HOUSEHOLD BEHAVIOR AND MICRONUTRIENTS
WHAT WE KNOW AND WHAT WE DON'T KNOW
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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
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FOREWORD

The International Food Policy Research Institute has been designated to take the lead in coordinating activities related to human nutrition across the 16 centers that constitute the Consultative Group on International Agricultural Research (CGIAR). A large part of that effort is organized around a five-year project initiated in May 1993 with funding from the Office of Health and Nutrition of the U.S. Agency for International Development. The objective of the project is to identify and implement cost-effective alternatives within the CGIAR for increasing micronutrient intakes. Taken together, micronutrient deficiencies affect a far greater number of people in the world than protein-energy malnutrition, with serious consequences for health, cognitive ability, and productivity.

This series of Working Papers on Agricultural Strategies for Micronutrients reports on activities undertaken on all aspects of the project, and so represents views and research findings from several disciplinary perspectives. The project will undertake activities in two broad areas. One component involves a coordinated effort between CGIAR centers and agricultural and nutrition research institutes in developing and developed countries to breed for nutritionally improved staple food crops. The second component, a collaborative effort between CGIAR centers and developing-country social science and nutrition research institutions, will undertake collection and analysis of household survey information to better understand the linkages between agricultural production, household resource allocation, and nutrition outcomes for improved policy formulation.

The first three papers in the series provide perspectives from the human nutrition, household economics, and plant nutrition/plant breeding disciplines. These papers were commissioned for presentation at an organizational workshop convened in Annapolis in 1994 and attended by an interdisciplinary group of persons, from within and outside the CGIAR, involved both in research on micronutrients and in implementing programs to reduce micronutrient malnutrition. Various research directions for the project were discussed. The authors of these three papers were asked to provide (1) a summary of what is known about micronutrients in their respective areas of expertise in a way that could be understood by those not trained in that discipline, (2) their judgments as to what are the significant gaps in knowledge, and (3) their opinions as to how project activities could best contribute to closing these gaps in knowledge and to reducing the micronutrient malnutrition problem.

This second paper, which addresses micronutrients and household behavior, was prepared by Jere R. Behrman, William R. Kenan Jr. Professor of Economics, University of Pennsylvania. Professor Behrman has published extensively on, among other topics, the many facets of the family decisionmaking process and is a recognized authority on household behavior and nutrition outcomes in developing countries. Also provided in this publication are formal comments on Professor Behrman's paper, which were presented at the organizational workshop by Beatrice Lorge Rogers, professor of economics and food policy and dean of academic affairs in the School of Nutrition at Tufts University.

Howarth E. Bouis
Series Editor
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1. INTRODUCTION

Shortages of micronutrients—such as iron, vitamin A, and iodine—are increasingly recognized as an important nutrition problem that affects millions of people, particularly in the developing world.\(^1\) The proximate determinants of micronutrient consumption are individual and household behaviors—in particular, how those behaviors affect the ingestion of micronutrients through the quantity and quality of food consumed by household members. The objectives of this paper are (1) to present the conceptual framework economists use to analyze the consumption of micronutrients by members of households; (2) to state what is generally known and accepted in the literature and what is not known about the key relationships implied by this framework and thereby to identify gaps in knowledge about household behaviors and micronutrients; and (3) to make recommendations about research questions and activities that should be undertaken to lessen micronutrient deficiency problems for humans in developing countries.

2. CONCEPTUAL FRAMEWORK FOR ANALYSIS OF HOUSEHOLD BEHAVIOR AND MICRONUTRIENT CONSUMPTION

Why is household behavior as it relates to micronutrient consumption of interest? The answer is that household decisions determine both the amount of individual human consumption of micronutrients (given a number of market and technological factors and household assets) and the effect of micronutrients that are ingested. Household behavior, therefore, may significantly affect efforts to lessen or eliminate micronutrient deficiencies. The nature of household behavior cannot be confidently deduced, however, only by observing households or by considering associations among observed variables. This behavior is complex, with a number of arguably important factors going unobserved, and the magnitudes of empirical effects, not just their direction, are likely to be important in assessing strategies for eliminating micronutrient deficiencies. Simple models of household behavior can illuminate this behavior as it pertains to micronutrients and provide guidelines for obtaining good estimates of critical behavioral responses. This section, therefore, presents a simple model of household behavior related to food consumption and then discusses a number of complications and extensions of this model.

SIMPLE MODEL OF HOUSEHOLD FOOD DEMAND

The basic model that economists use to analyze household consumption behavior is one in which household members act as if they are maximizing a household objective function subject to constraints imposed by the household's assets, prices of goods and services, technological production function relations for outcomes valued by the household and determined by the household, and the information set of the household. The objective function depends directly on, among other things, the quantity and composition of food consumed by household members and indirectly (for example, through health) on food consumed by household members. Household assets are broadly defined to include both human and physical assets as well as assets that reflect prior investment decisions (for example, schooling, buildings, and irrigation systems) and endowments that are given from the point of view of behavioral decisions (for example, innate abilities and genetic determinants of healthiness). The relevant prices are those for all items that are purchased or sold (or produced for own consumption) and include time as well as monetary costs. The technological production functions give relevant outputs that are produced by the household in part through household allocations of resources. For example, in this case, a critical production function is the one that determines the health of an individual household member as dependent upon such factors as the nutrients consumed by that individual, the exposure of that individual to waterborne and other infectious diseases, the genetic makeup of that individual, and aspects of curative health care. The constrained maximization of the household objective function depends on what information the household has about a number of factors, including its own endowments, prices, and production technology.
Figure 1—Household objective function for consumption of grain (G) and vegetables/fruits (V)

Figure 1 illustrates a critical component of this model: an objective function is defined for the two foods that the household is assumed to consume\(^2\)—grains (G) and vegetables/fruits (V)—and is maximized within a one-period framework, subject to a budget constraint that depends directly on the household's food expenditures and market prices.\(^3\) Every point in this figure represents some combination of grains and vegetables/fruits consumed by the household. For instance, point a represents consumption of \(G_a\) units of grains and \(V_a\) units of vegetables/fruits. Each curve in this figure gives various combinations of grains and vegetables/fruits that leave the household equally well-off along that line. That is, on the curve \(U_3 U_3\), the household perceives itself to be equally well-off at point a (with relatively more grains and relatively few vegetables/fruits consumed) as at point b (with more equal quantities of grains and vegetables/fruits consumed) and as at point c (with relatively less grains and relatively more vegetables/fruits consumed). Since the household perceives itself to be equally well-off at points a, b, and c, it is said to be indifferent among these points, and curves

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\(^2\)The limitation to two foods is for simplicity of geometric presentation. The algebraic extension to many foods is straightforward.

