challenge paper

HUNGER AND MALNUTRITION

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Investments to reduce hunger and undernutrition

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1. Introduction: The challenge of hunger and undernutrition

Current estimates suggest that there are approximately 925 million hungry people in the world. Just under 180 million pre-school children are stunted, that is they are the victims of chronic undernutrition. This deprivation is not because of insufficient food production. Approximately 2,100 kcals/person/day provides sufficient energy for most daily activities; current per capita global food production, at 2,796 kcal/person/day is well in excess of this requirement. Given that there is more than enough food in the world to feed its inhabitants, global hunger is not an insoluble problem.

Deprivation in a world of plenty is an intrinsic rationale for investments that reduce hunger and undernutrition, our focus in this paper, as with previous Copenhagen Consensus (CC) papers on this topic, Behrman, Alderman and Hoddinott (2004) and Horton, Alderman and Rivera (2008) is on the instrumental case for doing so. In its simplest form, the central argument of this paper is that these investments are simply good economics. Our solutions, however, represent a partial departure from those earlier CC papers. First, we re-introduce attention to solutions to hunger with a focus on investments that will increase global food production. This might seem strange given our observation that global food production exceeds global food needs. But as we argue in Section 3, these investments are needed for two reasons: to lower prices so as to make food more affordable; and because given the consequences of climate change, there can be no complacency regarding global food production. Second, previous CC papers on hunger and undernutrition have considered very specific interventions that focus on single dimensions of undernutrition. In this paper, we examine the economic case for bundling these. Our proposed investments are:

- Investment 1 – Accelerating yield enhancements
- Investment 2 – Market innovations that reduce hunger
- Investment 3 – Interventions reduce the micronutrient malnutrition and reduce the prevalence of stunting

We begin with background material that contextualizes our proposed solutions: What are the causes of hunger?; How many hungry and undernourished people are there in the world?; And what are the likely trends in hunger over the next 25-35 years? We then describe our three proposed investments explaining how each addresses the problems of hunger and undernutrition and describing their costs and benefits. Caveats and cautions are noted in section 4 and our concluding section summarizes the case for these investments.

2. Understanding global hunger

This section provides background material that contextualizes our proposed solutions. We cover the following topics:

- What are the causes of hunger? Here, we present a conceptual model that identifies the causes of hunger. We do so in a largely non-technical way, though we will also briefly explain how this can be derived using formally. We place our proposed solutions within this causal framework.
- How many hungry people are there in the world and where do they live?
- What are the likely trends in hunger over the next 25-35 years?

2.1 What are the causes of hunger?

Definitions

We begin with three definitions: food security, hunger and nutritional status.

The concept of *food security* has spatial and temporal dimensions. The spatial dimension refers to the degree of aggregation at which food security is being considered. It is possible to analyze food security at the global, continental, national, subnational, village, household, or individual level. The temporal dimension refers to the time frame over which food security is being considered. A distinction is often made between chronic food insecurity—the inability to meet food needs on an ongoing basis—and transitory food insecurity, when the inability to meet food needs is of a temporary nature (Maxwell and Frankenberger 1992). Transitory food insecurity is sometimes divided into two subcategories: cyclical, where there is a regular pattern to food insecurity, such as the “lean season” that occurs in the period just before harvest; and temporary, which is the result of a short-term, exogenous shock such as a drought or flood (Hoddinott, 2001). Mindful of these dimensions, we follow the current, standard definition of food security:

> Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals within households as the focus of concern. … Food insecurity exists when people do not have adequate physical, social or economic access to food as defined above (FAO, 2010, p.8)

Hunger is "A condition, in which people lack the basic food intake to provide them with the energy and nutrients for fully productive lives" (Hunger Task Force, 2003, p. 33). Hunger and food security are related but are not synonymous. An absence of hunger does not imply food security and, particularly in times of stress, households and individuals may go hungry in order to safeguard longer-term food security.

Nutrients provided by food combine with other factors, including the health state of the person consuming the food, to produce "nutritional status." Some forms of poor nutritional status often described as undernutrition reflect an absence of macro or micro nutrients which may be exacerbated by debilitating health stresses such as parasites.[1] Undernutrition with regard to macro and micro nutrients continues to be the dominant nutritional problem in most developing countries. Other forms of malnutrition, sometimes inelegantly termed overnutrition, result from the excessive caloric intake, exacerbated by diseases such as diabetes and low levels of physical activity are considerable concern in upper and many middle income countries. We do not consider overnutrition further.

A conceptual framework

Food security, hunger and undernutrition reflect the purposive actions of individuals given preferences and constraints. Our conceptual framework for thinking about these has four components: settings, resources, activities and outcomes.[2]

[1] Somewhat confusingly, FAO uses the word undernourishment but in a manner that is different from undernutrition. FAO defines undernourishment to exist when caloric intake is below the minimum dietary energy requirement (MDER) (FAO, 2010). The MDER is the amount of energy needed for light activity and to maintain a minimum acceptable weight for attained height. It varies by country and from year to year depending on the gender and age structure of the population.

[2] There are many many good conceptual frameworks for food security and nutrition and in setting this out we do not privilege ours over these others. We note that what we present here attempts to encompass approaches found in development economics, the food security literature, development discourse and nutrition. What we

‘Settings’ refers to the broader environment in which a household is situated and which create both opportunities and constraints to the actions by households and individuals. We describe these in terms of five categories: physical, social, legal, governance and economic.

The physical setting refers to the natural and man-made environment. It includes the level and variability of rainfall, access to irrigation, availability of common property resources such as grazing land, forests and fishery resources, elevation, soil fertility, the extent of environmental degradation, exposure to rapid onset natural disasters, distances to markets, and the availability and quality of infrastructure - health clinics, schools, roads, markets and telecommunications. The physical environment also incorporates phenomena that affect human health – temperature; rainfall; access to safe water; the presence of communicable human and zoonotic diseases all being examples.

The social setting captures such factors as the existence of trust, reciprocity, social cohesion and strife. The existence of ethnic tensions and conflicts, conflicts between other groups (eg the landless and the landed), gender relations and norms regarding gender roles, the presence (or absence) of civil society organizations are also part of the social setting. Norms of gender roles, of “correct” behaviors and folk wisdom – for example, what type of foods mothers “should” feed their children are also part of the social setting.

The legal setting can be thought of as the “rules of the game” under which economic exchange takes place. As such, it affects agriculture through restrictions and opportunities it creates for the production and sale of different foods, the regulation of labor, capital and food markets. The legal setting includes the formal and informal rules regarding the ownership and use of assets, political freedoms such as the right of expression and restrictions on personal liberties. The legal setting is linked, but is distinct from the governance setting. The governance

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describe here can be readily recast as an agricultural household model (Singh, Squire and Strauss, 1986) extended to incorporate health and nutrition (as in Behrman and Deolalikar, 1988; Behrman and Hoddinott, 2005; Strauss and Thomas 1995), extended to capture intra-household and gender allocation issues (Pitt, Rosenzweig and Hassan, 1990; Haddad, Hoddinott and Alderman, 1997) and dynamics of health and nutrition (Hoddinott and Kinsey, 2001). It can also be seen as an elaboration of Sen’s entitlement theory of famine (Sen, 1981a, 1981b). The discussion of resources bears similarity to components of Sustainable Livelihoods approaches (DfID, 1999). For children, the discussion of nutritional outcomes bears similarities to UNICEF’s Causal Framework of Malnutrition (Maxwell and Frankenberger, 1992, p. 25). This exposition builds on ideas found in Baulch and Hoddinott (2000), Hoddinott and Quisumbing (2010) and Hoddinott (2012).

setting captures how rules are developed, implemented and enforced. This includes the political processes which create rules – for example, centralized or decentralized decision-making, dictatorial or democratic and so on – and the implementation of these rules through bureaucracies, parastatals and third-party organizations.

Finally, the economic setting captures policies that affect the level, returns, and variability of returns on assets and, as such, influence choices regarding productive activities undertaken by individuals, firms and households. In our set-up, this has two principal components. There are macro-level considerations: economic policy (fiscal and monetary); balance of payments; exchange rates; foreign exchange reserves; opportunities and constraints for economic growth; and trends in growth and employment. There are meso-level or market level considerations that capture their structure, conduct, and performance as measured by price levels, variability, and trends as well as government policies towards these. While many markets affect the livelihoods and well-being of poor people of particular importance here is the functioning of the market for food. Relevant considerations here include the contestability of such markets, the extent of domestic, regional and international market integration and the presence and level of duties or quantitative restrictions (such as quotas) on internal and external trade.

Households have resources. They can be divided into two broad categories: time (or labor power) and capital. Time refers to the availability of physical labor for work. We divide capital into three categories. One are assets such as land, tools and equipment used for agricultural or nonagricultural production, livestock, social capital and financial resources that, when combined with labor, produce income. A second is human capital in the form of formal schooling and knowledge. Knowledge includes how to recognize and treat illness, how to maintain good health. It also includes knowledge of good nutrition practices such as appropriate complementary foods and the frequency of feeding of young children. The final resource is human capital in the form of health and nutrition status – specifically, the physical capacity to do work. Some household resources, such as health and schooling, are always held by individuals while others such as land and financial capital may be individually (for example, men and women may not pool their landholdings) or collectively owned.

Households allocate these resources to different types of livelihood strategies or activities. These activities can be divided in any number of ways, for example: agricultural activities; wage work outside the household; and non-agricultural own business activities. Some of these are a direct source of food while others generate cash. In addition, households may obtain food or cash income from transfers received in the form of remittances or gifts from other community members or from the community itself or through government interventions. Conditional on the resources available to the household, the choice of a particular set of activities is affected by perceptions of the level and variability of returns to each activity, the time period over which those returns are earned, and the correlation of returns across activities. For example, the household may decide to grow a mix of crops that embody differing levels of susceptibility to climatic shocks and returns.

These activities generate income. But the relationship between these allocations and outcomes such as food security, hunger or nutrition is not deterministic. First, random events or "shocks" can, and indeed do occur. Different environmental, economic, governance, social and legal settings will produce different combinations of possible shocks. These can affect the stock of assets, the returns to these assets in different activities and the relationship between income generated and consumption or other measures of well-being. Second, households allocate income to goods that affect food security and nutritional status, other goods, and savings. Choices made across these reflect preferences of households (either expressed collectively or as the outcome of bargaining amongst individual members), the prices of all goods that they face and the settings in which they find themselves. Goods that affect food security include food consumption at the household level (referred to as food access in much of the food security literature); goods directly related to health care, such as medicines; and goods that affect the health environment, such as shelter, sanitation, and water. These three goods, together with knowledge and practice of good nutritional and health practices (called "care behaviors") and the public health environment (for example, the availability of publicly provided potable water), affect illness and individual food intake, which in turn generates nutritional status or food utilization. Individual intakes are a reflection in part of individual needs, which themselves will vary by age and sex, by household choices such as decisions to protect the most vulnerable members in times of stress or to allocate calories to those with the highest work-related caloric needs, by norms regarding intra-household food allocation (for example, a norm that men eat before women or one where protein-rich foods are given to higher status household members) and, in the case of very young children, caregiver practices relating to the frequency with which infants are fed.

2.2 Global estimates of the prevalence of hunger and undernutrition

Hunger

From our discussion of definitions and our conceptual framework, there are a number of concepts that we could consider measuring: food security; hunger; household food acquisition; food intake; and nutritional status. While individual studies provide many measures of these, at the global level, information is limited to a specific measure of hunger and of elements of nutritional status. There are no estimates of the number of people who are food insecure. There are no direct estimates of the extent of hungry. That is there are no direct estimates based on a comparison of measured intakes and minimum dietary requirements. Instead, the most widely-cited data on the number of persons considered hungry come from the United Nations Food and Agriculture Organization (FAO). FAO constructs an indirect measure of the following form:

> [FAO] estimates the prevalence of undernourishment [or hunger] … as the proportion of the population in the Country with a level of Dietary Energy Consumption (DEC) lower than the Dietary Energy Requirements (DER) (Cafiero and Gennari, 2011).

The calculation of DER begins with country-level census data on population size, disaggregated by age and sex. The disaggregated data are needed because basal metabolic rates – which account for a large fraction of energy requirements for bodies at rest – differ by both age and sex. This then adjusted for a minimal Physical Activity Level (PAL) "compatible with a healthy life" (Cafiero and Gennari, 2011, p. 17) and with an allowance for the fact that a certain percentage of the female population will be pregnant in any given year (FAO, 2008).

DEC is based on combining two items of information. On an ongoing basis, FAO constructs estimates of mean per capita dietary energy supply (production + stocks - post-harvest losses + commercial imports + food aid - exports) into what is called a food balance sheet. When calculating the number of undernourished people, takes a three year average of these data. It then imposes a distribution on this supply. The distribution is often, but not always, taken from a household budget survey from which estimates of household caloric acquisition are derived.

