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Health, Nutrition and Population (HNP) Discussion Paper

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Health, Nutrition and Population (HNP) Discussion Paper

ESTIMATED ECONOMIC BENEFITS OF REDUCING LOW BIRTH WEIGHT IN LOW-INCOME COUNTRIES

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Abstract: Low birth weight (LBW) is a major contributor to infant mortality. Beyond that, reducing low birth weight could result in appreciable economic benefits. The present paper considers the potential benefits from reducing low birth weight in seven distinct categories: *1. Reduced infant mortality; 2. Reduced neonatal care; 3. Reduced costs of infant/child illness; 4. Productivity gain from reduced stunting; 5. Productivity gain from increased ability; 6. Reduction in costs of chronic diseases; 7. Intergenerational benefits.*

The paper reviews the evidence on the link between LBW and health outcomes and economic productivity. The overall benefits depend both on the economic environment and the manner in which future streams of income are discounted. Thus, the sensitivities of the overall estimates to different discount rates and to different assumptions about each of the component estimates are explored. Under plausible assumptions for low income countries, the economic benefits from reducing LBW are fairly substantial, on the order of magnitude of about $580 per infant moved from the LBW to non LBW category.   Varying the assumptions used will affect the total as well as the relative share of the seven categories, but under most assumptions the benefits far exceed the costs of known interventions.

Keywords: low birth weight, economic impact, cost analysis, nutrition

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Table of Contents

FOREWORD

Infant mortality is a key indicator for the fourth goal in the set of Millennium Development Goal (MDGs), that measure progress made in reducing poverty (MDG #4: reduce child mortality by two-thirds between 1990 and 2015). Infant mortality rate (IMR), a measure of child survival, is considered to be one of the strongest indicators of a country's well being, as it reflects social, economic and environmental conditions in which children (and others in society) live, including their health care.

This paper addresses a very important contributor to IMR, namely low birth weight (LBW), which experiences an inverse association with development. It reviews the evidence on the link between LBW, and health outcomes and economic productivity. To achieve the fourth MDG we must address the challenge of reducing LBW as an integral part of poverty reduction efforts. This will not only address child mortality, but it will also improve child morbidity, whose
consequences are often tragic, far-reaching and expensive. The authors therefore, present a
timely, and comprehensive examination of the ramifications of reducing LBW. Specifically, this paper considers the present discount values (PDV) of the expected economic benefits from seven major classes of benefits, including reduced infant mortality, reduced infant and child illness and chronic illness costs, productivity gains, and intergenerational benefits, that might be expected from shifting infants from LBW to non-LBW status. The bottom line is that the economic benefits from reducing LBW are fairly substantial: under plausible assumptions, about $580 per infant moved from the LBW to non-LBW category in a low-income context. This means that there may be a number of interventions to reduce LBW that are warranted purely on the grounds of saving resources or increasing productivity.

This paper is an exciting contribution to the Discussion Paper series and supports the Bank's work with its clients trying to achieve significant and measurable improvements in people's lives. With its appeal to a wide-reaching audience, since the findings touch many areas of development work from perinatal outcomes to education, disability and social protection, it is hoped further
discussion and research will be stimulated.

We welcome readers' comments.
Alexander S. Preker
Chief Editor, HNP Publications
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EXECUTIVE SUMMARY

Each year over 22 million infants are born with low birth weight (LBW) in developing countries, with an inverse association between the proportion of infants with LBW and economic development. Many of these LBW infants die at young ages, contributing significantly to neonatal mortality, which now makes up the largest proportion of infant mortality in many developing countries. 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 educational, economic, and other activities. LBW may also be important in light of new evidence that shows that LBW infants 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.

For all these reasons, LBW appears to have serious ramifications for national development and for health expenditures. This paper seeks to provide estimates of the potential economic gains from reducing LBW under a range of alternative assumptions. Estimates are made of the present discounted values (PDV) of expected economic benefits from seven major classes of benefits that might be expected from shifting one infant from LBW to non-LBW status:

1. Reduced infant mortality
2. Reduced neonatal care
3. Reduced costs of infant/child illness
4. Productivity gain from reduced stunting
5. Productivity gain from increased ability
6. Reduction in costs of chronic diseases
7. Intergenerational benefits

The PDVs of these benefits are estimated because it matters how soon a benefit is obtained since gains that are reaped soon can be reinvested to obtain further gains. This is not possible for some time for gains that are obtained only decades in the future. Base estimates are made for each of these seven classes of gains using the best estimates that could be found in the literature and a 5% real discount rate. The sensitivities of the overall estimates to different discount rates, and to different assumptions about each of the component estimates are explored.

The basic substantive bottom line is that *the economic benefits from reducing LBW are fairly substantial, under plausible assumptions on the order of magnitude of about $580 per infant moved from the LBW to non LBW category in a low-income context. This means that there may be a number of interventions to reduce LBW that are warranted purely on the grounds of saving resources or increasing productivity.* The estimated gains are primarily from increases in labor productivity, partially through inducing more education, with the gains from avoiding costs due to infant mortality and morbidity second in importance. If the appropriate discount rate is higher than 5%, then the relative gains would increase for the latter in comparison to the former. In contrast, 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 in current terms when they occur – are obtained decades after any resource-using interventions that might reduce the prevalence of LBW.

The bottom line with regard to research needs is that, though such estimates are suggestive, there is much that is known only poorly at best. There would be gains to improving estimates of the individual benefits, particularly those that are relatively large for reasonable discount rates (i.e., those related directly to productivity and to early life-cycle benefits), and of the discount rates themselves. There also would be gains from considering the nuances of the impact of continuous changes in birth weight rather than just the standard dichotomy of LBW (i.e., below 2500 grams) or not (2500 grams+). There probably would be even greater gains in understanding the implications for possible policies of improving information on the true resource costs – and not merely the governmental budgetary costs – of the many different interventions that have been suggested to lower the prevalence of LBW.

