

Economic and Nutritional Analyses Offer Substantial Synergies for Understanding Human Nutrition¹

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Abstract

There is growing recognition that interventions designed to improve human nutritional status have, in addition to their intrinsic value, instrumental value in terms of economic outcomes. In many cases, productivity gains alone provide sufficient economic returns to justify investments using benefit and cost criteria. The often-held belief that nutrition programs are welfare interventions that divert resources that could be better used in other ways to raise national incomes is incorrect. Many investments in nutrition are in fact very good economic investments. This recognition has developed out of work that integrates insights from nutrition and economics. Further exploration of this interface is the focus of this article, which seeks: 1) to outline recent contributions that integrate research results from both economics and nutrition, particularly in the context of poor countries; and 2) to describe some areas in which enhanced collaboration is likely to have substantial payoffs in terms of both improved knowledge and more informed policy choices. Collaborative cross-disciplinary research on the topics described here is likely to have substantial payoffs, not only in terms of our understanding of nutritional and economic issues, but also in the improved design of programs and policies that seek to benefit nutritional-related outcomes. *J. Nutr.* 137: 537–544, 2007.

Introduction

In May 2004 a panel of economists, including four Nobel laureates, was asked to rank ~40 potential interventions designed to tackle some of the world's most vexing development problems. A feature of this panel's deliberations was the use of benefit/cost analysis to rank investments in activities as diverse as fighting corruption, reducing global warming, reforming international trade, and improving water, sanitation, and education. The panel's conclusions, named the Copenhagen Consensus, were that interventions such as those designed to address micronutrient deficiencies and other dimensions of hunger and malnutrition were excellent investments (1). In fact, only interventions designed to address infectious diseases, such as HIV/AIDS, received a higher ranking. The Copenhagen Consensus has highlighted what many nutritionists have suspected, that interventions designed to improve nutritional status have, in addition to their intrinsic value, instrumental

value in terms of economic outcomes. In many cases, productivity gains alone provide sufficient economic returns to justify investments in nutrition using benefit/cost criteria. The often-held belief, that all nutrition programs are welfare interventions that divert resources that could be better used in other ways to raise national incomes, is incorrect; many investments in nutrition are in fact very good economic investments.

In both research and policy terms, the Copenhagen Consensus also disclosed the value of expanding the nascent interface between economics and nutrition. The exploration of this interface is the focus of this article. We outline recent contributions that have depended on integrating research results from both economics and nutrition, particularly in the context of poor countries; and we describe some areas in which enhanced collaboration is likely to have substantial payoffs in improved knowledge and informed policy choices. In doing so, we hope to stimulate further fruitful interactions and collaborations between these disciplines.

Links between nutrition and economic development

Malnutrition and economic development are linked. Economic growth clearly leads to reduced malnutrition both across and within countries. For example, Haddad et al. (2) found that for every 10% increase in income, malnutrition rates declined by ~5%. Similarly, the percentage of low birthweight births

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(LBW,⁵ births <2.5 kg), among all births, declines as national income rises; almost half of the variation in the percentage of births that are LBW across countries is inversely associated with variations in production per worker (3). Although such results indicate that economic improvements are likely to translate into improvements for nutrition, they also show that this occurs at a modest pace. For example, in Uganda it would take 33 y for a 5% per capita income growth (which would be higher than experienced since 2000) to halve the percentage of children aged 0–5 y that are underweight.

In interpretations of analyses such as these, causality is assumed to run from economic growth to improved nutritional outcomes. However, there is also important causality running in the other direction; that is, the economic benefits that are derived from improving nutrition.

The economic benefits of improving nutrition in poor societies

The economic benefits of improving nutrition in poor societies are derived from 2 sources: 1) saving resources that otherwise would have been used (say, by reducing the resources used to deal with mortality or morbidity), and 2) enhancing productivity.

