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Copenhagen Consensus – Challenges and Opportunities

HUNGER AND MALNUTRITION

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1. Introduction: The Challenge of Hunger and Malnutrition

While episodes of severe hunger such as famines receive considerable press coverage and attract much public attention, chronic hunger and malnutrition is considerably more prevalent in developing countries. It is estimated that at least 12 million low-birth-weight births occur per year and that around 162 million pre-school children and almost a billion people of all ages are malnourished. In poorly nourished populations, reductions in hunger and improved nutrition convey considerable productivity gains as well as saving resources that otherwise would be used for the care of malnourished people who are more susceptible to infectious diseases and premature mortality. While reducing hunger and malnutrition is often justified on intrinsic grounds, it is these potential gains in productivity and reductions in economic costs that provide the focus of our challenge paper.

Poverty, hunger and malnutrition are linked. Strauss and Thomas (1995, 1998) and Hoddinott, Skoufias and Washburn (2000) document the empirical literature relating dimensions of access and intakes of calories to household consumption levels. A reasonable reading of these studies suggests an income-calorie elasticity or around 0.2 to 0.3, though careful studies have also found estimates both higher and lower than this range. Behrman and Rosenzweig (2004) report that cross-country variation in GDP per capital in PPP terms is inversely related to the percentage of low birthweight (LBW, <2.5 kg,) births among all births and is consistent with almost half of the variation in the percentage of births that are LBW across countries.[1] Haddad, et al. (2003) estimate that the cross-country elasticity of pre-school underweight rates with respect to per capita income for 1980-96 is -0.5, virtually the same as the mean for the elasticity from 12 household data sets. These relationships have two important implications: that nutritional objectives such as the Millennium Development Goal of halving the prevalence of underweight children by 2015 are unlikely to be met through income growth alone and that successful efforts to reduce most forms of malnutrition are likely to have incidences of benefits concentrated relatively among the poor. These implications motivate, in part, our choice of the following opportunities:

- Opportunity 1 – Reducing the Prevalence of Low Birthweight
- Opportunity 2 – Infant and Child Nutrition and Exclusive Breastfeeding Promotion
- Opportunity 3 – Reducing the Prevalence of Iron Deficiency Anemia and Vitamin A, Iodine and Zinc Deficiencies
- Opportunity 4 – Investment in Technology in Developing Country Agriculture

We begin by setting the stage, discussing the nature and measurement of hunger and malnutrition, the current levels and trends in the geographical distribution among developing countries of some important types of hunger and the nature of the benefits from reduced malnutrition both in terms of productivity and in terms of direct resource use. This is essential to avoid repetition because many of the measurement issues, including those pertaining to impacts of improved nutrition over the lifecycle, are somewhat parallel among the various challenges and opportunities. Section 3 outlines a general framework for considering these opportunities. For each opportunity, we discuss: (i) the definition and description of the opportunity, (ii) how this opportunity partially solves the challenge, and (iii) economic estimates of the benefits and costs and how they relate to distributional and efficiency motives for policies. Our conclusion summarizes these opportunities, noting that potentially there are considerable gains in the sense of benefit-cost ratios exceeding one or relatively high internal rates of return to investing in some programs or policies to reduce hunger and malnutrition, particularly those directed towards increasing micronutrients in populations with high prevalences of micronutrient deficiencies – in addition to the intrinsic welfare gains to the individuals who would be effected directly by reduced hunger

[1] Their estimates suggest, however, that only a small part of this association between LBW and GDP per capita is due to the causal effects of LBW on productivity.

and malnutrition. Such investments may be relatively easily justified on anti-poverty grounds because the poor tend to be relatively malnourished. There also are some plausible efficiency grounds for such interventions due to the role that malnorishment plays, for example, in the spread of contagious diseases but the available estimates do not permit very satisfactory identification of social versus private rates of returns as would be required to assess the efficiency motive for subsidies.

2. Essential Background to the Challenge and Opportunity of Hunger and Malnutrition – Nature and Measurement, Geographical Distribution, and Potential Benefits

This section provides background material for understanding the opportunities in Section 3. It discusses the nature and measurement of hunger and malnutrition, current levels and trends in the geographical distribution of dimensions of hunger and malnutrition, and the nature of the benefits from reduced hunger and malnutrition, which are parallel over the life cycle for several of the opportunities.

2.1 The nature and measurement of hunger and malnutrition

Hunger can be defined as "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). It is measured in terms of availability, access or intake of calories relative to requirements that vary principally by age, sex and activities. Nutrients provided by food combine with other factors, including the health state of the person consuming the food, to produce "nutritional status." Indicators of nutritional status are measurements of body size, body composition, or body function reflecting single or multiple nutrient deficiencies. Table 1 describes measures of hunger and undernutrition important to this Challenge Paper.[2]

The most widely-cited data on the number of persons considered hungry come from the United Nations Food and Agriculture Organization (FAO). On an ongoing basis, FAO constructs estimates of mean per capita dietary energy supply (production + stocks - post-harvest losses + commercial imports + food aid - exports). Assumptions regarding the distribution of this supply are made based on data on income distribution, the distribution of consumption or, in some cases inferences based on infant mortality (Naiken, 2002). The constructed distribution is compared against minimum per capita energy requirements (Weisell, 2002) and from this, the proportion of persons whose access to food is below these requirements is estimated. FAO calls this the prevalence of undernourishment.

Criticisms of this approach are widespread. First, there are serious concerns about the quality of the underlying data on food supply (Devereux and Hoddinott, 1999). Second, the absence of good data on the distribution of food consumption mean that estimates of the prevalence of hunger are highly sensitive to changes in the shape of the distribution around the minimum requirements threshold. Third, Aduayom

[2] While food can relieve hunger through providing macronutrients such as calories and proteins and provide nutrients that lessen the forms of malnutrition characterized as "undernutrition" with respect to the nutrients that the food provides, more food does not relieve all forms of malnutrition. Some forms of malnourishment are relieved by reducing calories (e.g., obesity), others by reducing debilitating health stresses such as parasites. Undernutrition with regard to macro and micro nutrients historically has been and continues to be the dominant nutritional problem in developing countries, other forms of malnutrition – in particular those that lead to obesity and diets heavy in fats – are an increasing public health concern. In middle income countries such as Egypt, Mexico and South Africa, obesity levels amongst adults are rapidly growing and in some cases already exceed one quarter of the population.

and Smith (2002) show that in many cases the FAO approach significantly understates hunger prevalence when compared to those derived from household consumption surveys.

Despite these valid concerns, the FAO approach provides the only data available on a global basis over a relatively long time period. FAO (2003) estimates that over the last decade, the number of people undernourished in the developing world declined slightly from 816 to 798 million while population increased from 4050 to 4712 million persons. Overall, the proportion of persons undernourished fell from 20 to 17% between 1990-92 to 1999-2001. The hungry are found predominantly in Asia and the Pacific (505 million) and sub-Saharan Africa (198 million); these two regions account for nearly 90% of the world's hungry. However, these two regions exhibit different trends. In Asia, both the number and prevalence of undernourishment fell during the 1990s. The fall in the number of undernourished is almost entirely attributable to a fall in the number of undernourished in China; elsewhere the number of undernourished stayed relatively constant while population grew, leading to a decline in prevalences. In Africa, the number of malnourished increased with prevalences rising in some countries and falling in others. Despite these shifts, in the near future over twice as many of the hungry will be in Asia than in Africa. The distribution of the hungry *within* countries and by socio-economic groups is even less well documented. Preliminary work by the Hunger Task Force (2003) suggests that on a <u>global</u> basis:

- Approximately 50% of the hungry are in farm households, mainly in higher-risk production environments;
- Approximately 25% are the rural landless, mainly in higher-potential agricultural regions;
- Approximately 22% are urban; and
- Approximately 8% are directly resource-dependent (ie pastoralists, fishers, forest-based).

Both hunger and malnutrition reflect the interaction of purposive actions of individuals given preferences and constraints together with biological processes. In behavioral models, an individual's nutritional status often is treated as an argument in the welfare function of individuals or the households in which they reside (Behrman and Deolalikar 1988; Strauss and Thomas 1995), a reflection of the intrinsic value placed on nutritional status. Typically, welfare is assumed to increase as nutritional status improves, but possibly at a diminishing rate and increases in certain measures of nutritional status, such as body mass, may be associated with reductions in welfare beyond a certain point. In allocating resources, household decision makers take into account the extent to which these investments will make both their children and themselves better-off in the future as well as currently. These allocations are constrained in several ways. There are resource constraints reflecting income (itself an outcome because nutritional status can affect productivity) and time available as well as prices faced by households. There is also a constraint arising from the production process for health outcomes, including nutritional status. This constraint links nutrient intakes – the physical consumption of macronutrients (calories and protein) and micronutrients (minerals and vitamins) – as well as time devoted to the production of health and nutrition, the individual's genetic make-up and knowledge and skill regarding the combination of these inputs to produce nutritional status. There are interdependencies in the production of nutritional status and other dimensions of health; for example, malaria limits hemoglobin formation.

Many poor nutritional outcomes begin *in utero*. A number of maternal factors have been shown to be significant determinants of intrauterine growth retardation (IUGR), the characterization of a newborn who does not attain their growth potential. Most important are mother's stature (reflecting her own poor nutritional status during childhood), her nutritional status prior to conception as measured by her weight and micro-nutrient status, and her weight gain during pregnancy. Diarrheal disease, intestinal parasites, and respiratory infections may also lead to IUGR and where endemic (such as in sub-Saharan Africa), malaria is a major determinant. In developed countries, smoking is also a significant contributor to IUGR. IUGR is measured as the prevalence of newborns below the 10^{th} percentile for weight given gestational age (ACC/SCN, 2000b). Because gestational age is rarely known, IUGR is often proxied by LBW. As of 2000, it is estimated that 16% of newborns, or 11.7 million children have LBW (ACC/SCN, 2000b, ACC/SCN, 2003).[3] LBW is especially prevalent in south Asia where it is estimated that 30 per cent of children have birth weights below 2500g (ACC/SCN, 2003).

In pre-school and school-age children, nutritional status is often assessed in terms of anthropometry. "The basic principle of anthropometry is that prolonged or severe nutrient depletion eventually leads to retardation of linear (skeletal) growth in children and to loss of, or failure to accumulate, muscle mass and fat in both children and adults" (Morris, 2001, p.12). A particularly useful measure is height-for-age as this reflects the cumulative impact of events affecting nutritional status that result in stunting. As of 2000, it is estimated that 162 million children – roughly one child in three - are stunted (ACC/SCN, 2003). While stunting prevalences are highest in South Asia and sub-Saharan Africa, in South Asia, numbers and prevalence have been declining since 1990 whereas in sub-Saharan Africa, prevalence has remained largely unchanged and numbers have increased.

Multiple factors contribute to poor anthropometric status in children. One is LBW; a number of studies show a correlation between LBW and subsequent stature though, in the absence of any subsequent intervention, not between LBW and growth (Ashworth, Morris and Lira 1997; Hoddinott and Kinsey 2001; Li, et al. 2003; Ruel 2001). Another is reduced breastfeeding. Indeed, the first two years of life pose numerous nutritional challenges. Growth rates are highest in infancy, thus adverse factors have a greater potential for causing retardation at this time. Younger children have higher nutritional requirements per kilogram of body weight and are also more susceptible to infections. They are also less able to make their needs known and are more vulnerable to the effects of poor care practices such as the failure to introduce safe weaning foods in adequate quantities. Evidence from numerous studies clearly indicates that the immediate causes of growth faltering are poor diets and infection (primarily gastrointestinal) and that these are interactive (Chen 1983; NAS 1989). For these reasons, almost all the growth retardation observed in developing countries has its origins in the first two to three years of life (Martorell 1995).

While much of the work on hunger and nutrition is cross-sectional, an increasing body of knowledge indicates that many nutritional outcomes are the consequence of cumulative lifecycle processes. Specifically, a growing body of evidence indicates that growth lost in early years is, at best, only partially regained during childhood and adolescence, particularly when children remain in poor environments (Martorell, et al. 1994). Martorell (1995, 1999), Martorell, Khan and Schroeder (1994) and Simondon, et al. (1998) all find that stature at age three is strongly correlated with attained body size at adulthood in Guatemala and Senegal. Hoddinott and Kinsey (2001) and Alderman, Hoddinott and Kinsey (2003) find that children who were initially aged 12-24 months in the aftermath of droughts in rural Zimbabwe in 1994/95 and 1982-4 respectively were malnourished relative to comparable children not exposed to this drought. However, older children did not suffer such consequences; this is consistent with evidence that child development has "sensitive" periods where development is more receptive to influence and that during such periods, some shocks may be reversible while others are not.

Severe malnutrition in early childhood often leads to deficits in cognitive development (Grantham-McGregor, Fernald and Sethuraman 1999, Pollitt 1990). Though many studies from developed countries fail to show difference in developmental levels for children with LBW, there are few longitudinal studies from developing counties from which to generalize (Hack 1998). Moreover, recent studies indicate that the relationship between birthweight and cognitive function carries into the range of normal weights even in developed countries (Richards, et al. 2001; Matte, et al. 2001). Reduced breastfeeding – an effect of LBW as well as a common cause of childhood malnutrition - also has well-documented influences on cognitive development, even in developed countries (Grantham-McGregor,

[3] Other estimates are higher. Ceesay, et al. (1997) claim that there are over 22 million LBW children per year.

Fernald and Sethuraman 1999a). Malnourished children score more poorly on tests of cognitive function, have poorer psychomotor development and fine motor skills, have lower activity levels, interact less frequently in their environments and fail to acquire skills at normal rates (Grantham-McGregor, et al. 1997, 1999; Johnston, et al. 1987; Lasky, et al. 1981). Controlled experiments with animals suggests that malnutrition results in irreversible damage to brain development such as that associated with the insulation of neural fibers (Yaqub 2002). This is in keeping with the prevailing view that very young children are most vulnerable to impaired cognitive development.[4]

Micro-nutrient deficiencies, particularly iodine and iron, are also strongly implicated in impaired cognitive development. Iodine deficiency adversely affects development of the central nervous system. A meta-analysis indicates that individuals with an iodine deficiency had, on average, 13.5 points lower IQs than comparison groups (Grantham-McGregor, Fernald and Sethuraman 1999b). ACC/SCN (2003) reports that globally approximately 2 billion people are affected by iodine deficiency including 285 million children aged 6 to 12 years. Adequate iron intake is also necessary for brain development. More than 40% of children age 0-4 in developing countries suffer from anemia (ACC/SCN 2000a); further anemia in school-age children may also affect schooling whether or not there had been earlier impaired brain development.

Undernutrition, particularly fetal undernutrition at critical periods, may result in permanent changes in body structure and metabolism. Even if there are not subsequent nutritional insults, these changes can lead to increased probabilities of chronic non-infectious diseases later in life. The hypothesis that fetal malnutrition has far ranging consequences for adult health is bolstered by studies that track LBW infants into their adult years and document increased susceptibility to coronary heart disease, non-insulin dependent diabetes, high blood pressure, obstructive lung disease, high blood cholesterol and renal damage (Barker 1998). For example, while the various studies on the impact of the Dutch famine indicate few long-term consequences on young adults, more recent evidence shows that children whose mothers were starved in early pregnancy have higher rates of obesity and of heart disease as adults (Roseboom, et al. 2001). In contrast, children of mothers deprived in later pregnancy – the group most likely to be of LBW – had a greater risk of diabetes (Ravelli 1998).

The nutritional status of adults reflects in substantial part their nutritional experience since conception with, as noted, a number of possible long-run effects of early nutritional insults. But, in addition to such longer-run effects, there also may be important consequences of adult diets, for example, low energy or iron intakes or chronic diseases related to obesity, hypertension, and high cholesterol.

Lastly, malnutrition may have long-term consequences through the intergenerational transmission of poor nutrition and anthropometric status. Recall that stature by age three is strongly correlated with attained body size at adulthood. Taller women experience fewer complications during childbirth, typically have children with higher birthweights and experience lower risks of child and maternal mortality (Ramakrishnan, et al. 1999; World Bank 1993).[5]

2.2 The nature of the benefits from reduced malnutrition

[4] One exception is provided by Glewwe and King (2001) who find that malnutrition in the second year of life had a larger impact on the IQs of Philippine school children than that in earlier periods. This may reflect that with weaning risks increase.

[5] However, Behrman and Rosenzweig (2004) find that intergenerational birth weight effects are primarily genetic, not due to better nutrition in the womb, based on their analysis of identical twins in the United States. It is not clear whether this result generalizes to developing countries because there may be important compensating investments for LBW in developed societies that are not common in developing countries (and that may be reflected, for example, in the evidence noted suggesting stronger effects on cognitive development in the latter).

We now turn to micro evidence about productivity impacts of improved nutrition in developing countries – from conception through infancy and childhood and into adolescence and adulthood.[6] These many channels through which these gains may operate are grouped as follows: saving of resources that are currently directed to dealing with diseases and other problems related to malnutrition; direct gains arising from improvements in physical stature and strength as well as improved micronutrient status; and indirect gains arising from links between nutritional status and schooling, nutritional status and cognitive development and subsequent links between schooling, cognitive ability and adult productivities.

2.2.a Resource savings: One significant cost of malnutrition is higher mortality. The probability of infant mortality is estimated to be significantly higher for LBW than for non-LBW infants. Conley, Strully and Bennett (2003) conclude that intra-uterine resource competition – and, by inference, nutrition – explain a substantial portion of excess mortality of LBW children in the United States. In their study, an additional pound at birth led to a 14% decrease in mortality in the period between 28 days and one year for both fraternal and identical twins. In contrast, the risk of death in the first 28 days was elevated 27% for each pound difference in weight for fraternal twins compared to only 11% for identical twins, implying a large role for genetic factors. Ashworth (1998) reviews 12 data sets including two from India and one from Guatemala, and concludes that the risk of neonatal death for term infants 2000-2499 grams at birth is four times that for infants 2500-2999 grams and 10 times that of infants 3000-3499 grams. Relative risks of post-neonatal mortality for LBW compared to the two respective groups were two and four times as large. These risk ratios translate into fairly large differences in mortality rates given the relatively high mortality rates in many developing countries (see the discussion of Opportunity 1).

