are either directly or indirectly caused by malnutrition.[103] However, Frontier Economics estimates that it could be as high as 76% of total deaths across the community and health facilities combined based on data presented in the next section.

The more a child suffers from illness, the further they become malnourished. During episodes of illness they have increased energy and protein requirements, are less able to absorb nutrients, and often lose their appetite. The cyclical interaction between under nutrition and illness is potentially lethal.

3.5 Increased Vulnerability to Chronic Disease Later in Life

Not only does under nutrition threaten children's lives in the short-term, it can also increase their risk of obesity and chronic non-communicable diseases later in life. There is strong evidence to show that adults who were undernourished as children are more likely to experience high blood pressure, obesity and associated chronic diseases.[104] Specifically, poor foetal growth, small size at birth and continued poor growth in early life followed by rapid weight gain later in life raises the risk of coronary heart disease, stroke, hypertension and type 2 diabetes.[105]

As detailed in the next section, this translates into increased utilisation of health centres and increased expenditure on at-home treatments,[106] as well as reduced productivity and increased risk of premature death during working ages. The associated higher expenses can generate a significant financial burden on the health care system, which needs to be accounted for when estimating the cost of childhood undernutrition.

Children in this village in East Sepik suffer frequent and severe episodes of diarrhoea from lack of access to clean drinking water, and poor sanitation and hygiene.

Child undernutrition is estimated to cost the PNG economy up to 8.45% of GDP ($USD1.5 billion) per annum.

4. ECONOMIC COST OF CHILD UNDERNUTRITION

Not only does undernutrition claim children's lives, it also poses a major barrier to economic development. The economic impact of child undernutrition was brought to the attention of global policy makers when the World Bank published its ground-breaking report, 'Repositioning Nutrition as Central to Development' in 2006.[107] **In that report, the World Bank estimated that child undernutrition could decrease a low-middle income nation's GDP by 2-3% per year. Other studies published in the Lancet have shown that child undernutrition can result in losses as high as 11% of GDP.**[108]

Although PNG has one of the highest child stunting rates in the world, no studies have been done to estimate the economic cost of child undernutrition in terms of lost GDP. Save the Children therefore engaged Frontier Economics to undertake this task. This economic analysis is intended to inform the allocation of resources to more effectively support human and economic development in PNG.

Frontier Economics utilised the methodology and data detailed below to estimate the effect of undernutrition for children under the age of 5 in PNG on economic activity through three cost pathways:

1. Losses in productivity from a reduction in labour force due to increased childhood mortality (estimated to cost $USD 46 million or 0.26% of annual GDP);
2. Losses in potential income and productivity from poor physical status and reduced cognitive function (estimated to cost $USD 459 million or 2.54% of annual GDP); and
3. Losses from increased health care expenditure in treating diseases associated with childhood undernutrition (estimated to cost $USD3 million or 0.02 percent of annual GDP).

The data used for the analysis is discussed before each pathway is examined in more detail below.

4.1 Data and Methodology

Frontier Economics relied on the most recent and reliable publicly available data collected from both local PNG sources, such as the National Statistical Office of PNG and the PNG Household Income and Expenditure Survey 2009-2010, as well as international organisations such as the World Health Organization and UNICEF.

Where possible, Frontier Economics used data specific to PNG to quantify costs (such as population and birth rates, prevalence of disease and average incomes). However, global and regional estimates have been used where no data for PNG was available or appropriate. For instance, global risk ratios (RR) have been used to estimate the probability of a health-related event in children with or without undernutrition. Appendix A contains more detailed information on the assumptions and data sources used in Frontier Economics' analysis.

To estimate the cost of child undernutrition Frontier Economics adopted a consequence model approach, that describes the consequences of the status quo rates of prevalence of child undernutrition. This approach is commonly used in studies estimating the economic cost of child undernutrition, including by the World Bank (2007),[109] Martinez and Fernandez for the United Nations (2007),[110] and the Council for Agricultural and Rural Development (CARD), the World Food Programme (2013) and UNICEF.[111] For example, work by CARD et al. sought to estimate the prevalence of various nutrition indicators and their impact on the net present value of lost workforce, lost productivity and current health costs in Cambodia.[112]

The analysis seeks to quantify the costs of childhood undernutrition in the 2015-16 financial year (FY2015-16) through estimating the present and future losses incurred as a result of lower productivity and increased healthcare costs caused by undernutrition among children under the age of five.

While the exact approach for quantifying the cost differs depending on the disease or indicator in question,[113] Frontier Economics broadly used the following process to estimate the costs, as depicted in Figure 5:[114]

1. To estimate the deaths associated with childhood undernutrition, Frontier Economics calculated the number of deaths attributed to the six main indicators of childhood undernutrition (maternal undernutrition, suboptimal breastfeeding, wasting, underweight, vitamin A deficiency and zinc deficiency) using a combination of PNG specific, developing country and global data.[115] The net present value of an individual's lost income multiplied by the number of deaths arising from each condition provides the cost associated with mortality arising from childhood undernutrition.
2 To estimate the cost of the reduced productivity attributable to childhood undernutrition, Frontier Economics calculated the reduced earnings capacity of individuals with stunting, anaemia and iodine deficiency.
3. To estimate the increased healthcare costs arising from childhood undernutrition, Frontier Economics calculated the increased expenditure arising from treatment occurring at healthcare centres and treatment given at home.

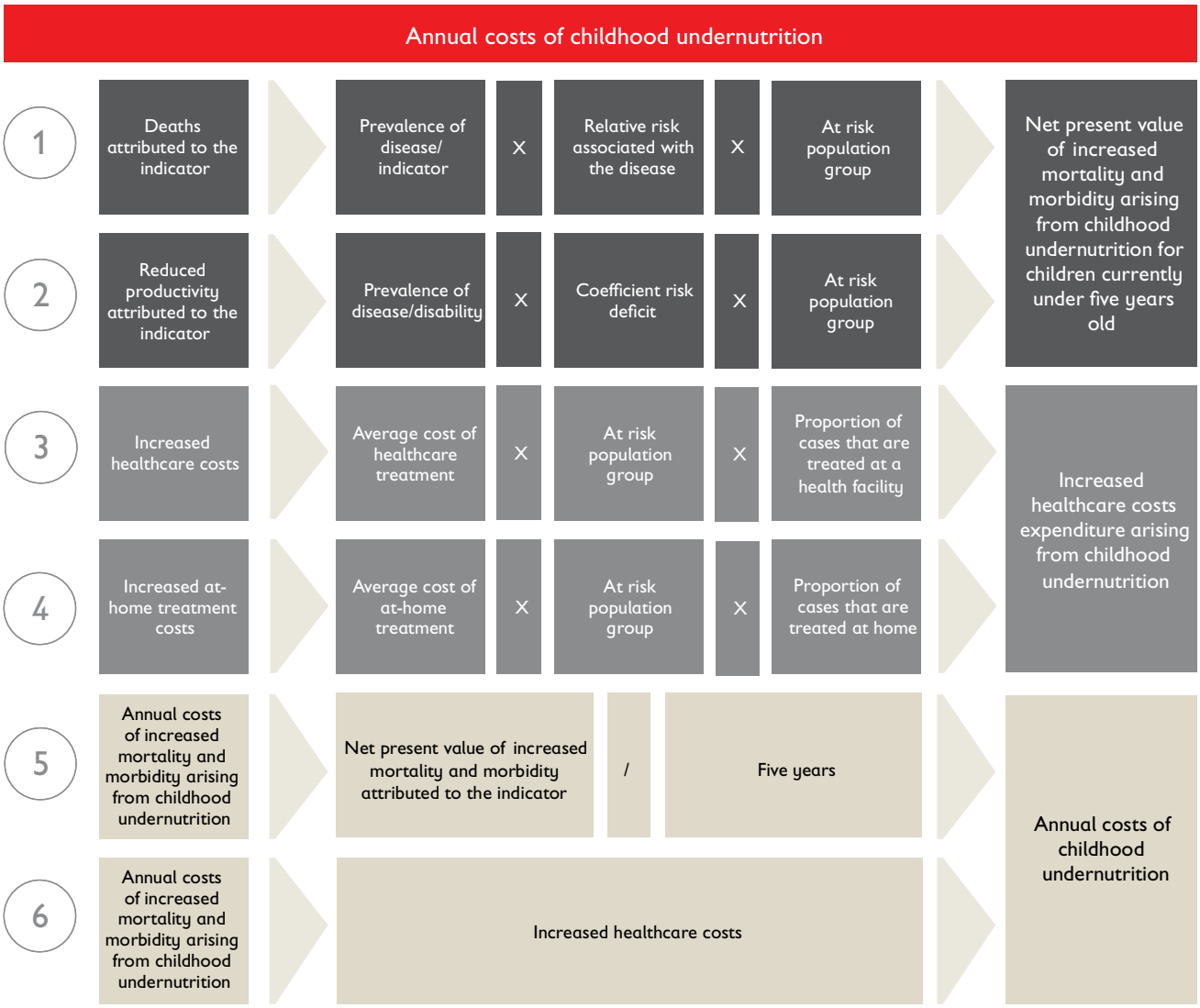
Frontier Economics has estimated the economic cost of undernutrition for each of these pathways on an annual basis.