The association of malnutrition with the risk of mortality is well established. The probability of infant mortality, for example, is estimated to be significantly higher for LBW than for non-LBW infants [e.g., (4) and (5)]. When the impact of poor preschool nutrition is added to the effect of LBW, Pelletier and Frongillo (6) estimate that 56% of child deaths in developing countries are attributable to malnutrition (83% of these are due to the more prevalent mild to moderate malnutrition rather than severe cases). Similarly, the availability of experimental evidence on the use of micronutrient supplements provides unambiguous evidence as to their role in reducing mortality in many environments, including ones in which individuals show few clinical symptoms of deficiencies.

In addition to increased mortality, malnutrition increases the risk of illnesses that impair the welfare of survivors, uses resources for health care services, and results in lost employment or schooling for caregivers. The magnitude of the use of resources differs according to the medical system, markets, and policies of a country. For example, Lightwood et al. (7) calculate that increased LBW due to maternal smoking in the U.S. cost \$263 million in 1995 and reflects the high levels of direct medical resources used. Similarly, 75% of the \$5.5–6 billion of medical costs due to LBW in the U.S., as estimated by Lewit et al. (8), is the result of increased health care in infancy. A further 10% is attributed to greater special education and increased grade repetition. The uses and costs for special education or for social services are substantial in developed countries (9).

In addition to averting the costs of mortality and morbidity, improved nutrition has substantial economic benefits stemming from both direct and indirect links between nutrition and productivity. These take 2 forms: physical and cognitive. Strauss and Thomas (10) reviewed various studies that found that, after controlling for a variety of characteristics, lower adult height is associated with reduced earnings as an adult. The association of productivity and stature may be due to capacity for manual

labor, but as it also occurs in urban settings and in developed countries, may also reflect that height is a proxy for concomitant cognitive development.

There is a large body of evidence that demonstrates the impact of dimensions of preschool nutritional status on cognitive development in preschool children (11), and there is a smaller amount of literature documenting the impact of preschool nutritional status on education and schooling-related outcomes (12,13). Such evidence points to at least 3 broad ways in which nutrition can affect cognitive function and education. First, malnourished children may receive less education. This may be for several reasons: because their caregivers seek to invest less in their education, because schools use physical size as a rough indicator of school readiness, or because malnourished children may have higher rates of morbidity and thus greater rates of absenteeism from school. Second, malnutrition may delay entry into school, which also may reduce the total amount of schooling. But even if delayed entry does not lead to less-completed schooling, late enrollment leads to lower expected lifetime earnings because of a shorter postschool work life for a given number of years of schooling (14). Third, malnutrition may reduce the capacity to learn. In part this is a direct consequence of the impact of poor nutrition on cognitive development. Additionally, a hungry child may be less likely to pay attention in school and, thus, learn less even if he or she has no long-term impairment of intellectual ability (15). These 3 pathways clearly interact; a child with reduced ability to learn will likely start school when older and spend less time in school as well as learn less while in class. This has long-term effects. A study of children from Guatemala shows that those who were stunted before school age have considerably lower scores on tests of reading, vocabulary, and noncognitive ability as adults aged 25–42 y, controlling for grade attainment, years spent doing skilled work, and age (16).

From the substantial literature on wages and schooling attainment, it might seem straightforward to infer that the impact of nutrition on education attainment is a result of productivity lost due to early malnutrition. However, whereas there are scores of studies on the association of education attainment and wages (17), there is considerable controversy as to the extent to which this association is made by failing to control for the fact that household choices reflect innate ability and motivation. The impact of unobserved factors, such as ability, motivation endowment, and some aspects of family background, confound the associations between wages and education [(18,19) and the references therein]. Wages, moreover, also may be directly influenced by cognitive ability, as well as by the influence of cognitive ability on schooling achieved. A series of studies show that reduced adult cognitive skills (conditional on the grades of schooling completed) directly affect earnings (20,21).

Micronutrients also have important productivity effects. Vitamin A deficiency can cause blindness with obvious consequences for productivity. Anemia is associated with reduced productivity both in cross-sectional data and in randomized interventions (22,23). The magnitude of lost productivity appears to depend on the nature of the task and the employment arrangement. For example, piece-work may have greater incentives for effort, whereas heavy physical labor may show greater increases in productivity; although anemia is a factor in productivity even with relatively light work (24).