When the impacts of poor pre-schooler nutrition are added to the effects of LBW, Pelletier, et al. (1995) venture the widely-cited estimate that 56% of child deaths in developing countries at attributable to the potentiating effects of malnutrition (83% of this, due to the more prevalent mild to moderate malnutrition rather then the severe cases most commonly monitored). More recently, WHO (2002) has claimed that malnutrition contributes to 3.4 million child deaths in 2000 (60% of child deaths).[7]

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[6] There are aggregate or macro alternatives, such as to define benefits in terms of an investment's impact on economic growth, typically measured in terms of growth in GNP per capita. This approach was used in the pioneering study by Coale and Hoover (1958) of the economic benefits of fertility reduction and more recently in combination with other methods to estimate the economic benefits of a broad strategy to improve health in developing countries (Commission on Macroeconomics and Health 2001). The latter's estimates of the relationship between cross-country economic growth rates, indicators of population health and a set of additional explanatory variables indicate that each 10% improvement in average life expectancy at birth is associated with an increase in the rate of economic growth of 0.3 to 0.4 percentage points per year. However, the associations found in cross-national analysis are unlikely to represent unbiased estimates of the causal effects of investments due to non-trivial omitted variable and endogeneity bias. For example, Behrman and Rosenzweig (2004) explore the relation between birthweight and productivity across countries: aggregate estimates indicate an association with over 40% of the variance in product per worker across countries, but estimates that control for micro endowments suggest that less than 1% of cross-country differences can be attributed to differences in birthweight distributions. Further, most of the available cross-national data are not sufficiently disaggregated to disentangle the effects of the types of investments being considered by the Copenhagen Consensus from similar broader investments in the population.

[7] Pelletier and Frongillo (2003), using data on changes in national malnutrition rates and mortality to get a different perspective on this association, also find an association of mortality and malnutrition. However, these associations do not control for changes in infrastructure or income that may both affect mortality directly as well as influence nutrition nor can they indicate a counterfactual of the impact of improved nutrition on expected mortality. Guilkey and Riphahn (1998) use longitudinal data on Filipino children with controls for the endogeneity of nutrition and other health care choices. Their simulations indicate that children with two months without weight gain in the first year of life (about 10 percent of their sample) have the risk of mortality elevated by 50%. Similarly, the scenarios show that if a mother is unable or unwilling to adopt standard recommendations on breastfeeding the hazard of child

The availability of experimental evidence on the use of micronutrient supplements provides unambiguous evidence on the relationship of mortality and vitamin intakes in many environments including ones that show few clinical symptoms of deficiencies. The potential to reduce child deaths by distributing vitamin A on a semiannual basis is particularly dramatic; meta-analysis of field trials indicate that such provision of vitamin A can reduce overall child mortality by 25-35% (Beaton, et al. 1993)**.** Amongst adults, anemia is a particular concern for the health of women of child bearing age not only because of elevated risk of adverse birth outcomes but also because the risk of maternal death is substantially elevated for anemic women; over a fifth of maternal deaths are associated with anemia (Ross and Thomas 1996; Brabin, Hakimi and Pelletier 2001).[8]

Beyond the issue of increased mortality, malnutrition increases the risk of illnesses that impair the welfare of survivors. This relationship between nutrition and both infections and chronic diseases can be traced through different parts of the life cycle. Children with LBWs – reflecting a range of causes, not all of which are due to dietary deficiencies – stay longer in hospitals in circumstances where births occur in such settings and have higher risks of subsequent hospitalization (Vitoria, et al. 1999). In addition, they use outpatient services more frequently than do children with normal birthweights. For young children, in general, malnutrition, including micronutrient deficiencies, leads to a vicious cycle with impaired immunity leading to infection with attendant loss of appetite and increased catabolism and, thus, an increased likelihood of additional malnutrition.

Increased morbidity has direct resource costs in terms of health care services as well as lost employment or schooling for the caregivers. The magnitudes of these costs differ according to the medical system, markets, and policies of a country. In developed countries the costs for the survivors can be substantial. Lightwood, Phibbs, and Glanz (1999) calculate the excess direct medical costs due to LBW in the United States attributed to one cause - maternal smoking - to be $263M in 1995. Similarly, 75% of the $5.5-6 billion of excess costs due to LBW in the United States estimated by Lewit, et al. (1995) is due to the costs of health care in infancy. A further 10% of these costs are attributed to higher expenditures for special education as well as increased grade repetition. Such expenditures for special education or for social services are substantial in developed countries (Petrou, et al. 2001). While these costs may be far less in low-income countries where, for example, the majority of births occur outside a clinical setting, these lower medical costs associated with LBW come at the expense of higher mortality. In the absence of an educational system that can recognize and accommodate the individual needs of students, moreover, some of these costs are not incurred during childhood but rather in the form of reduced productivity in adulthood.

The evidence for the fetal origins of chronic diseases described above is still being assessed. The fact that some consequences may not be observed until the affected individuals reach middle age is an important consideration for interpreting the range of evidence being assembled. There are few longitudinal studies that follow cohorts this far and extrapolation from shorter panels or from cohorts with different life histories is problematic. In addition, there are at least two other explanations for the association between LBW and adult diseases. LBW may be an indicator of poor socioeconomic status. Low SES may have a causal impact on adult disease probabilities via other variables such as poor nutrition later in life or higher rates of smoking. If so, LBW may only be a correlate and not a causal variable. A different possibility is that LBW may be due to a genetic predisposition to insulin resistance. This would tend to account for a higher pre-disposition for adult diabetes and coronary heart diseases that reflects genetics rather than aspects of the uterine environment that may be influenced by medical and

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mortality increases markedly. Care has to be taken, however, in interpreting the last association as causal because mothers may be less likely to be able to breastfeed infants who are at high risk.

[8] As with associations of child mortality and nutrition, it is difficult to prove causality with these associations.

nutritional interventions.[9] Finally, even if there are the effects proposed in the fetal origins hypothesis, due to the long lags, the present discounted value of improvements due to prenatal interventions to offset them is not likely to be very large (Alderman and Behrman 2003; also see Opportunity 1).

2.2.b Direct links between nutrition and physical productivity: There is considerable evidence of direct links between nutrition and productivity. Behrman (1993), Behrman and Deolalikar (1989), Deolalikar (1988), Foster and Rosenzweig (1993), Glick and Sahn (1997), Haddad and Bouis (1991), Schultz (1996), Strauss and Thomas (1998) and Thomas and Strauss (1997) all find that after controlling for a variety of characteristics, that lower adult height – as described above, a consequence in part of poor nutrition in childhood, is associated with reduced earnings as an adult. Thomas and Strauss (1997) estimate the direct impact of adult height on wages for urban Brazil. While the elasticity varies somewhat according to gender and specification, for both men and women who work in the market sector a 1% increase in height leads to a 2-2.4% increase in wages or earnings.[10] While their study is relatively sophisticated in the methodology used to account for labor selectivity and joint determination of health, this result is similar to others reported in the literature.

Low energy intakes can reduce productivity creating a vicious circle in which poor workers are unable to generate sufficient income to obtain sufficient calories to be productive. This relationship, sometimes dubbed the efficiency wage hypothesis, has been the object of considered theoretical work since Leibenstein (1957). Strauss and Thomas' (1998) review of the empirical literature notes that efforts to test this relationship empirically have been dogged by a number of problems: unobservable heterogeneity, measurement error, and observability issues. They note, "It is not obvious how to interpret a result that additional calories are associated with higher productivity if higher productivity workers are stronger and consume more calories" (p. 806). While individual fixed effects specifications can address unobservable fixed heterogeneity, they are especially susceptible to problems derived from measurement error. Thomas and Strauss (1997) lessen the latter problem by drawing on micro data in which caloric intakes were measured directly over a seven day period; in the Brazil data, they find that wages of workers in urban areas were positively and significantly affected by calories at low intake levels. Foster and Rosenzweig (1993a, 1994) find that calorie intakes have a significant affect on piece rates (but not time rates) in the Philippines where some workers engage in both time and piece rate activities so it is possible to control for unobserved individual heterogeneities.

Micronutrient status also has important productivity effects. Vitamin A deficiency can cause blindness with obvious consequences for productivity. Anemia is associated with reduced productivity both in cross-sectional data and in randomized interventions (Thomas, et al., 2004, Li, et al. 1994; Basta, Karyadi and Scrimshaw 1979). The magnitude may depend on the nature of the task. For example, piece work may have greater incentives for effort while heavy physical labor may show greater increases in productivity, though anemia is nevertheless a factor in productivity with relatively light work (Horton and Ross 2003).

2.2.c Indirect links: nutrition, cognitive development, schooling and productivity: Poorly nourished children tend to start school later, progress through school less rapidly, have lower schooling attainment, and perform less well on cognitive achievement tests when older, including into adulthood. These associations appear to reflect significant and substantial effects in poor populations even when

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[9] An additional aspect of the hypothesis of subsequent costs stemming from biological adaptation to deprivation *in utero* has a bearing on the estimation of the consequences of LBW. That is, the implications will be different if the consequences are a direct result of the deprivation compared to the possibility that they only manifest themselves if the deprivation is followed by relative abundance (Lucas, Fewtrell and Cole 1999, Cameron 2001).

[10] From a different perspective, Margo and Steckel (1982) found that the value of an American slave prior to the United States' Civil War fell by roughly 1.5 percent for every reduction in height of one inch.

statistical methods such as instrumental variables are used to control for the behavioral determinants of pre-school malnutrition. In productivity terms, the magnitudes of these effects are likely to be substantial, easily exceeding the effects of height on productivity even if the indirect effect of height on wages mediated by the relationship between height and schooling in included.[11]

There are at least three broad means by which nutrition can affect education. First, malnourished children may receive less education. This may be because their caregivers seek to invest less in their education, because schools use physical size as a rough indicator of school readiness or because malnourished children may have higher rates of morbidity and thus greater rates of absenteeism from school and learn less while in school. While delayed entry, the second way by which nutrition may influence schooling, does not necessarily lead to less completed schooling – although under standard models of the returns to schooling this would be an expected consequence of delayed enrollment if the opportunity cost of schooling increases with age – late enrollment leads to lower expected lifetime earnings. In order to maintain total years of schooling with delayed entry, an individual has to enter the work force when older. As Glewwe and Jacoby (1995) illustrate, for each year of delay in entry to primary school in Ghana a child in their study loses 3 percent of lifetime wealth. The third pathway from malnutrition to educational outcomes is via the capacity to learn, a direct consequence of the impact of poor nutrition on cognitive development described above. Additionally, a hungry child may be less likely to pay attention in school and, thus, learn less even if he or she has no long-term impairment of intellectual ability.[12] These three pathways clearly interact; a child with reduced ability to learn will likely spend less time in school as well as learn less while in class.

While there are many studies that document associations between nutrition and schooling (see Pollitt 1990 and Behrman 1996 for reviews), there are far fewer studies that persuasively portray the <u>causal</u> impact of child health and nutrition on school performance. Many of the observable factors that affect nutrition, such as family assets and parental education, are also ones that affect education. Similarly, unobservable attitudes about investment in children and intra-family equity influence heath provision and schooling decisions in a complex manner. Four recent studies represent the most complete efforts at distinguishing the distinct contributory role of nutrition on education from associations. Glewwe, Jacoby, and King (2001) track children from birth through primary school and find that better nourished children both start school earlier and repeat fewer grades. A 0.6 standard deviation increase in the stature of malnourished children would increase completed schooling by nearly 12 months. Using longitudinal data from rural Pakistan where school initiation is much lower, Alderman, et al. (2001) find that malnutrition decreases the probability of ever attending school, particularly for girls. An improvement of 0.5 standard deviations in nutrition would increase school initiation by 4% for boys but 19% for girls. As the average girl (boy) in the villages studied who begins school competes 6.3 (7.6) years of schooling, improvements in nutrition would have a significant effect on schooling attainment. Alderman, Hoddinott, and Kinsey (2003) track a cohort of Zimbabweans over two decades finding that *both* delayed school initiations and fewer grades completed for those children malnourished as children. Extrapolating beyond the drought shocks used for identification, the study concludes that had the median pre-school child in the sample achieved the stature of a median child in a developed country, by adolescence she would be 4.6 centimeters taller, had completed an additional 0.7 grades of schooling as

[11] Strauss and Thomas (1998) point out that an illiterate man would need to be 30 cm taller than his literate coworker to have the same expected wage.

[12] A few studies have attempted to investigate the tie between hunger and classroom performance using experimental designs. Available results, however, are not conclusive regarding long-term consequences, perhaps, in part, because controlled studies are hampered by difficulties in running experiments for an appreciable duration as well as the difficulty of encouraging parents to conform to the protocols of research design and the inability to use a placebo. Moreover, as shown in Grantham-McGregor, Chang and Walker (1997), while feeding children may improve attention, its impact on learning depends on the classroom organization. Also see Powell, et al. (1998).

well as started school seven months earlier. Finally, Behrman, et al (2003) investigate the impact of community-level experimental nutritional interventions in rural Guatemala on a number of aspects of education, using the well-known INCAP longitudinal data set dating back to the initial intervention in 1969-77 (when the subjects were 0-15 years of age) with the most recent information collected in 2002-3 (when the subjects were 25-40 years of age) and find that being exposed to a randomly available nutritional supplement when 6-24 months of age had significantly positive and fairly substantial effects on the probability of attending school and of passing the first grade, the grade attained by age 13 (through a combination of increasing the probability of ever enrolling, reducing the age of enrolling, increasing the grade completion rate per year in schooling, and reducing the dropout rate), completed schooling attainment, adult achievement test scores, and adult Raven's test scores.

It is relatively straightforward to infer from the impact of nutrition on schooling attainment to the productivity lost due to early malnutrition using the substantial literature on wages and schooling. There are hundreds of studies on the impact of schooling attainment on wages -- many of which are surveyed in Psacharopoulos (1994) and Rosenzweig (1995). Wages, however, are also directly influenced by cognitive ability, as well as by the appreciable influence of cognitive ability on schooling achieved. Poor cognitive function as a child is associated with poorer cognitive achievement as an adult, see Behrman, et al. (2003), Martorell (1995), Martorell, Rivera and Kaplowitz (1989), Haas, et al. (1996), Martorell (1999) and Martorell, Khan and Schroeder (1994). A series of studies show that reduced adult cognitive skills (conditional on grades of schooling completed) directly affect earnings (Alderman, et al., 1996; Altonji and Dunn, 1996; Boissiere, Knight, and Sabot, 1985; Cawley, Heckman and Vytlacil, 2001; Glewwe, 1996; Lavy, Spratt and Leboucher, 1997; Psacharopoulos and Velez, 1992).[13] It is possible to use these studies to estimate the magnitude of the productivity costs of poor nutrition. Alderman, Hoddinott and Kinsey (2003) use the values for the returns to education and age/job experience in the Zimbabwean manufacturing sector provided by Bigsten, et al. (2000) to infer the costs associated with poor nutrition in Zimbabwe. The loss of 0.7 grades of schooling and the seven-month delay in starting school there translates into a 12% reduction in lifetime earnings. Behrman and Rosenzweig (2004) take a more direct approach. They study a sample of adult identical twins in the United States and determine that with controls for genetic and other endowments shared by such twins (which would not be affected by programs to increase birth weight), the impact of LBW on schooling or wages is far larger than it appeared without such controls (e.g., the impact on schooling attainment is estimated to be twice as large, with a pound increase in birth weight increasing schooling attainment by about a third of a year).

3. Opportunities Related to Hunger and Malnutrition

Before turning to possible opportunities related to hunger and malnutrition in developing countries, it is important to be clear about the framework for representing such opportunities, including its strengths and limitations.

3.1 Framework for Considering Opportunities

To identify which of the nine areas of interest for the Copenhagen Consensus present real opportunities in the sense of having high expected benefit-to-cost ratios or high internal rates of returns, information is required on time patterns of expected resource costs and benefits, uncertainties for each of these time paths, and the appropriate discount rate. It is also important to identify the relevance of opportunities in terms of basic policy motives of distribution (e.g., alleviating poverty) and efficiency (e.g., narrowing the difference between private and social rates of return to an action). To have a realistic

[13] In addition, studies such as Behrman and Rosenzweig (2004) and Strauss (2000) estimate the total impact of LBW on earnings, including the indirect schooling effect, the direct impact of ability and any influence of stature.

perspective about what underlies the benefit-to-cost ratios or internal rates of returns on which the Copenhagen Consensus Expert Group will have to make their ranking, it is useful to review here some of the major components of such calculations.[14]

Benefits: Estimating the present discounted value of benefits due to an intervention is difficult for the following reasons: (1) Most interventions have multiple impacts, some positive and cutting across the different challenges considered here and some negative, because they affect the basic constraints under which entities such as households and firms and farms are making their decisions -- thus resulting in what Rosenzweig and Wolpin (1982) call "the unintended consequences" of programs and policies. (2) Most economic evaluations of the magnitudes of impacts must be made on the basis of imperfect non-experimental data, which raises problems of estimation due to endogeneity of right-side variables, unobserved heterogeneity, and selected subsamples.[15] Though there are a number of studies that provide evidence that controlling for such estimation problems can change impact estimates substantially (and even, in some cases, reverse the signs!), far too often associations in micro or in aggregate data are interpreted as if they reflect causal effects. (3) Even if the impacts are well-measured, they are not always in monetary or easily monetized terms. But they must be expressed in such terms in order to be made comparable to the costs and to the impacts of other changes. There are various means of doing so that are used in the literature. For example, options that are used to address the vexing problem of assigning a value to postponing mortality include the present discounted value of the estimated productivity of the individual that is foregone due to early mortality or the resource cost of the most effective alternative means of postponing such mortality. We utilize the latter approach below.[16] (4) Most impact estimates do not relate well to the basic policy motives of efficiency and distribution. In particular, the efficiency policy motive pertains to differences between private and social impacts due, for example, to externalities for which reason there may be an efficiency argument for public subsidies for an action. But most micro estimates present only private impacts and most aggregate estimates present only total impacts, so neither provide a basis for judging the efficiency case for interventions.