I. INTRODUCTION

Each year over 22 million infants are born with low birth weight (LBW, infants born weighing less than 2500 grams), in developing countries (Ceesay et al., 1997), with an inverse association between the proportion of infants with LBW and economic development.

Many of these LBW infants die at young ages, contributing significantly to neonatal mortality, which now makes up the largest proportion of infant mortality in many developing countries. Unfortunately, it is difficult to track trends in rates of low birth weight since they are partially masked by changes in the numbers of births in clinical settings (Ramakhrisnan, 2004). In some countries, these rates have been falling with the general improvement in economic conditions and the health of mothers. In others, however, rates have remained relatively static in the last several 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 educational, 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.

For all these reasons LBW appears to have serious ramifications for economic growth and for health expenditures. There have been several recent international meetings that have emphasized the possible importance of interventions to reduce LBW - the International Low Birth Weight (LBW) Symposium and Workshop held at the International Center for Diarrhoeal Disease Research in Bangladesh (ICDDR,B) in June 1999, the Technical Consultation on Low Birth Weight (jointly organized by the United States Department of Agriculture, the World Bank, and UNICEF) held in March 2000 at UNICEF in New York and the First World Congress on "The Fetal Origins of Adult Diseases" (sponsored by *The British Medical Journal*) held February 2001 in Mumbai, India, as well as the follow-up Second World Congress in 2003 in Manchester, England. However, the case for interventions related to LBW and the rationale for deciding among such interventions are often not as clear as would be desirable, and thus proponents of programs to reduce LBW are less effective than they might be. One major reason for this lack of clarity is that, for both the impacts of many interventions related to LBW and the impacts of LBW, knowledge of the magnitudes of effects is very limited. The current study seeks to contribute to this literature by providing estimates of the potential economic gains from reducing LBW under a range of alternative assumptions.[1]

II. CAUSES OF LBW AND ITS ECONOMIC IMPACTS

A. CAUSES OF LBW

Prematurity and Intrauterine Growth Retardation (IUGR) are the two main causes of LBW, with IUGR relatively important in developing countries and prematurity relatively more important in developed countries (e.g., Villar and Belizán 1982). Proximate determinants of prematurity may include multiple births, stress, anxiety and other psychological factors, high maternal blood pressure, acute infections and hard physical work (e.g., Kramer 1998). However, in many cases the causes of prematurity are unknown.

Proximate determinants of IUGR include abnormally small or blocked placenta and factors in the maternal environment that prevent normal circulation across the placenta and thus cause poor nutrient and oxygen supplies to the fetus. Maternal undernutrition, anemia, malaria, and acute and chronic infections (e.g., STDs, urinary tract infections) all contribute to this risk (Verhoeff et al. 2001). IUGR is also associated with first births, genetic, fetal or chromosomal anomalies, maternal disorders such as renal diseases and hypertension, cigarette smoking, pre-eclampsia, and possibly alcohol and drug consumption (e.g., Kramer 1998, Prada and Tsang 1998, Henriksen 1999).[2]

The most important risk factors for IUGR in developed countries are cigarette smoking and pre-eclampsia (and the effects of alcohol and drug consumption are probably also relatively high risk factors in such countries). In contrast, the most important risk factors for IUGR in developing countries include malaria in endemic areas and other infectious diseases, as well as, poor maternal nutritional status. This status is indicated by short maternal stature, low pre-pregnancy body mass index, and low gestational weight gain reflecting the mother's childhood nutrition as well as current malnutrition. Evidence for the role of nutritional deprivation comes from myriad sources including studies of the 1945 Dutch Famine (Stein, et al., 1975), as well as inference from randomized supplementation (Ceesay, et al. 1997, Lechtig and Klein 1980) and comparisons across identical twins (Behrman and Rosenzweig 2003).

In addition to the impact of energy deprivation during the third trimester, micronutrient deprivation can affect birth outcomes. This may be through the impact of micronutrient deficiencies on gestation via iron deficiency anemia (Allen and Gillespie 2001), as well as by the contribution of folic acid to neurological development in early pregnancy (Susser, Hoek and Brown 1998, Czeizel and Dudas 1992) and via the impact of iodine deficiency on overall child development (Allen and Gillespie 2001). There is also an association between zinc and birth outcomes, although the results from clinical trials are mixed (Caulfield, et al. 1998).

B. ECONOMIC IMPACTS OF LBW

The impacts of LBW may occur at various stages of the life cycle. It is useful to distinguish among three broad stages:

Neonatal period and infancy:
LBW is associated with higher morbidity and mortality (including stillborns as well as postpartum mortality), impaired immune functions, and poorer cognitive development. There are important differences

between IUGR and preterm LBW babies in the extent to which they tend to catch up in terms of child growth.[3] IUGR babies tend to catch-up partially during the first one or two years of their life, and then maintain that place somewhat below the means in anthropometric distributions as children and adults (averaging about 5 cm shorter and 5 kilograms lighter as adults). Preterm LBW babies who survive tend to catch-up gradually with non-LBW babies. Wherever possible this review attempts to focus more on IUGR than prematurity. However, given that the latter is more prevalent in developed countries where research have established long term data bases, we occasionally need to infer from outside our preferred focus.

From an economic perspective, LBW incurs two main costs in infancy. First, there are the costs associated with early death. In addition, there are the costs associated with additional medical care required. In developed countries the *additional* costs for the survivors can be substantial. For example, 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. In a similar vein, Lightwood, Phibbs, and Glanz (1999) calculate the excess direct medical costs due to low birth weight in the United States attributed to one cause - maternal smoking - to be $263 M in 1995. (See also, Boyle, et al. 1983, Petrou, et al. 2001).