Studies such as these may be used to estimate the magnitude of productivity costs resulting from poor nutrition. For example, Alderman et al. (14) find that preschool height influences subsequent height and education attainment in rural Zimbabwe. In

⁵ Abbreviations used: GNP, Gross National Product; LBW, low birth weight (<2.5 kg); PDV, present discounted value; PSM, propensity score matching estimates.

their sample, the mean initial height-for-age Z-score for children aged 6 mo to 6 y was -1.25 . Their estimates implied that if this population had the nutritional status of well-nourished children, they would have achieved an additional 3.4 cm of height in adolescence, an additional 0.85 grades of schooling, and a 6-mo reduction in the age at which they started school. Using the values for the returns to education and age or job experience in the Zimbabwean manufacturing sector that prevailed in the late 1990s, Alderman et al. show that the loss of schooling, and the increased delay in starting work due to low height-for-age Z-scores, translates into a 14% reduction in lifetime earnings. Note that this estimate of impact does not include the impact on learning per grade of schooling completed (that is, not only do malnourished children progress less in school, their learning may be conditioned upon attaining a certain grade) and there may be other longer-term consequences, such as a reduced chance of future disease and reduced inter-generational transmission of low human capital.

Behrman and Rosenzweig (3) take a more direct approach. They study a sample of adult identical twins in the U.S. and determine that, with controls for genetic and other family and community endowments shared by twins (which would not be affected by programs to increase birth weight), the impact of better intrauterine nutrition on schooling or wages is far greater than without such controls (e.g., the impact on educational attainment is estimated to be twice as large, with a half km increase in birth weight correlating with an increase in educational attainment by about one-third of a year). It is important to note that, in terms of productivity, the magnitude of these effects are substantial, easily exceeding the effects of height on productivity, even if the indirect effect of height on wages, mediated by the relation between height and schooling, is included. For example, Strauss and Thomas (25) estimate that for every 10% increase in the height of males in urban Brazil, labor income increases by 39%; but their estimates imply that an illiterate man would need to be 11 cm taller than his literate co-worker to have the same expected wage. However, their results are based on the strong assumption that there is no correlation between adult height and unobserved factors (such as parental background and genetic endowments) that also might affect labor-market outcomes. As discussed below, relaxing this assumption represents an important area for new work.

Valuing these benefits

We described, above, the multiple possible economic benefits of improved nutrition. Obtaining an economic value from all of these benefits involves a range of assumptions and includes the vexing problem of how to quantify the benefits of avoiding early mortality (26). Plausible candidates for estimating benefits include a consideration of the resources actually used by a society to avert a death, expected lifetimes earnings, or the statistical value of a life that is derived from the premium paid to a worker to induce him or her to accept employment that increases the risk of mortality (27). These factors can differ by orders of magnitude. Hence, there is a need to be explicit in indicating assumptions used for estimating this value and to offer sensitivity analysis when summing benefits that include reduced mortality.

Moreover, the total value of an economic benefit varies according to the country context. For example, reducing low birth weights in the U.S. has high and visible economic returns because it averts extensive resources used for neonatal emergency care as well as subsequent resources used for special education (9). In contrast, in rural South Asia, where relatively

few children are born in hospitals, and where special education programs to meet the needs of cognitive impaired children are rare, there are comparatively few savings in resources when LBW is avoided, but there are appreciable gains when higher education, better health, and greater productivity are obtained.

Despite the unavoidable uncertainties around estimates of the economic benefits derived from improved nutrition, a number of insights have been derived from recent studies exploring this topic. For example, Alderman and Behrman (28) estimate the economic benefits from preventing a LBW birth in a low-income context such as South Asia. These benefits include those derived from reduced infant mortality, reduced costs for neonatal care and infant/child illnesses, and reductions in the costs of chronic diseases as well as productivity gains associated from reduced stunting and increased cognitive ability. Alderman and Behrman also take into account the intergenerational transmission of these benefits. Because some of the benefits occur around the time of birth and others during a child's working life, those that incur earlier need to be given a different economic value to account for the fact that it is better to obtain a given monetary impact sooner rather than later. This is because money obtained sooner can be reinvested for further productive returns. This means, for example, that it is better to receive a benefit from reduced LBW, which occurs quickly (e.g., reduced neonatal medical costs), than one of equal monetary value that occurs decades later [e.g., reduced costs of the same magnitude of cardiovascular disease or diabetes in the later stages of life as emphasized by Barker (29) among others]. To compare benefits that occur with different time lags, they need to be discounted to account for the foregone reinvestment benefits if there are greater lags. With a 5% discount rate, for instance, the present discounted value (PDV) of \$10,000 of resource gains due to reduced adult chronic morbidity in 60 y is \$535 (see further discussion below).