In addition, impacts often are spaced over time, with different time patterns for different impacts. Because there is an opportunity cost in terms of waiting, the benefits must be discounted. But while the

[14] Knowles and Behrman (2003) discuss these issues at some length. The health issues we consider are often addressed using disability adjusted life years (DALYS). The approach can be adapted to accommodate assumptions on discount rates and to consider changes in productivity conceptually the same as with disabilities. While the DALY approach is generally used for cost effectiveness comparisons, it can be converted to cost-benefit analysis with assumptions similar, but not identical to those used here. See, for example, Levin et al. (1993). There are basic questions about how best to evaluate DALYS that are parallel to the questions discussed in the text for mortality. That is, what we argue is the preferred alternative for evaluating a DALY due to a particular intervention is to use the least-cost alternative means of attaining one DALY, but in some studies (e.g, see discussion of Opportunity 4 in Section 3.2 below), DALYS are evaluated by per capita income, which leads to much larger estimated benefits.

[15] Some of these issues also may be problems with experimental data, depending on the details of the experiments. There are a relatively few cases in which impact evaluations in developing countries are based on what appear to be good experiments such as those associated with the Mexican rural anti-poverty human resources investment program PROGRESA (e.g., Behrman, Sengupta and Todd 2003, Behrman and Hoddinott 2002, Gertler, et al. 2003) or smaller-scale experiments such as in NGO schools in Kenya (e.g., Miguel and Kremer 2002, 2004) or differential nutritional supplements among four rural Guatemalan communities (e.g., Martorell 1995, Behrman, et al. 2003) or with random assignment of vouchers among poor student applicants in urban Colombia (e.g., Angrist, et al. 2002).

[16] For other examples of such use, see Summers (1992, 1994), Van der Gaag and Tan (1997), Behrman and Knowles (2003) and Knowles and Behrman (2003). This strategy requires the identification of the least cost alternative action that has exactly the same effects as the one being valued. This is a strong requirement. But the alternatives also require strong assumptions. While there are examples in the literature of basing such assessments as the value of reducing mortality on expected lifetime earnings, for example, this methodology is fraught with pitfalls including the implicit ranking of the value of life as a function of wages within and across countries. In addition, assigning a value in proportion to earnings does not net out consumption from these earnings.

mathematics of discounting are well-understood, there does not seem to be agreement on what discount rate is appropriate. The choice of the discount rate can make a considerable difference for investments for which there are considerable lags (e.g., the impact of improved *in utero* nutrition on adult health five or six decades later). Table 2 provides some illustrations of the present discounted values (PDV) of an impact of $1000 over different time horizons and alternative discount rates. The PDV of $1000 received 50 years later is $608.04 with a discount rate of 1%, $371.53 with a discount rate of 2%, $228.11 with a discount rate of 3%, $87.20 with a discount rate of 5%, and $8.52 with a discount rate of 10%. For impacts with lags of this duration, the benefit (and thus the benefit-cost ratio) can be tripled by changing the discount rate from 5% to 3% or increased by ten by changing the discount rate from 10% to 5%. Thus whether a project with this benefit is a great choice or a lousy choice may depend critically on the discount rate that is used. For lags that are less long, the PDVs vary less with the discount rates, but they still may vary substantially even with lags of 5-10 years. Therefore any effort to compare projects across various domains (challenges) may end up only reflecting the different discount rates that different analysts choose rather than the true merits of the alternatives.

Costs: The present discounted value of the costs should equal the marginal resources needed for the intervention. Since a significant share of the total costs of an intervention typically is incurred at the time of the intervention, the question of what discount rate is appropriate is not likely to be as important for the costs as for benefits. Nevertheless, discounting still may be of some importance because the initial costs may be spread over some time and because there may be important recurring costs. Two other points about the relevant costs are important to mention because they are not always followed in the literature. First, the relevant costs are resource costs that do not include transfers even though transfers may be important parts of public sector budgetary costs.[17] Second, the relevant costs are those experienced by society, not only by the public sector. The private costs often include, for example, the time costs for members of society and the distortionary costs of raising revenues for interventions and of making the interventions. Both may be considerable. For instance, a major share of the costs of time-intensive interventions such as schooling or training often is the opportunity cost of time not spent in productive activities. For another example, it has been estimated that the distortionary cost (often called the "deadweight loss") of raising a dollar of tax revenue in the United States and in other countries ranges from $0.17 to $0.85, depending on the type of tax used (e.g., Ballard, Shoven and Whalley 1985, Feldstein 1995, van der Gaag and Tan 1997).

Benefits and costs: Three further points, finally, are common to both benefits and costs. First, both are *context dependent*. They both may depend importantly, for example, on relative prices, the state of the economy, and the nature of the health environment and broader aspects of the environment. High return policies in a society with high prevalence of a particular disease, for example, may not be very effective in a society with low prevalence of that disease. Second, for both benefits and costs there may be *aggregate effects* that have important feedbacks through changing relative scarcities and market prices, particularly in economies that are more closed to international trade. Third, serious assessments of impacts and of costs must incorporate *aspects of behavior* of individuals, collective units such as households (with intrahousehold distribution possibly affecting distribution by gender and by generation), and other entities – including governments (due to the endogeneity of policy choices).

In a nutshell, evaluation of opportunities is very difficult and is not likely to lead to a set of recommendations that are universally applicable in all developing country contexts. Claims that there are such interventions are likely to be misleading and costly in terms of their use of scarce resources. Our

[17] Operationalizing the point about transfers, however, may be difficult in many circumstances. Transfers in terms of money are fairly straightforward. In-kind transfers are more ambiguous. Goods such as food provided in-kind typically are (appropriately) considered transfers, but in-kind provision of services (e.g., subsidized schooling or health clinics) often are not considered transfers – though the real distinction is not clear.

discussion of opportunities is subject to these important caveats and for Opportunity 1 – reducing the prevalence of LBW – we explore how sensitive some of the estimates are to underlying assumptions to illustrate some of these points. But it should be noted that these qualifications and problems are not unique to this Challenge paper, but are pervasive for all the Challenge papers.

3.2 Four Opportunities for Reducing Hunger and Malnutrition

Opportunity 1 – Reducing the Prevalence of LBW[18]

Many of the 12 million LBW infants born each year die at young ages, contributing significantly to neonatal mortality, which makes up the largest proportion of infant mortality in many developing countries. Unfortunately, rates of LBW have remained relatively static in recent decades. Because LBW infants are 40% more likely to die in the neonatal period than their normal weight counterparts, addressing LBW is essential to achieve reductions in infant mortality. Moreover, many of the LBW children who survive infancy suffer cognitive and neurological impairment and are stunted as adolescents and adults. Thus, in addition to contributing to excess mortality, LBW is associated with lower productivity in a range of economic and other activities. LBW also may be important in light of new evidence that shows that LBW infants may have an increased risk of cardiovascular disease, diabetes and hypertension later in life. LBW may also be an intergenerational problem because LBW girls who survive tend to be undernourished when pregnant with relatively high incidence of LBW children.

Table 3 reproduces Alderman and Behrman's (2003) estimates of the PDV of the following seven different benefits of changing one infant from LBW to non LBW status for a discount rate of 5% in developing countries.

1. Reducing infant mortality: The probability of infant mortality is estimated to be significantly higher for LBW than for non-LBW infants. The studies by Conley, Strully and Bennett (2003) and Ashworth (1998) reviewed in Section 2 show an elevated risk of infant mortality associated with LBW that translates into fairly large differences in mortality rates given the relatively high mortality rates in many developing countries. The Indian and Guatemalan samples that Ashworth summarizes, for example, have neonatal morality rates of from 21 to 39 per 1000 births and post-neonatal mortality rates per 1000 neonatal survivors of from 25.3 to 60.0. The midpoint of these ranges, together with the midpoint of the percentage LBW in these samples (21.2% to 39.0%) and Ashworth's summary that for term infants weighing 2000-2499 grams at birth the risk of neonatal death is four times as high and the risk of post-neonatal death is two times as high as for term infants weighing 2500-2999 grams implies that the probability of an infant death (either neonatal or post-neonatal) drops by about 0.078 for each birth in the 2500-2999 grams range instead of in the 2000-2499 gram range.[19]

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[18] Because this opportunity is based on substantial work that we have undertaken that is summarized in Alderman and Behrman (2003), we begin with it as a more extensive illustration of the assumptions that underlie estimates of benefits and costs and the sensitivity of such estimates to alternative assumptions. We discuss the subsequent opportunities somewhat more briefly.

[19] Ashworth does not provide all the information necessary to make this calculation. As an approximation, Alderman and Behrman assume that the midpoint of the neonatal death rate (30.1) is the weighted average of infants with LBW (at the midpoint of that range, 32.5%) and of those not LBW, and that all LBW are in the 2000-2499 grams range and all non-LBW are in the 2500-2999 grams range. Given the fourfold risk for the former, this implies that the neonatal mortality rate of LBW is 61.0 and that for non LBW is 15.2, so the difference is 45.8 or a probability of 0.046. A parallel calculation for the twofold risk of mortality for the 2000-2499 grams range versus the 2500-2999 grams range among neonatal survivors with an overall mortality rate at the midpoint of 42.7 and a midpoint of the birth weight range of 32.5% implies that the postneonatal mortality rate for LBW infants is 64.4 and

How to value a life saved is a big question about which there is a range of views. One possibility, as noted above, is to use the resource costs of alternative means of saving a life. Summers (1992) suggests that World Bank estimates of the cost of saving a life through measles immunization were on the order of magnitude of $800 per life saved in the early 1990s. Adjusting this cost for inflation in the next decade and for the distortion costs of raising these revenues, the alternative resource cost of saving an infant's life is estimated to be about $1250. Therefore, based on this approach the estimated monetary benefit of reducing the infant mortality associated with LBW is about $97.50. This is the $1250 benefit times the excess probability that a LBW would have died in infancy. Alderman and Behrman assume that on average this benefit is obtained one year after the intervention so that the discount rate does not affect greatly the PDV of this benefit (see row 1 in Table 3).

2. Reducing the additional costs of neonatal medical attention due to LBW: This is the sum of the extra neo-natal care in hospitals as well as the additional costs of out-patient care. The former is the product of the costs of a day of a hospital stay times the number of additional days on average for children born weighing less than 2.5 kilograms and who are born in hospitals. Given that the share of children born in hospitals is small in most developing countries, under the assumption that these costs are incurred only for children born in hospitals, the contribution of this component to the total may be small, even though its costs are not discounted over many years.

Alderman and Behrman were not able to find any recent studies indicating the average length of neonatal stay for LBW children compared to children with normal weights in low-income countries. As an initial estimate based on experience in Bangladesh, Alderman and Behrman assume that duration of hospitalization for normal weight baby with normal delivery is 1-2 days and for LBW babies (between 1500-2500 grams) it is 5-7 days. For very LBW babies (below 1500 grams) the length of stay is 7-10 days.[20] Using the 2,000 Taka per day at private hospitals inclusive of medicine as the opportunity cost of care (governmental hospitals charge 200-300 plus medicine, but the cost of beds is subsidized) the extra direct hospital-related resource cost of hospitalization for a LBW child is $155 taken at the midpoint of the difference in days.[21] The extra total direct resource cost also includes the extra cost of time for the parents and the distortion costs from raising governmental revenues to finance the subsidized hospitalization and from inducing inefficient use of resources through their subsidized hospitalization. Under the assumption that the distortion costs are about 25% of the hospitalization costs as above and that time cost of the parents for the extended hospital stay is $15, the resource cost for longer hospitalization for a LBW baby is $209, which Alderman and Behrman assume is incurred close enough to the intervention that there is no discounting. However, in many low-income countries the majority of babies are born at home, and not in hospitals. While there may be some parallel costs for LBW babies born at home, they are likely to be much less. For their base estimates in row 2 of Table 3, therefore, Alderman and Behrman assume that 90% of the babies are born at home and the additional initial resource costs for those LBW babies are only 10% of those born in hospitals.

3. Reducing the additional costs of subsequent illnesses and related medical care for infants and children due to LBW: Ashworth (1998) reports a regular pattern of increased morbidity with lower birth weights, particularly in the first two years of life. For example, days with diarrhea among LBW children 0-6 months increase 33% compared to normal birth weight in Brazil and 60% for children 0-59 months in

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for non-LBW infants 32.2, so the difference is 32.2 or a probability of 0.032. Together these calculations imply that a shift of an infant from LBW to non LBW reduces the probability of mortality in such a population by about 0.078.

20 Dr. Mohammed Shahjahan of the Micro-nutrient Institute and former Medical Director of Save the Children Foundation's Children's Nutrition Unit in Dhaka provided this information.

21 The extra hospitalization direct resource costs for a VLBW child are $240, or $300 in total resource costs if the distortion costs are 25%.

Papua New Guinea. Barros, et al. (1992) show a doubling of the rate of hospitalization for dehydration in Brazil and a 50% increase in hospitalization for pneumonia. Victora, et al. (1999) report similar magnitudes of increases of pneumonia and acute respiratory disease for a number of countries. Such increased morbidity has direct and immediate costs as well as indirect costs due to the associated stunting (see 4 below). However Alderman and Behrman were not able to find estimates of the resource costs of such illnesses and related medical care. Estimates of out-of-pocket costs can be obtained from some household surveys, but these are likely to be substantial understatements of resource costs because in most developing economies medical care is subsidized and such costs do not include the opportunity costs of caregivers who are likely to be diverted from other activities because of illnesses of children. For their basic estimates, therefore, Alderman and Behrman assume that the additional total direct resource costs for such illnesses of LBW infants are $40, centered at the end of one year (Table 3, row 3).

4. The expected discounted loss of lifetime productivity due to stunting: The first component of this benefit from increasing the birth weight of a LBW baby to normal birth weight can be derived from the product of an estimate of the impact of LBW on adult height times an estimate of the difference in earnings attributed to low stature, under the maintained assumption that the impact on earnings reflects the impact on productivity. A second component comes from the fact that, as discussed in Section 2, stature also affects the timing and amount of school attended. Long-term follow up studies in the United Kingdom (Strauss 2000) indicate a loss of 0.5 Z scores in height for children born small for gestational age who average a kilo difference from the normal controls. In a study of identical twins Behrman and Rosenzweig (2004) also show a lasting impact of height of a similar magnitude; a difference of one kilo in birth weights for a full term baby leads to a 1.6 cm difference in adult heights. This is roughly a 1% difference. Li, et al. (2003) followed a cohort whose mothers received supplementation in a randomized experiment. They found that a one standard deviation difference in birth weight (0.5 kg. for boys and 0.4 kg for girls) led to 1.8 and 0.6 cm differences in adult heights. What do differences of this magnitude mean for productivity? Thomas and Strauss (1997), as noted in Section 2, estimate the direct impact of adult height on wages for urban Brazil. This result is similar to others reported in the literature. The direct effects on schooling of the nutritional shock studied by Alderman, Hoddinott, and Kinsey (2003) were estimated to lead to a 7% reduction in lifetime earnings. The impact of lifetime earnings in rural Pakistan from the impact on the probability of school enrollment from a 0.5 Z score improvement in nutrition was estimated at 1.6% (Alderman, et al. 2001). This study only considered age of school enrollment and not the full impact of nutrition on school achievement. Based on these studies, Alderman and Behrman assume for their basic estimates that the impact on productivity through stunting of increasing the birth weight of a LBW infant to above 2500 grams is about 2.2% of annual earnings that Alderman and Behrman assume to be $500 per year in constant prices over an assumed work life from 15 of age to 60 years old (row 4, Table 3).

5. The expected discounted increase in lifetime productivity due to increased ability with the reduction of LBW: Earnings are based not only on school attended and on direct anthropometric effects, but also on learning within school (Alderman, et al. 1996). This learning may be affected by the impairment of cognitive development that is associated with LBW, so reducing LBW may increase productivity through this channel.

What is the range of cognitive loss that may be a consequence of LBW? Bhutta, et al (2002) report a range of 0.3-0.6 standard deviation decrease in I.Q., a range that includes the decline in cognitive ability in the sample followed by Ment, et al. (2003) even after that cohort had improved over time. Extrapolation to the task at hand, however, is subject to a set of caveats additional to those mentioned above in Section 3.1. In particular, the two studies mentioned above investigate children whose birth weights reflect pre-maturity. Potentially offsetting this is the fact that Ment, et al. also noted that the improvements over time were associated with higher socio-economic status. By inference, these improvements may be less likely among low-income families with little education or access to quality pre-schools. The mental impairment, however, may not be only for extreme cases or for pre-maturity. Sorensen, et al. (1997) study the relation of birth weight and IQ over the normal range of birth weights and found the score of intelligence increased until a birth weight of 4200 grams. The difference between the LBW group and the children born at four kilos was roughly one half standard deviation of the score. Although Matte, et al. do not report standard deviations for their study of siblings with normal gestation, the magnitude of the increase in IQ is consistent with Sorensen, et al.

Whatever the magnitude of impairment, the impact of this change on subsequent earnings must be estimated. Altonji and Dunn (1996) provide one such estimate of the impact of IQ on earnings, conditional on years of schooling using data from the United States. For men, the impact of a half standard deviation decline in IQ on the logarithm of wages was 0.05, or slightly more than the impact of an additional year of post secondary schooling.[22] Using the same data set, but a different measure of ability, Cawley, Heckman and Vytlacil (2001) show that the estimated impact on wages of ability is substantially smaller conditional on levels of schooling. For example, in the cases of black males or females, the coefficients of a general measure of ability decline by a third when schooling is included in the model. For their purposes, the net impact of ability is both the direct impact on wages and the impact that works thought schooling choices.[23] Using the models in Cawley, Heckman and Vytlacil (2001) disaggregated by gender and ethnic group as well as including other background variables but without schooling, a half standard deviation decline in cognitive ability leads to 8-12% lower wages.