\(^3\)More generally, the budget constraint gives the limit on total household resources (including the time of household members as well as other household assets) that can be spent (or used in own production) to obtain food and other items. "Full income" is used in the literature to refer to the incorporation of time constraints in addition to monetary constraints in this budget constraint.
such as \( U_3U_3 \) are referred to as indifference curves. In Figure 1, these curves are drawn to reflect at least three important considerations:

1. The preferences or tastes embodied in the household objective function matter because there is diminishing marginal satisfaction to increasing the consumption of one item relative to the other. To illustrate, the points \( a, b, \) and \( c \) on the curve \( U_3U_3 \) have been selected so that the additional vegetables/fruits obtained by moving from point \( a \) to \( b \) (that is, \( V_b - V_a \), say 3 kilograms of vegetables/fruits per week) are identical to the additional vegetables/fruits obtained by moving from point \( b \) to \( c \) (that is, \( V_c - V_b \)). But the household would be willing to give up much more grain to get the first increment of 3 kilograms of vegetables/fruits per week by moving from \( a \) to \( b \) than it would be willing to give up to get the second increment of 3 kilograms of vegetables/fruits. That is, if the household is to remain indifferent, it will value every additional unit of vegetables/fruits consumed less in terms of forgone units of grain consumed (in terms of grain given up, \( G_a - G_b > G_b - G_c \)). At any point on the indifference curve, the slope of the curve gives the relative marginal trade-off between consuming more vegetables/fruits and consuming more grain. If vegetable/fruit consumption is relatively low, such as at point \( a \), the gain from a little more vegetable/fruit consumption obtained by giving up a little grain consumption is considerable, so the curve is relatively steep and the absolute value of the slope is relatively great, compared with a point such as \( c \), at which vegetable/fruit consumption is relatively great.

2. The household would prefer to consume more of both grains and vegetables/fruits rather than trading off between consumption of grains and vegetables/fruits along an indifference curve, so the level of household satisfaction is greater on the curve \( U_4U_4 \) than on \( U_3U_3 \), greater on \( U_3U_3 \) than on \( U_2U_2 \), and greater on \( U_2U_2 \) than on \( U_1U_1 \). It is hardly surprising that a point such as \( d \) is preferred to \( b \) and that \( b \) is preferred to \( e \). But a point such as \( d \) is preferred even to a point such as \( a \), even though grain consumption is much greater at \( a \) than at \( d \). Therefore, if the household's welfare is of interest, it may be misleading to attempt to characterize this welfare by some subset of items consumed, such as the quantity of grain, basic staples, or calories. A household with the consumption bundle at \( d \), even though it consumes less grain than the household with consumption bundle \( a \), is better off.

3. The indifference curves in Figure 1 are not drawn symmetrically around the 45-degree ray from the origin but are closer to the grains axis and asymptotically approach a minimum grain consumption at \( G_s \) that is a stylized representation of subsistence requirements.

Figure 1 gives a stylized representation of the household objective function, but it does not indicate what consumption bundle households actually consume. The household in this figure simply would prefer more to less—\( b \) (or \( a \) or \( c \)) over \( e \), and \( d \) over \( b \). To represent what consumption bundle the household would choose, it is necessary to represent the constraints on household consumption. Figure 2 illustrates what such constraints would look like if the household had a fixed amount of income for food expenditures and faced fixed prices for grains and vegetables/fruits. The solid straight line \( B_2B_2 \), for example, gives the budget constraint that the household confronts if it has 100 pesos for food expenditure and faces

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4 One indifference curve passes through every point in the figure, but only four are drawn for illustration.
prices of 5 pesos per kilogram of grain and 10 pesos per kilogram of vegetables/fruits. If this household devoted this entire expenditure to grains, it could purchase 20 kilograms, as indicated on the grains axis; if it devoted all of this expenditure to vegetables/fruits, it could purchase 10 kilograms, as indicated on the vegetables/fruits axis; and if it devoted this expenditure to both grains and vegetables/fruits, it could purchase any combination on the line $B_2B_2$ (for example, 16 kilograms of grain and 2 kilograms of vegetables/fruits). The slope of this budget constraint obviously reflects the relative prices of vegetables/fruits and grains, since those prices imply that obtaining and consuming 1 more kilogram of vegetables/fruits requires forgoing 2 kilograms of grain. This household could purchase any combination of grains and vegetables/fruits along this budget constraint (such combinations would exhaust the available food expenditure) or inside this budget constraint (which would leave some of the funds unspent). How does this household choose among the alternatives available to it in order to maximize its satisfaction? It does so by choosing the combination of grains and vegetables/fruits that enable it to be on the highest possible indifference curve. This combination is $e$, where the budget line $B_2B_2$ just touches (or is tangent with) the indifference curve $U_2U_2$. Such a choice gives the household higher satisfaction than feasible points inside the budget constraint, such as $g$ (which is on the lower indifference curve $U_1U_1$), or than other feasible points along the budget constraint, such as $f$ (which is on the budget constraint $B_2B_2$ and on the indifference curve $U_1U_1$). At the tangency at point $e$, the slope of the objective
function (which gives the ratio of the marginal gain from a little more vegetables/fruits to that for a little more grain) just equals the slope of the budget constraint (which gives the ratio of the marginal price of a little more vegetables/fruits to that for a little more grain). At any other point on the budget constraint, this marginal equality does not hold. For example, at f, the slope of the indifference curve is much greater than that of the budget line, indicating that the gains from increasing vegetable/fruit consumption a little by reducing grain consumption a little are much greater than the ratio of the vegetable/fruit price to the grain price—thus, household welfare could be increased by increasing vegetable/fruit consumption relative to grain consumption.