Taking this into account, Alderman and Behrman (29) find that the value of one LBW averted in a stylized low income country is \$510 with a 5% discount rate. The overall benefits are dominated in these estimates by the impacts on productivity through reducing stunting and cognitive ability (working in part through its effects on the amount of schooling acquired) with these 2 benefits accounting for over half (57%) of the total. Although there are considerable delays in receiving these productivity benefits, they persist over an individual's working life. That is, even if one makes no attempt at placing a value on the reduced mortality and fails to consider any of the savings in medical costs (either in childhood or later in life) attributed to changes in the number of LBW children born, each case of averted LBW still adds \$290 to the economy of a low-income country.

These particular estimates were made in terms of each LBW birth avoided. An alternate approach can consider expected benefits per capita or per vulnerable population reached. Whereas the benefits per capita may differ from the benefits for a subgroup, estimates of cost will also differ for a targeted population. Thus, Behrman et al. (27) find that the benefit of reducing iron deficiency is in the range of \$40–50 per capita but \$82–140 per pregnant woman. In the former case, the majority of the benefits come from increased productivity stemming from increased work capacity for all age groups as well as a lesser amount from improved learning. In the latter case, the benefits come largely from improved birth outcomes including, but not limited to, reductions in LBW births. Benefits of a similar magnitude are expected from reducing infant and child mortality with improved vitamin A status or from lowering infant mortality and raising lifetime productivity by reducing iodine

deficiency. These estimates are calculated per child <6 y of age, the target population, in the case of vitamin A and per woman of child bearing age in the case of iodine.

Horton (30) uses a related approach to estimate conservatively the productivity losses due to various types of malnutrition in low-income Asia at 2–3% of gross national product (GNP). Concentrating only on a single form of malnutrition, iron deficiency anemia, Horton and Ross (25) estimate that the median loss due to the reduced-work capacity of adults associated with anemia for 10 low-income countries is 0.6% of GNP. An additional 3.4% of GNP is lost due to the effects of anemia on the cognitive development of children. These estimates, which go as high as 8% for a country with high anemia rates such as Bangladesh, do not include estimates of savings in resources used to maintain or improve health or benefits from increasing life expectancy.

A third study by Horton et al. (31) focuses on such health expenditures, as well as lost productivity, from diet-related chronic disease in China and Sri Lanka. In the former country, these costs were estimated at 2.1% of GNP and in the latter, only 0.3%, the difference reflecting the demographics of the 2 countries as well as fact that China has moved further along on the nutrition transition than Sri Lanka. However, in both countries, the costs of chronic diseases are expected to rise over the next 2 decades. Although such diseases often reflect many lifestyle choices made by adults, the study projects that LBW will still be a major contributing factor to the noncommunicable disease burden even in 2025.

Areas for further synergy between nutrition and economics

To this point, our discussion of the links between nutrition and economic development has focused on the considerable value of recent analyses that build on research in both nutrition and economics. In this section, we outline 2 broad areas where further cross-fertilization would be of value with regard to methodology and constructing policy hierarchies. Before doing so, we provide some further background on the essential assumptions, aspects, and insights of economics that are likely to be relevant for future synergy. Our characterization of economics focuses on 2 broad areas. First, how economists think about what determines individual and group behaviors and, second, how economists think about policy alternatives.