Alderman, et al. (1996) use a different measure of cognitive ability – performance on Raven's matrices - in their study of wages in rural Pakistan. They find that a half standard deviation decline in this measure leads to a 6.5% reduction in wages in estimates that do not include schooling in the regression. The point estimate drops by two thirds in estimates that include both years of schooling as well as achievement in school. One can also infer the relation between scores on Raven matrices and household income in Ghana by looking at the product of the impact of ability on school achievement in Glewwe and Jacoby (1994) and the impact of achievement on household income from the same data source in Jolliffe (1998). In this case, a half standard deviation decline leads to a 5% decrease in total income.

While Boissiere, Knight and Sabot (1985) do not find a direct impact of Raven's scores on wages in their study of Kenya and Tanzania, they do find that this measure of ability influences schooling as well as learning conditional on years of school. Taking these pathways into account, a half standard deviation decline in ability would lead to a decline in wages of 8 and 5% respectively.[24] Similarly, Psacharopoulos and Velez (1992) find a modest direct effect of reasoning ability as measured by Raven's matrices on wages in Colombia together with a large impact of this measure of ability on wages through its impact of schooling. Thus, a half standard deviation change leads to a 3.5% direct change in wages (holding schooling constant) and a *total* impact on wages of 11.6%. This is also in the range of results from Chile reported by Selowsky and Taylor (1973. Their results imply that a one half standard deviation decline in child IQ leads to reduced earnings between 3 and 5%.[25]

An alternative approach that combines the fourth and fifth components of the seven LBW benefits being considered is to look directly at the earnings of individuals as a function of their birth

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[22] This result is based on a family fixed effects model. The estimated response is 40% less without fixed effects. Curiously, although the coefficient of IQ in the non-fixed effects model for women is larger than the corresponding coefficient for men, the fixed effects coefficient for women is negative, but not statistically significant.

[23] Hansen, Heckman and Mullen (2003) also point out that many measures of ability are affected by schooling.

[24] Based on Table 6 of Boissiere, Knight and Sabot (1985) and assuming that the coefficient of variation for ability is 0.3, the same as in both the Ghana and Pakistan studies.

[25] Selowsky and Taylor (1973) actually found that malnutrition reduced IQ by one standard deviation but they were addressing childhood malnutrition not LBW.

weight. That is, instead of summing the impact of low stature on wages with the impact of reduced cognitive function times an expectation of this type of impairment, simply compare directly earnings of children with similar opportunities at birth but different birth weights. The impact of birth weight on earnings in this case is the sum of the impacts on stature, on school investments and on cognitive ability, although the relative contribution of each is not elucidated.

Strauss (2000) finds that individuals aged 26 who were born small for gestational age (SGA) earned 10% less than individuals who had normal birth weights. The birth weights of the SGA group differed on average from the normal group by a kilogram. However, the difference in cognitive abilities on standard tests ranged from 0.13 to 0.37 standard deviations in follow-up measures between the ages of 5 and 16. Thus, even with a modest difference in measured ability and no difference in average years of schooling, he observed a significant difference in wages of the same magnitude – indeed greater - than with the assumption of a half standard deviation of cognitive ability and the range of wage effects of such a deficit derived from the wage equations that include cognitive ability. Similarly, using the within twins estimates in Table 2 of Behrman and Rosenzweig (2004), a one kilo difference in birth weight (0.98 ounces a week fetal growth) implies a difference of 18.6% in wages for adults.

Overall, considering either the total impact of LBW on wages or the sum of the impacts due to stunting, impaired cognitive development and schooling, the consequences on earnings of an infant moving from LBW to non-LBW can be assumed to be bracketed as between 5 and 10% per year.[26] Alderman and Behrman use 7.5% for their basic estimates, which – given their use of 2.2% for the expected productivity benefit from reduced stunting for the fourth benefit, implies about 5.3% for the expected productivity benefit from improved ability. They again assume annual earnings or productivity of $500 in constant prices for a working life from age 15 through age 60 (row 5, Table 3).

6. Reduced costs of chronic diseases associated with LBW: There has been considerable attention in recent years to these possible impacts of LBW in the "fetal origins" hypothesis described in Section 2. Given the heterogeneity of the chronic illnesses associated with fetal malnutrition it is difficult to assign costs to this array of diseases. Moreover, as noted, there are still relatively few studies that have been able to trace long-term impact and to assign them to nutritional deprivation in a particular trimester of pregnancy. As mentioned above, some consequences of fetal malnutrition that may affect adult health may not manifest themselves in LBW nor are all cases of LBW directly attributable to malnutrition. Moreover, the contribution of LBW to chronic disease may depend on the degree of deprivation in the rest of the individual's life, adding an additional dimension to any assumption. We further do not know how many children born small for gestational age will survive to ages at which chronic diseases are likely in current developing country conditions.

One study that does attempt to calculate the costs of LBW as well as those of subsequent nutritional and dietary patterns on chronic disease is Popkin, Horton and Kim (2001). Their estimates consider the cost of diet-related chronic disease to two economies – China and Sri Lanka. For China, all diet-related factors are estimated to account for costs totaling 2.1% of GNP in 1995. For Sri Lanka, these costs are estimated to be 0.3%. In both countries costs are projected to rise appreciably over the next generation, though the share of these costs attributable to LBW (compared to say, obesity) is projected to decline.

In their basic estimates for illustration Alderman and Behrman make two broad assumptions (row 6, Table 5). First, they assume that the cost in terms of lost productivity and increased medical care is

[26] This assumes that this differential remains constant over a worker's lifetime. Altonji and Pierret (2001) note that the impact of ability may increase over time as workers obtain more information by observation and that conversely the impact of schooling on wages may decline.

equivalent to ten years of earnings in a low-income population ($5000) and is experienced on average at age 60. Second, they assume that the probability of experiencing these chronic diseases is reduced by 0.087 by moving a LBW baby to a non LBW status.[27]

7. Cross-generational impacts of LBW: Alderman and Behrman also include an estimate of the second-generation impacts of the children born to women who were themselves LBW children. Since many women begin having children in their teens or early twenties, some of the costs on the second generation actually may occur before all of the direct costs to the earlier generation – for example, the reduced earnings of older adults and the costs of chronic illnesses for adults who themselves were LBW.

They were not able to find much persuasive evidence on the causal impact of mothers' LBW on that of their children. Indeed, as noted in Section 2, Behrman and Rosenzweig (2004) report that in data for the United Sates the significant positive correlation disappears if there is control for all endowments (including genetic endowments) using data on identical twins (which are a LBW population). Their findings suggest that the intergenerational correlations in birth weights between mothers and children are due to genetic influences and not to the nutritional status of mothers when they were in the womb, which presumably is what is of interest from a policy perspective. On the other hand, as also noted in Section 2, Krishnan, et al. (1999) find a small significant effect in the low-income context of rural Guatemala using the INCAP data in which mothers of current mothers were exposed to nutritional supplements made available in an experimental design at the community level. Therefore, in their basic estimates (row 7, Table 2) Alderman and Behrman illustrate some possible effects under the following assumptions: (a) these effects are only for mothers who were LBW, not fathers, and thus for about half of LBW infants; (b) on average these mothers have four children, born when the mother is 17, 20, 26 and 35; (c) For a mother who was LBW, the probability for each of her children of being LBW is one in five; (d) this probability is reduced to one in ten if she was not LBW; and (e) the benefits of reducing LBW for the children over their life cycles are the same as the benefits for the mothers/fathers, but lagged in time and therefore discounted more, with such possibilities over three generations of children.

Summary of basic estimates of PDV of benefits of shifting one infant from LBW to non-LBW: The final row of Table 3 gives the bottom line for Alderman and Behrman's basic estimates, subject to the many caveats and assumptions made above. For their basic estimates, the PDV of reduction of LBW per infant is about $580. That means that from a social point of view in purely economic terms it would be desirable to reduce the incidence of LBW infants in low-income populations as long as the true resource cost of doing so is less than $580 per affected infant. The last column gives the percentage contributions, among these seven individual benefits, in this overall benefit. The overall benefits are dominated in these estimates by the estimated impacts on productivity through reducing stunting and cognitive ability (working in part through its effects on schooling), with these two benefits accounting for over half (58%) of the total. While there are considerable delays in receiving these benefits, they persist over the many years of the working life with the result that their cumulative effects are considerable even when

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[27] Their reasoning for this approximation is as follows. For the illustrative stereotypical low-income developing countries, they assume that about 10% of adult deaths are due to these diseases under the assumption that the share of annual deaths will be the same as share of eventual cause of death (the information in Popkin, Horton and Kim suggests about 18% for China, but China has a much older population than do most low-income countries), about 15% of the adult population was LBW (which is much higher than China and a number of low-income countries, but lower than other low-income countries primarily in South Asia and Sub-Saharan Africa) and that the odds ratios for having these chronic diseases are twice as high for LBW as for non-LBW babies (consistent with information in in Popkin, Horton and Kim). Let X be the probability of having these chronic diseases for non-LBW babies (and 2X for LBW babies), where X = 8.7% is the solution to 10%=0.85*X + 0.15*(2X). Since the odds ratio for adults who were LBW babies is twice that for adults who were not LBW babies, the reduction in the probability of having these chronic diseases by moving a baby from LBW to non-LBW status is 0.087.

discounted to the time of the intervention at a 5% discount rate. The next largest PDV among the seven benefits is for reduced infant mortality (16%), with reduced neonatal care and cost of infant/child illness together (14%) and intergenerational benefits (8%) next. Though the estimated benefits from reduced infant mortality and reduced neonatal care and costs of infant/child illness are not huge, their relative contribution is appreciable because the benefits occur very early in the life cycle. Thus, there is not much of a lag before they are reaped after an intervention and the benefits are not discounted much. The intergenerational benefits are fairly large in some cases, but spread over a number of years and are assumed to start only after 17 years. The PDV of the reduction in costs of chronic diseases, even though at the time they occur they have fairly large constant dollar values per year, are fairly small (4%) because they are discounted for so many years.

Sensitivity of Basic Estimates of PDV of Reducing LBW to Selected Critical Assumptions: The estimates in Table 3 are conditional on a number of assumptions and, in some cases, informed guesses. We now summarize how sensitive they are to some of these assumptions.

(a) <u>Discount rates</u>*:* The basic estimates use a real discount rate of 5%. As noted in the discussion of Table 2, what discount rate is used can alter substantially the PDV of the benefits, particularly for those for which there are fairly large lags before they are obtained. Table 4, therefore, summarizes estimates that are identical to those in Table 3 with the single exception that the same range of discount rates as in Table 2 is used, including 5% for easy comparison. The overall effect of these alternative discount rates is a sum of PDV of benefits that ranges from 30% to 351% of that in Table 3 (bottom row of Table 4).[28] This is a considerable range. But the discount rates also vary in the table, from 1% to 20%. But even with small changes in discount rates the PDVs may vary considerably. For example, the sum of the PDV for all seven benefits with a discount rate of 3% is 170% as large as that with 5%. The sum of the PDV for all seven benefits with a discount rate of 10% is 47% as large as that with a discount rate of 5%. And many studies use discount rates within the 3% to 10% range. It certainly is not known that the “right” discount rate is 5% and not 3%, or vice versa. But, to illustrate, with 3% an intervention costing almost $1000 ($986) per infant moved from LBW to non-LBW would be warranted, while with 5% the maximum that would result is a favorable benefit cost ratio would be $580.

(b) <u>Changes in estimates of individual benefits</u>: The magnitudes of the estimates of the individual effects are also subject to uncertainty, as discussed above. Similarly, the estimated benefits will vary due to country-specific conditions. For example, a greater share of births in hospitals and higher costs of medical care will increase the second benefit from reduced LBW while higher average productivity will change the fifth benefit. To illustrate the implications of these uncertainties and inter-country differences, Alderman and Behrman present a set of seven simulations, each of which starts with the base estimates in Table 3, still with a 5% discount rate,[29] but increases one of the seven benefits by 50% (Table 4).[30] These simulations permit the examination, for example, of what difference would it make for the estimates of the PDV of overall benefits if the probability of infant mortality fell by 0.117 instead of by 0.078, if the lowest alternative cost of preventing such mortality were $1875 instead of $1250, if the resource costs for the extended hospital stay for LBW infants were $314 instead of $209, if the additional resource costs for

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[28] The PDVs of all of the benefits (except reduced neonatal care, which is not discounted) decline as the discount rate increases. But they decline at very different rates because of the different lags for the different benefits. As the discount rate increases, the benefits that are early in the life cycle (reduced infant mortality, reduced neonatal care, and reduced costs of infant/child illness) become relatively more important.

[29] Table 4 indicates what would happen if there were changes that increased each of the benefits. The implications of changes that reduced each of the benefits, of course, would be similar in spirit but opposite in sign.

[30] Under any assumed discount rate, a proportional [de]increase in the estimates of future benefits has an equal proportional change in the discounted benefit. Thus, one can vary the assumptions used in any column of Table 3 to explore other variations of the core assumptions in a manner parallel to that illustrated here.

LBW infants and children averaged \$60 instead of \$40, if the gain in annual earnings due to reduced stunting were 3.3% instead of 2.2%, if the relevant baseline earnings were \$750 rather than \$500, if the gain in ability were 8.0% rather than 5.3%, if the reduced lost productivity and medical care cost from chronic diseases averaged 15 rather than ten years of low-income earnings, or if the intergenerational effects were 50% larger than assumed in Table 3.

Each of these changes, of course, increases the total PDV of benefits with estimates that range from \$591 (chronic illnesses) to \$699 (productivity effects of ability) as compared with \$620 from Table 3. This means, not surprisingly, that under each of these alternative assumptions somewhat higher cost interventions would be warranted. But, because there are multiple benefits, increasing any one of the benefits by 50% increases the PDV of the sum of benefits by much less than 50% -- indeed by from 2% to 21%. The estimates in Table 5, finally, also illustrate the obvious point that it is much more important to pin down the magnitudes of some of the benefits than others. With a 5% discount rate it would appear most important to lessen uncertainty about the estimates of the impact on economic productivity and secondly on early life mortality and morbidity costs than on, at the other extreme, the costs and probabilities of chronic diseases.[31]

Cost estimates: Many interventions to address LBW problems have been proposed, including:[32]

- antimicrobial treatments
- antiparasitic treatments
- insecticide-treatment bednets
- maternal health records to track gestational weight gain
- provision of iron/folate supplements
- targeted food supplements
- social marketing regarding birth spacing or timing of marriage

While some of the recommended interventions focus solely on LBW, a number of other programs to reduce LBW also address other goals – for example, campaigns against smoking or consumption of other drugs during pregnancy - with benefits in terms of LBW possibly secondary. Ideally one would sum the expected PDV from all anticipated outcomes to estimate the benefits of such interventions. In any case most lists of possible interventions provide little guidance regarding priorities, either for using scarce public resources for the general purpose of alleviating problems related to LBW or for deciding which interventions have relatively high returns in which situations.[33]

Under the assumptions in Table 3 any intervention that costs less than \$580 per LBW birth averted in a low-income country is a suitable candidate in terms of a benefit-to-cost ratio greater than one. Rouse (2003) presents a brief review of the cost-effectiveness of interventions to prevent adverse

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[31] With a higher (lower) discount rate, the value of improved estimates would shift somewhat towards events earlier (later) in the life cycle.

[32] See, for example, Merialdi, et al. (2003) for a review of a number of interventions related to LBW that have been undertaken. Also, ACC/SCN (2000) contains a summary of a workshop on LBW held in 1999.

[33] The lack of apparent priorities probably means that advocates of using scarce public resources to alleviate problems related to LBW are much less effective in their advocacy than they might be, and that there is likely to be a lack of agreement regarding how any additional resources should be used even among those who agree that LBW is a major problem that warrants increased public resources.

pregnancy outcomes, including LBW. He indicates that it costs $46 per LBW infant averted with treatments for asymptomatic bacterial infections. In a specific example, based on treating over 2,000 women in Uganda for presumptive sexually transmitted disease, a reduction of 2% of LBW infants was reported (Gray, et al. 2001). As the therapy was reported as costing $2 per treatment, this resulted in an estimate of $100 per LBW averted. This is contrasted with a much smaller intervention targeted to pregnant women in Kenya with a poor obstetric history that reduced LBW by 14%. With drugs costing $2 this is presented as costing $14 per LBW averted. These studies did not report the costs of the delivery system that could identify the high risk women and target the services and the distortionary costs of raising and using public resources for such programs. But that the costs of medicine in these examples are substantially below the expected benefits in Table 3 suggests that these possibilities are promising.

Table 6 summarizes the implied benefit-to-cost ratios for variants on these three interventions with costs of medicine, respectively, of $100, $46 and $14 per LBW birth averted. For each of these costs of medicine there are three alternative multiplicative factors – two, five and ten -- to represent the total costs – e.g., the costs of screening women, staff costs, distortionary costs of obtaining the resources to fund the programs and due to the implementation of the programs. Finally, alternatives for the same six discount rates are presented. While each of the benefit-to-cost ratios for these interventions is subject to a number of strong assumptions, the range of benefit-to-cost ratios in Table 6 are suggestive. At a 5% discount rate, all but one of the benefit-to-cost ratios are greater than one – in many cases, much greater than one. The single exception is for the most expensive intervention in terms of the costs of medicine ($100 per LBW averted) with a multiplicative cost factor of ten. With higher discount rates, of course, the benefit-to-cost ratios decline. This Table suggests that these interventions might have attractive benefit-to-cost ratios for a range of non-medicine costs and discount rates – but certainly not for all reasonable non-medicine costs and discount rates. Therefore it would be valuable to attempt to refine the cost estimates to narrow down the probable estimates.