The costs of increased mortality and morbidity were estimated for children under five years of age and therefore cover a five year period. The calculation was adjusted to estimate the net present value of the increased mortality and morbidity on an annual basis.

Data limitations have required healthcare costs to be considered on an annual rather than ongoing basis, consistent with methodology adopted in other studies. In particular, Frontier Economics calculated the increase in annual healthcare cost associated with child undernutrition for children under the age of two. There are likely to be ongoing healthcare costs associated with child undernutrition related illnesses, however information on the recurrence of these conditions is not available. Therefore, to the extent this analysis considers annual, rather than ongoing, healthcare costs the estimate of economic value could be considered to be conservative.

Given data constraints, and consistent with the methodology used in similar studies, the estimated cost of childhood undernutrition was calculated as the sum of two components: (i) the present value in FY2015-16 of lost earnings occuring across the individual's lifetime, and (ii) the healthcare costs associated with undernutrition in FY2015-16.

FIGURE: 5 APPROACH TO ESTIMATING THE COST OF CHILDHOOD UNDERNUTRITION



Source: Frontier Economics

TABLE 1: ESTIMATED COSTS ASSOCIATED WITH CHILDHOOD UNDERNUTRITION ($USD MILLION) (FY 2015-16)

Pathway	Net present value of lost workforce due to premature deaths	Net present value of reduced productivity	Current health care costs	Total
Maternal nutrition	3	-	-	3
Suboptimal breastfeeding	18	-	1	18
Wasting	9	-	-	9
Stunting	-	320	-	320
Underweight	10	-	-	10
Zinc Deficiency	4	-	2	6
Iodine deficiency	-	51	-	51
Vitamin A deficiency	2	-	-	2
Childhood anaemia	-	88	-	88
Total	**46**	**459**	**3**	**508**

Source: Frontier Economics
Totals in table may not add due to rounding.

4.2 Lost Workforce due to Childhood Mortality

Premature death among children from undernutrition equates to a loss of future income for both the family and the country, leading to a direct loss in human capital for the economy.

It is estimated that 4,174 girls and 5,200 boys will die prematurely each year as a result of childhood undernutrition in PNG. These deaths account for the majority of deaths for girls and boys under 5 years, representing 76% of the total child mortality in the country.[116] This is significantly higher than the global estimate of deaths associated with child undernutrition.[117] This is potentially a result of the prevalence of suboptimal breastfeeding practices, which in this model accounts for 31% of deaths associated with undernutrition in PNG

Table 2 shows that these premature deaths cost the PNG economy $USD46 million, or 0.26% of the country's GDP in FY 2015-16.[118]

TABLE 2: ESTIMATED COSTS ASSOCIATED WITH PREMATURE DEATHS ARISING FROM CHILDHOOD UNDERNUTRITION ($USD MILLION) (FY 2015-16)

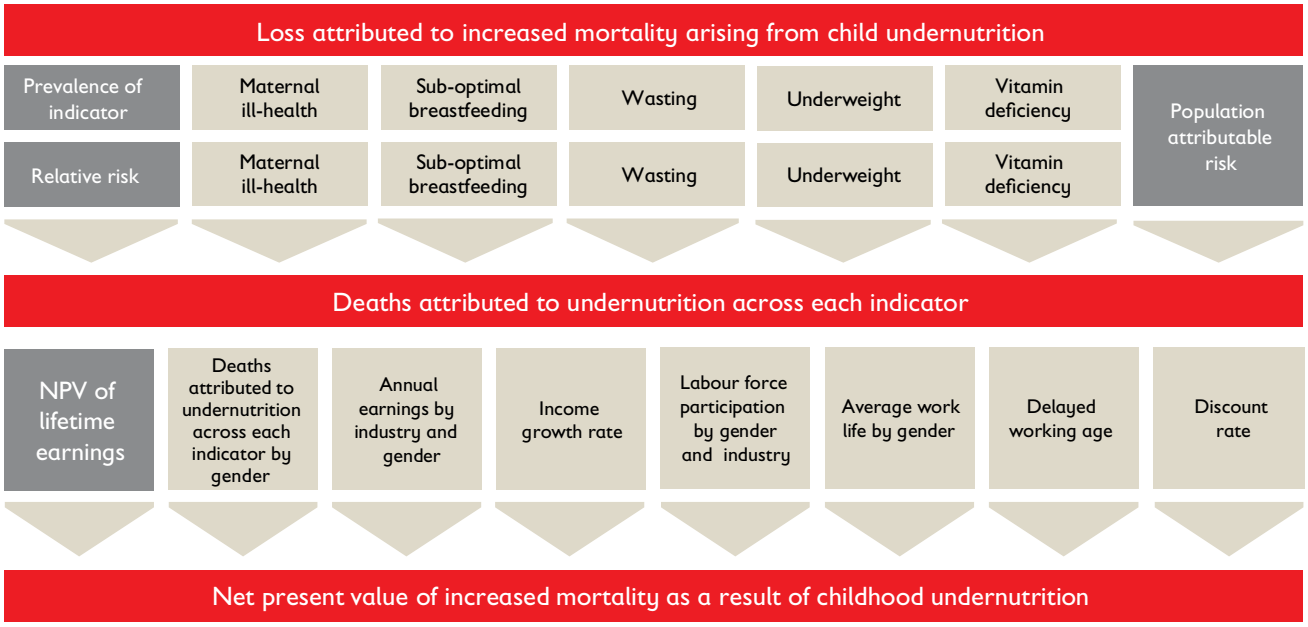
Pathway	Net present value of lost workforce due to premature deaths
Maternal nutrition	3
Suboptimal breastfeeding	18
Wasting	9
Stunting	-
Underweight	10
Zinc Deficiency	4
Iodine deficiency	-
Vitamin A deficiency	2
Childhood anaemia	-
Total	**46**

Source: Frontier Economics
Totals in table may not add due to rounding.

To estimate the economic cost of child mortality from undernutrition, a proportion of total childhood deaths caused by diarrhoea, acute respiratory infections, measles and other diseases[119] has been attributed to undernutrition. In particular, the population attributable risk (the proportion of deaths that would not occur in children under five in PNG if undernutrition were eradicated in this age cohort) is calculated by multiplying the prevalence of mortality caused by each disease by the increased risk of death from each disease as a result of undernutrition.

To place a monetary value on the lost productivity due to premature death, estimates of the average earnings by gender and industry of employment have been applied to the estimated years of life lost to calculate the net present value of future lost earnings (see Figure 6). The net present value estimation assumes a nominal discount rate of 5% and entry into the workforce at age 15. For neonatal deaths this involves a delay of 15 years before entering the workforce, for deaths from 6 to 59 months of age the delay is assumed to average 12.5 years. This economic value is only attributed to the proportion of children that would have been expected to participate in the labour force as adults (72% of the female population and 75% of the male population).[120]

FIGURE 6: APPROACH TO ESTIMATING THE COST ASSOCIATED WITH INCREASED CHILDHOOD MORTALITY



Source: Frontier Economics: CARD, UNICEF and WFP, 2013, The Economic Consequences of Malnutrition in Cambodia: A Damage Assessment Report.

4.3 Reduced Productivity due to Undernutrition

Undernutrition in childhood reduces productivity through two paths:

- Reduced productivity arising from poor physical status; and
- Reduced productivity arising from reduced cognitive function and deficits in schooling.