What happens to the (constrained maximization) optimal household choices if the household spends more for food at the same prices? The budget constraint moves out to a line such as $B_3B_3$ if food expenditures are increased somewhat, and further to a line such as $B_4B_4$ if the food expenditures are increased somewhat more. Does this mean that the household chooses to expand purchases of both grains and vegetables/fruits proportionately to the increases in total food expenditures? If the total food expenditures increase from 100 to 110 pesos, for example, would the household increase its consumption of both grains and vegetables/fruits by 10 percent? In general, the answer to this question is negative because of the nature of the preferences underlying the household objective function. Given the objective function in Figure 1, marginal increments on food expenditures are directed more toward vegetables/fruits than toward grains. Grains become relatively less critical as the household moves further above the subsistence level. (For some goods, consumption may decrease as total food expenditure increases; examples include some basic foods eaten by very poor people and considered “inferior,” such as grains, yams, potatoes, and other tubers.)

The locus of tangencies between the indifference curves and the budget constraints as total food expenditures increase is given by the curved line through points e, b, and d—the income-consumption line. The percentage change in grains consumed is less than the percentage change in total food expenditures, while the percentage change in vegetables/fruits consumed is greater than the percentage change in total food expenditures. Economists often summarize the relative response of one variable (X) to the change in another (Y) by the elasticity, which is defined as the percentage change in X divided by the percentage change in Y. If the percentage change is the same in both X and Y, the elasticity is one; if the percentage change is smaller in X than in Y, the elasticity is less than one and the response is said to be inelastic; and if the percentage change is greater in X than in Y, the elasticity is greater than one and the response is said to be elastic. In Figure 2, the response of grain consumption to a change in expenditure is inelastic and that of vegetable/fruit consumption is elastic.

What happens to the household choices if one of the prices changes, with food expenditure and the other price remaining constant (in peso terms)? In Figure 3, the price of grains is lower than in Figure 2, and the budget constraint shifts from $B_2B_2$ to $B_2B_2'$. If all food expenditure were on vegetables/fruits, of course, the lower grain price would not affect the amount of vegetables/fruits that could be purchased, so both $B_2B_2'$ and $B_2B_2$ have the same

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4 If all income is spent on food as in the present very simple example, income and expenditure are the same. If there are other commodities on which income is spent and savings to which part of income is devoted (that is, if there are more than two commodities that the household consumes), there still is a systematic relation between income and expenditures on grains and vegetables/fruits.
Figure 3—Constrained maximization of household objective function as grain price changes

intercept on the V axis (at which point the entire budget is spent on vegetables/fruits). If all food expenditure were on grains, however, the lower grain price would increase the amount of grain that could be purchased in direct proportion, so $B_2'$ is higher on the grains axis than $B_2$ (for example, if the price were 3 pesos per kilogram instead of 5 and income remained at 100 pesos, $B_2'$ would be at 33.3 kilograms and $B_2$ at 20 kilograms). The resulting budget constraint ($B_2B_2'$) is steeper than $B_2B_2$, reflecting that with the lower price of grain, the household has to give up more grain to purchase 1 more kilogram of vegetables/fruits. The effects of the lower price, such as in this case for grains, are often decomposed into a substitution effect and an income effect. The substitution effect reflects that the relative price of grains is lower than in Figure 2, so grains are substituted for vegetables/fruits, even if the expenditure is adjusted so that household welfare remains unchanged (that is, with the slope of the new budget line tangent to the same indifference curve that was the constrained choice in Figure 2, but at a point such as $j$, instead of $e$). The income effect reflects that the purchasing power of a given monetary expenditure on food increases with the lower price of grains (to the extent that some of the food expenditure is on grain), so that the household can move to a higher indifference curve (that is, to $U_3U_3$ rather than $U_2U_2$). The total effect of the lower grain price (a movement from $e$ to $h$) is the substitution effect (from $e$ to $j$) that causes more consumption of grains and less of vegetables/fruits, plus the income effect (from $j$ to $h$) that causes more consumption of both grains and vegetables/fruits (though not proportionately because of the different income elasticities noted above). The relative magnitudes of these
two effects determine whether vegetable/fruit consumption is higher or lower as a result of the lower grain price. If the substitution effect is large enough, vegetable/fruit consumption is lower, even though the household is better off with the lower grain price. Which effect is larger, moreover, may depend on how much lower the grain price is. The curve through e and h in Figure 3 gives the locus of household optimum consumption bundles with different grain prices; this curve implies reductions in vegetable/fruit consumption for somewhat lower grain prices but increases for much lower grain prices. Grain consumption is higher no matter how small or large the fall in grain prices, however, because both the substitution and the income effects work in the same direction.6

This simple framework implies certain conditions on household behavior: (1) the own-substitution effect (that is, the substitution effect for grain if the price of grain increases) is negative, and (2) there is symmetry in the cross-substitution effects (that is, the substitution effect for grain consumption due to an increase in the vegetable/fruit price is the same magnitude as the substitution effect for vegetable/fruit consumption due to an increase in the grain price). Objective functions cannot be observed directly, so such restrictions on the objective functions cannot be tested directly. But this framework also implies that there are demand functions that give the demand for a vector of choice variables (in this case, grains and vegetables/fruits) as dependent upon all of the predetermined variables from the point of view of household consumption behavior (in this case, grain and vegetable/fruit prices and total food expenditure) and upon parameters of the underlying constrained maximization process (in this case, the objective function parameters). There is considerable empirical work that attempts to estimate such systems of demand equations. Since consumption of micronutrients is determined by what foods and how much of those foods are consumed, good estimates of the demand system parameters for food can be used to obtain estimates of the demand for micronutrients, by applying micronutrient-to-food conversion factors. For such an indirect procedure to lead to good estimates of the demand for micronutrients, the estimates of the food demand system must be good in respects that are discussed further, for direct estimates of micronutrient demand and the level of aggregation of the food groups used must be such that there is not important intrafood-group substitution that is associated with the right-side variables in the food demand relations.7

This simple model has some important implications for considering household consumption behavior regarding micronutrient demands:

1. People make choices regarding their food (and other consumption) based on the constraints under which they operate and are not likely to change their micronutrient consumption choices unless they perceive that such changes improve their welfare.
2. If improved micronutrients cause the price of a particular food to change (for example, if the price increases because of enrichment or reinforcement with micronutrients) and households do not perceive the added micronutrients to offer compensating

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6For some goods, however, as already noted, consumption may decline as total food expenditure increases. In this case the substitution and the income effects for own-price changes may be opposing.