While there is less evidence on the impact of treatment for helminths on LBW (Steketee, 2003), given the body of information on the costs of delivery mechanisms, it should be possible to convert information on impact evaluations to estimates of costs per LBW birth averted. Similarly, while evidence on the relationship of malaria and LBW points to the strong contribution of malaria to poor birth outcomes and evidence on the feasibility of interventions is being accumulated, the complexity of programs to reduce malaria add to the challenge of assigning a marginal cost to these efforts. For example, the use of treated bed nets is estimated to reduce LBW by 28% in Kenya (Ter Kuile, et al. 2003), with externalities to neighboring villages. The benefit per LBW averted, nevertheless, was modest because the rate of LBW even in the untreated population was less than 10%. Adverse outcomes including small for gestational age and preterm births, however, occurred in 32% of births in the control group and 24% in the treatment group. Generalization of costs per LBW averted is also limited since only one of four previous controlled trials of bed nets – in the Gambia, and then only in the rainy season - had similar results. Even in the study on Kenya, wider inference is limited because overall adherence to the use of the nets was affected by knowledge of the vector (and fears of the insecticide) as well as age, temperature and number of household visitors. Moreover, even after two years, few individuals were willing to pay for the full costs of re-treatment, a condition for full effectiveness of the nets from a private perspective (Alaii, et al. 2003).[34]

[34] Though from a social perspective the use of such nets may be desirable even if individuals are not willing to pay the full marginal resource costs of the nets because there apparently are positive externalties (though not well measured) to the use of such nets.

Micronutrient supplementation may represent a cost effective means of reducing LBW. For example, an extensive field trial in a community in Nepal characterized by both high rates of LBW and of maternal anemia, supplementation with iron and folate was found to reduce LBW significantly (Christian, et al. 2003). Similar marked decreases in LBW were observed with iron supplementation for low income women in the United States (Cogswell, et al. 2003). Additional micronutrients were not found to affect birth weight in this study (though vitamin A has been shown to affect maternal mortality in that environment). The authors found that 11 women would need to be reached to prevent one case of LBW. The program required daily intakes of the supplementation and twice weekly visits by health staff. While no cost data were provided in the published study Christian and West (personal communication) estimated that the experimental costs of $64.3 per pregnant woman reached could be reduced to $13.14 in an ongoing program. Due to economies of scope such a cost would also allow provision of vitamin A at little marginal cost and, thus, might reduce both infant and maternal mortality. We return to micronutrient supplementation below.

Estimating the marginal costs of adverting one LBW birth by means of balanced protein energy supplementation is hampered, in part, by the modest gains reported in the literature (Kramer, 1993). Nevertheless, Merialdi, et al. (2003) claim that this is the one nutritional intervention for which a practical recommendation might be made (p S1626). In a study designed to address criticisms of earlier encouraging (but seasonal) results from the Gambia, Ceesay, et al. (1997) found that the provision of supplements to pregnant women reduced the prevalence of LBW by six percentage points. Concerns explicitly addressed in the design include the complexity and expense of the initial intervention and the need for intense experimental conditions. This was tackled by the use of a simple peanut and flour fortified biscuit baked in village clay ovens, though the protocol of having women consume the biscuits in the presence of birth attendants does set a high standard for full-scale projects. In principle, then, the reported reduction in LBW combined with Table 3 as well as the cost of the intervention could provide a benefit-to-cost ratio; unfortunately, however, costs do not appear to have been published.

Summary: The basic substantive bottom line is that the economic benefits from reducing LBW in low-income countries are fairly substantial, under plausible assumptions including a discount rate of 5%, on the order of magnitude of a PDV of $580 per infant moved from the LBW to non LBW category. This means that there may be a number of interventions that are warranted purely on the grounds of saving resources or increasing productivity. With a 5% discount rate, the gains are primarily estimated to be from increases in labor productivity, in important part through inducing more education, with the gains from avoiding costs due to infant mortality and morbidity together second in importance. If the appropriate discount rate is higher than 5%, then the relative gains would increase for the latter relative to the former. The estimated gains from reducing chronic diseases, a topic of considerable interest in recent years, are much less for any reasonable discount rate simply because the gains – even if large when they occur (e.g., productivity gains and savings in medical costs of 10-15 times annual earnings in our simulations in Tables 3 and 6)-– arise decades after any interventions that might reduce the prevalence of LBW and subsequently of these associated diseases.

Opportunity 2 – Improving Infant and Child Nutrition and Exclusive Breastfeeding Promotion

The nutritional literature emphasizes that undernutrition is most common and severe during periods of greatest vulnerability (Martorell 1997, UNICEF 1998). One such period is *in utero*. Opportunity 1 addresses that period. A second vulnerable period is the first two years or so of life. Young children have high nutritional requirements, in part because they are growing so fast. Unfortunately, the diets commonly offered to young children in developing countries to complement breast milk are of low quality (i.e., they have low energy and nutrient density), and as a result, multiple nutrient deficiencies are common. Young children are also very susceptible to infections because their immune systems are both developmentally immature and compromised by poor nutrition. In poor countries, foods and liquids are often contaminated and are thus key sources of frequent infections which both reduce appetite and increase metabolic demands. Furthermore, in many societies, suboptimal traditional remedies for childhood infections, including withholding of foods and breast milk, are common. Thus infection and malnutrition reinforce each other. The second opportunity that we emphasize is directed towards improving the nutrition of infants and young children.

Opportunity 2 differs from Opportunity 1 more with regard to type of interventions that may be promoted than in potential benefits. To a fair degree the expected gains from improved child nutrition are the same as those for changes in LBW. In both cases, there are immediate benefits in terms of reduced mortality and health care costs as well as subsequent benefits in improved productivity from associated cognitive development and increased stature. Even intergeneration transmission of nutritional shocks in childhood is perceived to be similar to those from LBW. Of the seven categories of benefits listed for Opportunity 1, perhaps the two that differ most from the current opportunity are numbers *2 Reduced neonatal care* and *6 Reduced costs of chronic diseases associated with LBW.* Neonatal care obviously is not relevant for children who are older than the neonatal phase, though childhood nutrition and feeding patterns also are believed to influence subsequent chronic disease. But, as noted in the discussion of Opportunity 1, with a 5% discount rate, these two benefits are only about a tenth of the overall benefit.

Infant and child nutrition is often depicted as the outcome of the combination of appropriate food and health inputs mediated through child care practices. Several implications follow from this observation. First, a number of other Challenge Papers address issues important for the reduction of malnutrition in infant and pre-school children. For example, repeated bouts of diarrhea are associated with growth faltering; thus improvements in water and sanitation are expected to convey benefits in terms of reduced malnutrition. Investments in women's education may also convey benefits in terms of reduced child malnutrition. Second, dietary quality – particularly access to micro-nutrients - is important for nutrition for children in this age group and these are covered under Opportunity three. Third, increasing dietary quality and quantity can be achieved, in part, by investments in agricultural research, the focus of Opportunity four. Fourth, some of the most promising interventions related to infant and child nutrition do not aim to increase the amount of food available or consumed but rather to change how it is provided to the infant. Those are the focus of this discussion.

Breastfeeding promotion and improved knowledge about the timing and composition of weaning foods are examples of this opportunity. The importance of exclusive breastfeeding in low income environments is well established.[35] Horton, et al. (1996) provide a study of the cost effectiveness of breastfeeding promotion in hospital settings in Latin America and find cost per death averted ($133-266 when the norm had been formula feeding in hospitals and $664-1064 when less dangerous practices were

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[35] This is the case despite some confusion in some of the literature about the direction of causality since some sick children will not breastfeed. To some degree, HIV/AIDS complicates this once relatively unambiguous understanding about the benefits of breastfeeding, but the importance of breastfeeding promotion and advice remains valid even if the optimal strategy depends on the costs and availability of substitutes as well as of antiretroviral therapy.

promoted in the hospital)[36] were similar to those for measles immunization and less than for oral rehydration therapy, a widely supported program. In terms of DALYs, the study concluded that the promotion was nearly as cost effective as vitamin A supplementation, one of the most cost effective programs among a wide range in the literature. While the relative risk of mortality – the study does not consider benefits other than reduction of mortality as well as diarrhea morbidity in the first six months of life – differs from those in poorer countries as does the alternative to formula feeding of early weaning with family diets as is common in Asia and Africa, this study provided underpinnings for a key element of child growth promotion strategies. However the study focuses only on the first, and to a limited extent, the third of the benefits that are discussed with regard to Opportunity 1 – which are a little less than a quarter of the overall benefits. In particular, this study ignores the relatively large productivity gains from reduced stunting and increased ability. If the proportional value of these other gains relative to measured mortality and infant/child illness gain are roughly the same for Opportunity 2 as for Opportunity 1, then the benefit-cost ratio with a 5% discount rate is on the order of magnitude of 4.8 and with a discount rate of 3% is on the order of magnitude of 7.35.[37] Thus this is a relatively attractive opportunity.

The results of the Horton, et al. study also feed into the "food versus care" debate. When cash or in-kind transfer programs are linked to attendance in health clinics or supplementary feeding programs, the value gained is arguably as much the services provided at the centers as the food or cash itself. An early review of supplementary feeding programs documented the range of costs in reaching net increment in consumption using inframarginal take home rations due to substitution as well as the high cost and irregular service delivery with on site feeding (Beaton and Ghassemi, 1982). The Integrated Child Care Program in Honduras (Atencion Integral al Ninez-Comunitara), one of the most cost effective community nutrition programs (Fiedler, 2003), has made an explicit decision to avoid reliance on supplementary food. The program aims to improve child care practices at home as well as to provide a simple diagnostic decision tree to identify causes of inadequate child growth. More than three quarters of the total costs – inclusive of the imputed opportunity costs of volunteers, but not of participating mothers – is for preventative rather than curative care. Fielder (2003) estimates that the annual long-term incremental recurrent costs were $4 per child. With initial estimates of more than 50% reduction of moderate and severe malnutrition in a country where malnutrition rates were estimated to be about 40% when the program began (Judith McGuire, personal communication), this is in the neighborhood of $20 per child prevented from becoming malnourished. Even if the program proves half as cost effective, and using only the third through fifth rows of Table 4 and any but the largest discount rates under the maintained assumption that the effects of moving from being undernourished to nourished are the same for infants and young children as those at birth, this type of investment generates a favorable benefit-cost ratio – 9.4 for a discount rate of 5% and 16.2 for a discount rate of 3%.

Other infant and child nutrition programs combine supplementary food with other inputs in ways that do not make it possible to identify the impacts of the individual components of the program, yet are thought to be successful. One example is the well-known Mexican rural anti-poverty human resource investment program, PROGRESA, that provides nutrition and health information to parents in addition to micronutrient supplements for infants and young children and income transfers to poor families. The combination is estimated by Behrman and Hoddinott (2002) to lead to a 1.2% increase in child height (with control for unobserved fixed effects), which in itself is estimated to lead to a 1-3% increase in life time earnings based on the estimates in Thomas and Strauss (1997). Information is not available with

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[36] These values incorporate an adjustment of the reported 100-200 in 1992 $ when the norm had been formula feeding in hospitals and $500-800 when less dangerous practices were promoted in the hospital for changes in the United States' cost of living index between 1992 and 2002.

[37] This estimate is based on the following logic. The costs are comparable to the costs of the least costly alternative and the benefits are assumed as in Table 3 to be about 0.21 of the total benefits (0.14 in the case of a discount rate of 3% as in Table 4), so the benefit to cost ratio is approximately 4.8 (7.35).

which to measure the costs of this intervention on its own (in part because PROGRESA provides a package of benefits), but back-of-the-envelope calculations suggest that the benefit-cost-ratio is likely to be greater than one.[38] For another example, Behrman, Cheng and Todd (2004) estimate a benefit-cost ratio of an early child development program in Bolivia that achieved increases in growth as well as in measures of cognitive development using marginal matching methods to control for selection into the program on unobserved characteristics. Based on their estimated program effects and extrapolating what these changes mean for schooling and subsequent earnings on the basis of studies in the literature (and used in Opportunity 1), they find benefit-cost ratios well above 1 (2.9 for a discount rate of 3%; 1.4 for a discount rate of 5%, even when assuming incremental costs to raising revenue as is done above.[39]

Opportunity 3 – Reducing the Prevalence of Iron Deficiency Anemia and Iodine, Vitamin A and Zinc Deficiencies

<u>Benefits from Reducing Micronutrient Deficiencies</u>

Iodine: The benefits from reducing iodine deficiency are conceptually similar to those from reducing LBW – indeed, an important means of reducing the LBW is to reduce iodine deficiencies in populations in which the prevalence of such deficiencies is high. Both for reducing LBW and reducing iodine deficiency, the main concerns are infant mortality and irreversible impairment of mental capacities which manifest in lower productivity later in life. That is, although iodine is a required nutrient throughout life, most documented consequences of deficiencies are from prenatal and early child deficiencies (Dunn, 2003). This evidence comes from epidemiological studies such as the 13.5 difference in IQ between deficient and normal individuals cited above as well as maternal supplementation studies (reviewed in Grantham-McGregor, Fernald and Sethuraman, 1999b and Black, 2003). The evidence on whether the effects of iodine deficiencies in utero can be reversed or whether supplementation or fortification to children can improve performance is less conclusive than the evidence on interventions before birth; though some recent evidence is encouraging (von den Briel, West, and Bleichrodt, 2000) it is generally recognized that the earlier an iodine deficiency can be addressed the greater the impact.

In addition to its influence on cognitive development iodine deficiencies have been linked to increased child mortality with two randomized trials of intra-muscular injections in extreme iodine deficient areas showing that treatment reduced infant and child mortality by 30% (Rouse, 2003). Similarly, a trial using iodine treated irrigation water reduced infant mortality by half in three villages in China (DeLong et al., 1997). In addition, deficiencies lead to lower birthweight or subsequent weight for age; Mason, et al. (2002) present cross sectional evidence that iodation of salt and or capsule distributions can account for as much as a 40% reduction in LBW.

Because the largest and most assured gains from reducing iodine deficiencies are similar to those for reducing LBW – that is they manifest in terms of birth outcome and cognitive functions – benefits are estimated along the lines discussed with regard to Opportunity 1. In table 9 we assume that infant and child mortality is reduced by 3 percentage points and the average gain in cognitive development in

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[38] Because PROGRESA provides a bundle of benefits – scholarships, nutrient transfers in kind for infants and young children, cash transfers, health and nutrition information – it is not possible to identify with confidence a benefit-to-cost ratio for the in-kind nutrition supplement in itself. As noted in Section 2, moreover, there is some ambiguity about what is the appropriate treatment of in-kind provision of goods and services.

[39] This study counts the costs of meals provided – a significant share of the total costs - as program costs and not as transfers with offsetting benefits. If the food should be counted only as transfers, the benefit-cost ratios would increase. However as noted in Section 2, there is some ambiguity about what is the appropriate treatment of in-kind provision of goods and services.

previously iodine deficient areas is similar to the average gain in preventing a LBW child. As the costs per expressed per woman, we assume five births per woman. For a 5% discount rate if the cost is less than $130 per deficient women reached the benefit-cost ratio is greater than one.

Vitamin A: Prior to the 1980s vitamin A supplementation campaigns were mainly advocated for communities with clinical symptoms indicating risk of blindness. However, in light of meta-analysis of field trials of mass supplementation to children 6 to 59 months of age that indicated an overall reduction in child mortality by 25-35% (Beaton, et al. 1993, Fawzi, et al. 1993) vitamin A promotion is now routine in low income countries. These and subsequent trials were less consistent in the rates of reduction in morbidity with greater reduction in severity than incidence of illness (Villamor and Fawzi, 2000).[40] Impacts on morbidity are also mediated by presence or absence of other deficiencies, for example zinc. As with morbidity, the evidence on vitamin A interventions and growth is mixed with little impact of supplementation on growth of moderately deficient children. Children who are severely malnourished or who also have serious infections, however, may benefit more from supplementation (Rivera, et al., 2003).

While initial evidence on prophylactic supplementation was based on provision to children 6 months or older, targeting of new born children may have as significant an impact on infant mortality with significant impact on infant mortality reported with supplementation as early as the first two days after delivery (Rahmathullah, et al., 2003). Moreover, although current recommendations for post-partum supplementation of mothers are aimed at improving the vitamin A status of the child, one large trial supplementing pregnant women with weekly low doses of vitamin A showed a marked decrease in maternal mortality in Nepal (West, et al., 1999). Additional trials are underway.

In addition to concerns for vitamin A status of young children there are recommended intakes of vitamin A for older children as well as adults. Indeed, supplements are regularly provided to school-age children, for example, in school feeding programs. However, while the cost of this supplementation may be low at the margin, there is little evidence on the economic returns to such programs in terms of reduced clinical costs or increased productivity.

Changes in rates of vitamin A deficiency do not correlate well with changes in mortality. For example, improvements in control of xerophthalmia and, presumably, mortality in Nepal and Bangladesh have not been accompanied by reduction in vitamin A deficiencies using serologic cutoffs (West, 2002). Thus, the estimates of benefits of prophylactic provision of Vitamin A or its precursors used here will be phased in terms of an illustrative benefit of reaching an at risk individual in a program rather than in terms of a reduction in a deficiency *per se*. This approach differs slightly from how we estimate benefits in the case of LBW (measured in terms of LBW prevented). This affects mainly how to interpret the cost per unit of benefit. These benefits are usually thought to be mainly from changes in mortality. While, as mentioned, a commonly mentioned figure for reductions in child mortality is 25-30%, it is also likely that the children missed in any wide-scale program are also likely to have higher than average risk of mortality (and also that the marginal costs of reaching these children are higher than average costs). Hence, we use a conservative 10% reduction in expected mortality. This reduction will be for infant plus child mortality for programs reaching newborns or their mothers and for incremental child mortality (only) for children reached after one year of age. We do not assume any reduction in costs of outpatient or clinic care for survivors. Fielder (2000) reports one case of blindness prevented for every seven deaths averted in the vitamin A prophylactic program in Nepal. This ratio may be higher then elsewhere so we assume a one-to-ten ratio below to estimate the impact on lifetime productivity of reducing blindness.