Apart from the reliability of census data, the construction of country-level DERs is relatively unproblematic. Other elements, however, are more controversial. Dietary energy supply is not measured directly and so any errors in its components, such as feed and stock estimates both of which are notoriously difficult to measure, are transmitted to it (Jacobs and Sumner, 2002). Of even greater concern is the construction of an assumed distribution of caloric intakes. Consider, for example, the distribution derived in the illustrative example from a "recent National Household Budget Survey conducted in the hypothetical country" (FAO, 2008, p6). This shows that for the poorest decile, average DEC is 1554 kcal/person/day. For the second richest decile, it is 3093 and for the richest decile, it is 3373. Both are problematic. The DEC figure for the poorest decile is nearly identical to the diet administered to volunteers during the Minnesota Starvation Experiment, an intake level which had it continued for more than the 24 weeks of the experiment would have likely led to the deaths of the participants (Keys *et al*, 1950). At the other end of the distribution, the rising levels of DEC are inconsistent with micro-econometric evidence of Hoddinott, Skoufias and Washburn (2000) and others that shows that caloric-income elasticities are virtually zero in relatively wealthy households. A second example is found in the technical appendix to FAO's *State of Food Insecurity in the World, 2010*. This shows that updating the distributional data for India reduced the estimated number of hungry people by 31 million people in 2005-07 and 57 million people in 2000-02.

While debates over this methodology continue, the numbers produced by FAO currently provide the only guide to global numbers of the hungry.[3] Table 2.1 provides these estimates for

[3] FAO's website notes, "During its meeting in 2010, the Committee on World Food Security (CFS) asked FAO to review its methodology for estimating undernourishment in order to provide more timely updates and incorporate

the periods 1969-71 to 2010. These show that a slow drift down in absolute numbers between 1969-71 and 1995-97. The number of undernourished remains relatively unchanged over the 2000s before first spiking up, then down, following the 2008 food price crisis. The global prevalence of hunger drops from 33 to 14 percent between 1969-71 and 2000-02, rising to 18 percent in 2009.

Table 2.2 provides a breakdown by the number of people considered undernourished by region.[4] The hungry are found predominantly in Asia (567 million) and secondarily in sub-Saharan Africa (217 million); these two regions account for more than 90 percent of the world's hungry. Unfortunately, even this regional disaggregation is not especially helpful. Six countries – China, India, Bangladesh, Pakistan, Ethiopia and the Democratic Republic of Congo accounted for 62 percent of the global hungry in 2006-08. Estimated changes in these countries dominate the "headline" changes in global estimates of hunger. For example, between 1990-92 and 2005-07, the number of hungry people fell by 80 million in China but rose by 65 million in India and 14 million in Pakistan. In sub-Saharan Africa, the number of hungry rose by 32 million in the DRC and this accounted for 60 percent of the continent's increase in undernourishment between 1990-92 and 2005-07.

Two further limitations should be noted. None of these estimates give us any sense as to the severity of hunger. They make no distinction between someone with DEC just slightly below the DER and someone whose DEC is 20 or 30 percent below this cutoff even though hunger for the latter person is significantly more severe and more debilitating. Second, they give no sense where the hungry are found within individual countries. Behrman, Alderman and Hoddinott (2004) cited statistics from the UN's Hunger Task Force (2003) that suggested that approximately 50 percent of those who are hungry globally are in farm households, 22 percent are the rural landless and 20 percent live in urban areas and eight percent are resource-dependent (pastoralists, fishers etc). Unfortunately, there have been no updates of these.

all relevant information, including analysis of the large number of household surveys that have become available in recent years. Therefore, no updated estimates for the number of undernourished people in 2009 and 2010 are reported, nor has an estimate been made for 2011." (FAO, 2012).

[4] Regional breakdowns are not available after 2006-08.

Undernutrition

In contrast to the somewhat messy approaches to defining and measuring hunger and food insecurity, a considerable body of knowledge exists surrounding the measurement of undernutrition.

Linear (height) growth failure is widespread in poor countries. An estimated 175 million or more preschool children are stunted, meaning their height given their age is more than two standard deviations below that of the international reference standard (Black et al. 2008; UN SCN, 2010). Table 2.3 provides data on the regional distribution of stunting along with trends in prevalences since 1990. In brief, globally the prevalence of stunting has been falling since 1990 but the regional distributional of this trend is uneven with rapid falls being observed in eastern Asia, a more gradual decline in Latin America and the Caribbean and no change in sub-Saharan Africa. The greatest concentration of stunted children is found in south central Asia. Table 2.4 provides comparable statistics on the prevalence of low weight-for-age, a Millenium Development Goal (MDG) indicator. These show a similar pattern of change over time.

The physical and neurological consequences of growth failure arising from chronic undernourishment are increasingly well understood. Chronic nutrient depletion, resulting from inadequate nutrient intake, infection, or both, leads to retardation of skeletal growth in children and to a loss of, or failure to accumulate, muscle mass and fat (Morris 2001); this lost linear growth is never fully regained (Stein et al. 2010). Chronic undernutrition has neurological consequences, adversely affecting the hippocampus, damaging chemical processes associated with spatial navigation, memory formation and reducing myelination of axon fibers; see Hoddinott *et al* (2011) for further discussion and references.

Micronutrient deficiencies are another important component of undernutrition. These are discussed at length in Behrman, Alderman and Hoddinott (2004) and Horton, Alderman and Rivera (2008) so our treatment here is brief. The greatest concern lies with deficiencies in Vitamin A, iron, iodine and zinc. Vitamin A deficiencies are associated with increased risk of infant and child mortality; Black *et al* estimate that they account for just over 650,000 deaths annually in children under five. Currently, approximately 163 million pre-school children are Vitamin A deficient with the highest prevalences found in central-south Asia (including India) and central and west Africa. Iodine deficiency adversely affects development of the central nervous system leading to mental retardation and stunted growth (UNSCN, 2010). While increased availability of iodized salt has reduced iodine deficiencies, UNSCN (2010) estimates that 1.8 billion people are iodine deficient as measured by low urinary iodine. The vast majority of these people – 1.3 billion – are found in Asia.

Anemia is widespread in the developing world. In women, this leads to increased risk of maternal mortality and ill-health and low maternal iron availability leads to reduced iron stores in newborns (UNCSN, 2010). Iron deficiency in children constrains cognitive development (UNSCN, 2010). Worldwide, more than 40 percent of pregnant women as are 47 percent of pre-school children (Black *et al*, 2008). Unlike Vitamin A and iodine deficiencies, these prevalences have remained stubbornly high over the last ten years. Zinc deficiency affects children's physical growth and leads to increased susceptibility to a number of infections including diarrhea and pneumonia (Brown *et al*, 2009). Currently, there are no global estimates of zinc deficiency.

2.3 The IMPACT model

In this section, we provide an application of the model described in section 2.1 to two outcome measures described in section 2.2, the number of undernourished people in the world and the number of undernourished children as measured by weight-for-age. We do so using the International Model for Policy Analysis of Agricultural Commodity and Trade (IMPACT) model. IMPACT is a partial equilibrium, multi–commodity, multi-country model.

IMPACT covers over 46 crops and livestock commodities including cereals, soybeans, roots and tubers, meats, milk, eggs, oilseeds, oilcakes, sugar, and fruits and vegetables. It includes a set of 115 countries/regions where each country is linked to the rest of the world through international trade and 281 food producing units (grouped according to political boundaries and major river basins) (Rosegrant *et al*, 2008). It starts with assumptions about specific aspects of the settings described in section 2.1. These include assumptions about population growth,[5] urbanization, and the rate of income growth. Note that the extensive degree of geographic disaggregation in the IMPACT model means that individual country-level variations in these assumptions typically have little impact on global-level projections. IMPACT also makes assumptions about international trade regimes for both agricultural and non-agricultural commodities; it is possible, however, to relax these. For example, Rosegrant (2008) describes the consequences for global food prices of trade distorting subsidies to biofuels. Crucially, however, IMPACT does not take one dimension of the physical setting – water availability and use – as given but instead models this explicitly.

In IMPACT, agricultural activities are carefully modeled. Growth in crop production in each country is determined by crop and input prices, exogenous rates of productivity growth and area expansion, investment in irrigation, and water availability. Other sources of income are, in IMPACT, assumed to follow from the World Bank's EACC study (Margulis et al. 2010), updated for Sub-Saharan Africa and South Asian countries. Demand for agricultural commodities is a function of prices, income, and population growth. Four categories of commodity demand are included: food, feed, biofuels feedstock and other uses. As a partial equilibrium model, demands for non-food related goods are not considered. The model links countries and regions through international trade, using a series of linear and nonlinear equations to approximate the underlying production and demand relationships. World agricultural commodity prices are determined annually at levels that clear international markets. IMPACT is designed to recognize that there are interlinkages within the agricultural sector and that exogenous changes can play out in complex ways. For example, urbanization and income growth mean that meat and dairy consumption are likely to grow rapidly as better off consumers diversify diets. While this means that the consumption of cereals per capita will decline, some of this decline is offset by increased demand for animal feeds. For a detailed description of the IMPACT methodology, please see Rosegrant *et al*. (2008).

IMPACT generates long term projections of food supply, demand, trade, and prices that enable us to estimate the trends in global food security between now and 2050. These can be

[5] Population projections are the "Medium" variant population growth rate projections from the Population Statistics division of the UN and income projections are estimated by the authors, drawing upon Millennium Ecosystem Assessment (2005).

thought as "business-as-usual" scenarios that would prevail in the absence of the investments we describe in section 3.1. These baseline scenarios do not consider the consequences for agricultural production of climate change; we return to these in section 3.2. With this in mind, we begin with projections for world prices of major agricultural commodities. These are presented in Table 2.6. Prices increase for all major agricultural commodities between 2010 and 2050. This is a result of significant rise in demand despite the increase in production and also due to constraints on crop productivity and area. Prices increases significantly with highest price increase in rapeseed oil followed by maize, wheat and rice. Rapeseed oil and soybean oil price increases are because of biofuel initiatives by EU and US that increase demand for these oils. With the increase in demand for livestock and the rise in feedstock prices, large price increases are seen in livestock sector particularly for pork and poultry. The price of pork increases by 55% and poultry by 47% between 2010 and 2050.

The baseline results for share of at risk of hunger are shown in Table 2.7. Globally, IMPACT predicts that under business-as-usual, there is essentially no change in the number of hungry people in the world in 2025 and only a modest decline, from 884 to 776 million by 2050. Given a predicted global population of 9.3 billion by the year 2050, this projection implies a decline in the prevalence of hunger from 16 to 8.2 percent. There are also significant regional variations in the distribution of hunger. In Latin America and the Caribbean there is a 24% decline in the population at risk of hunger between 2010 and 2050. South Asia which has the largest share of population at risk in 2010 only has a 26% decline which is slightly higher than seen in Latin America and the Caribbean. On the other hand, the share increases by significant amounts in Middle East and North Africa and Sub-Saharan Africa between 2010 and 2050.

IMPACT uses approximations of care behaviors, the household health environment and food intake to project the number of children that will be underweight in 2050. It uses elasticities of relationships between female education (where female secondary enrollment rates serve as proxy for improved care behaviors), access to health and sanitation (where life expectancy and access to safe water are used as proxies) and changes in food availability (a crude proxy for food intake) taken from a cross-country study by Smith and Haddad (2000).[6] Baseline projections for underweight are given in Table 2.8. The number of underweight children slowly drifts lower, from 163 million in 2010 to 147 million in 2025 and 118 million by 2050. Over this period, the distribution of underweight children becomes increasingly concentrated in two regions, South Asia and Sub-Saharan Africa. By 2050, 84 percent of all undernourished children reside in these regions.

3. Solutions to global hunger and undernutrition

In this section, we describe solutions to reducing global hunger and undernutrition. These are:

- Investment 1 – Accelerating yield enhancements
- Investment 2 – Market innovations that reduce hunger
- Investment 3 – Interventions reduce the micronutrient malnutrition and reduce the prevalence of stunting

3.1 Accelerating yield enhancements

Basic calculations

We consider the impact on our baseline projections of additional research and development investments in agricultural yield enhancements. We construct an alternative scenario that assumes significant, but plausible, increases in these investments with resulting increases in crop and livestock yields. These include research that enhances drought, heat and salt tolerance, identifying and disseminating varieties with enhanced yield potential, addressing virulent wheat rust, developing resistance to cattle diseases such as East Coast Fever (which would increase milk yields) and soil diagnostics that would permit optimal combinations of organic and inorganic fertilizers.[7] Specifically, the baseline IMPACT model assumes annual

[6] The data used to make this calculation are obtained from: the World Health Organization's Global Database on Child Growth Malnutrition, the United Nations Administrative Committee on Coordination- Subcommittee on Nutrition, the World Bank's World Development Indicators, the FAO FAOSTAT database, and the UNESCO UNESCOSTAT database.

[7] von Braun *et al* (2008) describe these in further detail.

global public investment in agricultural R&D of $5 billion per year. In our alternative scenario, we increase this annual investment by $8 billion to $13 billion.