For the most part, these costs differ according to the medical system, markets and policies of a country. These costs may be far less in low-income countries where the majority of births occur outside a clinical setting. On the other hand, these lower medical costs associated with LBW come at the expense of higher mortality and higher consequences for the survivors.

Childhood:

To the degree that children who have had pre-natal nutritional deprivation are smaller than their peers, they risk many of the consequences that are noted for children with malnutrition in early life.[4] In particular, stunted 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. These associations appear to reflect significant and substantial effects in poor populations even when statistical methods such as instrumental variables are used to control for the behavioral determinants of pre-school malnutrition.[5]

It is not always possible to determine whether the impact of stunting is a consequence of stature *per se* – in some societies size, as much as birth date, determines the time of school initiation – as opposed to associated problems with brain development or immunological impairment. Nevertheless, an appreciable literature has documented the association of birth weight and cognitive development, and interactive behavior or both (Grantham-McGregor, Fernald and Sethuraman 1999).

Some of the evidence for impaired school performance has focused on children with extremely low birth weights or very low birth weights (Saigal, et al. 2000, Hack, et al. 2002). Children in such circumstances may not be expected to survive in the immediate peri-natal environment of many low-income countries. However, there is substantial evidence that the relationship between birth weight and cognitive function carries into the range of normal weights as well as the range of low birth weights with a fair survival potential (Aylward, et al. 1989, Richards, et al. 2001, Matte, et al. 2001).[6] Even if, as Richards, et al. (2001) observe, this association between birth weight and cognitive ability partially attenuates over time (they followed a cohort for 43 years), the significant differences in function at age eight are strongly associated with educational attainment.

Some of the most detailed meta-analyses of cognitive function over time have been restricted to pre-term low birth weight children (Ment, et al. 2003, Bhutta, et al. 2002). This group may be different from term children that are small for gestational age, the category that forms the majority of cases of low birth weight in low-income countries. Another relevant difference is the economic conditions that survivors face. Despite the absence of a consensus on how much improvement there is in cognitive function, many studies show that cognitive dysfunctions are moderated by social and economic factors (Aylward 2003, Ment, et al. 2003).[7] This underscores the call by Grantham-McGregor, Fernald and Sethuraman (1999) for more studies of LBW in environments not conducive to countervailing investments, such as the low-income developing countries of interest in this paper.

As with health investments in infancy, increasing investments in education can mitigate a share of the long-term consequences of LBW on survivors. For example, nearly 10% of the costs estimated by Lewit, et al. (1995) are attributed to higher requirements for special education as well as increased grade repetition. Such requirements for special education or for social services are substantial in developed countries (Petrou, et al. 2001). In the absence of an educational system that can recognize and accommodate the individual needs of students, however, these costs are not observed much as up-front costs during childhood but as costs of reduced productivity in adulthood.

There is also evidence that LBW children require additional outpatient care and hospitalization during their childhood (Corman and Chaikind 1993, Stevenson, et al. 1996, Victora, et al. 1999). Part, but not all, of this is mediated by lower rates of breastfeeding noted among LBW children. Regardless of the pathway to increased morbidity, this has direct resource costs in terms of health care services as well as lost employment or schooling for the care givers. Among older children, increased morbidity also contributes to increased school absenteeism that may, in turn, influence subsequent achievement.

Adulthood:
There are at least three important types of possible effects of LBW on adult outcomes.

First, as with children with LBW, adults who were born small are likely to have their earnings and productivity lowered due to lower cognitive achievement or stature. The overall relationship between stature and productivity is well documented (Behrman 1993, Strauss and Thomas 1998). Similarly, the relationship between cognitive development and overall school achievement - as well as attainment of years of schooling - has also been shown in numerous studies (Alderman, et al. 1996, Boissiere, Knight, and Sabot 1985, Cawley, Heckman and Vytlacil 2001).

While there are a few studies of earnings that have followed LBW children into adulthood, most of these studies have limited data available to distinguish the direct impact of LBW from confounding variables. For example, Jefferis, Power and Hertzman (2002) find that birth weight over a normal range influences grade completion with an additional kilo leading to an increase of 0.17 on a scale from 0-5 (higher than A level). Adding additional variables for social class at birth or parental education improves the fit of the model markedly, but has little influence on the magnitude of the birth weight coefficient (see also Richards, et al. 2001, Sorensen, et al. 1997). Although the majority of studies of the impact of LBW do control for some measure of socio-economic class it can be argued that such variables are not the only, or the most, suitable controls for confounding factors. Some studies have provided a control for genetic or environmental conditions that may have contributed to the initial birth weight by taking advantage of the

fact that differences in weights over samples that were measured as part of a randomized evaluation of an intervention.

Behrman and Rosenzweig (2003) take another approach. They study a sample of adult monozygotic (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 low birth weight 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). This may reflect post-natal choices on investments (with fewer investments for children with greater birth weight), or a negative correlation of health and ability endowments. Similarly, Conley and Bennett (2000) find that family fixed effects models using siblings (not necessarily twins) indicate a much larger negative relation between low birth weight and the probability of completing high school than found in cross sectional models.

Second, fetal undernutrition at critical periods *in utero* 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. This hypothesis is bolstered by studies that track low birth weight 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 low birth weight – had a greater risk of diabetes (Ravelli, et al 1998). The fact that some consequences may not be observed until the affected individuals reached middle age is an important consideration for interpreting the range of evidence being assembled. There are few panels that follow cohorts this far and extrapolation from shorter panels or from less affluent cohorts with different life histories.

The evidence for the fetal origins hypothesis is still being assessed. At least two other explanations for the association between LBW and adult diseases have been offered. For example LBW may be an indicator of poor socioeconomic status. The 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 nutritional interventions.