[40] We concentrate here on benefits from the prophylactic provision of Vitamin A or its precursors. Additional therapeutic benefits have regularly been noted in clinical settings. For example, it is now standard practice to provide Vitamin A to children suffering from measles and to use Vitamin A to treat clinical signs of xerophthalmia.

Table 7 gives estimates of the benefits from reducing mortality and from increasing productivity for different discount rates. The basic assumptions underlying these estimates include that infant and child mortality rates drop by 25% from 0.10 to 0.075 with the drop concentrated among infants, the prevalence of blindness drops by 0.0025, and productivity of a blind person is a third of the average productivity of a person who is not blind.[41] (The assumptions regarding the value of reducing mortality and the life-time path of productivity of a person who is not blind are the same as for Opportunity 1 above.) The estimated benefit with a 5% discount rate is $37, with a fifth of that benefit coming from increased lifetime productivity for persons who are not blind but would have been blind without the intervention. In contrast to LBW, under these assumptions the benefits from the productivity gains over decades of work are relatively small in comparison with benefits from reducing early mortality.

Iron: The estimation of the benefits of reducing iron deficiencies must incorporate the fact that iron deficiency anemia can affect adult worker productivity directly, as discussed in Section 2, as well as through its impairment of child development. We have indicated the gains to iron supplementation in terms of LBW in the discussion of Opportunity 1. Regardless of birthweight, iron deficiency of young children appears to have irreversible consequences on development; Grantham-McGregor, Fernald and Sethuraman (1999b) find inconclusive evidence that subsequent treatment of young children can offset the consequences of earlier deprivation though prophylactic treatment may be beneficial. However, the inconclusive evidence from interventions is, in part, a consequence of ethical considerations that limit long-term interventions. In a review similar to our study, Ross and Horton (2003) find that a half standard deviation reduction in IQ due to iron deficiency anemia is consistent with the overall evidence (indeed, the most detailed long-term intervention they cite implies a one standard deviation diminution).

In addition to reduced cognitive capacity, iron deficiency can also affect schooling and hence future productivity by lowering effort and attendance; Kremer and Miguel (2004) found that treatment for worms reduced primary school absenteeism by 25% in Kenya. Similarly, productivity in adults can be affected by reduced capacity for effort. Based on their review of published studies – and hence they do not include the very recent study of benefits by Thomas, et al. (2004) - Ross and Horton assume this productivity loss is 5% for blue collar workers and 17% for heavy manual labor. They note that this is more lower than other assumed losses reported in the literature.

For our benefit estimates, we assume a 5% across the board loss of labor productivity due to current anemia in addition to the gains already discussed in Opportunity 1 through reducing LBW. This implies a total benefit of $815 with a 5% discount, which is about 30% above the estimate in Table 3 for the benefit through reducing LBW alone. However increased benefits come at increased costs because to obtain these additional ongoing productivity gains, there must be an ongoing flow of interventions over the work life in addition to the one-time intervention working through birthweights.

Zinc. Evidence from meta-analyses indicate that zinc supplementation of young children has an appreciable impact on growth with incremental increases in height or weight averaging over 0.3 standard deviations (Brown, et al.., 2002). Poorer growth at baseline was associated with increased response to treatment. The studies reviewed in this analysis excluded premature or hospitalized children though supplementation to mothers may also reduce LBW. Moreover, one intervention targeted at children born small for gestational age and motivated, in part, by evidence that zinc deficiency is associated with increased infectious disease morbidity indicated that daily supplementation at home reduced infant mortality by 70% (Sazawal, et al., 2001). While zinc deficiencies are not strongly linked with cognitive development (Black, 2003) the results on growth and mortality indicate potential benefits from targeted

[41] We have no basis other than casual observations for this assumption. For the contexts that we are considering in which manual labor is predominant, our intuition is that this is a conservative.

programs. However, trials in the literature do not generally provide experience on delivery mechanisms suitable for large scale interventions (except, perhaps, with multiple fortification). The potential benefits are, nevertheless, important when considering plant breeding for increased bioavailabilty as discussed further in Opportunity 4.

Key Interventions and Costs for Reducing Micronutrient Deficiencies

Broadly speaking, approaches to reducing micronutrient deficiencies can be categorized as either supplementation or food-based. The latter are further divided into fortification of foods commonly consumed and encouragement of increased consumption of micronutrient rich foods either through social marketing or horticulture. Often programs to increase production include social marketing since increased production does not by itself guarantee increased consumption. Successful programs may increase income and shift preferences as well as modify techniques of home food preparation.

The costs of supplements *per se* as well as fortificants are easily documented; the costs of delivery systems as well as their efficacy are somewhat harder to obtain. Unfortunately, it is harder still to derive meaningful costs from the sizable literature on social marketing or horticultural approaches in part because the opportunity costs of, say, home or school gardens are often not considered nor, when costs of any type are provided, is it standard to distinguish start-up from recurrent costs. Few studies that document a significant increase in micronutrient consumption following a food-based intervention assess whether the success is self-replicating or whether recurrent investments are necessary to maintain progress. Proponents of such interventions often indicate that, in addition to impacts on micronutrient status, such projects generate intangible benefits in terms of social capital or empowerment. This potential is not considered in the discussion that follows because we are unaware of persuasive empirical evidence of such possibilities. Finally, it may be possible to reduce micronutrient deficiencies by increasing the bioavailability of nutrients through agronomic research without significantly changing their perceived properties (and, thus, not altering consumer demand) or adding to the cost of production. As the stream of costs and benefits with such approaches differ substantially from other food-based approaches, they are addressed separately below.

These potential micronutrient interventions have both biological synergies and programmatic synergies. For example, utilization of food sources of vitamin A or its precursors is influenced by zinc status as well as the presence of intestinal helminthes (Jalal, et al., 1998) while iron absorption is improved when vitamin C is taken in the same meal. In turn, iron status may complement iodine utilization. Programmatic synergies occur when the delivery system for one micro-nutrient lowers the marginal costs for the provision of others. Home gardens to increase the availability of vitamin A precursors, for instance, also provide other nutrients and the logistics and promotion of dual fortification generates economies of scope.

Costs of Reducing Iodine Deficiencies. The addition of potassium iodine or iodate to table salt is a widespread practice in both developed and developing countries and has been estimated to add no more than US $0.02-0.07 per kilo, roughly 5% of the retail cost of salt (Goh, 2002). Impacts of successful interventions can be rapid and striking; China with an estimated 40% of the world's at risk population more than doubled the percentage of individuals consuming salt with at least 20 parts per million in a five-year period. In that period the share of school children with low iodine status (as measured by urine excretion) was reduced by 75% (Goh, 2002). Madagascar went from no iodated salt in 1992 to 98.3% coverage by 1999 with a corresponding elimination of low urinary iodine in school children.

These impressive programs do not imply that fortification is problem free; industry compliance requires monitoring. Many programs for fortification in Latin America in the 1950s and 1960s failed for this reason (Dunn, 2003). Where quality control is imperfect, reductions in goiter rates are less (Goh, 2002). When iodation is not mandatory, consumers need to be made aware of the benefits from using the more expensive fortified alternative. Moreover, a number of remote areas produce their own salt from mines or lake beds. Thus, an alternative or supplementary approach is to distribute iodated oil capsules or provide intra-muscular injections to pregnant women in high-risk under-served areas.[42] Two trials using the latter approach reduced one child death for every 18 women reached (Rouse, 2003). Capsule distribution to women may be similarly effective where fortified salt is not commonly used although it is redundant or even deleterious where iodine is regularly consumed in salt (Mason, et al., 2002). Indeed, it may be possible to reach new-born children with capsule distribution with up to a 72% reduction in infant mortality (Cobra, et al., 1997). Capsule distribution is relatively expensive, however, compared to fortification and may not be suited to preventing damage to children in the first trimester unless supplements are targeted to women of child-bearing age rather than to pregnant women or new-born children. Oil injections are also more expensive than fortification, although Levin, et al.. (1993. table 19-7) point out that when the five-year protection provided by this intervention is considered it provided benefits of $13.8 discounted 1987 $ for every dollar expenditure on protection. Regular supplementation is also possible and the costs of supplements have been estimated to be comparable to fortification ($0.05 a year, reported in Alnwick, 1998) but this excludes the likely appreciable costs of distribution.

Costs of Reducing Vitamin A Deficiencies. There is over two decades of experience with the provision of prophylactic vitamin A supplementation, little of it available when Levin, et al. (1993) illustrated that the intervention was one of the most cost effective medical interventions, with a benefit cost ratio of 146. With the safety of the dosage confirmed, the cost of screening within an age cohort is not cost effective (Loevinsohn, Sutter and Costales, 1997). Coverage of supplementation has generally been high during national immunization days against polio. It has been estimated that the average cost for reaching a child in such immunization days is about $1 and that the inclusion of vitamin A in such campaigns adds 2-10% to these costs (Goodman, et al. 2000). However, polio campaigns do not provide regular (twice yearly) contact and in many countries these have been concluded. Consequently a more sustainable approach may be to add vitamin A to routine immunization schedules or to conduct child health days or similar camps to provide services outside of routine clinic visits. As coverage in inoculations generally declines with age, targeting during these procedures offers a particularly effective window of opportunity to reach at-risk populations (Ross, 2002). Accordingly, the International Vitamin A Consultative Group recommends that 50,000 international units (IU) of vitamin A be provided at the same time as infant vaccines. The marginal costs of the supplement remain low for services connected with immunization programs; it is more problematic to attribute shares of the costs of community mobilization (including volunteer effort) to any of the various interventions provided. It is also difficult to determine the increased effectiveness of immunizations due to the adjuvant nature of vitamin A

Chung, et al.. (2000) attempt to translate the costs of supplementation in immunization campaigns into a cost per life saved assuming a 23% reduction in mortality when two doses are given annually and half that with one dose.[43] These estimates take into account the coverage rates; as over half the programs in the years studied achieved more than 80% coverage, the coverage rates used are high. The estimates also depend on the child mortality rates of the different countries. Using incremental costs of vitamin A of $0.10 and average costs of distribution of $0.43 they found that the cost per death averted in 1999 was $64 and $294 respectively. While the assumed cost of delivery was constant across countries, costs per death averted varied per country depending on the variables mentioned above; overall, costs per death averted tended to decline as child mortality rates increased. Chung, et al.. also observe that the relatively

[42] DeLong et al. (1997) claim that adding iodine to drinking water or to irrigation is a less expensive alternative than adding it to salt. However, little additional information on the efficacy of this strategy is available.
[43] This is based on Beaton et al. (1993) although they present more recent cases from Vietnam and the Philippines that are consistent with the earlier study.

few countries that have integrated supplement delivery into routine health services have lower rates of coverage than do national immunization campaigns.

Fieldler (2000) reports costs of $1.25 per child receiving two doses in Nepal's national program of distribution through community health workers. He estimates that this program cost $1.7 M but saved 1.5M in costs of reduced incidence of diarrhea and measles under the assumption that it costs $3.12 per disease incidence. Moreover, he estimates that the cost per life saved ranged between $289 and $489 depending on assumptions of coverage. In Uganda it cost $1 to $1.33 per child reached in child health days with a set of services including inoculations, growth monitoring, and vitamin A supplementation (Nutrition and Early Child Development Project, personal communication). In addition, demonstrations, skits, and songs were presented to provide information about child care as well as about food production and income generating possibilities. These costs, however did not include the opportunity cost of time of community volunteers.

While there is evidence that smaller more frequent dosages may be more effective than supplementation at four or six month intervals, this requires a different delivery system than commonly provided with immunizations. Similarly, the recommendation from the International Vitamin A Consultative Group that 400,000 IU be provided to mothers within the first six weeks of delivery implies a distinct intervention from those directly aimed at pre-school children. Likewise, the delivery mechanism for addressing maternal mortality with weekly doses is different than that for providing mega-doses to either mothers or their children and may not provide appreciable economies of scale. On the other hand, the costs of this potential intervention can be easily shared with a program to reduce LBW with regular supplementation of iron. While Rouse (2003) indicates that with reductions of death and costs similar to those observed in the Nepal study cited above would cost $193 per death adverted, it is also acknowledged that this study needs to be replicated. As the benefits from these interventions occur shortly after the costs, there is little sensitivity to assumptions on discount rates.

There also exist a number of promising vehicles for fortification to reduce vitamin A deficiency (Dary and Mora, 2002). Given the role of fat in absorption, cooking oil and margarine are particularly promising, although flour and sugar have been used and MSG piloted.

To our knowledge, only one study has directly compared the costs of supplementation, fortification and promotion of home gardening to prevent vitamin A deficiency in the same program environment (Phillips, et al., 1996). Using various outcome measures in terms of persons or adequacy reached, the study found that sugar fortification was generally less expensive than alternatives for the same outcome in Guatemala. For example, at medium levels of fortification the cost of achieving Vitamin A adequacy for high-risk groups (i.e. women and children) was half as expensive as capsule distribution and one fourth as expensive as encouraging home gardens under various assumptions about the drop out rate following discontinuation of input subsidies.

Fiedler, et al.. (2000) make a similar comparison of the costs of supplementation and a hypothetical fortification of wheat flour in the Philippines in order to ensure intake of at least 70% of recommended levels. They note that the opportunity costs of volunteers constituted 30% of supplementation costs while the capsules themselves comprised only 3% of the costs. They find that it cost roughly twice as much per child year of adequate intake achieved using supplementation as fortification. Their estimate of the full costs of supplementation was approximately $10 per year of adequacy achieved. They also note that the cost per year of adequacy achieved with supplements rises as parallel efforts of fortification increase. They also note that although fortification is more cost effective, it would miss more children than the supplementation program had been able to reach. Implicitly, then, the greater coverage with higher costs points to rising marginal costs of coverage

Some qualifications are needed before generalizing on the relative effectiveness of fortification in these studies. In particular, fortification may be effective in urbanized Latin America or in Asian economies where even rural markets are penetrated by processed foods yet not be as promising in rural Africa. While particular attention has been given to the local dietary role of the food to be supplemented, technical considerations also include the loss or potency during shipping and storage and the potential for discoloration that may reduce consumer acceptance. Moreover, when close substitutes are not fortified, even small increases in costs may not be easily passed on. Fortification programs in both the Philippines and Guatemala have been intermittently halted due to shortages of imported ingredients or the disinterest of producers. Similar marketing issues have prevented programs such as the MSG pilot in the Philippines from being brought to scale. On the other hand, Fielder, et al. (2000) indicate that 10 products marketed in the Philippines were fortified with vitamin A at the time of their study.

Moreover, with a few exceptions such as Muhilal, et al. (1988) and English, et al. (1997), studies that indicate the effectiveness of fortification or other food-based approaches use changes in consumption or changes in serum levels of vitamin A as outcome measures rather than either morbidity or mortality. Using changes in consumption is particularly problematic when assessing the promotion of gardens since plant-based sources, particularly green leafy vegetables, may be less effective for improving vitamin A status than previously assumed (de Pee, Bloem and Kiess, 2000). A review of food-based strategies noted that a number of recent evaluations have shown an impact of strategies to modify cooking and storage or cultivate home gardens on consumption of vitamin A rich foods – generally when linked with social marketing or nutrition education. However, few of these studies measure nutritional status and none reviewed by Ruel were designed to assess changes in morbidity or mortality. Moreover, most studies that focus on changes in intake do not contain information on costs. Pant, et al.. (1996), however, are able compare the effectiveness of nutrition education to mega-dose supplementation in Nepal. They found that both achieved similar reductions in the risk of mortality (by 36% and 43% respectively) although the capsule distribution program was more economical. The education program, however, was more effective at reducing cases of xerophthalmia.

Costs of Reducing Iron Deficiency Anemia. Supplementation to address iron deficiency anemia is more difficult than for iodine or vitamin A deficiency since it is not possible to provide mega-doses. Thus, with the exception of providing supplements to school children or other groups that assemble regularly, a health worker can not easily administer the desired treatment and must rely on patient compliance. Small dose supplements have fewer side effects and greater biological effectiveness when taken regularly but this increases the cost of treatment. However, as mentioned above, costs of regular monitoring of compliance may be less than the benefits when targeting to pregnant women in high density populations of South Asia where rates of both anemia and LBW are high. The evidence cited pertains to child survival but it is likely that similar programs will reduce maternal mortality although prospective studies are limited by ethical considerations as well as sample size requirements (Allen, 2000).

Due to problem of compliance, an intermittent schedule has been recommended, often in terms of weekly instead of daily supplements. Some of these studies have found little difference in efficacy as measured by serological indicators (Beard, 2000, Galloway and McGuire, 1996). However, meta-analysis of 22 trials concluded that weekly doses are less efficacious than daily doses (Beaton and McCabe, 1999). While the authors of this analysis acknowledged that it is not known what the relative cost implications are of designing delivery systems to reach the target groups, they concluded that weekly supplementation was not advised for pregnancy.

There are many vehicles for fortification of iron, either as single nutrients or in combination with others. This includes home based fortification with sachets to be sprinkled on food as well as industrial fortification of flours, rice and salt (Mannar and Gallego, 2002). Horton and Ross (2003) provide an estimate of a benefit-cost ratio using the costs of \$0.12 per capita derived from the early experience of compulsory fortification of corn flour and voluntary fortification of wheat flour in Venezuela and benefits estimated from 10 countries. The median value using productivity gains only was 6.3:1 and 35.7:1 when estimates of increased cognitive development were also included. Unfortunately, while initial survey data in Venezuela following the fortification showed a halving of anemia, rates returned to pre-fortification levels in subsequent years (Garcia-Casal and Layrisse, 2002). This may, perhaps, reflect declining economic conditions but no confirmation is available. Using a different set of assumption and programs to extrapolate from probably increases in hemoglobin to work productivity, Levin, et al. (1993) estimated that fortification could provide a benefit ratio of 84 and supplementation could achieve a ratio of 25.