This investment increases productivity; it can be thought of as a means by which, for a given set of inputs (the assets and labor described in section 2.1), output increases. Specifically, we estimate that this investment increases the yield growth rate for crops yields by 0.40 for all crops and the livestock yield growth by 0.20. The impact of higher research investment on yield growth rates is estimated by using the elasticity of yields with respect to research expenditures. The elasticitites are synthesized from the literature, including Alene and Coulibaly, 2009; Kiani, Iqbal, and Javed, 2008; Thirtle, Lin, and Piesse, 2003; Schimmelpfenig and Thirtle, 1999; and Fan, Hazell, and Thorat, 1998.

Yield growth has both income and price effects. The increase in productivity also generates increases in agricultural GDP growth, which leads to total GDP growth averaging 0.25 percentage points higher in the world as a whole. The impact of agricultural R&D-induced crop and livestock productivity growth on GDP growth is derived by linked analysis using ABARE's computable general equilibrium (CGE) model GTEM. The computable general equilibrium (CGE) model GTEM (Ahammad and Mi, 2005) is a multi-region, multi-sector, dynamic, general equilibrium model of the global economy. GTEM provides projections for a host of variables including gross regional product (a GDP equivalent for GTEM regional economies). The GDP variables from GTEM were used to validate the GDP (and population) input data to achieve cross-sectoral consistency with the partial general equilibrium agricultural sector model IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) through soft-linking. Once consistent GDP growth rates have been established, the GDP impacts of increased agricultural productivity growth can be estimated for any specified increase in productivity.

Table 3.1 shows the percent change in the world commodity prices between the baseline and *alternative scenario* for 2050. As a result of higher yields that increases production, the prices in for almost all the commodity decreases from the baseline. The largest decline in world prices is 68% for rapeseed oil followed by 22% for rice between baseline and *alternative scenario*. If we look into livestock, lower feedstock costs lower costs of production, leading to expansion in production and therefore lower prices. Prices of livestock decline by 11% to 12% between baseline and alternative scenario for 2050. Therefore, with the increase in productivity of both crop and livestock, prices are lower in the alternative scenario than the baseline in 2050.

Table 3.2 shows IMPACT's projections of the effect of this investment on the number of people projected to be hungry in 2050. The global number of hungry falls from 766 to 556 million people, a decline of 27 percent. With an estimated global population of 9.3 billion by 2050, this implies a global prevalence of hunger of 5.9 percent meaning that prevalence would be 63 percent less (5.9 v 16) in 2050 than it was in 2010. Table 3.2 also shows that this reduction is most pronounced in the two parts of the world where hunger remains most virulent. In this alternative scenario, both South Asia and Sub-Saharan Africa both have a 35% decline between baseline and *alternative scenario*. Other regions like Latin America and the Caribbean, Middle East and North Africa, and East Asia and Pacific also make significant reduction from the baseline.

Recall that in the IMPACT model, these improvements in production feed through to lower numbers of underweight children through increased food availability, one input into child nutritional status. Results are shown in Table 3.3. There is a reduction in the number of children predicted to be underweight, with this figure falling from 118 to 112 million with half of this reduction, six million children, coming in Sub-Saharan Africa. By contrast, the reduction in underweight prevalence in South Asia is only two million children, a fall of only six percent. This demonstrates the need to complement these investments with those that attack other causes of undernutrition.

Under this scenario of increased investments in agricultural R&D, an additional $8 billion dollar per year would, by 2050, reduce the number of hungry people in the world by 210 million and the number of underweight children by ten million. But while impressive numbers, these do not necessarily privilege these investments over others being considered under Copenhagen Consensus 2012. Mindful of this, we now construct a benefit: cost ratio for these investments.

Cost estimates are straightforward. Using a 5 percent discount rate, the net present cost of this additional investment between 2010 and 2050 is $154 billion. We also estimated the welfare impacts of agricultural research investments using a high discount rate where we double the discount rate to 10 percent and a low discount rate of 3 percent. The net present cost between 2010 and 2050 is reduced to $87 billion when high discount rate is used and is increased to $214 billion with the application of 3 percent discount rate.

There are five potential benefit streams: i) increases in welfare gains resulting from lower prices faced by consumers; ii) welfare gains from reduced yield volatility; iii) the option value of reduced yield volatility resulting from climate change; iv) productivity gains derived from the impact of increased caloric consumption on worker productivity; and v) the income gains in adulthood resulting from reduced undernutrition in early life. We consider i) and ii) here and the remaining points in the sub-sections that follow.

We estimate welfare gains by calculating the changes in consumer surplus, producer surplus, and net surplus arising from the investment-induced changes in crop yields, production and food prices. The benefit-cost ratio is then computed as the ratio of net present value of the net surplus to the net present value of the investment costs. The welfare component of the calculations follows a traditional economic welfare analysis approach to estimate the benefits to society on the consumer- and producer-side. On the consumer-side this is straightforward, as the IMPACT model has demand curves with demand elasticities, which allows us to calculate the consumer surplus. On the producer-side, it is not as straightforward, as the quantity supplied of each commodity is an area-yield equation, and does not represent the traditional supply curve that reflects the producer's marginal cost curve. Therefore, we have synthesized supply-curves by land-type for each activity from the area and yield functions, calculated the producer surplus for each of these supply-curves and then aggregated to the national level. The total changes in consumer and producer surplus, when combined, provide us with a benefit flow, which we then use in a benefit-cost analysis, to compare a technology's overall impact in the agriculture sector.

Because crop and livestock prices decline by more than the increases in productivity growth, there is a 3.87 percent decline in producer surplus. By contrast, consumer surplus rises substantially, by 16.91 percent. Thus, consumers (including net-consuming farmers in developing countries) gain substantially due to the lower prices and higher consumption in the high productivity scenario. Globally, this additional investment in agricultural R&D raises total welfare by 4.06 percent, and with a five percent discount rate yields a net present value of benefits of $2475 billion, see Table 3.4. The Internal Rate of Return to increased investments is 61 percent with a benefit-cost ratio of 16.1 indicating the high returns to expanded investment in agricultural R&D.

We assess these benefit-cost ratios under two additional discount rates (Table 3.5). In the high discount rate scenario, where the discount rate is set to 10 percent, producer surplus declines by 2.42 percent and the consumer surplus increases by 10.38 percent compared to 16.91 percent in the alternative scenario. In the low discount rate scenario, where the discount rate is set to five percent, producer surplus declines by 4.67 percent and the consumer surplus increases by a significant 20.47 percent. The total welfare using the high discount rate increases by 2.41 percent giving a net present value of benefits of $702 billion which is about one-third the value of net benefits in the alternative scenario. But even with this reduction in benefits due to the high discount rate, the benefit-cost ratio remains high at 8.07. On the other hand, when a discount rate of three percent is used, total welfare increases by five percent giving a net benefit of $4561 billion, almost twice the amount as seen with the five percent discount rate. Using the three percent discount rate, we obtain a high benefit-cost ratio of 21.31. These high rates of return to agricultural research are consistent with a large literature estimating the returns to agricultural research (Alston *et al*, 2009).

These investments in new crop varieties and livestock technologies are not country specific. An innovation that raises rice productivity can be readily transferred to Bangladesh or Thailand. For this reason, it does not make sense to try to disaggregate the costs of these increased investments by country or region. This means that we cannot calculate regional-specific benefit: cost ratios. But absent any sort of disaggregation, our results are open to the criticism that we do not say anything about the distribution of benefits. Is it the case, for example, that the increased consumer surplus is dominated by gains to western consumers? We can calculate changes in producer surplus, consumer surplus and welfare in different regions using different discount rates as shown in Tables 3.6, 3.7 and 3.8. These show clearly that welfare gains are dominated by benefits accruing to developing countries.

These benefit: cost ratios omit the fact that these investments are also variability reducing. Prior to the early 2000s, progress on this had been relatively slow. However, new research in the last ten years by both private and public sector actors has demonstrated that for rice (Pray *et al*, 2011; Serraj *et al* 2011), maize and wheat (Kostandini *et al*, 2009), it is possible to breed varieties that are both higher yielding and also less susceptible to drought and other climatic stresses. For example, Kostandini *et al* (2009) model the benefits associated with investments that increases drought tolerance in rice, maize and wheat while also achieving the yield gains described above. Specifically they measure the benefits of yield variance reductions as the money value of reduced variability in incomes to producers and reduced price variability to consumers. Calculating the value of these is complex. For producers, they need to account for the share of income derived from these crops, the size of the reduction in yield variability, elasticities of supply, adoption rates of these new technologies and risk preferences. For consumers, they need to account for price elasticities of demand, the share of expenditures that go to these staples and risk preferences. A number of these variables, such as the reduction in yield variability, are location specific and in their paper, Kostandini *et al* restrict their calculations to eight countries: Bangladesh, Ethiopia, India, Indonesia, Kenya, Nigeria, the Philippines, and South Africa. They estimate that yield variance reductions generate annual benefits to these eight countries of $569 million, $256 million to producers and $313 million to consumers.[8]

The Kostandini *et al* calculations suggest that our benefit: cost ratios are underestimates because the benefits of reduced yield variability are underestimated. As an order of magnitude exercise, consider the following. Suppose that these drought resistant varieties are made available on a wide scale starting in 2025. This is a conservative assumption given that large-scale trials of drought resistant maize are already scheduled for 2012. We conservatively assume that the $569 million is the total global benefit resulting from reductions in yield variance and will calculate the stream of benefits from 2025 to 2050. The present value of these benefits is $7,807 million, $5,280 million and $2,213 million under three, five and ten percent

[8] They conduct sensitivity analyses, noting that these findings are sensitive to the extent to which supply shocks induce price volatility.

discount rates respectively. Table 3.9 shows the benefit: cost ratios when this additional benefit is included. Even under the conservative assumptions used here, the benefit: cost ratios are large, ranging from 33.5 to 57.7 depending on the discount rate used.

Accounting for climate change

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) concluded that the evidence supporting global warming in unequivocal and that this is very likely to be a consequence of increased human greenhouse case concentrations. The extent of this warming is subject to uncertainty, depending on assumptions about income and population growth, land use changes and technological progress. The IPCC constructs a set of "Special Report on Emissions Scenarios" (SRES) that show that by 2050, global mean temperatures will rise by about 1^{o}C under most scenarios but that further rises are expected after that time with the magnitude of those rises being scenario dependent. How do the implications of climate change affect our proposed investments in yield enhancement?

Nelson *et al* (2010) provide a detailed assessment of the consequences of these climate change scenarios on global food supply, food prices, the prevalence of hunger and undernutrition in 2050. They do so by linking IFPRI's IMPACT model with the Decision Support System for Agrotechnology Transfer (DSSAT) crop model suite. DSSAT takes into account location-specific information on climate, soils, and nitrogen application to simulate multi-year outcomes based on crop management strategies, varietal improvements, changes in soil fertility and changes in weather.[9] Nelson *et al* note, "The modeling methodology reconciles the limited spatial resolution of macro-level economic models that operate through equilibrium-driven relationships at a national level with detailed models of biophysical processes at high spatial resolution" (Nelson *et al*, 2010, p6). This allows them to take into account location-specific effects of climate change in terms of its impact on temperature, precipitation and

[9] DSSAT is underpinned by detailed data inputs and modeling work. "Crop models require daily weather data, soil surface and profile information, and detailed crop management as input. Crop genetic information is defined in a crop species file that is provided by DSSAT and cultivar or variety information that … [is] … provided by the user. Simulations are initiated either at planting or prior to planting through the simulation of a bare fallow period. These simulations are conducted at a daily step and, in some cases, at an hourly time step depending on the process and the crop model. At the end of the day the plant and soil water, nitrogen and carbon balances are updated, as well as the crop's vegetative and reproductive development stage" (DSSAT, 2012).

increases in atmospheric concentration of CO_2.[10] These impacts are used to model consequences for crop productivity. In turn:

> The climate-change-driven productivity effects are incorporated into the hydrology and economic elements of the IMPACT model to assess the combined effects of economic, population, and climate scenarios. The process of modeling agricultural futures proceeds roughly as follows. Supply is determined at the food production unit (FPU) level by farmer responses to prices, conditioned by assumptions about exogenously determined area (AGRs) and yield growth rates (IPRs) as well as assumptions regarding climate productivity effects on irrigated and rainfed crops. Demand is determined at the national level by consumer responses to changes in national income and prices. When supply is greater than demand, exports occur. For the world, net trade in a commodity must be zero. World prices are adjusted to ensure this outcome for a year. This process is repeated for each year through to 2050 (Nelson et al, 2010, p. 20)

Nelson *et al* (2010) model these climate driven productivity changes under three income and population growth scenarios.[11] Table 3.10 shows baseline scenarios for the production of three crops, maize, rice and wheat. Compared to "perfect mitigation" – investments that would ensure that atmospheric concentration of CO_2 in 2050 were the same as those found in 2010 – climate change reduces maize production by 52.6 million metric tonnes, rice production by 37.6 million metric tonnes, and wheat production by 66.7 million metric tonnes. Linking these changes in agricultural production to the prevalence of child underweight, Nelson et al show that under their baseline scenario , absent perfect mitigation, child underweight would be 9.8 percent higher in 2050. This is an increase of 11.5 million in the number of undernourished children.