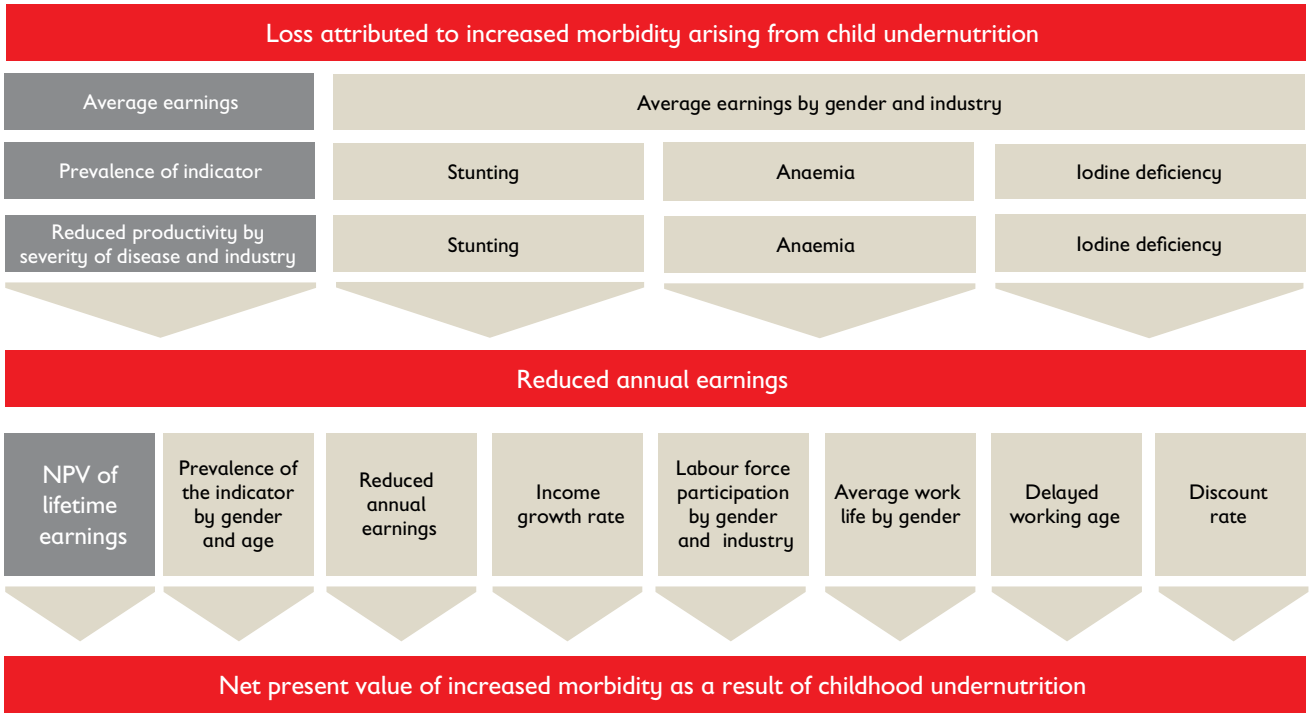
In PNG, undernutrition among children below 5 years of age is estimated to reduce the productivity of around **900,000 children**. The estimated value of the reduced productivity arising from increased morbidity and reduced cognitive ability, is $USD 459 million (FY 2015-16) annually (or 2.54% of PNG's GDP), accounting for the largest share of the costs associated with undernutrition in PNG. This total is comprised of $USD 320 million from reduced cognitive ability due to stunting, $USD 51 million from iodine deficiency and $USD 88 million from anaemia.[121]

This is most likely driven by the fact that PNG has above average levels of stunting, with almost 50 per cent of children under the age of 5 recorded as stunted (double the global average). This means that around half of the working age population had reduced productivity as a result of childhood undernutrition.

Compared to a child who did not suffer from undernutrition, children with severe stunting are likely to earn, on average, $USD 16,000 less over their lifetimes (with lifetime earnings streams of $USD 64,000 and $USD 80,000 for a child with and without severe undernutrition employed in the services industry, respectively).

To place a monetary value on the reduced productivity associated with undernutrition, estimates of average earnings by gender and industry of employment have been applied to the difference in productivity as adults between well-nourished children, and children with stunting and increased morbidity due to undernutrition (see Figure 7). As for mortality, the net present value calculation assumes a nominal discount rate of 5% entry into the workforce at age 15, and labour force participation rates as adults of 72% for females and 75% for males.[122]

FIGURE 7: APPROACH TO ESTIMATING THE COST ASSOCIATED WITH INCREASED CHILDHOOD MORBIDITY



Source: Frontier Economics

Table 3 provides an example of the calculations used to estimate the cost of undernutrition arising from reduced cognitive ability caused by stunting in male children. Given the degree of reduced cognitive ability (the coefficient risk-deficit) is likely to be larger with more severe stunting, and is likely to have a larger impact in less-manual industries (such as services), we have included varying degrees of reduced cognitive ability to reflect the degree of stunting suffered by the child and the industry where they are likely to be employed.

In order to compare the costs associated with reduced productivity arising from undernutrition among children below the age of five (a cost that can be thought of as occurring over a five year period) with PNG's annual GDP, as shown in Table 4, the costs in Table 4 are divided by five, to calculate an annual estimate of the cost of reduced productivity.

TABLE 3: ESTIMATED NET PRESENT VALUE IN FY2015-16 OF REDUCED COGNITIVE ABILITY FROM STUNTING IN MALES AGED UNDER 5 YEARS ($USD MILLION).

Industry	Coefficient risk-deficit	Disability incidence		Wage*	Labour force participation	Net present value of losses for males under five**
Services	20%	Severe	21%	8,449	13%	239.54
Services	11%	Moderate	28%	8,449	13%	174.64
Manual	10%	Severe	21%	2,923	58%	182.87
Manual	7%	Moderate	28%	2,923	58%	169.69
Total						**766.74**

Source: Frontier Economics, Alderman. H & Behrman. J (2004), Estimated Economic Benefits of reducing low birth weight in low-income countries; The World Bank (2008), The Cost of Undernutrition in Sri Lanka; Crosby et al. Food for Thought: Tackling Child Malnutrition to Unlock Potential and Boost Prosperity.

* Assumes the average wage in each industry grows at 3% over the average 14 years between when a child suffers from undernutrition and when they join the workforce

** These calculations include a discount rate of 5%, an assumed growth rate of 3%, and an average working life of 45.6 years that begins at age 15

Totals in table may not add due to rounding.

TABLE 4: ESTIMATED NET PRESENT VALUE IN FY2015-16 OF REDUCED PRODUCTIVITY ARISING FROM CHILDHOOD UNDERNUTRITION ($USD MILLION)

Pathway	Net present value of losses for females under five	Net present value of losses for males under five	Total net present value of losses for children under five	Total annual net present value of losses
Iodine deficiency	123	133	256	51
Childhood anaemia	184	258	442	88
Stunting	831	767	1,598	320
Total	**1,138**	**1,157**	**2,296**	**459**

Source: Frontier Economics
Totals in table may not add due to rounding.

4.4 Increased Healthcare Costs

Given the limited data availability, increased healthcare costs from undernutrition have been estimated based on:

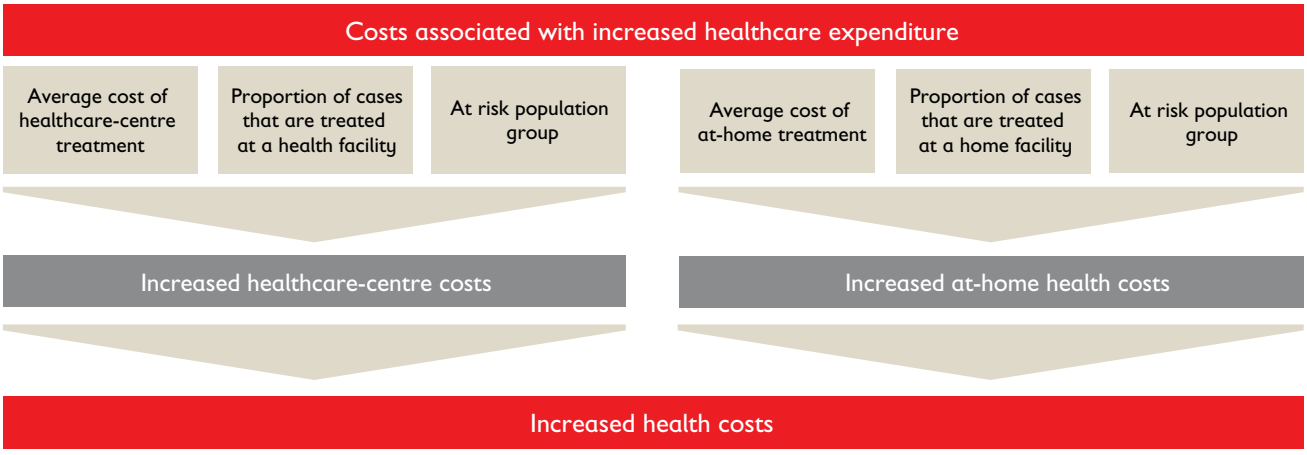
- diarrhoea and acute respiratory infections (ARI) arising from suboptimal breastfeeding practices, and
- zinc deficiency.

Not all cases of diarrhoea and ARI involve treatment at a health facility. Hence, the costs associated with increased use of healthcare centres and the costs associated with at-home treatment are presented separately, as shown in Figure 8 below.[123]

The increased healthcare costs arising from childhood undernutrition are estimated to be $USD 2.94 million (FY 2015-16). Of that, $USD 0.5 million can be attributed to suboptimal breastfeeding practices and the remaining $USD 2.4 million to zinc deficiency.