There is an additional aspect of the hypothesis of subsequent costs stemming from biological adaptation to deprivation in utero that has a bearing on the estimation of the consequences of LBW. The implications of the hypothesis 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). High rates of diabetes among Native Americans or Ethiopian immigrants to Israel, for example, seem to be an indirect effect of removal from an environment for which certain genes may once have been adaptive.

5

<u>Third</u>, LBW may have long-term consequences through the transmittal of the nutritional shock to the next generation. To the degree that there is a higher probability of stunted mothers having LBW children the range of biological and economic consequences is perpetuated. This has been indicated, for example, in the follow-up to an intervention for pregnant women in Guatemala in the 1970s (Ramakrishnan, et al. 1999). Behrman and Rosenzweig (2003), however, find that for the United States, the apparent relationship between the birth weight of a woman and that of her child in cross sectional estimates does not hold when twins are used to control for shared genetic and other endowments, suggesting that the nutrients received by mothers when they were in the womb are not correlated with their children's birth weights even though correlated endowments across generations result in correlated birth weights across generations.

C. APPROACH OF THE CURRENT ANALYSIS

The objective of this paper is to use the imperfect information that is available to undertake an economic assessment of the benefits from reducing LBW. This study is expected to help clarify the economic case for increasing the use of public resources for reducing LBW in developing countries. We recognize that not all returns are economic, but clarifying what the economic returns are will facilitate making comparisons among alternatives and help clarify how large the non-economic returns must be in order to change priorities indicated by the economic returns.

We first briefly discuss aspects of measuring the economic benefits for interventions that might reduce LBW. We then turn to empirical information about the benefits from reducing low birth weight. We finally present some simulations of the combined benefits of reducing LBW and how sensitive they are to alternative assumptions.

Considerations in Measuring Economic Benefits of Reducing LBW:
The benefits must include all impacts of a project/policy that lowered LBW valued at the prices that reflect the true marginal resource costs of those benefits. Several components of this statement merit elaboration

1) Many projects/policies that reduce LBW have multiple possible benefits. It is important that all are included so that the benefits are not undervalued. However, this may be difficult.

2) Benefits may be directly positive in the sense that reduced LBW would increase some desirable outcome such as schooling attainment, cognitive skills or labor market productivity – or they may take the form of reducing some costs, such as medical care costs associated with LBW.

3) For each benefit, the causal contribution of LBW must be assessed. Generally this is difficult because of standard estimation problems such as inappropriately attributing the effects of correlated factors to the program or policy of interest.[8] For example, if LBW and being born into a poor family are positively correlated and both have negative effects on schooling attainment, the failure to control for family background when assessing the impact of LBW on schooling attainment is likely to cause the impact of LBW on schooling attainment to be overestimated.

4) If the impacts are not estimated in direct monetary terms, they must be translated into monetary terms appropriate for the context under consideration so they can be summed across all the

6

benefits to obtain the total benefits. This may be difficult because there may not be prices with which to evaluate various benefits or the prices that are available do not reflect the true relevant marginal resource costs either because of market imperfections or because the available prices are for a different context (e.g., a different type country).[9] If prices are not available or very distorted, an alternative is to use the resource cost of the cheapest alternative means of attaining the same objective (Knowles and Behrman 2003).[10] It may be difficult, however, to know what is the resource cost of the cheapest alternative to attain the same particular impact, in part because many programs/policies have multiple impacts.

5) Clearly one of the most inherently controversial steps in aggregating benefits is the question how to value a reduction in mortality. One approach that appears in the literature is to value a life in accord with the expected discounted lifetime earnings of that individual. This is flawed, in part because it does not net out the costs of educating that individual or his or her consumption. More vexing is the fact that this approach values the life of an individual roughly in proportion to the productivity of the society in which he or she is born. The alternative used here does not attempt to put a figure on the value of a life but only to put a figure on the expected savings of resources. That is, we estimate the savings in reducing mortality in terms of the costs of other investments undertaken to reduce mortality (Summers 1992, 1994). The approach we use, however, is sufficiently transparent to allow one to alter this assumption and readily assess how the overall estimated returns would be affected.

6) The impacts are likely to occur over time, with different time paths for the impacts from alternative programs and policies. Therefore to make benefits comparable across programs/policies, the present discounted values of benefits usually are used. In such calculations there is recognition that "time is money" and that it is better to obtain a given monetary impact sooner rather than later because if it is obtained sooner, then it can be reinvested and further productive returns gained. This means, for example, that it is much better to have a benefit from LBW that occurs quickly (e.g., reduced neonatal medical costs) than one of equal monetary value that occurs late in the life cycle decades later (e.g., reduced probability of cardiovascular disease or diabetes in the latter stages of life). Table 1 gives some illustrations of how the PDV of $1000 received at some future date varies substantially (the range in this table is from $0.02 to $951.47) depending on (i) how long in the future is the impact and (ii) what is the appropriate discount rate. If the discount rate is 10% (what often is claimed to be a conservative estimate of the marginal rate of return to schooling), the PDV of a $1000 impact 20 years hence (e.g, the value of improving maternal health for women in the early third of their childbearing years) is only about $150, and the PDV of an $1000 impact 60 years hence (e.g., reducing the probabilities of cardiovascular diseases in later stages of life) is only a little over $3.00. If the discount rate is 5%, the PDVs are substantially higher - $377 and $54, respectively – but still much less than if the impact were to occur sooner.

7) The standard evaluation of benefits does not distinguish the benefits according to who receives them. The benefits are valued the same, whether the recipients are the very rich or the very poor. The standard measures, thus, may address the efficiency/productivity motive for policies, but not distributional motives. In some cases, therefore, efforts have been made to attach distributional weights to the benefits (e.g., weigh ones received by poorer members of society more heavily).