Having undertaken these calculations, Nelson *et al* simulate the impact of a number of investments that would offset the malign impacts of climate change on production. These include boosting productivity growth in a variety of crops and improvements in irrigation efficiency. The following example gives a flavor of these. Suppose that additional spending is

[10] Specifically, Nelson et al (2010) use version 4.5 of DSSAT, with atmospheric concentration of CO2 in 2050 set at 369 ppm, see Nelson et al (2010, pp. 14-18) for further explanation.

[11] These are: baseline (World Bank projections for global income growth and UN medium variant population projections); pessimistic (low income growth rates and UN medium variant population projections); and optimistic (high income growth rates and UN low variant population projections) .See Nelson et al (2010, Table 1.1) for further details.

undertaken that raises productivity growth in wheat production by two percent per year in seven developing countries that account for about 40 percent of global wheat production.[12] These investments reduce expected increases in wheat prices by just under 50 percent. It reduces the number of underweight children by 3.3 million with most of this reduction occurring in middle income developing countries. In so doing, it offsets 28 percent (3.3/11.5) of the predicted increase in children's undernutrition.

Nelson et al (2010) also note that climate change may well result in increased frequency of extreme weather events such as extended droughts. They give the example of a failure of the monsoon rains between 2030 and 2035 as an example. Were this to occur, their modeling suggests that global prices would rise as reduced supply from south Asia would not be offset by increased production elsewhere. Over the period 2030-2040, prices would first rise, peaking in 2035 at increases of 43 percent (wheat), 16 percent (rice) and 67 percent (maize) over trend before falling back to trend by 2040. In addition, this extended drought would increase the number of underweight children by around 900,000.

Moving from examples such as these to the calculation of benefit: cost ratios is enormously difficult. As Nelson *et al* carefully explain, different climate models produce different predictions of the geographic distribution of the impacts of climate change - impacts that are amplified by different assumptions regarding global income and population growth which affect the predicted trajectory of global food prices. In turn, this affects the benefits associated with investments in productivity enhancing investments in different crops and in different countries. They also note that climate change is expected to increase the frequency of severe weather events such as droughts but it is not possible to predict where and when these will occur and they note that their south Asia example is meant to be illustrative.

In light of all this, we do not calculate formal benefit: cost ratios of agricultural investments that mitigate the impact of climate change on yield levels and variability. Instead, we argue that these changes induced by climate change imply that there is an option value to investments in agriculture. To see this, consider the following. We take the predicted changes in price trajectories between 2030 and 2040 that an extended drought in south Asia between

[12] These are India, Pakistan, Argentina, Iran, Ukraine, China, and Kazakhstan.

2030 and 2035 would induce. We calculate the cost to consumers of this higher price based on current consumption levels for these three staples. The present value of this global cost is $247 billion. Based on the patterns we see in Tables 3.6, 3.7 and 3.8, we assume that a third of this cost is transferred to producers so the next welfare cost is $165 billion. We further assume that the probability of an event of this magnitude occurring is 25 percent and so the net present value of this cost – excluding costs created by higher price variability that might occur and the costs associated with increased child undernutrition – is $41 billion. The option value of agricultural investments that mitigate the impact of climate change on yield levels and variability is the amount of money that one would be willing to pay now to reduce the costs of such extreme weather events in the future. Assuming this option value is positive, it is a further stream of benefits in addition to those described above.

Calorie-productivity and undernutrition benefits

At least since the late 1950s, economists have hypothesized a link between caloric intake and worker productivity (Leibenstein, 1957), a link sometimes referred to as the wage efficiency hypothesis. In its simplest form, the argument is that individuals with very low caloric intakes, possibly exacerbated by low body mass, have insufficient energy to undertake remunerative labor. Dasgupta (1993) provides more details, noting that under this hypothesis, low caloric intakes are both a consequence and cause of poverty. Teasing out these links, however, is enormously complicated. The data demands are high, requiring detailed individual level information on intakes and physical activities as well as data that allows the analyst to account for the fact that, in econometric terms, both are endogenous. Given these data requirements, not surprisingly the empirical literature is scant. Carefully executed studies provide some evidence supporting the wage efficiency hypothesis but that this evidence tends to be locationally, temporally (eg harvest, season of peak labor demand, Behrman and Deolalikar, 1989) and sex specific (Pitt, Rosenzweig and Hassan, 1990). Given this heterogeneity, we do not calculate the additional benefit stream derived from the impact of increased caloric consumption on worker productivity. Instead, we note the important implication that the existence of these additional benefit streams implies that our benefit: cost ratios are conservative.

Lastly, Behrman, Alderman and Hoddinott (2004) and Horton, Alderman and Rivera (2008) have stressed that investments that reduce undernutrition in pre-school children provide considerable economic benefits. As discussed above, investments in agricultural research and development do reduce undernutrition but the magnitude of this change is relatively small.

3.2 Market innovations that reduce hunger

The conceptual model described in section 2.1 placed particular emphasis on the economic setting in which a household finds itself. We described the economic setting as capturing policies that affect the level, returns, and variability of returns on assets and, as such, influence choices regarding productive activities undertaken by individuals, firms and households. We noted that this included meso-level considerations that captured food market structure, conduct, and performance as measured by price levels, variability, and trends as well as government policies towards these. Roughly 80 percent of the global hungry and 75 percent of the world's poor live in rural areas and half the global hungry are smallholders. (UN Hunger Task Force, 2003) Given all this, are there investments that can improve these settings for smallholders, for example by linking 'farms to markets', reducing transaction cost or reducing risk? In this section, we consider two: i) the provision of market information through cellular phones; and ii) reducing barriers to fertilizer access.

Information and Communication Technologies

Models of perfect competition predict the maximization of social welfare. However, this prediction relies on a set of critical assumptions. One of these key conditions is the prevalence of perfect information. Since the publication of Stigler's (1961) seminal work, such assumption has been contested. Imperfect information is pervasive in many agricultural markets in developing countries, a consequence of remoteness, poor infrastructure and thin markets. The deployment of Information and Communication Technologies (ICTs) can remedy some of dimensions of imperfect information. Jensen (2010) argues some of the main gains of information in agricultural markets:

- Information, Arbitrage and Efficiency: Price differentials (in excess of transportation costs) can signal agents to reallocate their production towards higher-profit markets. In doing so, there are potential gains to aggregate welfare.

- Information, Market Power and Welfare Transfers: By lowering search costs, phones enable producers to research sales opportunities in more markets and to obtain better prices for their products. This argument holds also holds when farmers do not sell directly in markets. Even in the presence of monopsonistic middlemen, if farmers have better information, traders may need to offer higher prices to prevent farmers from selling their products directly in other markets. This argument also applies to input and transport costs as the following anecdote illustrates:

> I was in process to transport my produce of (approx 1000 boxes in 2 trucks) to Delhi when I got an SMS through RML that the freight rate from Kotgarh to Delhi is Rs 41.07 per box. I showed this message to the truck operator, who till then was citing a rate of Rs 44 per box. Following this I was able to settle the transporting deal at Rs. 41.07, finally saving around 3,000 rupees (Reuters, 2012).

- Reduced Price Variability: When there is no information (and limited arbitrage), prices tend to vary with local supply. However, when information is widespread (and there is more arbitrage), price fluctuations are related to aggregate supply.

- Production Patterns: Information can also affect land use patterns, where households can shift towards more profitable crops.

A small number of studies examine the impact of improved information flows on dimensions of smallholder welfare. These typically exploit the existence of natural experiments, such as the roll-out of cellular phone services or access to radio broadcasts. They provide a range of estimates. Some, such as Svensson and Yanagizawa's (2009) study of the impact of price dissemination via radio found large income gains through higher realized, on the order of an increase of 15 percent in maize income. Similarly large effects were found in Peru (Chong, Galdo, and Torero, 2005; Beuerman, 2011) and the Philippines (Labonne and Chase, 2009).

Others find much smaller (Goyal, one to six percent impacts on soya bean income in Madhya Pradesh, India) or no effects, Mitra, Mookherjee, Torero and Visara (2011) and Fafchamps and Minten (2012). The literature is suggestive of the possibility that gains to improved information flows are larger in sub-Saharan Africa than south Asia and that these are larger where products are more perishable.

Mindful of these variations in impacts, consider the following investment that increased farmer's access to market information through mobile phones. Our model here is the Reuters Market Light (RML) Program which is widely available in India (Reuters, 2012). Under RML, for a monthly fee, receive crop advisory SMS text messages. These are tailored to specific points in the crop cycle, including location specific information weather forecasts, local market price information, and local and international commodity information. Users can configure these messages so that they only receive information most relevant to them in their language of choice. In India, the monthly cost of this service is $1.50. We assume that messages are needed for six months and we convert this US dollar cost into purchasing power parity dollars so as to apply it across a number of countries. In our base model, the annual cost is PPP$21.92 per household or, assuming household sizes of 5.5 persons, PPP$3.98 per capita. We also undertake an alternative calculation where, perhaps because of scale economies, this cost is reduced by 50 percent. We assume that beneficiaries are responsible for the purchase of handsets. This can be thought of as a commitment device that self-selects those households who intend to use this information.[13]

In our base case, we take the simple averages of four African studies of the impacts of improved market information (results in parentheses): Svenson and Yanagizawa (15%), Futch and McIntosh (no effect), Aker and Fafchamps (no effect), and Muto and Yamano (positive impacts for bananas but no impact on maize) and assume that the average impact is a 3.75 percent increase in agricultural incomes through higher prices. Four papers presented evidence from south Asia: Mitra et al (no effect), Goyal (1.6%), Fafchamps and Minten (no effect) and Jensen (8%) and the simple average of their estimated impacts is a 2.4 percent increase in

[13] If we included handsets as part of the investment, there would be a risk of beneficiaries choosing to participate solely to receive the phone. Basic mobile phones in south Asia and much of Africa are cheap, around $15, and there is no reason why small groups of households could not pool their resources to purchase these.

agricultural incomes. We consider two alternatives to this: i) one where we assume benefits are lower[14], a one percent increase in south Asian countries and a two percent increase in Africa; and ii) one where the base case benefits are doubled, 4.8 percent for south Asia and 7.5 percent for Africa. To calculate benefit streams and the total value of benefits obtained, we consider two south Asian countries, Bangladesh and India, and four African countries, Senegal, Ghana, Kenya, and Tanzania. To make these results comparable across countries, calculations for all scenarios are based on the following assumptions:

- We consider the per capita household expenditures in rural areas as a proxy for income. We use the most recent household survey available for each of these countries. Data sources are the following:
    - Bangladesh: Mean per capita expenditure in rural areas from the Household Income and Expenditure Survey of 2005[15]
    - India: Mean per capita expenditure in rural areas from the 66th round of the National Sample Survey (2009/2010)[16].
    - Tanzania: Mean per capita expenditure in rural areas from the 2007 Household Budget Survey.
    - Kenya: Average per capita expenditure of the fifth decile from the Kenya Integrated Household Budget Survey (KIHBS 2005-2006)[17]
    - Senegal: Average rural per capita expenditure from the Enquête Sénégalaise Auprés des Ménages (ESAM-II)[18]
    - Ghana: Average rural per capita household expenditure from the Fifth Round of the Ghana Living Standards Survey (GLSS5).
- Also, we adjust household expenditures for inflation and for purchasing power parity (PPP) using the World Bank Development Indicators[19]. Thus, all are estimations are comparable across countries and expressed in 2010 PPP$.

[14] This is based on the fact that Mitra, Mookherjee, Torero and Visara (2012), and Fafchamps and Minten (2012) find no significant effect for some ICT interventions in India while Goyal's (2010) estimates suggest a one percent lower bound for the impact.

[15] http://siteresources.worldbank.org/BANGLADESHEXTN/Resources/295759-1240185591585/BanglaPD.pdf

[16] http://mospi.nic.in/mospi_new/upload/Press%20Release%20KI-HCE-66th_8july11.pdf

[17] http://siteresources.worldbank.org/INTAFRREGTOPGENDER/Resources/PAKENYA.pdf

[18] http://ns.ansd.sn/nada/site_enquete/CD_ESAM2/survey0/data/Rapport%20Esam2.pdf

- The share of crop sales in total income is a rough estimate (40% in Asia and 30% in Africa).
- The poverty elasticity of income is based on international experience (minus two), taking into account that the base is rural income.
- The affected population is assumed to be two million households in India, one million in Bangladesh. In Africa, the affected population is assumed to be 5% of the rural population.

These basic data are summarized in Table 3.11 and our results are reported in Table 3.12.

Under scenario 1 – with our base assumptions about benefits and costs – this investment always generates a positive rate of return. Across these six countries, the benefit: cost ratios lie between 1.41 (Tanzania) and 2.09 (Kenya). If we are very pessimistic about the benefits and if we believe that it is not possible to reduce costs (an especially strong assumption), then the benefit: cost ratios are only high enough to justify this investment in Kenya and Ghana. But under any other set of assumptions, these benefit: cost ratios exceed one and in some cases they do so by a considerable margin. For example, under the high benefit, reduced cost scenario, these range from 5.64 to 8.35.