Promotion of home gardening is not generally promoted as a strategy to reduce iron deficiency anemia; although iron absorption is enhanced when vitamin C is taken at the same meal, overall iron absorption from plant sources is low. Other food-based strategies include increased frequency of consumption of animal-based foods and changes in food preparation. An example is the provision of iron cooking pots in Ethiopia. A pilot trial found that the provision of pots (costing about $3 per pot) was less costly than providing supplements to the same population for a year (Ruel, 2001). No toxicity was noted.

In addition to supplementation and fortification, the mass provision of deworming medicine may affect anemia. Miguel and Kremer (2004) found that it cost $3.50 to increase school participation one child year via deworming of children in Kenya, presumably partially mediated through reduced anemia (though this was not assessed). Similarly, a combined program of deworming and supplementation was found to increase pre-school participation in Delhi. Using a range of plausible assumptions this was extrapolated to the estimated impact on earnings with an additional $29 expected for a cost of $1.70 per child (Bobonis, Miguel, and Sharma 2003). A similar intervention - a combination of deworming and daily supplementation - was found to improve motor and language development of preschool children in Zanzibar (Stolzfus, et al.. 2001).

It is possible that iron supplementation to non-anemic populations can have detrimental impact for women with reasonable iron stores, these risks are relatively small compared to the potential benefits (Allen, 2000). An additional potential cost recognized in the literature is the risk of increased infection. However, a recent meta-analysis of supplementation trials failed to find a significantly elevated risk of overall incidence of infections in children (Gera and Sachdev, 2002).

Summary of Benefits/Costs for Reducing Micronutrient Deficiencies

The available evidence suggests that the benefit-to-cost ratios may considerably exceed one for best practices for reducing micronutrient deficiencies related to iron deficiency anemia and iodine and vitamin A deficiencies in a number of developing country contexts. Such potentials are limited, of course, to areas in which the prevalence of such deficiencies is relatively high due to natural conditions and past market and policy developments.

Opportunity 4 – Investment in Technology in Developing Country Agriculture

Definition and description of opportunity: Approximately 798 million people are considered hungry. Further, inadequate access to food – both in terms of macro and micronutrients – is associated with malnutrition amongst children and adults. Technological improvements in developing country agriculture may have important effects on reducing hunger and malnutrition. In this opportunity, we focus on technological change embodied in improved cultivars - improved genetic material in seeds that permits increased grain yield; higher levels of micro-nutrients; greater responsiveness to other inputs such as fertilizer or water; reduced need for complementary inputs such as pesticides and herbicides; greater tolerance to pests, droughts or other stresses; shorter maturity times; improved post-harvest qualities (e.g. greater resistance to disease or pests when stored) and improved taste. A broader definition of technological improvements would add to this improved agronomic practices such as integrated pest management whereby pests are controlled through crop rotation and the careful use of natural predators and the use of trees for shade, green fertilizer and nitrogen fixation in soils; and improvements in complementary inputs such as fertilizers and pesticides (Kerr and Kolavalli, 1999).

How does this opportunity partially solve the challenge: From Malthus (1817) to the early 1980s, hunger was seen as a consequence of inadequate food production, or increases in production in a world characterized by rapidly growing population. However, the last 25 years, have seen a recasting of the problem of world hunger in terms of access or “entitlement” to food. Formalized most famously by Sen (1981, 1999), hunger results when resources of individuals and households – reflecting the assets they hold and the returns on those assets - are inadequate to acquire sufficient food conditional on prices.

Investing in research, in technological improvements to developing country agriculture provides the opportunity to reduce hunger and malnutrition through four channels: increasing net returns on assets – land and labor – by farm households in areas where hunger is endemic; increasing labor demand in rural areas, thereby increasing the incomes of landless laborers; reducing the costs of food which benefits net food consumers in both rural and urban areas; and by improving access to micronutrients.

Increasing net returns on assets – land and labor – by farm households in areas where hunger is endemic. There is overwhelming evidence, surveyed in Kerr and Kolavalli (1999), Lipton with Longhurst (1989) and Runge, Senauer, Pardey and Rosegrant (2003) that improved cultivars have been associated with dramatic increases in yields. It is important to note, however, that technological change in agriculture extends well beyond the development and dissemination of hybrid varieties of rice and wheat that became known as the Green Revolution. Byerlee (1996) cited in Kerr and Kolavalli (1999) notes that most farmers have replaced their varieties at least twice since the introduction of high yielding rice and wheat in the late 1960s. These second generation modern varieties contribute yield gains of about 1% annually. Whether these increases in yields lead to increases in incomes, particularly among poor households, is less clear-cut. The answer depends on the pattern of adoption over time, the ability to obtain and use complementary inputs such as water and fertilizer, as well as changes in input and output prices. In turn, these are affected by market and institutional arrangements such as access to credit and market structure.

Increasing labor demand in rural areas, thereby increasing the incomes of landless laborers. Improved cultivars have the potential to increase the demand for labor through several channels. Increased yields imply that additional labor is needed for harvesting and processing. The prospect of higher yields may also encourage farmers to weed more intensively which also increases labor demand as does the introduction of short-duration varieties that make it possible to increase the number of crops planted and harvested over a given period and cultivars with increased drought-resistance that allows food to be grown in more marginal areas. Incomes, particularly those of landless laborers, will rise if wages increase, if the amount of employment rises or if both occur. The increase in wages and employment depends critically on the elasticity of labor supply. In the short run, wages will rise if labor supply is highly inelastic and employment will rise if labor supply is highly elastic. In the longer run, labor supply may become more elastic if higher wages induce in-migration and labor demand may fall, or grow less rapidly, if labor costs rise relative to labor-substituting inputs such as machinery. While it is possible that increased profitability as well as the time demands of multiple cropping may encourage mechanization, the bulk of the evidence indicates that in much of South and East Asia, the introduction of improved cultivars increased wages and employment in Bangladesh, India, Nepal, Pakistan, the Philippines and Thailand, though the effects were uneven within and across these countries (Abler, et al. 1994, Anderson, et al. 1988, Alauddin and Tisdell, 1986, David and Otsuka, 1994, Goldman and Smith, 1995, Pinstrup-Andersen and Hazell, 1985)

Reducing the costs of food that benefit net food consumers in both rural and urban areas. Increases in output can lead to reductions in food prices thus benefiting net food consumers in both rural and urban areas. Even modest price changes can generate significant welfare gains where food purchases, especially staples, comprise a large share of household budgets. The magnitude of the price fall will depend on the price elasticity of demand, the existence and extent of price controls on food, and the extent to which local food markets are integrated into regional, national and global food markets. It will also be affected by changes in demand brought about by population and income growth. Again, there is considerable evidence from Asia (Bangladesh, India, the Philippines) that food prices have gradually declined as higher yielding cultivars have spread (Byerlee and Moha, 1993, Quizon and Binswanger, 1986, Warr and Coxhead, 1993). In China, Fan, Fang and Zhang (2001) estimate that investment in agricultural research led to higher output and, in turn lowered food prices that account for 30% of the reduction in urban poverty between 1992 and 1998. In India, expenditures on agricultural research are associated with higher outputs and higher outputs are associated with a reduction in food prices, with an elasticity of 0.23. In turn, a ten% decline in food prices is associated with a reduction in urban poverty of 3.5% (Fan, 2002).

Improving access to micronutrients. As explained in Section 2 and in Opportunity 3, micro-nutrient deficiencies are costly. Traditionally, such deficiencies have been addressed via efforts to diversify diets and through the fortification of foods during processing. However, plant breeding work undertaken in the last ten years– using both conventional crop-breeding and biotechnology – shows that it is possible to breed rice and wheat plants that are more dense in iron, zinc and Vitamin A.

There are several possible constraints that would prevent such an approach – commonly refereed to as biofortification – from being successful. First, farmers might be reluctant to adopt such varieties if they compromised yields or incomes. Second, consumers might not be willing to eat such foods. And third, micro-nutrient intakes might not be increased very much (Bouis, 2002). With respect to the first question, Graham, Welch and Bouis (2001) and Welch's (2002) reviews suggest that these nutritionally enhanced cultivars are more resistant to disease and environmental stress. Their roots extend more deeply into the soil, by tapping more subsoil moisture and nutrients, they are more drought resistant and require less irrigation. Their roots release chemical compounds that unbind trace minerals present in most soils and thus they require less chemical inputs. Lastly, nutritionally enhanced seeds produce seedlings with higher survival rates and more rapid initial growth (Bouis, 2002).

Regarding consumer preferences, in the case of iron and zinc, mineral micronutrients comprise less than 10 parts per million in milled rice, so it is unlikely that such amounts will affect the taste, appearance or texture of rice or wheat in a manner that affects consumer demand. However, this may not be the case for vitamin A; higher levels of beta-carotene turn light colored varieties of rice to dark yellow, producing "Golden Rice". Consumers also may resist golden rice since it is a product of genetic modification through gene splicing. However, in many cases, nutritional enhancement can be achieved through conventional crop breeding.

Research on the third question is ongoing. Preliminary results from Bangladesh, however, suggest that a 50% increase in iron intakes derived from fortified rice would reduce anemia by as much as 6% (Bhargava, Bouis and Schrimshaw, 2001) and that Golden rice would increase provitamin A by 79 – 90% in women and pre-school children (Bouis, 2002a).

<u>Economic estimates of the benefits and costs</u>: There are a number of specific issues associated with assessing the benefits and costs associated with improved agricultural technologies. First, there is the issue of the appropriate assessment of costs. As a general guide, it takes about 7-10 years to develop a new variety with reliably improved attributes along some dimensions. But as Runge et al. (2003, p. 85) point out, "New crops not only carry forward the genes of earlier varieties, they also carry the crop

breeding and selection strategies of earlier breeders." It is not always clear whether measured costs include the marginal costs of the development of a particular variety or some combination of marginal and fixed costs such as those associated with basic R & D. Second, there is no guarantee that crop breeding will be successful, so there is a legitimate question as to whether discount rates should include a risk premium. Third, estimated returns will be sensitive to assumptions regarding demand and supply elasticities, whether markets are open or closed to trade, whether prices are endogenous or exogenous, whether environmental effects are included, and the unit of analysis, (e.g. local or regional assessments) may omit spillover effects into other regions or to other commodities (Alston, et al., 2000). Fourth, two-thirds of estimates of rates of return on technological investments in developing country agriculture that have been produced since 1958, and 80% of those published since 1990 are found in the "gray literature" rather than as formal journal articles. Gray literature estimates could potentially be lower than those found in journal articles if "publication bias" discourages the publication of "non-results" or may be more error-prone if they are dominated by work that was not considered sufficiently rigorous for journal articles.

Alston, et al. (2000) provide the most comprehensive survey of returns to investments in agricultural R & D. The average estimated social rate of return (SRR) across the 1700-odd studies they considered is high, 79.3%, but there is significant variation around this mean. The median estimated social rate of return is approximately 44%. This can be translated into a benefit-cost (BC) ratio by noting that SRR ≈ BC(i) where i is the discount rate (Alston, et al., 2000). Under this formula, the benefit-cost ratio is 14.7 using a 3% discount rate and 8.8 using a 5% discount rate[44]. Median estimated rates of return by geographical region are: 34.3% in sub-Saharan Africa, 49.5% in Asia and the Pacific and 42.9% in Latin America and the Caribbean. They also undertake a meta-analysis to determine whether these estimates are sensitive to characteristics of the research or the researchers. These suggest that rates of return have not declined over time nor do they appear sensitive to the inclusion of spillover effects or market distortions. However, reported results do appear to be sensitive to a number of characteristics: specifically, they are lower when a longer gestational period for research is assumed or specified, when the principal researcher is based at a university or when the results are published in a non-refereed publication.

There are a number of additional reasons to be cautious about these estimates. First, there are important issues relating to the assumed distributions over time of both costs and benefits. While some attention is paid to the distribution over time of benefits,[45] it is not always clear how costs are distributed across time. Given the nature of discounting, assuming that costs are spread-out evenly as opposed to being largely "up-front" can significantly increase the benefit-to-cost ratio. Second, a number of studies appear to estimate benefits based on data taken from experimental plots. Actual increases in farm yields may be lower, especially where water control is imperfect and where there are difficulties obtaining inputs on a timely basis – characteristics that apply especially in much of sub-Saharan Africa. Third, while assumptions are often stated about the extent of adoption, it is less clear whether the distributions of adopters – particularly by farm management skills – are taken into account. Bourdillon, et al. (2003) illustrate this in their analysis of the impact of new maize hybrids introduced in Zimbabwe in the mid-1990s. Unconditional comparisons of means suggested that adopters enjoyed considerable gains in gross incomes, on the order of 50%. However, when controls for household characteristics were included as well as taking into account the endogeneity of the adoption decision, the increase in gross incomes was considerably less, on the order of 10%.

[44] Note that this approximation assumes that benefits flow in perpertuity; relaxing this assumption will lower the estimated benefit-cost ratio.

[45] In particular, new varieties breakdown over time. For example, Byerlee (1993) notes that mutation of rust pathogens means that new varieties of hybrid wheat typically have a life span of seven years before they need to be replaced.

Lest these caveats appear too negative, we again note the core reasons for including investment in agricultural technologies as one of our opportunities. In our view, these represent the single most effective means of increasing incomes of those groups across and within developing countries who suffer from hunger. While these caveats suggest that returns may not be as high as is sometimes claimed, they are likely to be sufficiently high to justify increased public investment.

Because improved cultivars that are more dense in iron, zinc and Vitamin A are still being developed, there are no *ex post* assessments of rates of return to these investments. There are, however, a number of *ex ante* assessments. In addition to being somewhat speculative, these assessments of benefits depend critically on three assumptions. The first relates to the increase in micro-nutrient density within these improved cultivars. The second relates to coverage or take-up amongst those with micro-nutrient deficiencies. Take-up could be relatively high, but if it is concentrated amongst populations where deficiencies are limited or non-existent, they will have little impact. The third relates to bioavailability or bioconversion – the ability of the human body to use the micro-nutrients found in these improved grains. Even if density within the grains is greatly increased and even if take-up amongst affected populations is high, impact will be minimal if these micronutrients are not bioavailable.

Bouis (2002a, 2002b) provides estimates of the benefit-to-cost ratios of the dissemination of iron and zinc dense varieties of rice and wheat in India and Bangladesh. He assumes a 25-year time period. There are no benefits in the first 10 years, only costs associated with plant breeding and dissemination. Using a 3% discount rate, and incorporating an allowance for maintenance costs over the following 15 years, the present value of these costs is estimated at $35.9 million. Benefits accrue from years 11 to 25. Conservatively, it is assumed that these improved varieties are adopted on only 10% of the area devoted to rice and wheat, and that they reduce anemia rates by only 3%, averting 44 million cases of anemia annually. The present discounted lifetime value of a case of anemia averted is $27.50, as calculated by Horton and Ross (2003). Using these assumptions, the total present value of nutrition benefits is $694 million, giving a benefit-to-cost ratio of 19 or an internal rate of return of 29%.[46] In addition to using conservative assumptions and omitting the beneficial impact of higher zinc intake or on individuals who increase iron intake but remain anemic, these calculations omit the fact that these iron and zinc dense varieties produce higher yields. Table 8 shows the impact on benefit-to-cost ratios of relaxing these assumptions.

Zimmerman and Qaim (2003) provide *ex ante* benefit-to-cost ratios for the dissemination of Golden Rice in the Philippines. They ignore the costs of the basic research undertaken on these varieties, focusing only on the marginal costs associated with adapting, testing and disseminating these biofortified rice varieties in the Philippines over a seven-year period. They take into account the need for public information campaigns to encourage consumers to eat this new rice and also assume that there will be recurrent costs for maintenance research and monitoring. Using the cost figures they provide, the present discounted value of these costs over a 25-year period with a 3% discount rate is $9.5 million. They only consider benefits to three target groups: pre-school children, pregnant women and lactating mothers. These are calculated in terms of averted disability adjusted life years from reduced mortality, and reduced incidence of temporary or permanent disability resulting from blindness. Each DALY is assumed to carry an opportunity cost of current per capita income, $1030.[47] A variety of scenarios are presented. Assuming benefits occur in years 8 to 25, under the "pessimistic scenario", a 25% coverage rate, low density of beta-carotene (1.6 μG/G), processing loss of beta-carotene of 25 percent, and poor bioconversion, Golden

46 Bouis only presents estimates for a discount rate of 3%. Under the assumption that the benefits are distributed evenly over the 11-25 year period, with a discount rate of 5% the benefit-cost ratio of 11.6.

47 As noted above, these gains probably would be reduced considerably if each DALY were evaluated at the least-cost alternative of obtaining a DALY.

Rice produces a present discounted value of $135.8 million. The benefit-to-cost ratio is 14.3.[48] Under the optimistic scenario, with 100% coverage, higher density of beta-carotene (3.0 μG/G), no losses of beta-carotene during processing and better bioconversion, Golden Rice produces a present discounted value of $753.9 million and a benefit-to-cost ratio of 79.3.

4. Conclusions

Reducing hunger and malnutrition, endemic in many parts of developing world, is intrinsically important. But so too are many of the other challenges considered at this conference. Our focus here has been on the *economic* case for investing in activities that reduce hunger and malnutrition. We have focused on four opportunities

- Reducing the Prevalence of Low Birthweight
- Infant and Child Nutrition and Exclusive Breastfeeding Promotion
- Reducing the Prevalence of Iron Deficiency Anemia and Vitamin A, Iodine and Zinc Deficiencies
- Investment in Technology in Developing Country Agriculture

While the opportunities described here represent our current view of the most promising approaches several other opportunities, in part covered by other Challenge Papers, have important implications for reducing hunger and malnutrition in that successes in these other challenges will affect nutrition and, conversely improvements in nutrition will influence the other challenges. For example:

- Women's education and status. Numerous studies show strong correlations between maternal education and reductions in undernutrition amongst pre-school children. While some of this work is subject to caveats (for example, maternal education may be correlated with unobserved family background characteristics), progress on the challenge relating to lack of education is likely to produce benefits in terms of reduced malnutrition.