Alternatively and more frequently, distributional weights are implicitly imposed by attempting to target particular populations through the nature of the policy. For example priority may be given to a problem that is prevalent largely among the poor. Given that LBW is more concentrated among poorer families, policies/programs that address LBW tend to have implicit pro-poor weights in this sense.

D. EMPIRICAL EVIDENCE ON BENEFITS FROM REDUCING LBW

The existing relevant information on these benefits is not only from the nutrition, epidemiological and biomedical literatures, but also from the socioeconomic and demographic literatures. Because information regarding many aspects of these processes is imperfect, the paper provides simulations under alternative assumptions to see how robust the estimates are to changing some of the critical assumptions. The paper focuses on low-income developing countries and the nature of LBW in such countries. That is, we consider the price and resource cost structures that are typical of low-income developing countries However, we do not attempt at making the estimates specific to any country or group of countries. We discuss how the results can be extrapolated to other price and resource environments. To the degree that the data allow any distinction – concentrate more on the impact of IUGR than prematurity. Finally, we focus the discussion on the reduction of LBW mainly in terms of crossing a threshold of 2500 grams, although many of the benefits carry over a continuum and only at relatively high levels are there additional costs from increasing birth weight.

As noted above, accounting for the timing of the benefits is critical. Any benefits in terms of changes in neonatal mortality are relatively immediate, and these are likely to be more important in developing countries than in more developed countries. On the other hand, many low-income countries are not able to make much investments in post-partum medical attention or in special education for children whose cognitive development has been affected by LBW. Thus, many of the identifiable benefits beyond reducing neonatal mortality from reducing childhood investment costs due to low LBW in developed countries may occur as improved productivity and health later in life in developing countries. For such reasons, we require appropriate discounting to account for the lags between initial cause and subsequent impacts. As a base case we use an assumed discount rate of 5%, but because of uncertainty regarding what discount rate is appropriate, we subsequently ascertain whether the conclusions are sensitive to assumed discount rates. Table 2 summarizes the PDV of the following seven different benefits of changing one infant from LBW to non LBW status for a discount rate of 5%. The total benefits of changing many infants from LBW to non-LBW status, of course, would be a multiple of these estimates depending on how many infants are so affected.[11]

1. Reducing infant mortality:
The probability of infant mortality is estimated to be significantly higher for LBW than for non-LBW infants. Using data on fraternal and identical twins, Conley, Strully and Bennett (2003) conclude that intra-uterine resources 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 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 the rate. This review also located three studies from low-income countries that look at relative risk of mortality in the first 11 months from all cases using a dichotomous low birth weight variable (including children with less than 2 kgs birth weight) but restricting to term births. These studies showed an elevated risk of infant mortality between 1.7 and 2.6.

These risk ratios translate 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.[12]

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.[13] Summers (1992) suggests that World Bank estimates of the cost of saving a life through measles immunization was 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. This benefit is obtained within a year or so of the assumed intervention occurring possibly when the LBW baby is in the womb. Thus, we 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 2).

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. In principal, a similar up-front cost due to increase utilization of health care in early childhood can be estimated.

We have been unable to find any recent journal articles indicating the average length of neonatal stay for LBW children compared to normal weights in low-income countries. As an initial estimate based on experience in Bangladesh we assume that duration of hospitalization for normal weight baby with normal delivery is 1-2 days and for LBW babies (between 1500-25 grams) it is 5-7 days. For very LBW babies (below 1500 grams) the length of stay is 7-10 days.[14] Using the 2,000 Taka per day at private hospitals inclusive of medicine as the opportunity cost of care (government 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.[15] 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 extend hospital stay is $15, the resource cost for longer hospitalization for a LBW baby is $209, which we assume is incurred close enough to the intervention that there is no discounting (i.e., the discounting is for much less than a year). 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 our base estimates in row 2 of Table 2, therefore, we assume that 90% of the babies are born at home and the additional resource costs for those LBW babies are only 10% of those born in hospitals.[16] Conservatively, we do not consider the incremental costs of home care in the neonatal period. As is illustrated below, the methodology we employ allows this – or any other component of the estimated benefits - to be varied to accommodate different conditions.

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 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. The former was only observed for IUGR children while the latter was observed for these children as well as for LBW due to prematurity. 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 we have not been able to find estimates of the resource costs of such illnesses and related medical care. From some household surveys such as some of the LSMS, it is possible to obtain estimates of out-of-pocket costs. But these are likely to be substantial understatements of the resource costs because in most developing economies the costs of medical care are 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 our basic estimates, therefore, we guess that the additional total direct resource costs for such illnesses of LBW infants are $40, centered at the end of one year (Table 2, 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.[17] A second component comes from the fact that stature also affects the timing and amount of school attended (see Alderman, Hoddinott, and Kinsey 2002, and the references in that study).

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 (2003) 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) 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. While the Brazilian study is particularly 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. Indeed, height is even a significant explanatory variable for wages in the United States (Strauss and Thomas 1998). Nevertheless, the direct impact of height on wages is likely less than the impact of schooling on wages over plausible ranges for each,[18] even if the indirect effect of height on wages mediated by the relationship between height and schooling in included.

In a study that distinguishes the impact of stunting from other socioeconomic conditions that persist in households prone to nutritional deprivation, Alderman, Hoddinott, and Kinsey (2002) find that a childhood shock that led to 0.63 Z score decline in height in Zimbabwe had a causal impact of 0.4 years less achieved schooling and a 3.7 month delay in initiating enrolment, as well as a lasting influence on height. The direct effects on schooling 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.

We use these results – most of which, are admittedly about stunting in general and not necessarily that due to LBW – to infer in our 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 we 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 2).