Investments that increase competition in the fertilizer market

It is well established that low adoption of improved land management practices is one of the main factors behind lagging agricultural productivity in many developing countries. Although an increase in fertilizer use is not the only solution to this problem, countries that have increased their agricultural productivity have also considerably increased their use of fertilizer. Several regional and local policies have been promoted in the past years to stimulate sustainable fertilizer use with mixed results, but not much has been said about the high and increasing dependence of developing regions on imported fertilizer, which is a highly concentrated industry at the global level. As shown in Table 3.13, a small number of countries control most of the production capacity for the main nitrogen, phosphate, and potash fertilizers. The top five countries control more than half of the world's production capacity for all major fertilizer products. Similarly, except for China, the industry shows a high level of concentration among

[19] http://data.worldbank.org/data-catalog/world-development-indicators

firms within each main producing country. In most cases, the top four firms control more than half of each country's production capacity.

The high levels of concentration in the fertilizer industry mainly result both from high requirements of raw materials, which are not available worldwide, and from potential economies of scale in production, which result in cost efficiencies. However, high concentration in an industry may also result in market power exertion and tacit collusion among firms, which may allow a few companies to take full advantage, for example, of international price spikes in energy and grain markets to the detriment of farmers' wealth. Consider Figure 3.1. This shows that during the food crisis of 2008, where oil and agricultural prices drastically increased, ammonia and urea prices exhibited even higher price spikes. By mid-2008, when the crisis was felt most, ammonia and urea prices were 2-3 times larger than in mid-2007; oil and corn prices, in turn, were 1.5-1.9 times larger. The market power effects could be outweighing the cost-efficiency effects in this highly concentrated industry.

Hernandez and Torero (2011) analyze this issue formally. Specifically, they examine the relationship between fertilizer (urea) prices and market concentration in the fertilizer industry using annual data from a panel of 38 countries. Concentration is measured as the top-4 concentration ratio (CR4), the sum of the market shares of the four largest firms operating in the market. The shares are measured both in terms of production capacity and number of plants. The analysis accounts for the relative importance of fertilizer imports on use in each country. The estimation results indicate a positive correlation between prices and market concentration. A 10% decrease in the top-4 concentration ratio using production capacity to measure market share leads, on average, to an 8.2% decrease in fertilizer prices, while a 10% decrease in the top-4 concentration ratio using number of plants, leads to an 11.6% decrease in prices.

This evidence suggests that there could be considerable welfare gains if this concentration could be reduced. One option could be the forcible break-up of this concentrated industry. But it is not immediately obvious that this is a good idea. Quite apart from the disruption this would cause, this could well lead to a loss of economies of scale. Regulation is another possibility but imposing price restrictions, as well as regulations governing exports, might well lead to unproductive rent seeking.

Another alternative is to invest in the construction of new production capacity. The underlying logic for this investment is that private sector actors are deterred from entering these markets by the joint existence of high fixed costs and strategic pricing behavior by incumbents. Here, we consider the case of public investment in production capacity with the understanding that the operation of the facility would be turned over to the private sector. Based on the Hernandez and Torero (2011) study, we take the impact of increased competition on prices and use this to estimate its impact on fertilizer intake and crop production. From this, we calculate costs and benefits over a 40 year time horizon (2010-2050) for the same four countries that we considered for ICT investment, India, Bangladesh, Senegal, Ghana, Kenya and Tanzania. We also estimate impact on poverty.

We start with the Hernandez and Torero findings; an 8.2% decrease in prices could be considered as a conservative scenario while an 11.6% decrease could be regarded as an optimistic scenario. Gruhn, Goletti and Roy (1995) report an average elasticity of fertilizer demand with respect to prices of around -1.62 based on work by David and Otsuka (1994) in Asia. Similarly, Bumb, Johnson and Fuentes (2011) assume that the elasticity of crop production with respect to fertilizer use is 0.25. With these elasticities, an estimated impact of the change in prices on both fertilizer intake and crop production can be derived, as shown in Table 3.14. A 10% increase in competition in the fertilizer industry will increase crop production by 3.3% in a conservative scenario and by 4.7% in the optimistic scenario.

The simulated effect on crop production, assuming a conservative scenario, can be used to approximate the impact on poverty reduction using some countries in South Asia (India and Bangladesh) and Africa (Senegal, Ghana, Kenya and Tanzania) as examples. A poverty elasticity of income of -2.0 is assumed based on international experience. The share of crop sales in total income is assumed to be 40 percent in South Asia and 30 percent in Africa. Based on these calculations, a 10 percent decrease in the level of concentration in the fertilizer industry reduces poverty by 2.6% in the South Asian countries and by 2% in the African countries (Table 3.15). This is equivalent to 20.1 million people in India, 2.7 million in Bangladesh, one hundred thousand in Senegal, two hundred thousand in Ghana, four hundred thousand in Kenya and half a million in Tanzania. Overall, there will be a total poverty reduction of 24 million people in the six countries.

In order to decrease the top-4 concentration ratio in South Asia and Africa by 10 percent, it is necessary to build a fertilizer plant in each region with a corresponding annual production capacity of 1.2 million metric tons (MT) and 0.7 million MT (recall that in the conservative simulation analysis above, the concentration measure is based on production capacity).[20] The new plant will absorb this share-reduction of the top-4 firms in each market and will not be large enough to be among the top-4 producers in each region. We assume that the cost of building a 1.2 million MT plant in South Asia would roughly equal around US$1.2 billion and the cost of building a 0.7 million MT plant in Africa would roughly equal US$700 million.[21] For the purpose of our cost: benefit analysis, these investment costs are prorated based on the relative amount of (nitrogen) fertilizers consumed by each country. For example, India accounts for 93% of the total fertilizer used between India and Bangladesh, so we ascribe 93% of the building costs of the plant in South Asia (around US$ 1,111 million) to India. We assume that the cost per MT of (nitrogen) fertilizer production is US$130 for a plant size over 1,000 MT of capacity per day, see Kim, Taylor, Hallahan and Schaible (2001).

We assume that only 20% of the rural population in each country will experience an effective increase in their income (increase of 1.3% in South Asian countries and of 1% in African countries, based on the simulation above). This (conservative) scenario accounts for the fact that some farmers may already be using the optimal amount of fertilizer while the increase in fertilizer use for several others may still not reach a certain level which results in higher income. As with our work on ICTs, per capita household expenditure in rural areas is used as a proxy for rural income using the most recent household surveys in each country.

Results are given in Table 3.16. These show that at both three and five percent discount rates, the net present values of these investments are positive for all countries except Kenya.

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[20] These numbers are equivalent to 10% of the annual production capacity reported by the top-4 firms in each region according to IFDC Worldwide Fertilizer Capacity Listing by Plant.
[21] These cost estimates are based on the estimated cost of a nitrogen fertilizer plant currently under construction in the Delta and Lagos States of Nigeria.

The total net present value of such a policy over a time horizon of 2012-2050 (39 years) will be equal to US$20.4 billion assuming an annual discount rate of 3% and to US$12.5 billion assuming an annual discount rate of 5%.

3.3 Bundling intervention that reduce micronutrient deficiencies and reduce the prevalence of stunting

In Behrman, Alderman and Hoddinott (2004), Copenhagen Consensus solutions to undernutrition covered a range of interventions including those relating to low birthweight, Improving infant and child nutrition in populations with high prevalence of child malnutrition, addressing micronutrient deficiencies and new investments in agricultural technologies. Two of these, addressing micronutrient deficiencies and new investments in agricultural technologies were ranked highly by the 2004 Copenhagen Consensus panel while efforts to reduced low birthweights and improving infant and child nutrition were seen as “Fair” investments. The 2008 Copenhagen Consensus, based on the paper by Horton, Alderman and Rivera (2008), continued to rate micronutrient interventions highly with vitamin A and zinc supplements for children ranked first, iron and iodine fortificants third and biofortification fifth. One component relevant to stunting, community based nutrition programs, was ranked ninth.

In this section, we do the following. For highly ranked micronutrient interventions, vitamin A, zinc, iron and iodine, we update benefit: cost ratios based on new studies published since 2008. Second, since the publication of those earlier Copenhagen Consensus papers, there have been two major developments in the evidence base related to interventions that will reduce the prevalence of growth failure. These are: the work by Bhutta *et al* (2008) on establishing which interventions have been demonstrated to have the most powerful effects on reducing stunted linear growth and the monograph by Horton *et al* (2010) that provided detailed costings on these interventions. These new sources provide the basis for our second set of investments related to undernutrition: a package of interventions that will reduce stunting.

Updated estimates of highly ranked micronutrient interventions

We update benefit: cost ratios for iodine, iron, Vitamin A and zinc. All of these are described by Bhutta et al (2008) as having sufficient evidence of benefits to support their widespread implementation. We note that we now have benefit: cost estimates of a novel delivery form, Doubly Fortified Salt - fortified with both iodine and iron. In Table 3.17, we summarize the principal benefit: cost estimates from previous Copenhagen Consensus estimates as well as new results that have emerged since 2008.

Several results emerge. First, the benefit: cost ratios for iodized salt continue to be overwhelmingly high with most recent calculations from Rajkumar *et al'*s (2012) work in Ethiopia suggesting that this is 81, a ratio higher than that reported by Horton, Alderman and Rivera (2008) but within the range suggested by Behrman, Alderman and Hoddinott (2004). Second, the most recent benefit: cost ratios for Vitamin A supplementation lie towards the bottom end of earlier estimates but this appears to be an artifact of a much lower monetary valuation of averted mortality. While Behrman, Alderman and Hoddinott's (2004) initial benefit: cost ratio for iron supplementation for pregnant mothers now looks far too high, several studies provide estimates for a range of delivery mechanisms for iron between 6.7 and 23.8. Horton *et al* (2011) note that the figure of 37 for home fortification is probably too high because the study on which it is based assumes far lower distribution costs than those found in other papers. We also now have a stand-alone estimate for zinc supplements for children, 2.85.

Investments that reduce the prevalence of stunting

Recall that in our conceptual framework, that the proximate determinants of nutritional status were health status and individual food intake which themselves were a consequence of good nutritional and health practices, the health environment and food availability at the household level. Bhutta *et al* (2008) undertake a systematic review identifying those interventions for which there is compelling evidence of their impact on mortality and stunting between birth and 36 months.[22] They argue that there exists rigorous evidence to support the large-scale implementation of the following interventions:

[22] The methods they use to establish their criteria of compelling evidence is carefully detailed in their paper.

- Interventions that improve the health of mothers. This includes iron fortification of staples, universal salt iodization and iron-folic acid supplementation for mothers during pregnancy;
- Interventions aimed at improving care behaviors. This includes community based nutrition programs that provide information on breastfeeding and complementary feeding. It also includes dissemination of change behaviors that increase the frequency and effectiveness of hand washing. Bhutta *et al*'s pooled analysis of six studies of hand washing counseling reduces the risk of diarrhea by 30 percent.
- Interventions that address ill-health related causes of poor pre-school nutrition. Vitamin A is important for the immune system. Bhutta et al report pooled analyses of trials of Vitamin A supplementation showing that mortality in children six to 59 months declines by 24 percent; however, there is no impact on anthropometric measures. Therapeutic zinc supplementation reduces the duration of diarrhea by 15 to 24 percent. Finally, deworming has small effects on linear growth but in areas with high rates of intestinal helminthiasis can reduce anemia by five to ten percent;
- Interventions that improve the quantity and quality of a child's diet. Bhutta et al's analysis of seven interventions where children aged six to 23 months received food supplements showed that these increased height-for-age by 0.41 standard deviations - a large increase – in food insecure populations. Further, they find that the application of WHO's guidelines for the treatment of children with severe acute malnutrition (which includes ready-to-use therapeutic foods) reduces mortality by 45 percent.

Having identified these interventions, Bhutta *et al* construct a cohort model that assesses the cumulative impact of these interventions in the 36 countries which collectively account for 90 percent of the moderately or severely stunted children worldwide.[23] They find that these would reduce stunting at age 36 months by 36 percent and mortality by 25 percent.

[23] These countries are: Afghanistan, Angola, Bangladesh, Burkina Faso, Burundi, Cambodia, Cameroon, Congo (DR), Cote d'Ivoire, Egypt, Ethiopia, Ghana, Guatemala, India, Indonesia, Iraq, Kenya, Madagascar, Malawi, Mali, Mozambique, Myanmar, Nepal, Niger, Nigeria, Pakistan, Peru, Philippines, South Africa, Sudan, Tanzania, Turkey, Uganda, Vietnam, Yemen and Zambia.

Horton *et al* (2010) estimate the budgetary costs of scaling up these nutrition interventions in these high burden countries. Their cost estimates are based on what is called the "program experience" approach. Under this approach, per unit costs are derived from actual program experiences operating these interventions in poor countries. The context from which these have been taken – whether they are part of outreach programs, stand-alone interventions or components of primary health services – is considered as is the collective packaging of these interventions. As Horton *et al* stress (2010, p. 10), an attraction of this approach is that it produces more conservative estimates of costs because unlike other costing methods it takes into account the fact that interventions may well not operate a maximum efficiency. They account for differences in costs across countries (see Horton *et al*, 2010, Table 2.2) and assume, as do Bhutta *et al* (2008), that it may not be possible to reach all children; in fact Horton *et al*'s cost estimates are based on 80 per cent coverage. Per child costs of these interventions are given on Table 3.18. In sub-Saharan Africa and south Asia, the total cost per child is $96.10 with nearly 60 percent of accounted for by the provision of complementary foods. In India, where the cost of supplementary feeding is higher, the per child cost is $111.62.

