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 global 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).