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) reports 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, must be done with a set of caveats. In particular, the two studies mentioned above investigate children whose birth weights reflect pre-maturity while, as mentioned, most of the results we draw upon focus on IUGR. 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. (2001) 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, we must then estimate the impact on subsequent earnings. While a number of studies of wage or earning determination recognize the role of various measures of cognitive ability on earnings, the majority of these studies are concerned with removing the bias on estimated returns to schooling if intelligence – which partially determines both wage and schooling investments - is not controlled for. Other studies consider ability in the context of how it enhances returns to schooling and, thus, concentrate on the second cross derivative of earnings with respect to schooling and ability. A number of studies that include ability in wage equations focus on the amount of variance explained – or more accurately, on that left unexplained. For our purposes, we need to estimate the magnitude of the wage response to differences in ability but we do not need to assess the degree to which ability, or any cluster of variables that account for different dimensions of cognitive ability, dominates the set of factors that influence earnings.

Altonji and Dunn (1996) provide one such estimate of the impact of IQ on earning, 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.[19] 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 ('g' in the literature) decline by a third when schooling is included in the model. For our purposes, the net impact of ability is both the direct impact on wages and the impact that works thought schooling choices.[20] 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 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.[21]

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. Taken these pathways into account, a half standard deviation decline in ability would lead to a decline in wages of 8 and 5% respectively.[22] 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 in their study lead 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. Selowsky and Taylor (1973) used IQ impairment in childhood attributed to malnutrition to estimate the transmittal of this impairment to adult IQ and wages. Their results imply that a one half standard deviation in child IQ leads to reduced earnings between 3 and 5%.[23] Although they found that lower IQ reduced the years of schooling, their estimated model has no indirect effect on wages via this decreased schooling because they did not find a significant effect of years of schooling on wages.

An alternative approach that combines the fourth and fifth components of the seven benefits that we consider is to look directly at the earnings of individuals as a function of their birth 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, we can compare 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. The fact that this approach is distinct from the studies used above helps narrow the plausible range of impact.

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[24]. 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 test ranged from 0.13 to 0.37 standard deviations in follow-up measurement 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 in 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 (2003), 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, we can bracket the consequences on earnings of an infant moving from LBW to non-LBW as between 5 and 10% per year.[25] We use 7.5% for our basic estimates, which – given our 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. We again assume annual earnings or productivity of $500 in constant prices for a working life from age 15 through age 60 (row 5, Table 2).

6. Reduced costs of chronic diseases associated with LBW:
There has been considerable attention in recent years to these possible impacts of LBW. Given the heterogeneity of the chronic illnesses associated with fetal malnutrition it is difficult to assign costs to this array of diseases. Moreover, 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 may make. We also do not know how many children born small for gestational age will survive to ages at which chronic diseases are likely.

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- PHK). Their estimates consider the cost of diet-related chronic disease to two economies – China and Sri Lanka. For the former, all diet related factors were estimated as accounting for costs totaling 2.1% of GNP in 1995. For the latter these costs were estimates to be 0.3%. In both countries the costs were projected to rise appreciable over the next generation, though the share of these costs attributable to LBW (compared to say, obesity) would decline. These estimates differ from ours in at least two respects. First, PHK estimate costs for the economy, not in terms of per LBW averted. Second, PHK discount the average loss of earnings (that they assume to be ten years per adult mortality) only to the year of death, not to the year of the presumed interventions than might affect LBW, as done here.

In our basic estimates for illustration we make two broad assumptions (row 6, Table 5). First, we assume that the cost in terms of lost productivity and increased medical care is equivalent to ten years of earnings in a low-income population ($5000), and is experienced on average at age 60. Second, we assume that the probability of experiencing these chronic diseases is reduced by 0.087 by moving a LBW baby to a non LBW status.[26]

7. Cross-generational impacts of LBW:

We also include an estimate of the second round 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 adults and the costs of chronic illnesses for adults who themselves were LBW .

We have not been able to find much persuasive evidence on the causal impact of mothers' LBW on that of their children. Indeed Behrman and Rosenzweig (2003) 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, as is well-known, 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, Ramakrishman, 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 our basic estimates (row 7, Table 2) we 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:

14

The final row of Table 2 gives the bottom line for our basic estimates, subject to the many caveats and assumptions made above. For our 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 infant so affected.

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 accumulative effects are considerable even when 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 relatively 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.

E. SENSITIVITY OF BASIC ESTIMATES OF PDV OF REDUCING LBW TO SELECTED CRITICAL ASSUMPTIONS

The basic illustrative estimates in Table 2, as we have tried to make clear, 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.

Discount rates:
The basic estimates use a real discount rate of 5% to reflect the fact that a dollar of benefits received in the future is worth less than a dollar of benefits received now because the latter can be reinvested and earn a return.   As noted in the discussion of Table 1 above, 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 such as some of the productivity benefits, reductions in chronic diseases and some of the intergenerational benefits. Tables 3 and 4, therefore, summarize estimates that are identical to those in Table 2 with the single exception that the same range of discount rates as in Table 1 is used, including 5% for easy comparison. Table 3 gives the PDV of the seven benefits and their sums. Table 4 gives the percentage contributions in the total benefit of each of the seven component effects. The PDVs for most of the benefits change a fair amount (though not that for reduced neonatal care, which is assumed to occur fairly quickly after any intervention to increase birth weight).

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 2 (bottom row of Table 3). This is a considerable range. But the discount rates also vary fair amount in the table, from 1% to 20%. However there still is a considerable range for the discount rates in the table that are closest to the 5% used in Table 2. 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 with a PDV of cost per infant moved from LBW to non-LBW of almost $1000 ($986) would be warranted, while with 5% the maximum would be $580 (and, with 10%, $273).