Data limitations mean the methodology involves several key assumptions that are likely to result in a conservative estimate of healthcare costs. First, although there are also significant opportunity costs to families and communities arising from the increased risks of these illnesses, only the direct financial costs have been estimated. Second, while the analysis considers healthcare costs on an annual basis, it is possible there may be some ongoing healthcare costs associated with the illness. Third, there is some evidence that undernutrition is also associated with increased prevalence of other illnesses, for example tuberculosis and malaria; however, there was inadequate data available to enable this to be included in the analysis. Finally, it was not feasible to calculate risks deriving from the undernutrition-infection cycle, such as the costs of recurring bouts of illness that are due to the cyclical interaction between undernutrition and infection.

FIGURE 8: APPROACH TO ESTIMATING INCREASED HEALTHCARE COSTS ASSOCIATED WITH UNDERNUTRITION



Source: Frontier Economics: CARD, UNICEF and WFP, 2013, The Economic Consequences of Malnutrition in Cambodia: a Damage Assessment Report

Table 5 provides an example of the calculations used to estimate the health care costs arising from suboptimal breastfeeding practices amongst infants aged 6-24 months. The population attributable risk calculates the proportion of cases of diarrhoea and acute respiratory infection (ARI) that are attributed to poor breastfeeding practices, the cost of which can be calculated by assuming an average cost of health centre treatment of $USD 2.32 and an average cost of at-home treatment of $USD 0.54.

TABLE 5: ESTIMATED HEALTHCARE COSTS INCURRED IN FY 2015-16 AS A RESULT OF NO BREASTFEEDING AMONGST INFANTS AGED 6-24 MONTHS ($USD MILLION)

Condition	Prevalence of no breastfeeding	Relative risk	PAR	Cases	Health centre cases*	Home cases	Cost**
Diarrhoea	14.9%	2.07	13.7%	414,376	124,313	290,063	0.44
ARI	14.9%	1.17	2.5%	7,691	4,845	2,846	0.01

Source: Frontier Economics: DHS 2006; Black et al. 2013, Maternal and child undernutrition: global and regional exposures and health consequences. 12; World Development Indicators 2016; Wiltshire and Mako (2014), Financing PNG's free primary health care policy, pp.17-18; CARD, UNICEF and WFP, 2013, The Economic Consequences of Malnutrition in Cambodia: a Damage Assessment Report.

*Assumes 30% of diarrhoea and 63% of ARI cases are treated at a health centre.

**Assumes cost of treatment at a health centre is on average $USD 2.32 per case and the cost of at-home treatment is on average $USD 0.54 per case.

Totals in table may not add due to rounding.

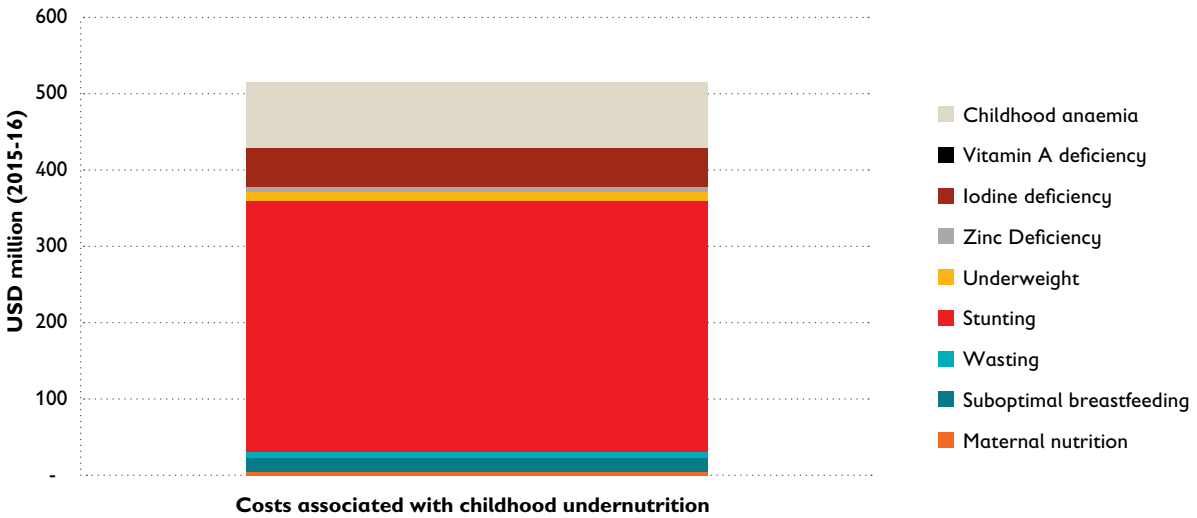
4.5 Total Costs Associated with Undernutrition

As shown in Table 1 and Figure 9, undernutrition in children in PNG aged between 0 and 5 years of age in FY2015-16 is estimated to cost $USD 508 million (equivalent to 2.81% of the country's annual GDP).[124] This significantly exceeds PNG's projected health sector and education sector budgets for 2017 ($USD 385 million and $USD 366 million respectively).[125] The overall cost associated with undernutrition is the sum of lost productivity arising from increased mortality, reduced productivity arising from increased morbidity, and increased healthcare costs.

In particular:

1. The cost of lost workforce due to childhood mortality associated with undernutrition is estimated to be $USD 46 million annually (0.26% of PNG's GDP).
2. The loss in potential income as a result of reduced productivity associated with childhood undernutrition is estimated to be $USD 459 million annually (2.54% of PNG's GDP).
3. Increased health care expenditure as a result of childhood undernutrition is estimated to be $USD 3 million annually (0.02% of PNG's GDP).

FIGURE 9: ESTIMATED NET PRESENT VALUE IN FY2015-16 OF COSTS ASSOCIATED WITH CHILDHOOD UNDERNUTRITION ($USD MILLION)



Source: Frontier Economics

4.6 Sensitivities

In any estimation of costs, the estimates are sensitive to a range of assumptions, including the discount rate used, the prevalence of stunting and wasting, the assumed reduction in productivity as a result of undernutrition, and the rate at which multiple diseases exist within the same child. As such, comparison between the estimation of the costs associated with childhood undernutrition in PNG and estimations in studies of other countries is subject to caveats. For instance, Frontier Economics' estimation of the costs of reduced productivity arising from stunting assumes varying degrees of reduced earnings capacity dependent on the degree of stunting suffered and the sector in which the individual is employed. However, some studies assume the same reduction in earnings capacity regardless of the severity of stunting or the area of employment.[126] This means that Frontier Economics' estimation of the cost of undernutrition amongst females employed in the manual sector with moderate stunting (for instance) will be lower than estimates performed in other countries

As discussed in more detail below, an upper bound of the estimate is $USD 1.5 billion (equivalent to 8.45% of GDP). This analysis relies heavily on assumptions made about an individual's lifetime earnings stream. The estimate reflects the large proportion of the PNG population currently employed in low-wage, labour-intensive industries. It therefore potentially understates the economic cost of undernutrition, compared to countries with a higher average income.

While care has been taken to use data from reputable, international organisations, data availability in developing countries can be problematic. For instance, different nutrition deficiencies often coexist within the same child, yet little information is available regarding the extent to which ARI and diarrhoea (for example) affect the same child. To simply add up the impact of each individual pathway would result in double counting of the cost of undernutrition. However, without country-specific information regarding the extent to which these diseases coexist, an accurate adjustment cannot be made. Table 6 below shows Frontier Economics' approach to reducing the potential for double counting. In these tables, the number of childhood deaths has been statistically adjusted to account for the presence of multiple diseases (as in CARD et al. (2013)),[127] using the assumption that a child cannot have its productivity reduced further than the assumed reduction arising from stunting (even in cases where it may suffer from both stunting and anaemia, for instance).

TABLE 6: ADJUSTMENTS TO NUMBER OF DEATHS ARISING FROM CHILDHOOD UNDERNUTRITION TO ACCOUNT FOR MULTIPLE DISEASES WITHIN ONE CHILD

	Unadjusted			Adjusted		
Age group	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Neonatal	844	1,018	1,863	819	988	1,807
1-5 months	1,178	1,471	2,649	1,107	1,383	2,490
6-59 months	2,958	3,723	6,681	2,248	2,829	5,078
Total	**4,980**	**6,213**	**11,193**	**4,174**	**5,200**	**9,375**

Source: Frontier Economics: CARD, UNICEF and WFP, 2013, The Economic Consequences of Malnutrition in Cambodia: a Damage Assessment Report

Totals in table may not add due to rounding.

TABLE 7: RANGE OF ESTIMATES OF ANNUAL LOST PRODUCTIVITY IN FY2015-16 AS A RESULT OF CHILDHOOD UNDERNUTRITION ($USD MILLION)[128]

	Female		Male	
	Lower-bound	**Upper-bound**	**Lower-bound**	**Upper-bound**
Suboptimal breastfeeding		25		27
Childhood anaemia		37		52
Stunting	166	166	153	153
Total	**166**	**228**	**153**	**231**

Source: Frontier Economics
Totals in table may not add due to rounding.