7There are estimates of food demand systems that are translated into nutrient demands (for example, Pitt 1983, Strauss 1984, and Murty and Radhakrishna 1981). Behrman and Deolalikar (1987) suggest that the aggregation into fairly large food groups in these estimates may cause substantial biases in estimated nutrient elasticities with respect to income. Bouis and Haddad (1992) and Subramanian and Deaton (1994) claim that Behrman and Deolalikar overstate such effects, though Subramanian and Deaton still find them to be considerable.
advantages, the own-substitution effect means that households will tend to substitute away from such foods, probably reinforced by the income effect.

3. Changes in prices of other foods (or, more generally, of other goods and services) have an effect on the consumption of a particular food (and the micronutrients obtained from it), even if its own price does not change, because substitution and income effects will still occur.

4. If incomes or relative prices change over time, households respond in ways that change the absolute amount and the composition of their food consumption, and thus their micronutrient intakes. If, as a result, people consume more of the micronutrients perceived by nutritionists to be deficient in diets (for example, by eating more vegetables/fruits), micronutrient deficiencies may fall. But such deficiencies also may increase if, for example, over time, with more income, households reduce their consumption of "inferior" foods that are rich (either now or because of future breeding developments) in critical micronutrients.

5. Critical to understanding the determinants of consumption of micronutrients are the magnitudes of responses to variables, such as prices and income, that can be obtained from good estimates of food demand systems or from good direct estimates of micronutrient demand systems.

EXTENSIONS AND COMPLICATIONS
OF THE SIMPLE MODEL OF HOUSEHOLD DEMAND

The simple model described has important implications for thinking about and evaluating household behavior regarding consumption of micronutrients. Further insight can be gained by considering in less detail some complications related to the following series of questions.\(^8\)

**What If the Household Is Engaged in Production?**

The simple standard model does not consider the possibility of household production. That possibility, however, may have important implications if (1) markets for the services of the household's productive assets (for example, labor, land, and genetic endowments) are nonexistent or imperfect and (2) there are transaction costs for engaging in markets so that buying prices differ from selling prices. For these reasons, it may not be possible to separate the household income-generation decisions from household consumption decisions or it may be necessary to adopt a much more limited definition of predetermined income than the conventional measures, since much of what is in conventional income may reflect concurrent household consumption decisions, including the consumption of nutrients. Such possibilities are emphasized in the farm-household literature\(^9\) (or, more generally, firm-household, since the same considerations may hold for households engaged in commercial or light manufacturing activities). In the extreme case, a household may be completely autarkic because of a lack of markets. In such a case, rather than having a given predetermined income so that the budget constraint is linear, as in Figures 2 and 3, the household may have a production possibility frontier in which the options that it faces reflect diminishing marginal returns to

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\(^8\) The presentation of some issues in answer to one question rather than another is somewhat arbitrary, but facilitates a simpler presentation.

household productive assets, the services of which cannot be traded in markets (for example, labor and land, if there is neither a land rental market nor a labor market) as in Figure 4. This figure is drawn to reflect the assumptions that the household can produce greater income if it chooses to consume more grain and obtain more energy, which affects labor productivity; that there are diminishing returns to increasing calorie consumption, given the fixed genetic endowments of household members; and that markets are nonexistent, so that the income constraint for such a household is the production possibility frontier, which is a concave curve in relation to the origin rather than a straight line. The income trade-off for consuming grains versus vegetables/fruits in this case depends on the amount of grain consumption. This trade-off is given by the slope of the production possibility frontier. At a general level, the household maximizes its satisfaction by following the same general rule as for Figure 2: it chooses the consumption bundle at which the marginal trade-off in income generation between grains and vegetables/fruits is the same as the marginal trade-off in terms of the objective function—that is, at a point such as $h$, at which the indifference curve is just tangent to the production possibility frontier. This possibility of a household with access to no markets—and many more limited cases of missing markets—complicates the analysis of household behavior because all of the assets and prices that affect production must be included.

\[\text{Vegetables/Fruits (kilograms)}\]

\[\text{Grains (kilograms)}\]
in the analysis of the consumption-demand decisions that affect micronutrient and other consumption.

Some important insights into the role of micronutrients in household behavior can be obtained from good estimates of the production functions into which micronutrients enter directly. Possible examples include production functions for health, agricultural productivity, wage-market productivity, and cognitive achievement. Good estimates of such production functions must control for the choice aspect of many of the right-side variables, including the micronutrients themselves. But also note that changes in production functions may significantly affect micronutrient deficiencies, even if micronutrients do not enter directly into such production functions. For example, if new technologies are developed for products that are low in micronutrients or that are not consumed by the producers but only sold on markets, the induced increased income of producers may increase micronutrient intakes by moving the budget constraint out.