We now consider estimates of the economic benefits of implementing this package of interventions. We begin with stunting. In Behrman, Alderman and Hoddinott (2004), benefits of reduced prevalence of stunting are constructed by stitching together estimates of the impact of linear growth failure: on attained height and then monetizing this impact by applying estimates of the impact of height on earnings derived from wage regressions where height appears as an argument; and on grade attainment and cognitive skills, again monetizing this impact by applying estimates of the impact of schooling or cognitive skills on earnings derived from wage regressions where these education-related outcomes appear as arguments. More recently, Hoddinott *et al* (2011) provide direct estimates of the impact of stunting in early life on later life outcomes. Specifically, they follow up on a group of approximately 2,300 individuals who participated in a nutritional supplementation trial in Guatemala in the late 1960s and early-mid 1970s. These persons were traced as adults, aged somewhere between 25 and 42 at the time of interview, and data obtained on their schooling, marriage and fertility histories, earnings, health and consumption levels. Hoddinott *et al* find that multiple malign effects of growth failure persist into adulthood including, inter alia, lower levels of per capita consumption. Treating stunting as endogenous, Hoddinott *et al* find that stunting reduces per capita consumption by a massive 66 percent. They emphasize that stunting carries such high costs because it has a large impact on cognitive skills and that these skills have high returns in the labour market.

We use this information as follows. Suppose starting in 2015, the full package of interventions described above is implemented. This benefits a cohort of individuals born in 2015 whom we assume enter the labor market at age 21. We treat an increase in per capita consumption due to moving one of these individuals from being stunted to not-stunted as equivalent to an increase in per capita permanent income. We multiply the point estimate, 0.66, by 0.36 in recognition of Bhutta *et al's* estimate that this package of interventions will reduce stunting by 36 percent. We apply this predicted increase in income, 23.8 percent, to predicted per capita incomes of four countries where stunting is widespread and which represent a range of income levels, Bangladesh, Ethiopia, India and Kenya, for the period 2036 to 2050, that is the first fifteen years of their working lives. Using both a three and five percent discount rate, we construct the net present value of these increased earnings. We replicate this exercise making an even more conservative estimate of the increment in income, 15 percent.

Results are reported in Table 3.19. Using the most conservative assumptions – a 15 percent increase in income, a five percent discount rate and data from Ethiopia – yields a benefit: cost ratio of 15.0. Relaxing these conservative assumptions, either by using a three percent discount rate or our point estimate of the predicted increase in income, yields benefit: cost ratios between 23.8 and 138.6. These vary across countries because of pre-existing differences in income levels and predicted growth rates.

Note that at least in two other ways these benefit: cost ratios are conservative. First, some of these interventions – such as salt iodization and iron fortification of staples – convey benefits to all, not just pregnant women and young children. Second, these estimates do not account for the reduction in child mortality which we know to be substantive. Black et al (2008) indicate that "Maternal and child undernutrition is the underlying cause of 3·5 million deaths, 35% of the disease burden in children younger than 5 years and 11% of total global DALYs".

Ascribing a monetary benefit to this is difficult as it entails ascribing a monetary value to a lost life, an exercise that, as Behrman, Alderman and Hoddinott (2004) describe in detail, has myriad pitfalls. Given these significant challenges, we do not calculate such a benefit stream, instead noting that the additional benefits of reduced mortality likely mean that our benefit: cost ratios are underestimates.

4. Desiderata and caveats

In undertaking these calculations, we are aware of a number of important desiderata and caveats. We note four here: Issues relating to measurement and discounting; global trade regimes; gender; and responses to the most virulent forms of hunger, famine.

Behrman, Alderman and Hoddinott (2004) provide an exhaustive review of measurement and discounting issues as they relate to calculations for Copenhagen Consensus type exercises. Rather than recount all this in detail, we remind the reader of several important points. First, the investments being considered here convey benefits many of which are obtained well into the future – for example, investments made to reduce stunting do not begin to generate monetary benefits until 2036. This makes them especially sensitive to the choice of discount rate. As Behrman, Alderman and Hoddinott note the present discounted value of $100 received 50 years later is $608.04 with a discount rate of 1% but only $8.52 with a discount rate of 10% and so, in their words, "whether an investment is a great choice or a lousy choice" depends critically on the discount rate used. Second, our cost estimates are based on the marginal public costs of undertaking these investments. They exclude any private costs associated with these such as the time costs incurred by mothers in taking their children to clinics to receive therapeutic zinc supplements when they have diarrhea. They also exclude distortionary or deadweight costs associated with raising public funds for these investments. Finally, where there are diseconomies of scale associated with program implementation, costs may be underestimated. That all said, we note that for a number of our benefit: cost estimates, we use multiple discount rates and, where possible, use actual program costs as a guide to the cost estimates presented here. And of course these considerations apply to all investments being considered by the Copenhagen Consensus, not just those presented here.

We began the substantive discussion with a conceptual framework that noted that hunger and undernutrition reflect the purposive actions of individuals given preferences and constraints. The settings in which our investments are placed offer both opportunities and threats to the reduction of hunger and undernutrition, global climate change being an excellent example of the latter. Here we note that all our benefit: cost estimate rely on *ceteris paribus* assumptions regarding these settings. Improvements in settings which, for example, increase returns to human capital, would increase our estimates of benefits from investments that reduce stunting. The discussion of benefits from investments in yield enhancements relies critically on assumptions regarding the global trade regime for agricultural commodities. This is especially important when we consider the impact of climate change on global food prices. As Nelson *et al* (2010) make clear the consequences of climate change for crop production are unevenly distributed across the globe. Global trade reduces the adverse impact of lowered production in some regions because it permits consumers in those adversely affected localities to access production from other parts of the world less badly affected. We have not explicitly assessed the consequences of both climate change and a breakdown in global agricultural trade; suffice it to say that if this were to occur, that the welfare costs – for example in terms of the number of children undernourished – would likely be significantly higher.

Investments aimed at reducing hunger and undernutrition cannot be gender blind. Gender considerations enter into our investments in two ways.

1) Gendered investments in agriculture. We can think of no better statement of the importance of this than the following:

> The rationale for considering gender in agricultural research relates to agricultural productivity, food security, nutrition, poverty reduction and empowerment. In all of these, women play a critical but often under-recognized role and face greater constraints than men. (Meinzen-Dick *et al*, 2011)

2) Women's education. As noted in Behrman, Alderman and Hoddinott, there are many studies showing strong correlations between maternal education and reductions in undernutrition amongst pre-school children. With the caveat that some of these correlations may reflect unobserved characteristics such family background, increasing women's education is likely to produce benefits in terms of reduced undernutrition.

Behrman, Alderman and Hoddinott (2004) noted as part of their desiderata that improvements in infrastructure – specifically communication and transportation - would reduce possibilities of famine. Since 2004, there have been considerable investments, both private and public in infrastructure, particularly in sub-Saharan Africa. Despite these, was a minor famine, in 2005 in Niger, which poor communication played a role and a major famine in 2011 in Somalia where it is estimated that tens of thousands of people, many of them pre-school children, died. What does this tell us about investments to prevent famine? Here, we note the following.

The last twenty years have seen considerable public investment in early warning systems, most notably in the Famine Early Warning Systems Network (FEWS NET).[24] FEWS NET combines agro-climatic monitoring data largely derived from meteorological satellites with information on crop and livestock production, food market flows, geographically disaggregated price data and information of households' livelihoods (information which is not dissimilar to our description of 'activities' found in section 2). FEWS NET combines information from these disparate sources to place localities within an Integrated Food Security Phase Classification (IPC). The IPC "is a standardized scale that integrates food security, nutrition, and livelihood information into a common classification of the severity of acute food insecurity outcomes" (FEWS NET, 2012) The IPC ranges from Phase 1 ("No Acute Food Insecurity") to Phase 5 ("Catastrophe"). FEWS NET issued a warning in November 2010 noting that rainfall would be below average in southern Somalia and that, "Pre-emptive livelihood support could mitigate likely La Niña impacts in the eastern Horn" (FEWS NET, 2011) followed by an update in March 2011 indicating that food insecurity was reaching extreme levels in some parts of Somalia. Despite these warnings, international requests for assistance were not made until June 2011. This suggests that, at least in terms of eliminating the most catastrophic aspects of famine-conditions, that the problem lies not so much with communications and information flows than with international decision making in response to this information. One way in which this could be addressed is through the creation of a rapid response draw-down fund where donor countries pre-commit a certain level of funds that could be automatically drawn on in response to movements along the IPC scale.

[24] See www.fews,net for further details.

5. Summary

In our introduction, we noted that deprivation in a world of plenty is an intrinsic rationale for investments that reduce hunger and undernutrition. This paper argues, as did earlier Copenhagen Consensus papers by Behrman, Alderman and Hoddinott (2004) and Horton, Alderman and Rivera (2008) that in addition to this intrinsic rationale, these investments are simply good economics.

Unlike those earlier papers, we have put greater emphasis on solutions which focus on agriculture. Investments that enhance crop and livestock productivity and that reduce yield losses given climatic stresses have a benefit: cost ratio of 16.07 when we use a five percent discount rate. When we also account for benefits derived from reduced yield variability, this rises markedly to 50.36. This figure is much higher than that reported in previous Copenhagen Consensus estimates. Note that it does not account for productivity effects associated with higher caloric consumption in poor countries or the benefits accrued through reduced child undernutrition. Further, in a world where climate change is occurring but the severity and distribution of that change is uncertain, investments that increase yield productivity have a significant option value. While everyone benefits from these investments, they are especially valuable to the approximately 925 million people who are hungry. An additional $8 billion dollar per year would, by 2050, reduce the number of hungry people in the world by 210 million and the number of underweight children by ten million.

We consider two market interventions that can increase rural incomes while reducing hunger and poverty. These are expenditures that improve access to market information through SMS messaging and interventions that reduce concentration in fertilizer markets. Across the countries and scenarios we consider, SMS messaging appears particularly promising. It has a modal benefit: cost ratio around four with these going as high as 8.35. This intervention is relatively cheap to provide, costing in our base case, PPP$3.98 per capita. We suspect that as these technologies continue to develop, scale economies will drive costs down further while movement by smallholders out of staples into higher value, perishable products, will increase benefits.

We update previous Copenhagen Consensus estimates of the benefit: cost ratios associated with reducing Vitamin A, iodine, iron and zinc deficiencies. Based on current estimates that there are approximately 163 million pre-school children who are Vitamin A deficient, an annual investment of $50 million would eliminate this deficiency in this age group using the cost estimates from Rajkumar *et al* (2012). If instead we use the higher cost estimate provided in Horton *et al* (2010) - $1.20 per year and apply this to children 6-24 months (so the total cost per child is $2.40) – the annual cost would be $391 million dollars. Iodine deficiencies are widespread but the cost of iodizing salt is cheap, $0.05 per person per year. An investment of $100 million per year would eliminate the iodine deficiencies affecting 1.8 billion people. Annually, there are approximately 200 million pregnancies in the world and approximately 40 percent of these pregnant women are anemic. The annual cost of eliminating maternal anemia during pregnancy, assuming that supplements could be provided during ante-natal visits, is $160 million dollars.

A novel estimate that we provide is for investments that will allow the scale up of a bundled set of interventions that reduce the prevalence of stunting. Under the most conservative assumptions that we consider, these yield a benefit: cost ratio of 15. If we relax these, the benefit: cost ratio rises to somewhere between 23.8 and 138.6. In the country with the largest number of undernourished children in the world, India, these benefit: cost ratios lie between 44 and 138.6. Note that these calculations do not explicitly account for the benefits from salt iodization and iron fortification of staples that will accrue more widely across populations and which previous Copenhagen Consensuses have perceived to be very promising investments. Nor do they place a monetary value on the additional benefits that this bundle of investments will have through reduced child mortality. Figures from Horton *et al* (2010) indicate that a $3 billion investment would provide this bundle of interventions to 100 million children.[25]

[25] Globally, there are approximately 356 million children under the age of five.

As with all calculations of benefit: cost ratios, there are caveats and desiderata. Salient ones here include the mechanics underlying the calculation of present values, assumptions made about the global trade regime, the salience of gender and the need to improve the speed with which international resources are deployed to combat famine. Mindful of these, investments to reduce hunger and undernutrition would appear to have powerful positive benefits, both intrinsically and instrumentally.

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Tables

Table 2.1: Global estimates of undernourishment (hunger), 1969 - 2010

Period	**Number of undernourished (millions)**	**Prevalence (percentage)**
1969-71	875	33
1979-81	850	25
1990-92	848	16
1995-97	792	14
2000-02	836	14
2006-08	850	13
2009	1023*	18
2010	925*	16

Source: SOFI, 2010 (for 1969-71 and 1979-81) and spreadsheet downloaded from FAO for all others. Data for 2009 and 2010 are FAO extrapolations based on United States Department of Agriculture projections.