As discussed above, any estimate of the net present value costs are sensitive to the assumed discount rate used in the calculation. As stunting accounts for the largest share of total costs associated with childhood undernutrition Frontier Economics have performed an analysis to determine how sensitive the cost estimate is to the assumed discount rate (the analysis assumes a discount rate of 5%) and the assumed reduction in productivity (the analysis assumes a discount rate of between 7 and 20% depending on the severity of stunting and the industry in where the child would be employed).[129] Table 8 below shows that the depending on the assumptions used, the cost estimate ranges from USD$161 million to USD$1.5 billion. Even if we assume only a small difference in the earnings capacity of stunted versus non-stunted children, and a relatively high discount rate of 8%, the cost of undernutrition in PNG is still significant at $USD 161 million annually.

TABLE 8: SENSITIVITY OF ESTIMATE OF ANNUAL COST IN FY 2015-16 ASSOCIATED WITH UNDERNUTRITION TO ASSUMED DISCOUNT RATE AND REDUCED EARNINGS CAPACITY ASSOCIATED WITH STUNTING ($USD MILLION)

Reduced earnings capacity	Discount rate		
	3%	**5%**	**8%**
7%	778	391	161
10%	951	477	196
20%	1,529	766	314

Source: Frontier Economics
Totals in table may not add due to rounding.

Malnutrition is entirely preventable...

5. COST EFFECTIVE SOLUTIONS

Undernutrition is entirely preventable. No child's survival or development should be threatened by undernutrition when the solutions for preventing it are well known and highly cost-effective.

Reductions in stunting and other forms of undernutrition in PNG can be achieved through proven interventions targeting the first 1000 days from pregnancy to a child's second birthday As outlined below, these are relatively low-cost interventions with extremely high returns on investment. Action is needed to bring them to scale, not only to prevent children dying from undernutrition, but also to help ensure half of PNG's population can reach their full growth potential and contribute productively to the economy. This will contribute to the effectiveness of other interventions designed to lift children and their families out of poverty.

5.1 Nutrition Specific Interventions

There is broad international consensus on the types of interventions that most effectively address child undernutrition.[130] In 2008, The Lancet published a series on maternal and child nutrition, which reviewed the effectiveness of interventions that address the immediate causes of child undernutrition – inadequate dietary intake and disease. This series recommended investing in proven interventions that target the first 1000s day period, as summarised in the table below.[131]

NUTRITION-SPECIFIC INTERVENTIONS TARGETTING THE FIRST DAYS (FROM PREGNANCY TO 24 MONTHS)		
Lifecycle Stage	Class of intervention	Specific interventions
Adolescence-Pregnancy	Maternal nutrition to prevent low birthweight baby	Multiple micronutrient supplementation (iron, folic acid, Vitamin A, iodine). Food supplementation for underweight mothers (protein-energy supplementation). Deworming and malaria prophylaxis to prevent disease that compromises nutrition status.
0-6 months	Infant and Young Child Feeding	Breastfeeding, with early initiation within one hour of birth and continued exclusive breastfeeding for the first six months.
6-24 months	Infant and Young Child Feeding	Continued breastfeeding up to 24 months. Safe, timely, adequate and appropriate complementary feeding from 6 months onwards.

0-24 months	Infant and Young Child Feeding	Vitamin A supplementations Treatment of other micronutrient deficiencies (iron and zinc).
Lifecycle Stage	Class of intervention	Specific interventions
	Prevention and treatment of severe acute malnutrition	Treatment of acute malnutrition and/or micronutrient deficiencies in children through providing energy-dense, fortified food, and micronutrient supplements (Vitamin A, iron and zinc).
	Prevention of disease that compromises nutrition status	Promoting access to appropriate health services for the prevention and treatment of disease that compromise nutrition. Promoting good sanitation and hygiene practices and access to clean water to prevent diarrhoea and other diseases that compromise nutrition. Deworming.

As recognised in the PNG National Nutrition Policy 2016-2026, it is crucial to scale-up investments in nutrition-specific interventions to prevent, control and treat undernutrition, including low birthweight, stunting, wasting and underweight. This requires a focus on addressing the likely determinants of undernutrition in PNG, specifically sub-optimal maternal nutrition and sub-optimal infant and young child feeding practices.

As detailed in Section 2, maternal nutrition in PNG is most likely influenced by household food security and geography, with the majority of the population living in rural areas with diets that are typically low in animal or vegetable-source protein. However, maternal nutrition is also influenced by social and cultural norms. Accordingly, it is critical to promote access to information and counselling on optimal maternal nutrition to improve maternal health and reduce low birthweight babies, as well as expanding access to micronutrient supplementation where diets are low in essential nutrients. This includes using behaviour change communication models and channels that are most likely to be appropriate in given geographic contexts, including targeting not just mothers but other family members who may influence their decisions on food intake and use of health services. Such interventions will rely on existing efforts to address health system bottlenecks, including a weak medical supplies system, insufficient health workforce numbers, distribution and capacity, and inadequate financing for outreach, that hinder scale up of already approved nutrition-specific interventions (e.g. iron folate supplementation, breastfeeding promotion).

In addition to interventions aimed at improving maternal nutrition, it is crucial to address suboptimal infant and child feeding practices which, as acknowledged by the Government of PNG, are likely to be a major contributor to child undernutrition and increased risk of illness and death.[132] As detailed in Section 2, the World Health Organization recommends exclusive breastfeeding for the first six months of life as the healthiest and safest feeding practice for infants. This is because it provides all the nutrients an infant needs in a form that can be readily absorbed, as well as containing important anti-bodies

from the mother's immune system to prevent infection and disease. It also keeps infants safe from contaminants contained in food and unhygienic environments that cause disease and lead to nutrient loss.

The World Health Organization recommends introducing complementary feeding after 6 months, but such food must be prepared in a hygienic and sanitary way, to help minimise the risk of infection for infants. In a context such as PNG where there is insufficient access to safe drinking water and sanitation services, these deficits remain a major barrier to improved nutritional practices.

Although there are a range of policies in PNG that conform to WHO guidelines on infant and young child feeding, the low rate of exclusive breastfeeding in the first six months suggests the need for scaling up nutrition education and counselling for families, and addressing barriers to exclusive breastfeeding practice, particularly in geographic areas where there are high rates of child undernutrition. For many families in PNG, regular mobile clinic outreach and patrols are an essential means of receiving health services, information and advice alongside fixed clinical services. Ensuring all available health services incorporate information and advice on optimal maternal nutrition, and infant and young child feeding, and that relevant staff have the knowledge, capacity, skills and time to offer such education and counselling will be critical to achieving sustained behaviour change. So too will broader efforts to increase knowledge and influence social norms through evidence-based and well-designed communication strategies, including the use of innovative delivery channels, such as Facebook and mobile SMS messages, given the wide penetration and uptake of digital technology in PNG and lack of coverage of health services in remote areas.

Women attending a health clinic in Wewak, East Sepik

5.2 Nutrition-Sensitive Interventions

Nutrition-specific interventions alone will not be sufficient to combat child undernutrition in PNG. It is also critical to invest more in nutrition-sensitive interventions to address the underlying causes of undernutrition, such as those relating to food security; health services; family planning; education; women's empowerment and water, sanitation and hygiene. These interventions will help accelerate progress in improving nutrition by enhancing the household and community environment in which children develop and grow, and by increasing the effectiveness, coverage, and scale of nutrition-specific interventions.[133]

A multi-sectoral approach is required to address the multiple determinants of undernutrition in PNG. However, as explicitly recognised in the PNG National Nutrition Policy 2016-2026, there are limited nutrition components in the sectorial plans in the Department of Health, Agriculture & Livestock, Education and Community Development & Religion.[134] Furthermore, there are few examples of inter-sectoral collaboration between government departments in delivering nutrition outcomes.[135] Accordingly, as acknowledged by the Government of PNG, national leadership and coordination is required to bring a multi-sectoral approach to scale, while also demanding considerable energy and technical capacity at the local level.[136]

The prioritisation of nutrition-sensitive investments should be based on evidence of the specific determinants of undernutrition in different geographic contexts in PNG. As outlined in section 2 of this report, the World Bank has analysed 2009-10 PNG Household Income and Expenditure Survey (HIES), with a focus on examining the association between geography, household wealth, education levels, food intake and disease incidence on child nutritional outcomes.[137] Based on this analysis, some areas of focus for nutrition-sensitive interventions in PNG may include:

- **Gender and education** – nutrition is intricately linked to women's biological, economic and socially constructed gender roles.[138] For biological reasons, women are more vulnerable to nutritional deficiencies.[139] This is exacerbated in conditions where women are uneducated, have unequal social status and limited decision-making power over the allocation of household resources.[140] Educating girls helps break the cycle of intergenerational malnutrition, since it tends to delay the age of first pregnancy and reduce the risk of giving birth to a low birthweight baby. It also increases the likelihood of the mother being informed of, and empowered in relation to, a range of healthy practices including optimal maternal, infant and young child feeding practices, use of family planning for healthy birth spacing, and seeking healthcare for prevention and treatment of disease. But in PNG, less than 20% of the female population receive an education beyond primary school level, particularly in rural areas.[141] Special efforts are therefore needed to address the social inequities that impact girls accessing education, and being empowered to delay pregnancy until after adolescence. Addressing gender inequalities, family and sexual violence, and improving access to education – particularly on nutrition and diet, adolescence and family health – for both boys and girls, and their families – will help address the underlying causes of nutrition.