- Addressing infectious diseases such as malaria and the HIV/AIDS pandemic. For example, HIV/AIDs increases hunger and malnutrition directly by reducing the income and food security of affected households and by interfering with the intergenerational transmittal of agricultural and other productive skills. In addition, young orphans and children with chronically ill caregivers risk higher rates of malnutrition. HIV also imposes a dilemma in assessing the increased risks of breastfeeding against the risks of not breastfeeding. Conversely, nutrition affects HIV/AIDS since nutritional status is a major factor influencing a person's risk of infection. Well-nourished HIV positive individuals live longer; and respond more positively to treatment. Moreover, the efficacy of certain anti-retroviral drugs is diminished when they are not taken on a full stomach. (ACC/SCN, 2003; Castleman, et al., 2003; and Stillwaggon, 2002).

- Improving infrastructure to reduce possibilities of famine or chronic hunger. Famines and chronic undernutrition typically currently do not reflect food shortages in the aggregate so much as inadequate access to food for poorer segments of the population – either due to short-run shocks or chronic conditions. Inadequate food access, in turn, reflects limited purchasing power in the short-run or longer-run, often exacerbated by food price shocks in partially segmented markets. Communication and transportation infrastructure investments can serves to lessen localized prices shocks that may be an important factor in famines, and may lead to increased growth and therefore lessened chronic undernutrition.

[48] These estimates only use a 3% discount rate. Again assuming that the benefits are distributed evenly over the 8-25 year period, a 5% discount rate produces a benefit-cost ratio of 8.5

- Effective improvements in water and sanitation lead to reductions in diarrhea. As noted in Opportunity 2, repeated diarrheal infections are correlated with growth faltering, particularly for children less than three years of age.

- Trade barriers impose considerable costs on developing countries. The majority of hungry and malnourished people in developing countries are poor. The majority of poor people in developing countries live in rural areas and depend directly or indirectly on agriculture for their livelihoods. Changes in the returns to agriculture in developing countries, thus, may have a major impact on hunger and malnutrition in developing countries through affecting the income of the poor and through affecting the prices that the poor pay for basic staples and other foods. These changes, in turn, may have impacts throughout the lifecycle, from conception onwards, since changes in the resources that households have and the prices that they face may trigger nutritional changes over the lifecycle with effects such as are reviewed in the last part of Section 2.

In the four opportunities that we have enumerated to directly address hunger and malnutrition - subject to the caveats we enumerate - there are a range of considerable benefits from: resource saving arising from reduced mortality; resource saving arising from reduced morbidity; direct links between nutrition and physical productivity; and indirect links between nutrition, cognitive development, schooling and productivity. While we have drawn upon recent evidence of project impacts and costs we note that our main conclusions about the high returns to investing in nutrition and in agricultural technology repeat general observations that have been made earlier in the literature and yet, to a fair degree, the potential investments remain to remain under-resourced.

As summarized in Table 9, the estimates discussed in Section 3 suggest considerable possible gains to be had in investing in these opportunities, in the sense of benefit-to-cost ratios exceeding one or relatively high internal rates of return to investing in programs or policies to reduce hunger and malnutrition – in addition to the intrinsic welfare gains to the individuals who would be effected directly by reduced hunger and malnutrition.[49] The gains appear to be particularly large for reducing micronutrient deficiencies in populations in which prevalences are high. Moreover, the people who are likely to benefit from these interventions tend to be relatively poor, so such investments are likely to have important gains in terms of the objective of reducing poverty as well as in terms of increasing productivity. Finally, while the available studies generally do not distinguish well between private and social rates of returns to these interventions, on the basis of limited studies and casual observations it would appear that there are important aspects of the potential gains that are social beyond the private gains due to externalities related to contagious diseases and to education – so there is likely to be a case for the use of some public resources for such interventions on efficiency grounds in addition to the case on poverty alleviation grounds.

[49] As is discussed in Sections 2 and 3, however, there are considerable qualifications that must be made with regard to these estimates. That in many cases the benefit-cost ratios exceed one by a fair amount, moreover, suggests that there may be a high payoff to understanding better what is causing many of the estimates to be so large. If these large values are not artifacts of the estimation procedures, then such values suggest substantial market and/or policy failures or disequilibria in order that private maximizing behaviors have not driven them to values close to one. Identifying what are the relevant market and policy failures would be informative about what policy changes are likely to be high in the efficiency policy hierarchy.

Table 1: Measures of hunger and malnutrition		
Indicator	**Interpretation**	**Most common means of reporting**
	1: Measures of hunger	
Proportion of undernourished persons in a population	An indicator of inadequate food availability, access or intake. Reducing this is a Millennium Development Goal indicator.	Percentage of individuals with food availability, access or intake of food below some threshold.
	2: Anthropometric measures of malnutrition	
Prevalence of LBW	An indicator of intrauterine growth retardation resulting from short maternal stature, poor maternal nutrition before or during pregnancy, infection and smoking.	Percentage of children with birthweights below 2500 grams
Prevalence of low height-for-age (stunting)	Children's skeletal (linear*)* growth compromised due to constraints to one or more of nutrition, health, or mother-infant interactions. This is an indicator of chronic nutritional deprivation.	Expressed as a z score or as the percentage of individuals stunted. Z scores are calculated by standardizing an individual's height-given-age and sex against an international standard of well nourished people.[a] Individuals with z scores below –2 are classified as stunted; with z scores below –3 are classified as severely stunted.
Prevalence of low weight-for-height (wasting)	People suffer thinness resulting from energy deficit and/or disease-induced poor appetite, malabsorption, or loss of nutrients. This is an indicator of transitory nutritional deprivation.	Expressed as a z score or as the percentage of individuals wasted. Z scores are calculated by standardizing an individual's weight-given-height and sex against an international standard of well nourished individuals.[a] Individuals with z scores below –2 are classified as wasted; with z scores below –3 are classified as severely wasted.
Prevalence of low weight-for-age (underweight)	This is a composite measure of nutritional status, reflecting both chronic and transitory nutritional deprivation. This is a Millennium Development Goal indicator.	Expressed as a z score or as the percentage of individuals underweight. Z scores are calculated by standardizing an individual's weight-given-age and sex against an international standard of well nourished individuals.[a] Those with z scores below –2 are classified as underweight; with z scores below –3 as severely underweight.
Prevalence of low body mass index in adults or adolescents	Adults suffer thinness as a result of inadequate energy intake, an uncompensated increase in physical activity, or (severe) illness.	Expressed as Body Mass Index (BMI). BMI is calculated by dividing weight in kilograms by the square of height in meters. Individuals are considered to be chronically energy deficient if they have a BMI below18.5, overweight if they have a BMI greater than 25, and obese if they have a BMI greater than 30.
	3: Measures of micro-nutrient deficiency	
Prevalence of iodine deficiency	Iodine deficiency results from low intake of iodine in the diet.	Expressed by clinical inspection of enlarged thyroids or in terms of iodine concentrations in urine (μg/L). The benchmark for the elimination of iodine deficiency is to have less than 20% of the population with levels below 50 μg/L
Prevalence of low hemoglobin (anemia) in preschool, school-age children, nonlactating or nonpregnant women.	Children suffer from anemia, either as a result of low iron intakes or poor absorption, or as a result of illness. Severe protein-energy malnutrition and vitamin B12/folate deficiency can also lead to anemia. Women suffer from anemia as a result of low iron intakes, poor absorption, illness, or excessive losses of blood. Severe protein-energy malnutrition and vitamin B12/folate deficiency can also lead to anemia. Anemia is rare in adult men except in cases of extreme iron-deficient diets.	Expressed as grams of hemoglobin per liter of blood. Cutoffs to define anemia are 110 g/L for children 6-59 months, 115 g/L for children 5-11 years and 120 g/L for children 12-14 years. Cutoffs to define anemia are 120 g/L for nonpregnant women, 110 for pregnant women and 130 for adult men.

Prevalence of vitamin A deficiency	Vitamin A deficiency results from low intake of animal products containing high amounts of absorbable retinal or plant products high in beta-carotene. Diarrhoea, fevers and some infections can interfere with the absorption or Vitamin A or utilization of retinal.	Clinical deficiency is estimated by combining night blindness and eye changes – principally Bitot's spots to form a total xerophthalmia prevalence. Subclinical deficiency is assessed as prevalence of serum retinal concentrations below 0.70µmol/L.

Source: ACC/SCN (2000a), Alderman, Behrman and Hoddinott (2004), Allen and Gillespie (2001), Gibson (1990), Millennium Task Force on Hunger (2003) and Morris (2001).

[a] A z score of -1 indicates that given age and sex, the person's characteristic (e.g., height, weight-for-height, weight) is one standard deviation below the median person in that age/sex group

Table 2. Present Discounted Value (PDV) of $1000 Gained Different Years in the Future with Different Discount Rates

Years in Future	Annual Discount Rate					
	1%	2%	3%	5%	10%	20%
5	$951.47	$905.73	$862.61	$783.53	$620.92	$401.88
10	$905.29	$820.35	$744.09	$613.91	$385.54	$161.51
20	$819.54	$672.97	$553.68	$376.89	$148.64	$26.08
30	$741.92	$552.07	$411.99	$231.38	$57.31	$4.21
40	$671.65	$452.89	$306.56	$142.05	$22.09	$0.68
50	$608.04	$371.53	$228.11	$87.20	$8.52	$0.11
60	$550.45	$304.78	$169.73	$53.54	$3.28	$0.02

Table 3. Base Estimates of Present Discounted Values (PDV) of Seven Major Classes of Benefits of Shifting one LBW Infant to non-LBW Status, with 5% Discount Rate

	PDV	% of Column
1. Reduced infant mortality	$92.86	16%
2. Reduced neonatal care	$41.80	7%
3. Reduced costs of infant/child illness	$38.10	7%
4. Productivity gain from reduced stunting	$99.34	17%
5. Productivity gain from increased ability	$239.31	41%
6. Reduction in costs of chronic diseases	$23.29	4%
7. Intergenerational benefits	45.12	8%
Sum of PDV of seven benefits	$579.82	100%

Source: Alderman and Behrman (2003, Table 2).

Table 4. Estimates of Present Discounted Values (PDV) of Seven Major Classes of Benefits of Shifting one LBW Infant to non-LBW Status, with Different Discount Rates

	Annual Discount Rate					
	1%	2%	3%	5%	10%	20%
1. Reduced infant mortality	$96.53	$95.59	$94.66	$92.86	$88.64	$81.25
2. Reduced neonatal care	$41.80	$41.80	$41.80	$41.80	$41.80	$41.80
3. Reduced costs of infant/child illness	$39.60	$39.22	$38.83	$38.10	$36.36	$33.33
4. Productivity gain from reduced stunting	$351.46	$249.20	$180.17	$99.34	$28.61	$4.28
5. Productivity gain from increased ability	$846.71	$600.35	$434.06	$239.31	$68.91	$10.32
6. Reduction in costs of chronic diseases	$239.45	$132.58	$73.83	$23.29	$1.43	$0.01
7. Intergenerational benefits	421.99	219.53	122.26	45.12	7.61	0.84
Sum of PDV of seven benefits	$2,037.54	$1,378.27	$985.61	$579.82	$273.36	$171.83
Sum as % of that for 5%	351%	238%	170%	100%	47%	30%

Source: Alderman and Behrman (2003, Table 3).

Table 5. Impact of Increasing One-at-a-time Each Benefit by 50% Relative to Table 2, with 5% Discount Rate

	1	2	3	4	5	6	7
1. Reduced infant mortality	**$139.29**	$92.86	$92.86	$92.86	$92.86	$92.86	$92.86
2. Reduced neonatal care	$41.80	**$62.70**	$41.80	$41.80	$41.80	$41.80	$41.80
3. Reduced costs of infant/child illness	$38.10	$38.10	**$57.15**	$38.10	$38.10	$38.10	$38.10
4. Productivity gain from reduced stunting	$99.34	$99.34	$99.34	**$149.01**	$99.34	$99.34	$99.34
5. Productivity gain from increased ability	$239.31	$239.31	$239.31	$239.31	**$358.97**	$239.31	$239.31
6. Reduction in costs of chronic diseases	$23.29	$23.29	$23.29	$23.29	$23.29	**$34.93**	$23.29
7. Intergenerational benefits	45.12	45.12	45.12	45.12	45.12	45.12	**$67.68**
Sum of all seven benefits	$626.25	$600.72	$598.87	$629.49	$699.48	$591.46	$602.38
Sum relative to that in Table 2	108%	104%	103%	109%	121%	102%	104%

Source: Alderman and Behrman (2003, Table 5).

Table 6. Estimates of Benefit-to-Cost Ratios for Alternative Costs for Three Different Treatments to Move LBW Infant to non-LBW Status, with Different Discount Rates[a]

	Annual Discount Rate					
	1%	2%	3%	5%	10%	20%
$100*cost factor of two	10.19	6.89	4.93	2.90	1.37	0.86
$46*cost factor of two	22.15	14.98	10.71	6.30	2.97	1.87
$14*cost factor of two	72.77	49.22	35.20	20.71	9.76	6.14
$100*cost factor of five	4.08	2.76	1.97	1.16	0.55	0.34
$46*cost factor of five	8.86	5.99	4.29	2.52	1.19	0.75
$14*cost factor of five	29.11	19.69	14.08	8.28	3.91	2.45
$100*cost factor of ten	2.04	1.38	0.99	0.58	0.27	0.17
$46*cost factor of ten	4.43	3.00	2.14	1.26	0.59	0.37
$14*cost factor of ten	14.55	9.84	7.04	4.14	1.95	1.23

[a] The three different treatments are described in the text. The costs provided from the studies cited there (i.e., $100, $46, $14) are the estimated direct costs of medicine per LBW birth averted. The multiplicative cost factors (2, 5, 10) used in this Table are illustrative possibilities for the direct staff and non-medicinal material costs of screening and administering these medicines, the direct bureaucratic costs of running the programs, and the distortionary costs of raising revenues to run these programs and of implementing these programs.
Source: Alderman and Behrman (2003, Table 6).

Table 7. Estimates of Present Discounted Values (PDV) of Two Classes of Benefits of Vitamin A Intervention, with Different Discount Rates

	Annual Discount Rate					
	1%	2%	3%	5%	10%	20%
1. Reduced mortality	$40.94	$30.64	$30.34	$29.76	$28.41	$26.04
2. Productivity gain due to reduced blindness	$26.63	$18.88	$13.65	$7.53	$2.17	$0.32
Sum of PDV of these two benefits	$67.57	$49.52	$43.99	$37.29	$30.58	$26.36

Source: See text.

Table 8: Simulated Discounted Costs And Benefits Of Iron And Zinc Dense Rice For India And Bangladesh Assuming 3% Discount Rate				
	Variety adoption rate			
	10%		20%	
	Anemia reduction rate			
	3%	8%	3%	8%
Total costs	35.9	35.9	43.7	43.7
Total nutrition benefits	694.2	1851.2	1388.4	3702.4
Total agricultural benefits	2142.7	2142.7	4285.3	4285.3
Nutrition benefits/ costs	19.3	51.5	31.8	84.7
(Nutrition + agricultural) benefits/costs	79.0	109.6	129.8	182.8
Notes: All monetary amounts are in $ million. Source: Bouis (2002b)				

Table 9. Summary of Benefits and Costs for Opportunities Related to Hunger and Malnutrition[a]

Opportunities and targeted populations	Benefits	Costs	Benefits/ Costs	Discount Rates	Other Remarks
1. Reducing LBW for pregnancies with high probabilities LBW (particularly in S. Asia)					
1a. Treatments for women with asymptomatic bacterial infections	$580-986	$200-2000	0.58-4.93	3-5%	
1b. Treatment for women with presumptive STD	$580-986	$92-460	1.26-10.71	3-5%	
1c. Drugs for pregnant women with poor obstretic history	$580-986	$28-280	4.14-35.20	3-5%	
2. Improving infant and child nutrition in populations with high prevalence of child malnutrition (fairly widespread in poor populations in developing countries)					
2a. Breastfeeding promotion in hospitals in which norm has been promotion of use of infant formula	$131-134	$133-1064	4.80-7.35	3-5%	
2b. Integrated child care programs	$376-653	$40	9.4-16.2	3-5%	
2c. Intensive pre-school program with considerable nutrition for poor families			1.4-2.9	3-5%	
3. Reducing micro nutrient deficiencies in populations in which they are prevalent					b
3a. Iodine (per woman of child bearing age)	$75-130	$0.25-5.0	15-520	3-5%	c
3b vitamin A (pre child under six years)	$37-43	$1-10	4.3-43	3-5%	
3c. Iron (per capita)	$44-50	$0.25	176-200	3-5%	
3d Iron (pregnant women)	$82-140	$10-13.4	6.1-14	3-5%	c
4. Investment in technology in developing agriculture					
4a. Dissemination of new cultivars with higher yield potential			8.8 – 14.7	3-5%	
4b. Dissemination of iron and zinc dense rice and wheat varieties			11.6- 19	3-5%	
4c. Dissemination of Vitamin A dense rice, "Golden Rice"			8.5 - 14	3-5%	

[a] These estimates are based on extensive assumptions that are discussed in the text and in the underlying studies, are subject to considerable uncertainties, and cannot be understood without reference to those discussions. The estimates are all of total (private plus social) benefits relative to total (private plus social) costs -- and therefore do not provide information about the differences between social and private benefit-to-cost ratios (or rates of returns) that would be necessary to assess the efficiency case for public subsidies.

[b] Under Opportunity 3 on micronutrients we assume fortification Is not targeted but that supplements are.

[c] Benefits and costs in Opportunity 1 are in terms of LBW prevented while Opportunities 3a and 3d are per woman, though both interventions result in more favorable birth outcomes.

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