Table 2.2: Regional estimates of undernourishment, 1990-2008

	1990-1992	1995-1997	2000-2002	2006-2008
Africa	**170.9**	**193.6**	**203.3**	**223.6**
Northern Africa	*5.0*	*5.4*	*5.6*	*6.1*
Sub-Saharan Africa	*165.9*	*188.2*	*197.7*	*217.5*
Latin America and the Caribbean	**54.4**	**53.4**	**50.8**	**47.0**
Asia	**607.1**	**526.2**	**565.7**	**567.8**
Oceania	**0.7**	**0.8**	**1.0**	**1.0**

Source: spreadsheet downloaded from FAO.

Table 2.3: Global and regional prevalences of stunting

	1990	1995	2000	2005	2007	Number (million)
	Prevalence (%)					2005
Africa	40.3	39.8	39.3	38.8	38.5	56.9
Eastern	48.1	47.4	46.7	46	45.7	
Middle	45.3	43.8	42.3	40.8	40.3	
Northern	29.4	27.4	25.5	23.7	23.0	
Southern	35.4	34.7	34.1	33.5	33.3	
Western	38.1	38.1	38.1	38.1	38.1	
Asia	48.6	43.1	37.7	32.6	30.6	111.6
Eastern	35.9	28.2	21.7	16.3	14.4	
South-central	60.7	54.6	48.4	42.3	39.9	
South-eastern	47.0	41.5	36.2	31.3	29.4	
Western	28.2	25.9	23.7	21.6	20.9	
Latin America and the Caribbean	23.7	20.9	18.1	15.7	14.8	9.2
Caribbean	15.0	12.0	9.6	7.5	6.9	
Central America	32.5	28.6	25.1	21.8	20.6	
South America	20.9	18.3	16	13.9	13.1	
Oceania		39.8	39.1	38.5	38.2	
All developing countries	44.4	40.1	36.1	32.5	31.2	177.7

Source: UNSCN (2010) and Black *et al* (2008).

Table 2.4: Global and regional prevalences of underweight

	1990	1995	2000	2005	2007	Number (million)
			Prevalence (%)			2005
Africa	21.5	21.1	20.5	19.9	19.6	31.1
Eastern	25.6	24.6	23.6	22.7	22.3	
Middle	24.3	23.3	22.3	21.4	21	
Northern	10.8	10	9.2	8.5	8.2	
Southern	11.7	12.1	12.5	13	13.2	
Western	25.1	24.4	23.6	22.8	22.5	
Asia	33.8	30	26.4	23	21.6	78.6
Eastern	16.2	11.5	8.1	5.6	4.8	
South-central	49.9	44.6	39.4	34.4	32.5	
South-eastern	30.6	26.6	22.9	19.6	18.3	
Western	12.8	10.7	9	7.5	7	
Latin America and the Caribbean	7.5	6.2	5	4.1	3.8	2.7
Caribbean	8.4	6.8	5.5	4.5	4.1	
Central America	10.6	8.5	6.8	5.4	4.9	
South America	6.1	5.1	4.2	3.5	3.2	
Oceania		18.5	17.3	16.2	15.8	
All developing countries	28.7	25.7	22.8	20.3	19.3	112.4

Source: UNSCN (2010) and Black *et al* (2008).

Table 2.5: Projected Change in World Commodity Prices Presented as the Percent Change between Baseline 2010 and Baseline 2050

Commodity	World Commodity Prices (% Change)
Beef	20%
Pork	55%
Lamb	2%
Poultry	47%
Milk	8%
Rice	34%
Wheat	40%
Maize	56%
Millet	12%
Sorghum	32%
Other Grains	14%
Soybean	24%
Soybean Oil	51%
Rapeseed	47%
Rapeseed Oil	92%

Source: IFPRI IMPACT Projections 2011

Table 2.6: Baseline Projections for People at Risk of Hunger in 2010, 2025 and 2050

Region	People at Risk of Hunger (Millions)		
	2010	**2025**	**2050**
East Asia and Pacific	177	131	122
Europe and Central Asia	23	23	21
Latin America and the Caribbean	60	61	45
Middle East and North Africa	17	21	24
South Asia	318	310	235
Sub-Saharan Africa	240	275	268
Developing	835	821	716
Developed	49	50	50
World	884	870	766

Source: IFPRI IMPACT projections 2011.

Table 2.7: Baseline Projections for Number of Malnourished Children in 2010, 2025 and 2050

Region	Number of Malnourished Children (Millions)		
	2010	**2025**	**2050**
East Asia and Pacific	20	13	8
Europe and Central Asia	4	3	3
Latin America and the Caribbean	8	7	4
Middle East and North Africa	4	3	2
South Asia	74	65	50
Sub-Saharan Africa	41	44	39
Developing	150	135	106
Developed	12	12	12
World	163	147	118

Source: IFPRI IMPACT projections 2011

Table 3.1: Projected Change in World Commodity Prices Presented as the Percent Change between Baseline and Alternative Scenario for 2050.

Commodity	World Commodity Prices (% Change)
Beef	-11%
Pork	-12%
Lamb	-12%
Poultry	-12%
Milk	-9%
Rice	-22%
Wheat	-18%
Maize	-16%
Millet	-20%
Sorghum	-18%
Other Grains	-16%
Soybean	-18%
Soybean Oil	-18%
Rapeseed	-18%
Rapeseed Oil	-68%

Source: IFPRI IMPACT Projections 2011

Table 3.2: Projected Change in People at Risk of Hunger Presented as the Percent Change between the Baseline and Alternative Scenario for 2050.

Region	Share at Risk of Hunger (Millions)		
	2050 Baseline	**2050 Scenario**	**% Change**
East Asia and Pacific	122	103	-15%
Europe and Central Asia	21	21	-4%
Latin America and the Caribbean	45	36	-20%
Middle East and North Africa	24	20	-18%
South Asia	235	152	-35%
Sub-Saharan Africa	268	175	-35%
Developing	716	507	-29%
Developed	50	49	-1%
World	766	556	-27%

Source: IFPRI IMPACT projections 2011

Table 3.3: Projected Change in Number of Malnourished Children Presented as the Percent Change between the Baseline and Alternative Scenario for 2050

Region	Number of Malnourished Children (Millions)		
	2050 Baseline	**2050 Scenario**	**% Change**
East Asia and Pacific	8	7	-12%
Europe and Central Asia	3	2	-15%
Latin America and the Caribbean	4	4	-18%
Middle East and North Africa	2	1	-19%
South Asia	50	48	-6%
Sub-Saharan Africa	39	33	-13%
Developing	106	96	-10%
Developed	12	11	-7%
World	118	106	-10%

Source: IFPRI IMPACT projections 2011.

Table 3.4: Percent Change in Producer Surplus, Consumer Surplus and Welfare between Baseline and Alternative Scenario

	Base (Billions)	Alternative Scenario with 5 percent discount rate (Billions)	% Change
Producer Surplus	40011	38461	-3.87%
Consumer Surplus	24716	28895	16.91%
Welfare	64727	67357	4.06%

Source: IFPRI IMPACT projections 2011.

Table 3.5: Change in Producer Surplus, Consumer Surplus and Welfare with different discount rates

	Five percent discount rate (Billions)	High Discount Rate Scenario (10 percent discount rate) (Billions)	Low Discount Rate Scenario (3 percent discount rate) (Billions)
Producer Surplus Change	-1550	-493	-2750
Consumer Surplus Change	4179	1282	7525
Welfare Change	2629	789	4775

Source: IFPRI IMPACT projections 2011.

Table 3.6: Change in Producer Surplus, Consumer Surplus and Welfare using a five percent discount rate by region

	(Billions)			
Region	**Producer Surplus Change**	**Consumer Surplus Change**	**Welfare Change**	**Share of welfare change**
East Asia and Pacific	-483	1332	850	32.3%
Europe and Central Asia	-153	317	164	6.2%
Latin America and the Caribbean	-176	465	289	11.0%
Middle East and North Africa	-61	233	172	6.5%
South Asia	-193	623	430	16.4%
Sub-Saharan Africa	-111	455	344	13.1%
Developing	-1179	3438	2259	85.9%
Developed	-370	741	371	14.1%
World	-1550	4179	2629	

Source: IFPRI IMPACT projections 2011.

Table 3.7: Change in Producer Surplus, Consumer Surplus and Welfare using a ten percent discount rate by region

	(Billions)			
Region	Producer Surplus Change	Consumer Surplus Change	Welfare Change	Share of welfare change
East Asia and Pacific	-157	415	258	32.7%
Europe and Central Asia	-51	104	54	6.8%
Latin America and the Caribbean	-54	144	90	11.4%
Middle East and North Africa	-19	68	49	6.2%
South Asia	-63	186	123	15.6%
Sub-Saharan Africa	-33	124	91	11.5%
Developing	-377	1045	668	84.7%
Developed	-116	238	122	15.5%
World	-493	1282	789	

Source: IFPRI IMPACT projections 2011.

Table 3.8: Change in Producer Surplus, Consumer Surplus and Welfare using a three percent discount rate by region

	(Billions)			
Region	Producer Surplus Change	Consumer Surplus Change	Welfare Change	Share of welfare change
East Asia and Pacific	-849	2383	1534	32.1%
Europe and Central Asia	-294	616	323	6.8%
Latin America and the Caribbean	-317	834	517	10.8%
Middle East and North Africa	-109	428	319	6.7%
South Asia	-337	1119	783	16.4%
Sub-Saharan Africa	-203	859	656	13.7%
Developing	-2089	6214	4125	86.4%
Developed	-661	1311	650	13.6%
World	-2750	7525	4775	

Source: IFPRI IMPACT projections 2011.

Table 3.9: Benefit: cost ratios of investments that increase yields and reduce yield variability

	Discount rate		
	Three percent	Five percent	Ten percent
Benefits derived from yield enhancement (billion USD)	4561	2475	702
Cost (billion USD)	214	154	87
Benefit: Cost ratio	21.31	16.07	8.07
Benefits derived from yield enhancement (billion USD)	4561	2475	702
Benefits derived from reduced yield variability (billion USD)	7807	5280	2213
Total Benefits (billion USD)	12368	7755	2915
Cost (billion USD)	214	154	87
Benefit: Cost ratio	57.79	50.36	33.51

Source: Authors' calculations

Table 3.10: Predicted impact of climate change on production of maize, rice and wheat

		Developed	**Developing**	**World**
Maize	Predicted output under climate change (mmt)	454.8	629.7	1084.5
	Predicted output with perfect mitigation (mmt)	525	612.1	1137.1
	Predicted loss under climate change (mmt)	-70.2	17.6	-52.6
	Percentage loss due to climate change	-13%	3%	-5%
Rice	Predicted output under climate change (mmt)	17.6	398.1	415.7
	Predicted output with perfect mitigation (mmt)	19.9	433.4	453.3
	Predicted loss under climate change (mmt)	-2.3	-35.3	-37.6
	Percentage loss due to climate change	-12%	-8%	-8%
Wheat	Predicted output under climate change (mmt)	243.2	598.8	842
	Predicted output with perfect mitigation (mmt)	261.3	647.4	908.7
	Predicted loss under climate change (mmt)	-18.1	-48.6	-66.7
	Percentage loss due to climate change	-7%	-8%	-7%

Source: Authors' calculations based on figures found in Nelson et al (2010, Table 2.5).