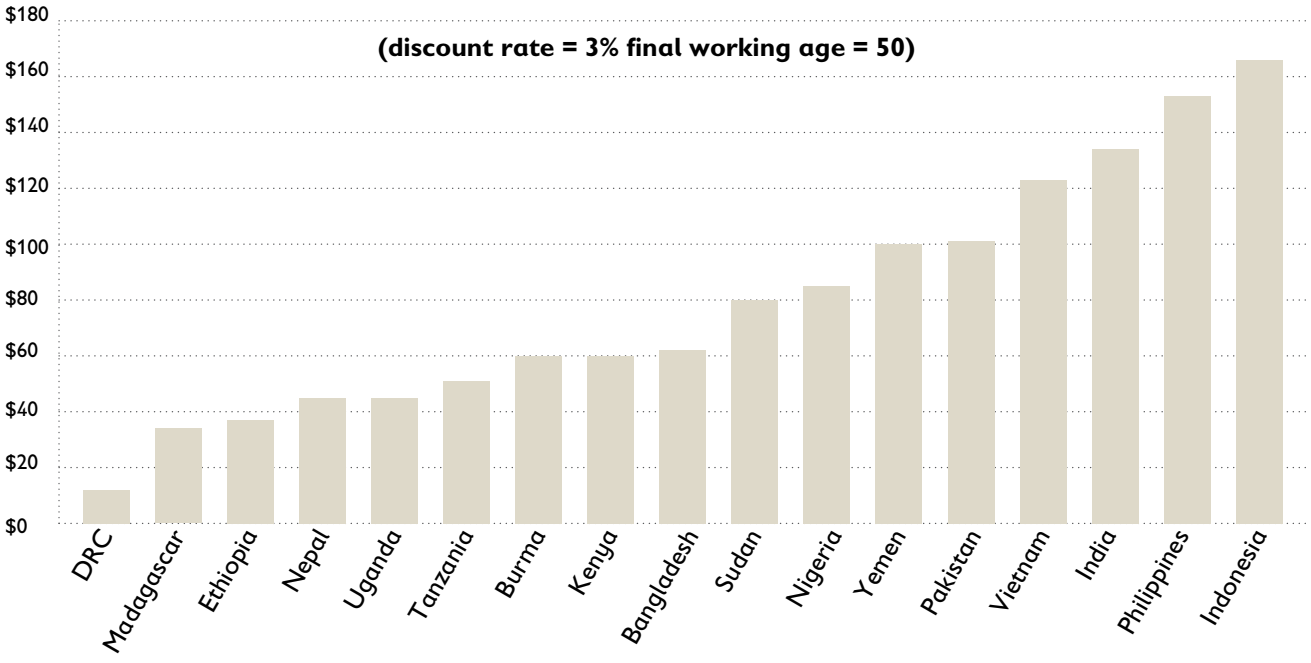
- **Water, sanitation and hygiene** – as detailed in section 2, lack of access to safe water, sanitation and poor hygiene can directly impact on a child's nutritional status in three main ways: via diarrhoeal diseases, intestinal worm infections and chronic injection of pathogens from the environment.[142] Diarrhoeal diseases and intestinal parasitic infections can cause loss of appetite and impede the absorption of nutrients – meaning even if a child is eating enough nutritious food, their bodies are not able to benefit from the nutrients, and they remain at risk of undernutrition.[143] At the same time, undernourished children have weakened immune systems which make them more susceptible to more severe and prolonged episodes of diarrhoea. Even in the absence of diarrhoea, children who are exposed to a high load of pathogens as a result of living in unsanitary conditions are likely to experience recurring inflammation and damage to the gut, leading to malabsorption of nutrients.[144] Investment in improved water, sanitation and hygiene in PNG - particularly behaviour change and infrastructure at the household level – could therefore help reduce the impact diarrhoea and other disease on the nutrition status of children.
- **Agriculture and food security** – Agriculture systems have a crucial role in provision of food, livelihoods, and income.[145] In PNG, subsistence agriculture is the main occupation of 80% of the population, including women.[146] However, ensuring equitable access to adequate affordable, nutritious food is more challenging. As detailed in section 2, there is a lack of dietary diversity in rural areas, particularly in highland areas where diets are typically based on root vegetables. Investments in agriculture should not only focus on increasing the quantity of food produced, but also improving the quality of food from a nutritional perspective. This includes promoting crop and dietary diversity, including small animal husbandry, as well as assessing the potential to increase the nutritional content of foods through post-harvest fortification. For example, staple crops such as flour and maize could be fortified with iron, zinc, folic acid and other B vitamins. Legal precedent exists in PNG for iron-fortification of rice.[147] It is also important to improve the storage and preservation of foods to cover the 'lean' seasons and ensure year-round access to nutritious food. This is particularly important for areas vulnerable to climactic shocks.

5.3 Cost-Benefit Returns of Investing in Nutrition

Investing in nutrition will have high social and economic returns for PNG. Through helping to increase the survival, health and productive capacity of the population, nutrition can fuel broad-based, sustainable economic growth. Indeed, nutrition investments are critical to driving progress for other Sustainable Development Goals (SDGs), particularly health, education, women's empowerment and poverty alleviation.

Not only does investing in nutrition provide high social and economic returns at the macro level, there is evidence to show that nutrition-specific investments are highly cost-effective. In 2008, the Copenhagen Consensus evaluated the cost-benefit returns of interventions designed to address development challenges. It found that micro-nutrient supplementation for children had the highest cost benefit ratio among 17 development interventions, offering a median global return of $16 for every dollar invested.[148] In 2015, the Copenhagen Consensus published even more promising findings about the cost-benefit returns of nutrition-specific interventions.[149] It found that every dollar spent on nutrition in the first 1,000 days of a child's life can give a saving of an average $USD 45 and in some cases as much as $USD 166, as shown in Figure 11 below. This finding was based on an analysis of nutrition-specific interventions in 17 countries with a high burden of stunting (nine countries in Africa and the Middle East, five in South Asia, and three in East Asia, whose combined population in 2012 exceeded 2.5 billion).

FIGURE 11: REDUCING STUNTING: BENEFIT FOR EVERY DOLLAR SPENT BY COUNTRY



Source: Horton S and Hoddinott J (2014) for Copenhagen Consensus

6. TIME FOR ACTION

Never before has there been a better time to invest in nutrition in PNG. Not only is there a compelling humanitarian and economic rationale to do so. Political momentum is building to make this a reality.

The United Nations General Assembly has proclaimed a Decade of Action on Nutrition, 2016-2026. Member States have committed to undertake ten years of sustained and coherent action to achieve the Sustainable Development Goals of ending all forms of malnutrition by 2030. This commitment was made in recognition that progress in reducing malnutrition to date has been far too slow and uneven across regions, countries and populations groups. This has come at a cost to people's lives and sustainable development. The aim of the Decade of Action is to coordinate and strengthen multi stakeholder efforts across sectors to ensure food and nutrition security for all.

Not only is nutrition being prioritised at the international level, it is also gaining increased attention domestically within PNG. In 2016, PNG became a member of the Scaling up Nutrition (SUN) Movement. The SUN movement brings together governments, civil society, the United Nations, donors, businesses and researchers in a collective effort to improve nutrition. By becoming a SUN member, the PNG Government has committed to four strategic objectives identified in the SUN Movement Strategy and Roadmap.

- Bringing people together
- Coherent policy and legal framework
- Aligning programs around a Common Results Framework
- Financial tracking and resource mobilisation

Joining the SUN network has served as a catalyst to review existing approaches and interventions to improve nutrition outcomes in PNG. The PNG National Nutrition Policy 2016-2026 was approved by Prime Minister Peter O'Neil in September 2016 and is awaiting approval from Cabinet. It has been revised to ensure alignment with the SUN Principles, Strategy and Roadmap. Accordingly, there is no better time for international donors, UN agencies, the private sector and civil society to support the PNG Government in determining how to combat the challenge of child undernutrition in PNG.