**What Is Demanded?**

The household generally demands goods and services for consumption purposes and—if the income-generation decision is not separable from consumption behavior—for production purposes. Within a one-period model, these are current demands for current consumption and current production. But in a more realistic characterization of reality, a period is likely to be short enough (for example, a year) so that a household also likely has current demands for resource uses that are expected to increase future consumption and production; these demands are called investment demands. Food is a major component of current consumption expenditures for most poor households, typically accounting for one-half or more of such expenditures. Among major nonfood current consumption expenditures of the household’s full resources are items such as clothing, shelter, fuel, beverages, transportation, entertainment, leisure, and expenses related to raising children. Important current directly productive inputs for farm households typically include seeds, water, fertilizers and pesticides, hired labor, and services of bullocks and of machinery and equipment. Major investment expenditures include expenditures to improve human resources (for example, through education or health) as well as physical resources (for example, through purchases or construction of

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11Knowledge of nutritionists may be critical for appropriate specification of the roles of micronutrients in these production functions, because the bioavailability of micronutrients often depends on the form in which they are consumed and interactions with other nutrients (and nonnutrients) consumed at the same time. For example, Calloway (1995) notes that requirements for thiamine, riboflavin, and niacin are related directly to total energy intake; the vitamin B₆ requirement increases with increasing protein intake; the need for vitamin E increases with the amount of essential polyunsaturated fatty acids in the diet; hemoglobin-iron is more readily absorbed than other food forms of iron, but tannins interfere with absorption; zinc absorption is enhanced by the presence of animal-source protein and diminished by the presence of phytate (and possibly calcium); alkaline processing improves niacin availability (but is destructive to riboflavin and thiamine); and vitamin A in its essential retinol form is present only in animal-source foods and only three of the plethora of precursor carotenoids in plants are significant vitamin A sources for humans.

12Usually, such control is through some simultaneous estimation technique, such as using instrumental variables with the right-side asset and price variables in demand relations used as the instruments. But the instruments must be independent of the disturbance term in the production function that is being estimated in order to obtain consistent estimates, a condition that may be difficult to achieve, since, often, there are plausible unobserved choice variables that enter into the production function. Behrman and Lavy (1995), for example, show that the estimation of the health/nutrition effect on child cognitive achievement changes substantially if there is control for unobserved allocated inputs, such as parental time spent with the child. Also, if the first-stage estimates do not reflect sufficient correlation with the instruments, the instrumented estimates may be more biased than the uninstrumented ones, though the examples provided in the literature are for very low first-stage correlations (for example, Nelson and Startz 1990a, 1990b; Bound, Jaeger, and Baker 1993; Deaton 1995).
houses, irrigation systems, livestock, trees, land, or machinery and equipment). For all of these goods and services, even in poor rural societies, there are typically many varieties available or great quality variations in what is available.

Household demand for micronutrients is likely to reflect not that micronutrients are choice variables that appear directly in the household objective function, but that micronutrients have indirect effects through choice variables that do appear in the objective function or simply are characteristics of multidimensional goods (foods) that enter directly into the household objective function.  

The net result of these indirect effects is a set of demand relations for these micronutrients that depends (like all other household demand relations) on all predetermined assets (human, physical, financial), all prices that the household faces, and all of the parameters in the underlying objective function and production relations (with assets, prices, and technological parameters, including those for household production for components of income/production decisions that are not separable from consumption decisions). Consistent estimation of these demand relations would be useful for this chapter, because such estimates would indicate how changes in right-side variables such as prices or schooling affect the intake of micronutrients. But such estimates may be difficult to obtain for at least two reasons. First, the relevant numbers of prices and assets may be quite large, which may make data requirements substantial. Second, some important unobserved prices, assets, and parameters are likely to vary significantly among households and, if they are correlated with observed right-side variables but not controlled in the estimates, cause estimates of observed effects to be biased. For example, genetic-based abilities and robustness or differences in preferences may be associated with the extent of schooling of household members and may affect all household demands, with biased estimates of schooling effects resulting if these unobserved heterogeneities across households are not controlled in the estimation process.

**What Is Predetermined in These Decisions?**

Knowing what factors are predetermined in household allocation decisions is critical for obtaining good estimates of household demand relations or household production relations that are informative about the determinants of micronutrient consumption or about the effects of micronutrients on various outcomes. "Predetermined" in this context means uncorrelated with the disturbance term in the relation being estimated. The disturbance term in a household demand or household production function typically includes all of the determinants not

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13While, in many cases, this distinction between direct and indirect effects is somewhat arbitrary (for example, are parents likely to be interested in the cognitive achievement of their children directly, or in the indirect effects of such cognitive achievement on the expected income of their children?), it does seem relevant for the micronutrients of primary interest. These micronutrients seem to affect the choice variables in the objective function indirectly rather than directly. For example, the extent of vitamin A consumption is not likely to enter directly into the objective function, though it is associated with different foods the consumption of which directly affects satisfaction and itself directly affects variables such as health and cognitive development that may directly affect satisfaction (or indirectly affect satisfaction through affecting productivity).

Some household demand analysis focuses not on the commodities that households purchase or produce to consume, such as grains and vegetables/fruit, but on the characteristics of those commodities, such as their sweetness, bulk, appearance, and nutrient content (for example, see Bouis 1995 for a recent application to the analysis of nutrient demand patterns in developing countries). The channels through which micronutrients may indirectly reflect or affect household satisfaction are many, including the association with foods that are desired, at least, in part, for other attributes (for example, taste, status, or energy); the impact on current health that may enter directly or indirectly (through productivity and therefore the command over resources) into the objective function; and human resource investments (through affecting learning capacities and long-run health).
observed in the data (for example, unobserved genetic factors, abilities, tastes, soil quality, and management abilities), as well as measurement errors. If right-side variables in the relations being estimated are not independent of the disturbance terms, their estimated coefficients are not interpretable, because they include not only their own true effect, but also any correlated effect of the unobserved factors in the disturbance term. If, for example, one is estimating the effect of income on micronutrient consumption and if income, in part, reflects the consumption of micronutrients through their productivity effects, the failure to control for the concurrent choice of income and micronutrient consumption (which both depend on the same unobservable characteristics, so income is not independent of the disturbance term) may lead to incorrectly attributing the effect of micronutrients on income to the effect of income on micronutrients. Or, if one is estimating the effect of micronutrients on cognitive achievement in a cognitive achievement production function, the failure to control for the concurrent choice of cognitive achievement and micronutrient consumption (which both depend on the same unobservable characteristics, so micronutrients are not independent of the disturbance term) may lead to incorrectly attributing the effect of other unobserved choice variables (such as time allocations) or unobserved given variables (such as genetic factors related to health and learning, desire to learn, and the general environment) to micronutrients.