Economists posit that individuals or groups such as families behave as if they are maximizing their welfare subject to the constraints that decision-makers (i.e., these individuals or the decision-makers in the families) understand that they face in terms of resources, policies, markets, and social networks. This has several important implications:

Individuals and families will respond to changes in their perceptions of constraints possibly by changing any or all of their behaviors. If poor malnourished families have increased resources, they will use them as they perceive is best, which does not necessarily mean dedicating most of the additional resources to better nutrition. If policies are directed toward improving the nutrition of particular types of household members such as preschool children or school-age children, for example, households are likely to shift part of these gains to other household members through allocating fewer resources to the direct beneficiaries of the policies. Efforts to preclude households from making such reallocations, if effective, result in household

welfare as assessed by household decision makers (as opposed to policy makers or international experts) increasing less for the resources devoted to this effort than would occur without these efforts.

Individuals and families make decisions within a life-cycle framework in the presence of important factors such as genetic endowments that are not observed by analysts. This means that if one wishes to find the impact of, say, early childhood nutrition on later-life education or labor market outcomes, it may be critical to control for the endogenous choices related to early childhood nutrition. The simple association between early childhood and nutrition is not likely to capture only causal effects, but also decisions based on the household's knowledge of these (unobserved by analysts) endowments.

For a household to take advantage of policy changes, such as nutritional interventions, it typically must use additional scarce household resources. At times there are monetary costs. But almost always there are time costs. To evaluate the full costs of any intervention, these private household costs must be included in addition to the direct governmental costs of the intervention.

Economists consider 2 basic motivations for policies: 1) to improve efficiency or productivity, and 2) and to improve distribution of resources, which most commonly is interpreted to mean to improve the command over resources of the poorer members of society. A situation is inefficient if, given resources and constraints, one entity can be made better off without making any other entity worse off. A situation is efficient if the incentives at the margin for all members of society to undertake an action just equal the marginal (or additional) social cost of resources for that action. The social resource costs may differ from the private resource costs because market prices that private individuals must pay may be more or less than the future social costs of the good or service obtained. This difference may be due to so-called market failures (e.g., the failure of market prices to capture spillover or external effects such as those related to the spread of contagious diseases or pollution; poorly functioning capital markets for human resource investments). In some cases, the differences may stem from governmental regulations that preclude market prices reflecting true resource costs (e.g., minimum or maximum prices). Furthermore, the manner in which governmental revenues are raised, or how they are spent, change private incentives and result in economic distortions estimated to be $\geq 25\%$ of governmental budgets (32). Some important implications of these considerations follow.

There may be efficiency-distribution tradeoffs in which policies improve one at the expense of the other, so it is important to get the balance right, which depends on how society values the productivity-distribution tradeoff. But, in a number of cases, the efficiency and distributional gains may be complementary, particularly if the distributional concerns focus on the poor, because inefficiencies in capital and information markets are most likely to affect the poor. A program that improves information about nutrition, for example, is likely to increase efficiency (because private markets are unlikely to produce enough of such information) and particularly help the poor (because they are likely to have been most misinformed). Because some intervention has high returns (e.g., provision of micronutrients in some contexts) does not necessarily mean that public resources should be devoted to supporting that intervention. If the private returns are high, then

there are strong incentives for private investments that maximize private welfare. For some micronutrients, for example, this may occur with fortification costs that are passed on to consumers. Only if the social returns are greater than the private returns is there an efficiency justification for using public resources to support the intervention. Again, distributional considerations are additional to efficiency concerns but are conceptually distinct. If there are concerns, for example, about the command over resources by the poorer members of society, it may be socially desirable for society to give up productivity, if necessary, to provide more resources to poorer people, but it is also desirable to make such decisions with conscious awareness of what the tradeoffs are.

First example of increased future synergies between economics and nutrition: cross fertilization on methods

Economists and nutritionists working at the interface of their disciplines are joined methodologically by the emphasis they place on the analysis of individual and household level data. Interactions across disciplines in the design of data collection instruments can have appreciable payoffs. Economists can gain from the careful attention that nutritionists pay to minimizing measurement error in the field as well as the importance that nutritionists place on validation and replication studies. Nutritionists often use experimental designs to uncover causal effects, an approach that economists have relatively recently begun to adopt, and economists could benefit from learning how nutritionists design and implement such experiments. Nutritionists can benefit from the experience of economists in designing survey instruments to obtain data on income, earnings, wealth, and other dimensions of socio-economic status and by the experience of economists in analyzing nonexperimental data and counterfactual experiments.