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 (Table 4). This triad, to illustrate, accounts for 18% of the PDV of total benefits with a discount rate of 3%, 30% with a discount rate of 5%, and 60% with a discount rate of 10%.

Changes in estimates of individual benefits:
The magnitudes of the estimates of the individual effects are also subject to considerable 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 element of the benefits. To illustrate the implications of these uncertainties and inter-country differences, we have undertaken a set of seven simulations, each of which starts with the base estimates in Table 2, still with a 5% discount rate,[27] but increases one of the seven benefits by 50% (Table 5). 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 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 2.

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 2. 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 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.[28] 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.

F. Linking to Interventions Related to LBW

One practical use of the benefits estimated above would be to adapt the cost structure to a particular environment and compare the expected discounted benefit with the cost of an intervention in terms of costs per LBW reduced. While it is beyond the goal of this study to provide a consensus estimate of the costs of different interventions in such terms, it is useful to include a discussion with some illustrations.

A range of interventions to address low birth weight problems have been proposed.[29] Some specific examples include:
· 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. 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.

In addition to these interventions aimed at averting LBW, there a range of interventions that may reduce the impact, including postnatal nutrition program (Victora, et al. 2001) and a number of educational interventions. These incur additional costs which, to a degree are reflected in the benefits of avoiding LBW discussed above, especially the second and third components.

Under the assumptions in Table 2 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 pregnancy outcomes, including LBW. He indicates that it costs $46 per low birth weight 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 low birth weight averted. None of these studies reports 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 2 suggests that these possibilities are promising.

While there is less evidence on the impact of treatment for helminths on LBW (Steketee, 2003), given the body of information on the costs pf 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, however, 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 restricted 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).[30]

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 2 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.

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 three 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 program and due to the implementation of the program. 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 (by definition), the benefit-to-cost ratios decline. With a 10% discount rate for the most expensive in terms of medical costs per LBW birth averted ($100) and with a cost multiplicative of five, for example, the benefit-to-cost estimate is 0.55. This table suggests, in summary, 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.

G. CONCLUDING COMMENTS

The basic substantive bottom line of this study 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 in comparison to the former. In contrast 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 in current terms when they occur (e.g., productivity gains and savings in medical costs of 10-15 times annual earnings in our simulations in Tables 2 and 5)-– occur decades after any resource-using interventions that might reduce the prevalence of LBW and subsequently of these associated diseases. And the estimated benefits from reducing chronic diseases would be even less if the appropriate discount rate is higher, such as the 12% that is assumed by Popkin, Horton and Kim (2001).

The bottom line with regard to research needs is that, though such estimates are suggestive, there is much that we do not know or do not know very well. There would be gains to improving estimates of the individual effects, particularly those that are relative large for reasonable discount rates (i.e., those related directly to productivity and to early life-cycle benefits), and of the discount rates themselves. There also would be gains from considering the nuances of the impact of continuous changes in birth weight rather than just the standard dichotomy of LBW (i.e., below 2500 grams or not).[31] There probably would be even

greater gains in understanding the implications for possible policies of improving information on the true resource costs – and not merely the governmental budgetary costs[32] – of the many different interventions that have been suggested to lower the prevalence of LBW. For both the benefits and the costs, finally, there would be gains from developing estimates that distinguish between the private and the social rates of returns for interventions and to elucidate the distribution of benefits.

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ANNEX 1 – THE TABLES

Table 1. 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 2. 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%

Table 3. 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%

Table 4. Percentage Composition for Total 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	5%	7%	10%	16%	32%	47%
2. Reduced neonatal care	2%	3%	4%	7%	15%	24%
3. Reduced costs of infant/child illness	2%	3%	4%	7%	13%	19%
4. Productivity gain from reduced stunting	17%	18%	18%	17%	10%	2%
5. Productivity gain from increased ability	42%	44%	44%	41%	25%	6%
6. Reduction in costs of chronic diseases	12%	10%	7%	4%	1%	0%
7. Intergenerational benefits	21%	16%	12%	8%	3%	0%
Sum of seven benefits	100%	100%	100%	100%	100%	100%

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%

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.

NOTES

[1] We follow, in a broad sense, a related effort by Horton and Ross (2003) to provide a range of the economic benefits that could materialize with a reduction in iron deficiency.

[2] Children born in high altitudes (>3000) meters tend to be smaller at birth (Jere Haas, personal communication) but this LBW may be less deleterious than similar levels in lower elevations.

[3] There is a further important distinction between symmetrical (i.e., proportional, due to restriction early in pregnancy) and asymmetrical growth restriction (i.e., non-proportional, with normal length and head circumference but low weight due to restriction late in pregnancy) in utero. Neonatal mortality rates are higher among asymmetrical IUGR infants, but if they survive, they have a better prognosis for long-run growth and development than for symmetrical IUGR infants. If IUGR infants are symmetrical and head growth is affected, there tends to be a higher probability of a negative impact on neurological functions, more so for boys than for girls.

[4] Comparatively few studies have evaluated the impact of LBW on cognitive development in settings where malnutrition is common in childhood and only one of the studies reviewed by Grantham-McGregor, Fernald and Sethuraman (1999) compared the consequences of LBW with other forms of childhood malnutrition. Richards, et al. (2002), however, do distinguish the impact of LBW from postnatal growth in the United Kingdom.

[5] Studies that use such controls include Alderman, Behrman, Lavy and Menon (2001), Alderman and Hoddinott (2002), Glewwe, Jacoby and King (2000), Glewwe and King (2001) and Glewwe and Jacoby (1995).

[6] Hack (1998) reports that the impact of IUGR on adult performance is confined to extreme cases.

[7] But see Currie and Hyson (1999) for a study that shows that LBW reduces education more for higher economic stratum in the United Kingdom than lower strata relative to what normal birth weight children in the respective groups attain.