The independence of the disturbance term is not a second-order technical statistical requirement that needs to be followed only in esoteric academic studies; rather, it (or its equivalent) is essential for drawing inferences about the real world from casual observations or from systematic analysis. In some contexts, independence of the disturbance term can be obtained by careful experimental methods, and in others, by using estimation methods such as instrumental variables (but, as already noted, good instruments themselves must be independent of the disturbance term and sufficiently correlated with the right-side variables being instrumented, and good instruments often are difficult to find).

**Who in the Household Receives the Micronutrients? Whose Objective Function Is It?**

To this point, the focus of this paper has been on household consumption of micronutrients. But the distribution of micronutrients within the household may be critical, because some household members may have relatively greater micronutrient deficiencies in comparison with their "needs." Claims are frequent that infants and small children (particularly daughters or higher birth-order children), pregnant and lactating women, females in general, and the elderly have relatively great nutritional deficiencies. Claims also are frequent that the nature of intrahousehold distribution of nutrients depends on the relative power of various household members as they bargain over household resources, with, for example, children in households where women have greater power receiving more nutrients. The simple model of household food demand easily can be expanded to accommodate these possibilities. Rather than consider the foods or micronutrients available on an aggregate level for the whole household, it is necessary to consider foods and micronutrients for individual household members. The objective function also, conceptually, can be modified to represent the different preferences and bargaining strengths of different household members.¹⁴

¹⁴There is a growing literature that attempts to formalize allocations between husbands and wives within various frameworks, including cooperative and noncooperative games. See Haddad, Hoddinott, and Alderman 1993 and Behrman 1996 for surveys and for references to other studies.
A number of empirical difficulties, however, arise in estimating the nature of such intrahousehold allocations. First, data are required on individual micronutrient consumption rather than on total household micronutrient consumption. Such data are available in a few data sets, but not in most data sets that have been used to explore nutrient demands. Second, data on "needs" or "requirements" are also necessary to assess the relative micronutrient deficiencies of different household members. But considerable controversy exists about what these requirements are. Moreover, some of these needs may themselves reflect household decisions (for example, regarding time allocation and work intensity), which must be taken into account in making assessments about relative deficiencies but almost never are. Third, to test the bargaining power stories about what determines intrahousehold allocations, some indicator of individual bargaining strength that is independent of the disturbance term (that is, independent of heterogeneous tastes and productivities that are in the disturbance term) is needed, but finding such an indicator (short of the experiment of randomly distributing resources among members of different households) is difficult indeed.

Who Knows What?

Earlier this paper stated that the standard model of the constrained maximization of the household objective function depends on what information household members have about a number of factors, including their own endowments, prices, and production technologies. The standard economic literature on household demand generally assumes that household members have good information when they make these decisions, though the applied literature has in some cases explored the role of imperfect information, particularly with regard to nutrient demand. In other dimensions of economic analysis, however, information problems have increasingly been viewed as central to understanding economic phenomena (for example, principal-agent problems in which principals have no or imperfect information about conditions such as work intensities of agents). Information problems also may be central to rationales for policy interventions on efficiency grounds. For example, if poor households are making fully informed decisions that involve using some of their resources for purposes other than to lessen micronutrient deficiencies, and the prices they face reflect the true marginal social costs of the goods and services that they consume, then policy interventions that cause them to change their decisions to consume more micronutrients are likely to be inefficient and to lower the household's welfare (for example, by moving from a point such as e in Figure 2 to a point such as for g), even if they do result in more micronutrient consumption. However, if households are operating on the basis of imperfect or incorrect information about

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15A change is efficient in the sense in which economists use the term if it can improve the situation of one entity without worsening the situation for any other entity. If there is inefficiency, the welfare of some individuals could be improved without lessening that of others—which would seem socially desirable. If prices reflect the true marginal social costs of goods and services, satisfaction of all marginal considerations of the type that are discussed earlier (for example, the tangency conditions, so that the extra gains due to small increases in grain relative to those in vegetable/fruit consumption are equal to the relative prices of the two foods) result in efficiency. If the rest of the economy is not efficient, removing any one inefficiency does not necessarily make the overall economy more efficient (this situation is referred to as the second-best argument in the economic literature because if the first-best situation with no inefficiencies cannot be attained, it is not necessarily desirable to remove all but one inefficiency, since some of the inefficiencies may offset one another). Nonetheless, in the absence of specific evidence to the contrary, removing any one inefficiency is likely to increase overall efficiency and thus be desirable on efficiency grounds. Though efficiency is a major factor in considering economic reasons for policy interventions, since it leads to more output at a point of time and greater growth over time, there also may be other important economic reasons for policy interventions, such as distribution concerns. An economy may be efficient but have a distribution of consumption that its members view as undesirable (for example, because it is very unequal).
any variable related to the determination of household behavior, including the micronutrient content of various foods or the effects of micronutrients on productivity, cognitive achievement, or health, improved information leads to improved household welfare and can lead to greater efficiency. Information, moreover, often is a public good (in the sense that more information for one individual does not reduce what is available for others), in which case private incentives to collect, analyze, and disseminate information may be socially inadequate and public policies (for example, subsidies) to improve information are efficient. Information problems are therefore of substantial interest, since they open up possibilities of policy interventions that may increase efficiency and improve micronutrient consumption.