In many circumstances, nutritionists are obliged to use data from nonexperimental designs to investigate correlates of nutritional status, or to assess interventions designed to improve nutrition. Often, however, variables that appear as regressors in associational studies may be endogenous, reflecting the impact of unobserved individual and household characteristics, responses to markets, or to factors that determine the placement of governmental services. If so, the interpretation of such associations is problematic. For example, Pelletier and Frongillo (6), using data on changes in national malnutrition rates and mortality, find statistically significant associations between mortality and malnutrition. However, these associations do not control for changes in infrastructure or income that may affect mortality directly or influence nutrition nor can they indicate a counterfactual of the impact of improved nutrition on expected mortality.

Economists use a number of techniques to address the limitations associated with associational studies, including instrumental variables techniques and propensity score matching (PSM). Alderman et al. (14) provide an illustration of the power of the former of these approaches in the context of nutrition. Their study, as noted above, examines the relation between preschool nutritional status in rural Zimbabwe (measured in 1983, 1984, or 1987) and subsequent stature and schooling attainments measured in 2000. An associational regression, that is, one that does not take into account the endogeneity of preschool height or the confounding effect of

unobservables or the bias toward zero of random measurement error, finds that the coefficient for preschool height-for-age Z-scores on grade attainment is 0.222 ($P < 0.01$). Taking into account the endogeneity of this measure of nutritional status and of random measurement error using instrumental variables, and using a fixed effects estimator to sweep out the impact of fixed unobservable factors at the level of the mother, produces a coefficient for preschool height-for-age Z-scores on grade attainment of 0.678 ($P < 0.05$), a 3-fold increase in the estimate of the impact of preschool nutritional status on subsequent schooling outcomes.

Behrman et al. (33) provide an illustration of the use of the PSM method to evaluate the impact of the Mexican antipoverty and human resource program, PROGRESA. This program included nutritional supplements for infants and small children and used an experimental design in which there were random treatment assignments among 506 rural communities for 2 y in 1998 [see Psacharopoulos and Patrinos (17) for details and for evidence that this program had a significant impact on linear growth of young children based on the experimental design]. Behrman, et al. (34) compared the impact of exposure to the PROGRESA nutritional supplement program when children were 0–2 y of age in 1998–2000 on the age of school enrollment ~5 y later, using 1) the differential exposure to treatment from the experimental design (5.5 y vs. 3 y) and 2) PSM estimates with a new sample that had not been exposed to the program prior to the 2003 survey. For the PSM estimates, 1) logit estimates were made of program participation as a function of individual, family, and community characteristics not affected by the program, and 2) individuals exposed to the program were compared with individuals who were not exposed but who were similar in the propensity to receive program treatment as predicted by the logit estimates. Both the estimates, based on the differential exposure to the experimental intervention and the PSM estimates, indicate that the program significantly reduced the age of entry to school statistically and on average (~0.1 y younger). That the PSM estimates are similar to the experimental estimates is reassuring because PSM can be used in many contexts in which experiments cannot (or at least, have not) been conducted (see also discussion of structural models, below).

Both Alderman et al. (13) and Behrman et al. (34) point to another methodological area where interdisciplinary work would be of value: namely, collaboration on long-term longitudinal studies. An important limitation of many economic analyses of the benefits of improved nutrition is that they stitch together data and estimates from a variety of sources, as in the Alderman et al. (14) study that uses estimates of the returns to schooling from another study to estimate the loss of earnings associated with the poor preschool nutritional status. An alternate approach would be to obtain direct estimates of economic returns, for example, by tracking individuals who had participated in a nutrition intervention over time, thus building a picture of how subsequent human capital (health and education) accumulates and how this can translate into income generation and improved living standards. Although researchers in either discipline can undertake (and in a very limited way, have undertaken) such work, it would be richer if it married the expertise of nutritionists with that of economists.