[8] See Knowles and Behrman (2003) for a discussion of these problems.

[9] The circumstances in the developing countries in which we are interested may differ appreciably from the circumstances in the countries that are studied in the best examples in the literature (often more developed countries, with much different price structures, institutions, and resource levels). For example, the returns to cognitive development and other skills are likely to differ considerably with the level of development. Also, many low-income countries are not able to make the investments in post-partum medical attention nor in special education for children whose cognitive development has been affected by LBW

[10] This methodology involves using estimates of cost effectiveness ratios for alternative interventions to attain a particular benefit as a basis for valuing that benefit. The implicit assumption is that discounted social benefits are at least equal to discounted social costs in the case of investments in which the cost-

effectiveness ratio is at a minimum. If this is not the case, the cost-effectiveness ratio does not provide an accurate estimate of social benefits, but instead an upper bound.

[11] This assumes that affecting many infants does not affect the marginal gains/costs. Generally this seems a safe assumption, but there may be some exceptions. For instance, if LBW were reduced to developed country levels in some high LBW countries such as in South Asia and all the infants affected as a result had more schooling, then the expanded supply of more-schooled labor when they entered the labor force might reduce the returns to schooling.

[12] Ashworth does not provide all the information necessary to make this calculation. As an approximation, we 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 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.

[13] While there are examples in the literature of basing such as assessment on expected lifetime earnings, this methodology is fraught with pitfalls including the implicit ranking of the value of life as a function of wages within a community. In addition, assigning a value in proportion to earnings does not net out consumption from these earnings.

[14] We are indebted to Dr. Mohammed Shahjahan of the Micro-nutrient Institute and former Medical Director of Save the Children Foundation's Children's Nutrition Unit in Dhaka for this information.

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

[16] This is surely on the low end of the scale but can be varied as illustrated in the discussion. There is a wide range reported in WHO and similar data set an done which does only weakly correlates with income. For example, Malawi reports 55% of deliveries in medical facilities while Guatemala reports half this rate. See:
 http://www.who.int/reproductive-health/publications/MSM_96_28/msm_96_28_table4.html

[17] The impact of LBW on earnings is considered here in terms of the reduction of earnings for those individuals who are affected. This both gives an estimate of the returns to preventing LBW and also indicates how LBW influences the distribution of earnings. An alternative approach found in some related literatures is to estimate the impact on overall GNP, in which case, one need to consider the share of wages and the share of LBW in the entire economy.

[18] For example, 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.

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

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

[21] This is not strictly comparable with the wage results since it works only through skills measured in test scores and also because Jolliffe uses average household scores. Nevertheless, it is indicative of the plausible range for the economic impact on reduced cognitive ability. Using wage data in Glewwe (1999) along with the estimates in Glewwe and Jacoby (1994), the estimated impact of lower ability on private wages is –3%. The impact on government wages is –1%.

[22] 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.

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

[24] SGA is not identical with IUGR (de Onis, Blossner and Villar, 1998) but often it is used as a proxy for IUGR when gestational age is not know precisely.

[25] We assume 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. We effectively assume that these opposing factors tend to balance out.

[26] Our reasoning for this approximation is as follows. For our illustrative stereotypical low-income developing countries, we 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 2001-PHK, suggest about 18% for China, but China has a much older population than 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 PHK). 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.

[27] We consider in Table 5 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.

[28] With a higher (lower) discount rate, as is suggested by the discussion above of Tables 3 and 4, the value of improved estimates would shift somewhat towards events earlier (later) in the life cycle.

[29] 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 held at ICDDR B's Matlab Training Center in June 1999.

[30] 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.

[31] Some studies investigate the continuous nature of the impact of birth weight on various outcomes over the life cycle and find that there are continuous effects. Behrman and Rosenzweig (2003) report, for example, that the standard dichotomous measure has significant associations with various outcomes when included in regressions by itself, but not when a continuous measure of birth weight is included – and the continuous measure is more strongly associated with the outcomes of interest. Such results suggest that the usual focus on the 2500 grams cutoff may be somewhat misleading because there may be considerable gains from increasing birth weight in cases in which the birth weight gain does not cross that cutoff (either below or above it). However, we have not been able to find sufficient information about possible continuous effects to be able to explore them in this paper (though we do report the results from some studies that address these continuous effects).

[32] The costs should include all costs of a project/policy valued at the prices that reflect the true marginal resource costs. Several components of this statement merit elaboration even though some of these are parallel to considerations for the benefits, but are repeatedly briefly nevertheless to clarify that they are important considerations for the costs as well as for the benefits. (1) For many projects/policies – including those related to reducing LBW -- there are many costs. It is important that all are included so that the costs are not undervalued, but this may be difficult. (2) The relevant costs are the marginal resource costs, whether experienced by the public or the private sector. This is NOT the same as the impact on governmental budgets for two major reasons. First, part of governmental expenditures may be transfers that merely redistribute command over resources but do not in themselves use resources (though typically some resources will be used to raise resources for and to administer such programs). Second, an important part of the true resource costs are not borne by the public sector, but by private entities due to distortions that are caused either by raising revenues for the programs or through the activities of the program (e.g., through inducing private behaviors based on regulations or subsidized charges rather than on the basis of the true marginal resource costs). (3) The costs may occur over time, not just at the initiation of a project/policy. As for the benefits, therefore, the PDV of costs should be used. Typically, however, major costs are early-on (e.g., the costs of reducing LBW, the additional neonatal and infant medical costs from increasing survival rates of LBW infants), while many of the benefits may be years later. Therefore the benefits tend to be discounted much more than the costs to obtain the respective PDVs. (4) There may be distributional questions about the costs as well as for the benefits (see above), both with regard to the collection of governmental revenues and with regard to the distortions introduced by the policies.

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