Table 3.11: General assumptions used to calculate benefits and costs of ICT intervention

	Bangladesh	India	Kenya	Ghana	Senegal	Tanzania
PC Rural Income (LCU)	13,236	12,636	17,496	458	127,340	197,016
Source	HIES	NSS	KIHBS	GLSS 5	ESAM II	HBS
Year	2005	2009/10	2005/06	2005/06	2001	2007
CPI Index survey year	100.0	143.8	114.5	105.5	95.7	114.8
CPI Index 2010	144.6	151.9	180.1	188.9	114.5	150.8
PC HH Income LCU 2010	19,140.1	13,351.3	27,529.9	820.5	152,376.5	258,753.5
Exchange rate (LCU / $PPP), 2010	28.14	17.95	37.28	1.12	264.90	518.23
Rural HH PC Annual Income ($PPP)	680.1	743.8	738.4	731.6	575.2	499.3
Proportion of Ag income	40%	40%	30%	30%	30%	30%
Rural HH PC Ag Exp - Annual ($PPP)	272.0	297.5	221.5	219.5	172.6	149.8
Cost per year						
Conservative Cost ($PPP)						
Household	21.92	21.92	21.92	21.92	21.92	21.92
Per capita	3.98	3.98	3.98	3.98	3.98	3.98
Optimist Cost						
Household	10.96	10.96	10.96	10.96	10.96	10.96
Per capita	1.99	1.99	1.99	1.99	1.99	1.99
Affected Population (thousands)	1000	2000	995	585	280	1195

Source: Author’s calculations

Table 3: 12: Estimates of impacts and benefit: cost ratios of ICT intervention under different benefit and cost scenarios

	Bangladesh	India	Kenya	Ghana	Senegal	Tanzania
Scenario 1: Base benefits, base costs						
Increase in income (%)	2.40%	2.40%	3.75%	3.75%	3.75%	3.75%
Reduction in Poverty	1.9%	1.9%	2.3%	2.3%	2.3%	2.3%
Increase in income ($PPP)	6.53	7.14	8.31	8.23	6.47	5.62
Net benefit PC	2.55	3.16	4.33	4.25	2.49	1.64
Benefit: Cost ratio	1.64	1.79	2.09	2.07	1.63	1.41
Scenario 2: Conservative benefits, base costs						
Increase in income (%)	1.0%	1.0%	2.0%	2.0%	2.0%	2.0%
Reduction in Poverty	0.8%	0.8%	1.2%	1.2%	1.2%	1.2%
Increase in income ($PPP)	2.72	2.98	4.43	4.39	3.45	3.00
Net benefit PC	-1.26	-1.00	0.45	0.41	-0.53	-0.99
Benefit: Cost ratio	0.68	0.75	1.11	1.10	0.87	0.75
Scenario 3: High benefits, base costs						
Increase in income (%)	4.80%	4.80%	7.50%	7.50%	7.50%	7.50%
Reduction in Poverty	3.8%	3.8%	4.5%	4.5%	4.5%	4.5%
Increase in income ($PPP)	13.06	14.28	16.61	16.46	12.94	11.23
Net benefit PC	9.08	10.3	12.63	12.48	8.96	7.25
Benefit: Cost ratio	3.28	3.59	4.17	4.14	3.25	2.82
Scenario 4: Base benefits, reduced costs						
Increase in income (%)	2.40%	2.40%	3.75%	3.75%	3.75%	3.75%
Reduction in Poverty	1.9%	1.9%	2.3%	2.3%	2.3%	2.3%
Increase in income ($PPP)	6.53	7.14	8.31	8.23	6.47	5.62
Net benefit PC	4.54	5.15	6.32	6.24	4.48	3.63
Benefit: Cost ratio	3.28	3.59	4.18	4.14	3.25	2.82

Scenario 5: Conservative benefits, reduced costs						
Increase in income (%)	1%	1%	2%	2%	2%	2%
Reduction in Poverty	0.8%	0.8%	1.2%	1.2%	1.2%	1.2%
Increase in income ($PPP)	2.72	2.98	4.43	4.39	3.45	3.00
Net benefit PC	0.73	0.99	2.44	2.4	1.46	1.01
Benefit: Cost ratio	1.37	1.50	2.23	2.21	1.73	1.51
Scenario 6: High benefits, reduced costs						
Increase in income (%)	4.80%	4.80%	7.50%	7.50%	7.50%	7.50%
Reduction in Poverty	3.8%	3.8%	4.5%	4.5%	4.5%	4.5%
Increase in income ($PPP)	13.06	14.28	16.61	16.46	12.94	11.23
Net benefit PC	11.07	12.29	14.62	14.47	10.95	9.24
Benefit: Cost ratio	6.56	7.18	8.35	8.27	6.50	5.64

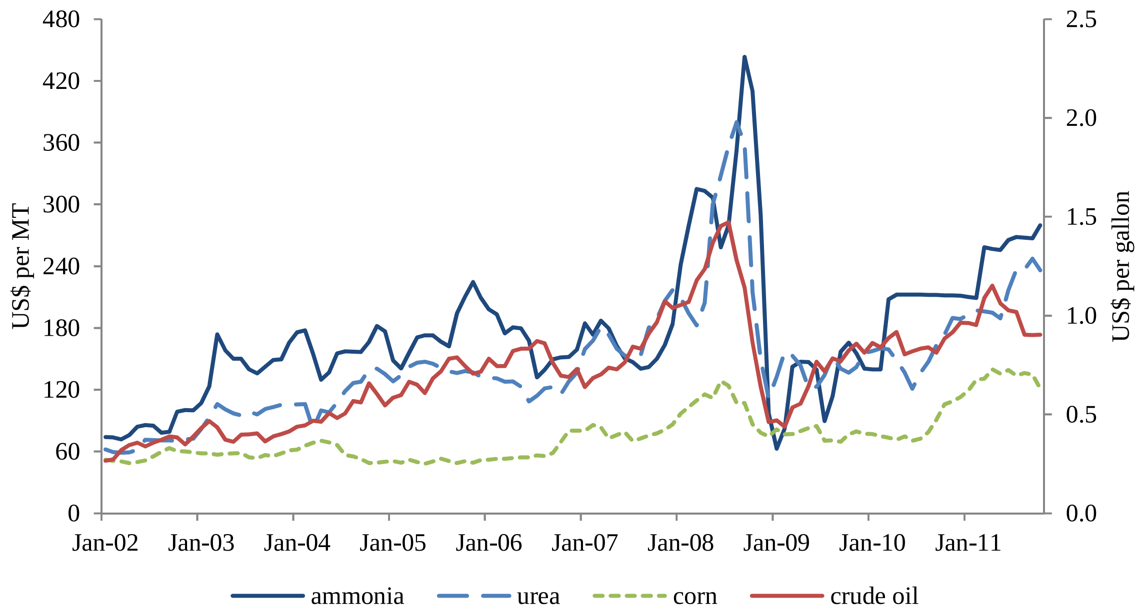
Source: Authors' calculations

Table 3.13: Concentration of World Fertilizer Production Capacity, 2008/09

Fertilizer	Top-5 countries (% of World in parenthesis)	Top-5 Capacity (000 MT)	Top-5 Share (% of World)
Ammonia	China (22.8), India (8.9), Russia (8.5), United States (6.5), and Indonesia (3.9)	84,183	50.6
Urea	China (33.1), India (13.1), Indonesia (5.4) Russia (4.2), and United States (4.1)	95,802	59.9
DAP/MAP	China (23.3), United States (21.2), India (11.4), Russia (6), and Morocco (4)	22,896	65.9
Phosphoric Acid	United States (20.9), China (19.3), Morocco (9.6), Russia (6.2), and India (5.3)	28,274	61.3
Potash	Canada (37.6), Russia (13.2), Belarus (9.9), Germany (8.2), and China (7.7)	39,687	76.7
NPK	China (29.3), India (8.2), Russia (6), France (4), and Turkey (3).	47,186	50.4

Source: IFDC Worldwide Fertilizer Capacity Listing by Plant.

Figure 3.1: Real monthly ammonia, urea, corn and crude oil prices, 2002-2011



Note: Prices deflated by CPI, 1982-84=100. The prices correspond to Ammonia US Gulf barge, Urea US Gulf prill import, No. 2 yellow corn FOB US Gulf, and Oklahoma crude oil FOB spot price.
Source: Green Markets, Energy Information Administration, and FAOSTAT.

Table 3.14: Impact of increased competition on fertilizer intake and crop production

	Conservative	Optimistic
Decrease in fertilizer prices	8.2%	11.6%
Elasticity of fertilizer demand to prices	-1.62	-1.62
Increase in fertilizer use	13.3%	18.8%
Elasticity of crop production to fertilizer use	0.25	0.25
Increase in crop production	3.3%	4.7%

Source: Gruhn, Goletti and Roy (1995) and Bumb, Johnson and Fuentes (2011).

Table 3.15: Impact of increased competition on poverty reduction (conservative scenario)

	India	Bangladesh	Senegal	Ghana	Kenya	Tanzania
Decrease in global concentration	10%	10%	10%	10%	10%	10%
Decrease in global fertilizer prices	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%
Increase in crop production	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Crop sales as % of income	40%	40%	30%	30%	30%	30%
Increase in average rural income	1.3%	1.3%	1%	1%	1%	1%
Poverty elasticity of income	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
Poverty reduction	2.6%	2.6%	2%	2%	2%	2%
Total rural population (million)	772	105	5.6	11.7	19.9	23.9
Poverty reduction (million)	20.1	2.7	0.1	0.2	0.4	0.5

Source: Author's calculations

Table 3.16: Cost-benefit analysis

	India	Bangladesh	Senegal	Ghana	Kenya	Tanzania
Rural income						
Rural per capita annual income in $PPP	743.8	680.1	575.2	731.6	738.4	499.3
Rural affected population (million)	154	21	1	2	4	5
Annual income of affected population in $ PPP million	114,836	14,282	644	1,712	2,939	2,387
Fertilizer use						
Country consumption of nitrogen fertilizers in '000 MT	39,972	3,198	128	256	896	512
Increase in fertilizer consumption	13.3%	13.3%	13.3%	13.3%	13.3%	13.3%
Increase in consumption of nitrogen fertilizers in '000 MT	5,316	425	17	34	119	68
Change in income						
% Increase in average rural income	1.3%	1.3%	1.0%	1.0%	1.0%	1.0%
Total increase in annual income for affected population in $ PPP million	1,493	186	6	17	29	24
Change in costs						
Cost of building plant in region (prorated) in $ PPP million	1,111	89	50	100	350	200
Variable cost per MT in US$	130	130	130	130	130	130
Total variable annual costs for increased fertilizer use in $ PPP million	691	55	2	4	15	9
Net present value at 3% discount rate (2012-2050) in $ PPP million	17,176	2,885	46	190	-33	142
Net present value at 5% discount rate (2012-2050) in $ PPP million	12,532	2,130	22	116	-113	56

Source: Author’s calculations

Table 3.17: Benefit: Cost ratios of micro-nutrient interventions

		Previous Copenhagen Consensus Estimates		New estimates			Current estimates of cost per beneficiary
Micronutrient	Intervention	BAH	HAR	Rajkumar et al (2012)	Horton et al (2011)	Other	
Iodine	Salt iodization	15-520	30	81			$0.05 (HAR)
Iodine and iron	Doubly fortified salt			2.5	2 - 5		$0.25 (Horton)
Iron	Supplements, mothers and children 6-24 months			23.8			$0.96 (Rajkumar)
	Supplements, pregnant mothers	82 -140		8.1			$2.00 (Horton 2010)
	Fortification, general		7.8				
	Fortification of wheat flour				9.1	6.7 (Casey, 2011)	$0.17 (Horton)
	Home fortification				37		$1.20 (Horton)
	Biofortification	11.6-19	16.7				< $0.01 (Horton)
Vitamin A	Supplement	4.3 - 43	6.1 -250	12.5			$0.29 (Rajkumar)
Zinc	Supplement			2.85			$1.26 (Rajkumar)

Source: Authors' compilation. BAH is Behrman, Alderman and Hoddinott (2004). HAR is Horton, Alderman and Rivera (2008).

Table 3.18: Per child costs of interventions to reduce stunting and mortality at age 36 months

Intervention	Child age range (months)	Cost per unit	Total cost per child
Community based nutrition programs that provide information on breastfeeding, complementary feeding, handwashing and distribute micronutrient powders and iron-folate supplements	0 – 59	$7.50 per child	$7.50
Vitamin A supplementation	6-59	$1.20 per year	$4.80
Therapeutic zinc supplementation for management of diarrhea	6-59	$1.00 per year (assumes two or three treatments per year)	$4.00
Multiple micronutrient powders	6-23	$3.60 per course; 3 courses recommended	$10.80
Deworming	12-59	$0.25 per round; one round recommended per year	$1.00
Iron-folic acid supplementation for mothers during pregnancy		$2.00 per pregnancy	$2.00
Iron fortification of staples	12-59	$0.20 per year	$0.80
Universal salt iodization	12-59	$0.05 per year	$0.20
Providing complementary foods to 80 percent of children in south Asia, 50 percent in Africa and East Asia, 10 percent elsewhere	6-23	$0.11 per day $0.14 per day in India	$56.88
Community based management of severe acute malnutrition	6-59		$8.13*

Source: Horton et al (2010).

* This is calculated by taking the per-child cost of community management of severe acute malnutrition ($200 per treated child) and multiplying it by the prevalence of severe acute malnutrition.

Table 3.19: Benefit: cost estimates of investments that reduce stunting

		23.8 percent income increase		15 percent income increase	
		Discount rate		Discount rate	
		Five percent	Three percent	Five percent	Three percent
Bangladesh	Increased income,				
	NPV	3647	7165	2303	4523
	Cost	96.1	96.1	96.1	96.1
	Benefit: Cost ratio	**38.0**	**74.6**	**24.0**	**47.1**
Ethiopia	Increased income,				
	NPV	2289	4496	1445	2838
	Cost	96.1	96.1	96.1	96.1
	Benefit: Cost ratio	**23.8**	**46.8**	**15.0**	**29.5**
Kenya	Increased income,				
	NPV	3713	7295	2344	4605
	Cost	96.1	96.1	96.1	96.1
	Benefit: Cost ratio	**38.6**	**75.9**	**24.4**	**47.9**
India	Increased income,				
	NPV	7875	15470	4972	9767
	Cost	111.62	111.62	111.62	111.62
	Benefit: Cost ratio	**70.6**	**138.6**	**44.5**	**87.5**

Source: Authors' calculations.