A current example of such a collaborative effort is the study of wage production functions and how they relate to physical and cognitive development in Guatemala (30). This study builds upon the rich multifaceted Institute of Nutrition for Central America and Panama (INCAP) data collection, spearheaded by

nutritionists, that permits a much richer characterization of physical and cognitive development than usually used by economists. At the same time, it builds on the insights and methodologies of economists for dealing with the behavioral determinants over the life cycle of the indicators of physical and cognitive development. The results demonstrate that the collaboration results in a richer and much different understanding than would have resulted with either economists or nutritionists undertaking the study in the ways that are standard in their respective disciplines (see reference 29, pages 44–45).

A further example of possible rich cross-fertilization is the potential use of structural models to investigate the “counterfactual” impacts of nutritional interventions before they are undertaken or even if they are not undertaken. Such structural models capture the basic underlying relations for the behaviors of households subjects to the various constraints noted above, and consequently, what would happen if those constraints were changed, such as by a nutritional intervention. Todd and Wolpin (34) provide an example in which they first compare the predictions of their structural estimates based on preprogram data with those from the experimental design for the PROGRESA program and find them quite similar. They then assess the counterfactual policies to determine what would have happened if scholarships had been larger or smaller or targeted to different school ages. At the cost of the assumptions regarding the underlying model structure, this approach permits exploration of counterfactual interventions. To our knowledge, it has not yet been applied to nutritional issues, but the potential is considerable for greater insights from doing so.

Second example of possible increased synergies between economics and nutrition: constructing policy hierarchies

The existing evidence suggests that there are considerable economic benefits to investing in nutrition. But there remains considerable scope for further improving these. In particular, current knowledge provides limited information on policy hierarchies, that is, a ranking of interventions in terms of their benefit:cost ratios, in large part because little is known about the costs of such interventions and in part because of the difficulty in evaluating all of the benefits. This represents another area where interdisciplinary collaboration would have meaningful payoffs.

For example, the discussion of the benefits associated with lowered incidence of LBW implies that any intervention that costs less than \$510 per LBW, averted in a low-income country such as in South Asia, is a suitable candidate for investment because the benefit:cost ratio would be >1 . However, as Behrman et al. (27) describe, it is challenging to assemble evidence on the costs associated with interventions that would generate this benefit. The pilot programs and experimental designs needed to prove the efficacy of interventions rarely assemble sufficient information on costs to make this assessment.

In part, the difficulty stems from the difference between the unit costs of a field trial and the costs of a program going to scale. Moreover, an economic understanding of program costs needs to include an understanding of project adherence and the costs of increasing such adherence. These are issues even for the assessment of cost effectiveness. Moreover, all too often, private costs and distortion costs in raising revenues for public expenditures (see above) are ignored. For some interventions, particularly mass programs to combat subclinical micronutrient deficiencies,

studies based on experimental designs provide relatively precise estimates of the expected outcomes with improved nutritional status. For example, the role of Vitamin A in reducing child mortality has been repeatedly demonstrated (35). Having a single target group and a single outcome measure makes it fairly straightforward to indicate delivery systems that are the most cost effective or to provide the unit cost of service delivery in a given setting (36). One challenge in such studies is to determine the fixed costs of administration or mobilization as well as to distinguish start-up costs of programs not yet fully developed from the running costs for mature programs. Similarly, apportioning such costs to a given component of an overall service is difficult. This is a generic issue to the costing of services and not specific to supplementation programs (37). Other challenges are to incorporate the private costs and the distortion costs of raising revenues for such programs. So, even for relatively simple programs, the measurement of true total resource cost is challenging.

Moreover, only a few studies, such as Phillips et al. (38), directly compare the costs of alternative service delivery in the same environment, i.e., in the cited case, the costs of supplementation, fortification, and promotion of home gardening to prevent vitamin A deficiency. Fiedler et al. (39) make a similar comparison of the costs of supplementation and a hypothetical fortification of wheat flour in the Philippines, both aimed at ensuring intake of at least 70% of recommended levels. The study illustrates 2 points relevant to the economic analysis of interventions. First, they note that the time (opportunity) costs of volunteers constituted 30% of supplementation costs, whereas the capsules themselves comprised only 3% of the costs. They also find that the unit cost of supplementation increases not only with scale of supplementation but as parallel efforts of fortification increase. These costs, however, do not point to an unambiguous fortification strategy; although fortification is more cost effective, it would miss more children than the supplementation program was able to reach. Implicitly, then, a greater coverage with higher costs points to rising marginal costs of coverage and imply that a suitable targeted dual approach might be the most efficient.