**What Is the Time Period of Interest?**

The discussion so far gives a one-period perspective, though the possibility of investment demand that does not yield returns until subsequent periods has been mentioned. But a multiperiod approach may be essential for understanding if resources can be transferred over time or if there is learning over time. To analyze the determinants and effects of micronutrients for poor populations in rural areas of developing countries, who have limited means of transferring resources over time—including limited and imperfect credit markets—it may be important to consider household behavior in different stages of agricultural production (for example, planting, cultivating, and harvesting) in different seasons (for example, the kharif and rabi seasons in South Asia). Within such a context, the effects of unanticipated income on the micronutrient consumption of households may differ depending on the stage and season in which such income is received. If so, the apparent household demand for micronutrients may vary significantly across short periods of time and will not be well understood if the analysis ignores the nature of such agricultural stages and the mechanisms for transferring resources over time.
3. WHAT IS KNOWN AND WHAT IS NOT KNOWN ABOUT HOUSEHOLD BEHAVIOR AND MICRONUTRIENTS

The characterization of how much is known about household behavior and micronutrients is inversely associated with how closely individual studies consider micronutrients per se. A great deal is known and generally accepted about many dimensions of the general framework of household behavior summarized earlier, and a fair amount is known and generally accepted about many dimensions of household behavior and calories and protein-energy malnutrition (PEM). Much less, however, is known and generally accepted about household behavior and micronutrients. What is "known" in the sense of having been confirmed by careful systematic studies and what is "generally accepted" in the sense of being believed to be true by many individuals working in a field, moreover, are not always the same. This section reviews selected dimensions of the literature on these topics with reference to some of the empirical questions suggested by the previous discussion.

HOW RESPONSIVE IS MICRONUTRIENT DEMAND TO INCOME INCREASES?

Probably the most widely accepted empirical result regarding household demand behavior is that there are systematic changes in the composition of household expenditures as income increases, with declining shares devoted to "necessities" such as food, clothing, and shelter and increasing shares devoted to relative "luxuries," such as entertainment and consumer durables. Food expenditures, typically a large share of total expenditures for poor households, tend to become a smaller share of total expenditures as income increases. In other words, total food demand tends to be income inelastic, with estimates from various poor populations suggesting that total food expenditures increase about 5-10 percent in response to a 10 percent increase in income.\footnote{Alderman (1986) surveys a number of these estimates. A 19th-century Prussian statistician by the name of Ernst Engel was among the first to emphasize the systematic changes in household expenditure patterns as income increased and to show that the share of food in total income tended to decline, a result that is widely characterized as "Engel's law." Some claim that there are exceptions. For example, Lipton (1983) suggests that "Engel's law is repealed" because his analysis of cross-sectional data implies an increasing share of food expenditures in total household expenditures for very poor households in India.} If nutrient consumption was directly proportional to food expenditures, such results would imply that nutrient intakes also would increase by about 5-10 percent in response to a 10 percent increase in income. Based in part on such results, some commentators have suggested that the most effective means of reducing malnutrition is the general process of development, with its concomitant income increases.\footnote{For example, the World Bank (1980, 59) states: "There is now a wide measure of agreement on several broad propositions. Serious and extensive nutritional deficiencies occur in virtually all developing countries, though they are worst in low-income countries. . . . Malnutrition is largely a reflection of poverty: people do not have income for food. Given the slow income growth that is likely for the poorest people in the foreseeable future, large numbers will remain malnourished for decades to come. . . . The most efficient long-term policies are those that raise the income of the poor. . . ."}

Until recently, most of the emphasis on malnutrition in developing countries was on energy inadequacies. Numerous studies, therefore, have attempted to estimate calorie-income elasticities. Some controversy has arisen over whether the estimates for poor populations, in fact, are consistent with calorie-income elasticities of about the same magnitude as the total
Food expenditure-income elasticities (for example, 0.5 to about 1.0) or whether they might be much lower (for example, 0.1 or lower). Dimensions of this controversy include (1) the extent to which food composition shifts toward more expensive calorie sources as income increases, so that calories increase much less than total food expenditures, (2) the extent to which estimates of calorie-income elasticity based on expenditure surveys are upwardly biased by common measurement errors in calories that are calculated from food expenditures and in income that is represented by total household expenditure, (3) the extent to which the difference between food obtained by the household and food consumed by household members (which may go to guests, employees, animals, and wastage) increases with income, so that estimates based on the former are misleading, (4) the extent to which calorie-income elasticity is higher for very poor people than for even moderately poor people, (5) the extent to which estimated calorie consumption and calorie use elasticities are consistent with observed weight differences among individuals from households with different incomes, and (6) the extent to which estimates capture the effect of predetermined income on calorie consumption, particularly within the context of dynamic, multiperiod considerations with limited possibilities for transferring resources across periods. The consensus view now is that calorie consumption is much less responsive to income increases than was the consensus perception a decade ago, though there remains some divergence in views.

What implication does this controversy have for the almost unstudied question of how responsive micronutrient consumption is to income? The most important implication is that the calorie-income debate illustrates how substantially different conclusions about the nature of empirical realities can emerge from what may seem, from a distance, to be very similar approaches. Therefore, systematic consideration of the data-modeling-estimation issues in a particular context may be critical to obtain a better understanding of reality.

Are there, in addition, inferences that can be made about the magnitude of micronutrient-income elasticity from the calorie-income elasticity debate? The answer to this question seems to be that little can be inferred. True, the current “consensus” view (and, even more, the “revisionist” view) that calorie-income elasticities are lower than food expenditure-income elasticities is consistent with the possibility that as incomes increase, people purchase more expensive foods that are richer in micronutrients than the basic staples that are the primary source of calories, and that such micronutrients are less likely than calories to “leak” away from household members. But it is also consistent with the possibility that more expensive calories are largely more processed and higher status foods that are not necessarily much, if at all, richer in micronutrients (for example, white shelled, whole long-grained rice instead of unshelled broken-grain rice). To learn more about household demand for micronutrients, it thus seems necessary to turn to studies that address these demands directly.