The PNG government and donors should seize this opportunity to scale up investments to combat child undernutrition in PNG. We recommend they:

1. Commit sufficient financial and technical resources to support the implementation of the PNG National Nutrition Policy 2016-2026, including multi-year funding to finance:
    a. *Nutrition-specific interventions* targeting the first 1000 days of a child's life, with a focus on promoting optimal maternal nutrition, infant and young child feeding practices, and access to health services to prevent and treat diseases that contribute to undernutrition.
    b. *Nutrition-sensitive interventions* addressing the underlying causes of undernutrition, with a focus on improving food security (including diversification and fortification of staple foods), increasing access to quality education (especially for girls), family planning, and improving access to clean drinking water, and good sanitation and hygiene.

2. Establish national and provincial multi-sectoral coordination mechanisms to provide leadership, oversight and accountability for the implementation of the National Nutrition Policy 2016-2026. It is critical to ensure nutrition interventions are costed, and adequately resourced and evaluated from the national to the district level and below.

3. Declare and implement interim targets to support the achievement of the Sustainable Development Goal on nutrition, particularly for the reduction of low birthweight, stunting and wasting.

4. Establish a national monitoring and evaluation framework to track nutrition funding, outcomes and impacts. This should include establishing reliable baseline data, and the publication of progress updates on a biennial basis to ensure transparency and accountability for the achievement of targets.

The PNG Government cannot tackle this challenge alone. A mix of funding sources will be required to accelerate progress in reducing the very high rates of child undernutrition in PNG. It is critical for multilateral and bilateral donors to consider how current and future allocations of overseas development assistance could be revised to increase investments in nutrition-specific and nutrition-sensitive interventions. A failure to do so may jeopardise the impact of other aid investments designed to promote human and economic development in PNG.

CONCLUSION

This report has detailed the profound human and economic cost of child undernutrition in PNG. Almost one in two children in PNG are robbed of their potential to fully develop due to undernutrition. The cognitive and physical impairments suffered from undernutrition in the first 1000 days of life – from pregnancy to a child's second birthday – are largely permanent and irreversible. Undernutrition therefore has lifelong consequences, and can threaten a child's very survival.

Not only does undernutrition come at huge cost to individual children and their families. It also comes at great cost to the PNG economy. As detailed in this report, Frontier Economics estimates that child undernutrition costs the PNG economy the equivalent of 2.81% of its annual GDP through:

1. Losses in productivity from a reduction in labour force due to increased childhood mortality, estimated at $USD 46 million (0.26% of GDP);
2. Losses in potential income and productivity from poor physical status and reduced cognitive function, estimated at $USD 459 million (2.54% of GDP); and
3. Losses from increased health care expenditure in treating diseases associated with childhood undernutrition, estimated at $USD3 million (0.02% of GDP).

The estimate of 2.81% of GDP is regarded as conservative, and the economic impact could be as high as 8.45% of GDP (1.5 billion USD per annum) using alternative assumptions.

This report has shown that there is a compelling social and economic imperative to invest in child nutrition in PNG. What we now need is political will, leadership and funding to make this a reality. With the right investments, every child in PNG can achieve her or his full growth potential, with significant returns for the PNG economy. If we could unleash the productive capacity of around 50% of the PNG population, millions could be lifted out of poverty.

Now is the time for scaling up investments in nutrition in PNG. A failure to do so may undermine the country's potential for human and economic development. But most importantly, a failure to do so may cost more children's lives.

APPENDIX A

Summary of data	PNG specific or Global?	Source
General		
Assumed discount rate to calculate the net present value of future cash flows.	Global	Hoddinott et al. (2013), *Copenhagen consensus challenge paper- hunger and malnutrition.*
Assumed the average growth rate over the past three years to forecast future wages	PNG	Trading Economics, *Papua New Guinea Economic Indicators*, available at < http://www.tradingeconomics.com/papua-new-guinea/indicators>.
PNG's GDP in 2016 to calculate the cost of undernutrition as a proportion of GDP.	PNG	2016 Index of Economic Freedom (2016), *Papua New Guinea*, available at < http://www.heritage.org/index/country/papuanewguinea>.
Estimated number of births in PNG in 2015	PNG	UNICEF (2016), *UNICEF State of the world's children* using 2015 estimates from the United Nations Population Division.
Estimated population in PNG in 2015	PNG	UNICEF (2016), *UNICEF State of the world's children* using 2015 estimates from the United Nations Population Division.
Proportion of the population in each age group in 2010	PNG	National Statistical Office – Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables*
Labour force segmentation to calculate potential future earnings.	PNG	National Statistical Office – Government of Papua New Guinea (2011), *PNG Census tables.*
Labour force participation to calculate potential future earnings.	PNG	The World Bank, *World Bank Data Table* using data from the International Labour Organisation, *ILOSRAT database.*
Average annual salaries and wages paid by industry group and sex in 2001 to calculate potential future earnings.	PNG	National Statistical Office- Government of Papua New Guinea (2001), *Census of Business Activities.*

Summary of data	PNG specific or Global?	Source
Reduced productivity arising from increased mortality		
Estimated PNG Child mortality levels in 2015 to calculate the increased mortality arising from undernutrition	PNG	World Health Organisation (2015), *WHO database* using data from CME Info based on research of the UN Inter-agency Group for Child Mortality Estimation.
Adjustments to account for the same disease being present in the same child (co-infection)	Global	Rockhill, Newman & Weinberg (1998), Use and misuse of population attributable fractions. *American Journal of Public Health. 88(1):15-19.*
Relative Risk (Diarrhoea and ARI by breastfeeding behaviour) to estimate the increased effect of suffering from diarrhoea and ARI as a result of undernutrition.	Global	Black et al. (2013), Maternal and child undernutrition: *global and regional exposures and health consequences.*
Relative Risk (Mortality arising from ARI, measles, diarrhoea) to estimate the increased likelihood of dying from ARI, measles and diarrhoea as a result of undernutrition.	Global	Olofin et al. (2013), *Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: a pooled analysis of ten prospective studies.*
Relative Risk (Mortality and morbidity arising from Vitamin A and Zinc deficiency) to estimate the increased likelihood of suffering from or dying from vitamin A and zinc deficiency as a result of undernutrition.	Global	Black et al. (2013), *Maternal and child undernutrition and overweight in low-income and middle income countries,* The Lancet.
Relative Risk (Birth weight) to estimate the increased likelihood of dying as a result of low birth weight.	Global	Black et al. 2013, *Maternal and child undernutrition: global and regional exposures and health consequences.*
Relative Risk (maternal conditions – low BMI and Height) to estimate the increased likelihood of a child dying as a result of maternal ill-health.	Global	Black et al. (2013), *Maternal and child undernutrition and overweight in low-income and middle income countries,* The Lancet.

Summary of data	PNG specific or Global?	Source
Relative Risk (maternal conditions anaemia) to estimate the increased likelihood of a child dying as a result of maternal ill-health.	Global	Imdad et al. (2012), *Routine Iron/Folate supplementation during pregnancy: effect on maternal anaemia and birth outcomes.*
Proportion of low weight births in PNG in 2009-2013	PNG	UNICEF (2016), *UNICEF state of the world's children* using data from 2009-2013.
Child mortality by cause (ARI, diarrhoea and measles) to calculate the number of deaths attributable to ARI, diarrhoea and the measles.	PNG	World Health Organisation (2015), *WHO database* 2015 .
Prevalence of low BMI in mothers to estimate the increased likelihood of a child dying prematurely as a result of maternal ill-health.	PNG	Department of Health of Papua New Guinea, UNICEF PNG, University of PNG and Centre for Disease Control and Prevention (2011), *Pacific Journal of Medical Studies* Volume 8, No. 2.
Prevalence of low height for age in mothers to estimate the increased likelihood of a child dying prematurely as a result of maternal ill-health.	PNG	Gibson, (2000), *Nutritional status of PNG's population and its determinants*, p.4
Prevalence of anaemia in mothers to estimate the increased likelihood of a child dying prematurely as a result of maternal ill-health.	PNG	World Health Organisation (2011), *WHO database* 2011.
Prevalence of wasting (severe or moderate) in children to estimate the increased probability of dying.	PNG	National Statistical Office – Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables.*
Prevalence of underweight (severe or moderate) to calculate the number of deaths attributed to underweight.	PNG	National Statistical Office – Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables.*
Prevalence of stunting, underweight and wasting by rural and urban areas, by regions and by sex and age groups.	PNG	National Statistical Office – Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables.*
Prevalence of low birth weight (severe or very severe) to calculate the number of deaths arising from low birth weight.	PNG	National Statistical Office – Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables.*