Collaboration across disciplines also helps to assess the value of different benefits that occur at different times due to a nutritional intervention. The resources saved with lower morbidity arising from better nutrition provide one important example. The resources used as a result of morbidity are generally different from fees charged at hospitals and even differ from these fees plus any subsidies provided. For example, morbidity tends to use household resources, in the form of the time necessary to care for an ill child, in addition to monetary resources used for medical care. Furthermore, resources are used beyond those of public and household expenditures because the process of raising governmental revenues generally uses resources for administration and due to economic distortions. Thus, the full economic resources that are saved when morbidity rates are reduced include many components beyond the direct reduction of public sector resources.

Various considerations, as noted above, arise with the need to compare benefits that occur with diverse time lags so that they can be added to obtain the total benefits or to make comparisons with other interventions and time lags. For example, although conceptually the resource gains of reducing noncommunicable diseases of adults are calculated in a manner similar to the resource gains of reducing childhood morbidity, the gains that are obtained earlier have the advantage of being invested to obtain future gains (therefore, future benefits should be

discounted). A resource gain of a given magnitude due to reducing childhood morbidity is worth more in terms of present discounted value (PDV) than an equal resource gain due to reducing adult chronic diseases. At a 5% (10%) discount rate, for example, the PDV of \$10,000 of resource gains due to reduced adult chronic morbidity in 60 y is \$535 (\$33). Therefore, for example, \$1000 of resources saved through reducing infant morbidity have a higher PDV than \$10,000 of resources saved 60 y later by reducing adult chronic diseases.

The integration of the PDV of benefits and the PDV of costs to obtain benefit:cost ratios provides a powerful tool with which to decide not only on the relative priorities of different nutritional interventions, but to compare nutritional interventions with other alternatives ranging from education to environmental concerns to international trade policies. This places nutritional programs into a common metric with other potential investments and, as noted in the introduction, such efforts suggest that a number of nutritional projects are competitive in terms of economic returns with more conventional public investments (27,31). Considerable possibilities remain, however, of improving such estimates particularly with better estimates of costs and with explicit identification between the private and the social benefit/cost estimates (or rates of return) to inform whether there are efficiency reasons for using public resources for such interventions.

That the existing estimates in a number of cases indicate benefit:cost ratios considerably greater than one for a number of nutritional interventions also raises an important question for future investigation: if nutritional investments are such good investments, why have they not been adopted? Are there information problems so that the relevant decision makers, whether private individuals or governmental officials, do not understand the promise for nutritional interventions? Are the private returns below the social returns so that the private incentives for investing in them are inadequate? Are imperfect capital markets constraining nutritional investment choices? Do available estimates exaggerate the real benefits or underestimate the real costs? The correct answers to these questions might illuminate the priority of nutritional interventions among the broader set of social policies, but also for understanding what specific policies are likely to be of high priority.

Information is clearly only one element in determining which nutrition policies are pursued (40). Nevertheless, to the degree that analysis shifts the agenda, economists with a perspective in common with finance and planning ministries can complement any dissemination of findings on effective nutrition policies conveyed through sectorial ministries and health professionals, hopefully increasing support for promising approaches. In addition, because many experimental findings are subject to doubt concerning external validity, economists can offer structural behavioral models to interpret results and, again, complement the structural biological models that are applied to general results of impact evaluations. Jointly, such interpretations may assist in relating nutritional knowledge to policy concerns in specific settings and thus promote their adoption.

This article summarizes recent positive synergy between research in nutrition and economics, particularly related to economic development. We illustrate several major examples, for which prospective synergy appears to be considerable. There have been extensive gains from such synergy in the past. Building upon research in the fields of economics and nutrition and developing collaborative cross-disciplinary research are likely to have consequential payoffs in terms of understanding basic nutritional and economic issues.

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