Summary of data	PNG specific or Global?	Source
Rates of 3 suboptimal breastfeeding behaviours for infants <1 months and 1-5 months.	PNG	National Statistical Office – Government of Papua New Guinea (2006), *Demographic and health survey 2006 National Report.*
Reduced productivity as a result of increased morbidity		
Stunting risk deficit by sector to calculate the reduced earnings capacity as a result of different degrees of stunting	Global	Alderman & Behrman (2004), *Estimated Economic Benefits of reducing low birth weight in low-income countries*; The World Bank, (2008), *The Cost of Undernutrition in Sri Lanka*; Crosby et al.(2013), *Food for Thought: Tackling Child Malnutrition to Unlock Potential and Boost Prosperity.*
Anaemia risk deficit to calculate the reduced earnings capacity as a result of anaemia.	Global	The World Bank, (2008), *The Cost of Undernutrition in Sri Lanka*; Strauss & Thomas (1998), *Human resources: empirical modelling of household and family decisions*. In Behrman, and Srinvasan (eds.), *Handbook of development economics* (pp.1883-2023). Amsterdam, New York and Oxford: Elseview Science.
Iodine deficiency risk deficit by sector to calculate the reduced earnings capacity as a result of iodine deficiency.	Global	Horton (1999), *Opportunities for investments in nutrition in low income Asia.*
Ailment prevalence (anaemia) to calculate the reduced earnings capacity as a result of anaemia.	PNG	World Bank (2016), World Development *Indicators 2010.*
Ailment prevalence (iodine) deficiency to calculate the reduced earnings capacity as a result of iodine.	PNG	Temple, Mapira, Adeniyi & Sims. (2004), *Iodine deficiency in PNG.*
Ailment prevalence (diarrhoea and ARI) to calculate the reduced earnings capacity as a result of diarrhoea and ARI.	PNG	Rudan, Boschi-Pinto, Biloglav, Mulhoulland & Campbell (2008), *Epidemiology and etiology of childhood pneumonia;* WHO (2013), *Diarrhoeal disease fact sheet.*
Prevalence of stunting (severe or moderate) to calculate the reduced earnings capacity as a result of stunting.	PNG	National Statistical Office- Government of Papua New Guinea (2009-2010), *Household Income and Expenditure Survey statistical summary tables*

Summary of data	PNG specific or Global?	Source
Increased healthcare costs		
Costs of treating diarrhoea and ARI at a healthcare centre (based on the cost of medicine and the cost of treatment).	PNG	Wiltshire & Mako (2014), *Financing PNG's free primary health care policy: User fees, funding and performance.*
Costs of treating diarrhoea and ARI at home (based on the cost of paracetamol).	PNG	Wiltshire & Mako (2014), *Financing PNG's free primary health care policy: User fees, funding and performance.*
Transport costs to health centre (taken as the average cost of visiting a private hospital, church hospital, government hospital or clinic and government health centre or aid post) to calculate the cost of treatment at a health centre.	PNG	Australian Aid and Asian Development Bank (2012), *Impact of Out-of-Pocket Expenditures on Families and Barriers to Use of Maternal and Child Health Services in Asia and Pacific.*
Likelihood of parent taking child to health centre (diarrhoea) to calculate the cost of treatment at a health care centre.	PNG	Papua New Guinea (2016), 2015 Sector Performance Annual review, *Assessment of Sector Performance 2011-2015 National Report*, using data from the National Health Information System.
Likelihood of parent taking child to health centre (ARI) to calculate the cost of treatment at a health centre.	PNG	World Bank (2016), *World Development Indicator* using data from National Statistical Office – Government of Papua New Guinea (2006), *Demographic and health survey 2006 National Report.*
Likelihood of a woman delivering her baby in a health facility to calculate the cost of treatment at a health centre.	PNG	World Health Organisation (2010), *PNG Country profile department of making pregnancy safer.*

ENDNOTES

1. According to the Papua New Guinea Household Income and Expenditure Survey 20 HIES 2009-2010, the child stunting rate is 48.2%. However, it is estimated that the rate is now 49.5% based on modelling undertaken by the according to the International Food Policy Research Institute, as published in for the 2016 Global Nutrition Report: From Promise to Impact, Ending Malnutrition by 20302016:, see Table A3.2 Countries ranked from lowest to highest, child stunting prevalence, p. 120.
2. Ibid.
3. International Food Policy Research Institute (2016), Global Nutrition Report: From Promise to Impact, Ending Malnutrition by 2030,2016, Table A3.2 Countries ranked from lowest to highest, child stunting prevalence, p. 120.
4. PNG Department of Health (2015), Annual Report on Child Morbidity and Mortality for 2015: http://pngpaediatricsociety.org/wp-content/uploads/2013/05/2015-Annual-Child-Morbidity-and-Mortality-Report.pdf
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6. International Food Policy Research Institute (2016), Global Nutrition Report: From Promise to Impact, Ending Malnutrition by 2030, Table A3.2 Countries ranked from lowest to highest, child stunting prevalence, p. 120.
7. The Independent State of Papua New Guinea (2017), 2017 National Budget Speech, <http://www.treasury.gov.pg/html/national_budget/files/2017/2017%20Treasurer's%20Budget%20Speech.pdf>
8. In the National Nutrition Policy 20164-20263, the Government of PNG explicitly acknowledged: "The problem of malnutrition continues to be a significant impediment in the health, social and economic development of PNG. The Last National Nutrition Policy (NNP) was released in 1995 and despite engaging partners from various sectors, struggled to realise significant improvements in the health and nutrition of the PNG population (page viii)."
9. The World Bank Group (2015), Policy Research Working Paper, 7301 Stagnant Stunting Rate Despite Rapid Economic Growth in Papua New Guinea.
10. Ibid.
11. Papua New Guinea National Nutrition Survey 2005
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17. See note 2.
18. 2015 Joint Child Malnutrition Estimates (UNICEF, WHO, and World Bank), as reproduced in the 2016 Global Nutrition Report: From Promise to Impact, Ending Malnutrition by 2030 2016, Table 2.2 p.16.
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31. Highlands Region consists of the following provinces: Chimbu (Simbu); Eastern Highlands; Enga; Hela; Jiwaka (newly established in 2012); Southern Highlands and Western Highlands.

32. Islands Region consists of the following provinces: Autonomous Region of Bougainville (North Solomons); East New Britain; Manus; New Island; and West New Britain.

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113. That is, whether we are estimating the cost associated with increased childhood mortality, reduced productivity or increased healthcare costs.

114. In order to estimate the cost of childhood undernutrition, Frontier Economics calculated the net present value of increased mortality and morbidity associated with undernutrition for all children below the age of 5. As such, to calculate the cost per annum associated with undernutrition we have divided the net present value of increased mortality and morbidity by 5 before adding the associated health care costs (health care costs are calculated on an annual basis).

115. In order to estimate the deaths attributed to each indicator we calculated the population attributable risk (PAR), which provides an indication of the risk of mortality arising from each disease/indicator among children with undernutrition. The formula used to calculate the population attributable risk is:

$$\frac{\text{prevalence of disease x (relative risk-1))}}{\text{(1+(prevalence of the disease x (relative risk-1)))}}$$

Multiplying the PAR by the number of childhood deaths provides an estimation of the total number of deaths caused by childhood undernutrition.

116. Using available PNG specific data on causes of death for children under five and relative risk factors from developing countries, undernutrition is estimated to account for 9,399 childhood deaths across the various indicators (maternal nutritional status, suboptimal breastfeeding, wasting, underweight, Vitamin A deficiency and zinc deficiency). The prevalence of mortality for children under the age of 5 is on average 6% for children under five (UNICEF 2016, State of the World's Children, Table 1- Table 2), resulting in a total number of under five deaths of 12,400. 9,375 childhood deaths is 76% of 12,400 childhood deaths in total.

117. World Bank (2006), Repositioning Nutrition as Central to Development, p.23.

118. Adjusted to account for multiple diseases within one child.

119. 'Other diseases' includes septicaemia, unspecified febrile illness, tuberculosis, meningitis, hepatitis and cellulitis.

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123. Costs of at-home treatment are assumed to be 0.54 USD (the cost of ARI medication).

124. Given the significant number of assumptions underlying Frontier Economics' analysis, comparison between Frontier Economics estimation and estimations in studies of other countries is subject to caveats. In particular, while Frontier Economics estimation of the costs of reduced productivity arising from stunting assumes varying degrees of reduced earnings capacity (ranging from 5% to 20%) dependent on the degree of stunting suffered and the sector in which the individual is employed, some studies assume the same reduction in earnings capacity regardless of the severity of stunting or the area of employment. Assuming a constant rate of reduction in earnings of 20% results in an estimated cost of 766 million USD (equivalent to 4.23% of PNG's GDP).

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128. The lower bound estimates of the costs of reduced productivity arising from childhood undernutrition only includes the effects of stunting, recognising that this estimate is not reflective of all the costs associated with childhood under-nutrition, but does not include double counting. The upper bound of the estimate accounts for the other pathways of reduced productivity arising from undernutrition such as stunting, anaemia and iodine deficiency on productivity, but some double counting may be present.
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