Unfortunately, relatively few studies focus on the demand relations for micronutrients in comparison with the large literature concerned with calorie demands. Five studies that analyze demand relations for micronutrients for samples of rural Indian households (Behrman

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18 This summary should be qualified by the observation that the author has been involved in this debate and coauthored one of the major papers arguing the revisionist view that calorie-income elasticity is much smaller than previously claimed (Behrman and Deolalikar 1987). Studies from economists associated with IFPRI also have figured prominently in this debate. Bouis and Haddad (1992), also arguing the revisionist view, summarize many of the studies that have contributed to this debate. Studies that are too recent to have been included in this survey are Alderman and Garcia 1993; Behrman, Foster, and Rosenzweig 1996; and Subramanian and Deaton 1994.
and Deolalikar 1987), rural and urban Indonesian households (Pitt and Rosenzweig 1985; Chernichovsky and Meesook 1984), Nicaraguan households (Behrman and Wolfe 1984a), and rural Philippine households (Bouis 1991) are summarized here. These studies report some substantial differences in micronutrient-income elasticities. The Indian study yields income-elasticity estimates of 0.06 to 0.19 for protein (depending on whether level estimates or differences over time are used), 0.30 to −0.22 for calcium, −0.11 to 0.30 for iron, 0.19 to 2.01 for carotene, −0.08 to 0.18 for thiamine, 0.69 to 0.01 for riboflavin, −0.15 to 0.21 for niacin, and 0.15 to 1.25 for ascorbic acid. The rural Indonesian study reports very low micronutrient-income elasticities (below 0.03) for all of the nutrients considered (that is, calories, protein, fat, carbohydrates, calcium, phosphorus, iron, vitamin A, and vitamin C). The all-Indonesian study reports much higher nutrient-income elasticities (for example, from 0.70 to 1.20 for calories, protein, fat, carbohydrates, calcium, iron, vitamin A, thiamine, riboflavin, niacin, and vitamin C for the lower 40 percent of the population by expenditure on Java). The Nicaraguan study reports significant income elasticities in the range of 0.04 to 0.11 for calories, protein, iron, and vitamin A (with statistically significant, but quantitatively small, nonlinearities). The Philippine study reports an iron-income elasticity of 0.44, a calorie-income elasticity of 0.16, and insignificant income elasticities for vitamin A and vitamin C.

Some of the considerable differences among these estimates probably reflect the different measures of micronutrients and income that are used. The Indian and Philippine studies focus on nutrient intakes from 24-hour food-recall data with food-to-nutrient conversion factors applied at fairly disaggregated food levels from relatively small samples (120 to 448 households). The Nicaraguan study considers nutrient intakes from one-week food-recall data with food-to-nutrient conversion factors applied at fairly aggregate food group levels (15 food groups) from a stratified national sample of 3,726 households. The Indonesian studies use nutrients available to the household, based on recall regarding food expenditure in the month previous to the survey, with food-to-nutrient conversion factors applied at fairly aggregated levels (that is, 11–13 food groups) from much larger national probability samples. Studies of calorie-income elasticities with the same Indian and Philippine data show that the source of the nutrient indicator can make a considerable difference; estimates are much higher with expenditure-based than with food intake data. The income indicators also differ across the studies: the Indian and Nicaraguan studies use annual income, the rural Indonesian study uses annual profits, the rural and urban Indonesian study uses monthly total expenditure, and the Philippine study uses total expenditure and income (with the time periods unclear). The calorie demand literature, again, suggests that the choice of income indicator may matter. Presumably, within a one-period framework, it would seem preferable to use income components that are predetermined in the sense defined earlier, which would be best approximated in these studies by profits (as in the rural Indonesian study) or possibly by instrumented expenditure or income (as in the Indian and Philippine studies, though no information is provided on which to judge how satisfactory the instruments used are). The large differences between the two Indonesian studies, for example, apparently reflect, in substantial part, the difference between ignoring measurement errors and endogeneity problems by using total expenditure in the all-Indonesian study and using what arguably is predetermined income in the rural study. The large differences between the alternative estimates for some micronutrients for the Indian sample also suggest that the estimation method matters, so a priori
modeling should be used to choose the most appropriate estimates. From a dynamic perspective, moreover, it is not clear that any of these studies use a truly predetermined income measure, and all but the all-Indonesian one use nutrient and income indicators defined over different time periods, which may lead to interpretation problems if there are differences across agricultural production stages and difficulties in transferring resources over time (as found for the calorie demand estimates in Behrman, Foster, and Rosenzweig 1996). Thus, there is a need for more careful analysis of micronutrient demand relations to ascertain the magnitude of the income effects that are important before it will be possible to answer the basic question of how much micronutrient deficiencies will fall as a result of general economic growth and, more important, income increases among the poorer members of society, including those increases originating from increased agricultural productivity. Without further study, one cannot be sure to what extent the differences in the estimates across the studies reflect differences in the contexts of the studies or differences in the statistical biases due to different data and estimation strategies.

HOW RESPONSIVE IS MICRONUTRIENT DEMAND TO PRICE CHANGES?

On a general level, there is evidence of substantial price responsiveness in household demand for micronutrients, with considerable support for the basic propositions of demand models discussed previously—negative compensated own-price responses and symmetric cross-price responses.

Studies of food demand in poor developing countries also tend to find substantial responses to prices. The all-Indonesian study by Chernichovsky and Meesook (1984), discussed earlier, for example, presents own- and cross-price elasticity (uncompensated for income changes) estimates for 13 food groups for the population deficient in calories, separately for Java and the outer islands. Their estimates of the own-price elasticities are significant in every case, with 22 of the 26 negative and 19 of the 26 indicating negative elastic responses (that is, food group consumption drops more than 10 percent if there is a 10 percent increase in the price of that group). Their estimates of the cross-price elasticities are significantly above or below zero in over three-fifths of the 312 possibilities, with about one-half of the significant estimates positive and the other half negative. Alderman (1986, 25) surveys a number of such studies and reports that they show that “the poor are quite responsive and that most elasticities decline with increased income.” Such estimates imply both that prices may be important determinants of household food demand (particularly for poorer households) and that food composition responses to price changes may be complicated by cross effects with both substitutes and complements. Thus, predicting household responses to food price changes associated, for example, with changes in micronutrients may be difficult without careful food demand studies because, although the own effects are fairly predictable, the cross effects apparently are complex and often substantial.

Direct studies of micronutrient price responses are relatively few. Four of the studies whose income estimates were summarized earlier, however, also contain price estimates. The all-Indonesian study in Chernichovsky and Meesook (1984) reports significant price

\(^{19}\)The exceptions are 0.52 for corn and 1.07 for legumes, both in Java (compared with –3.28 and –2.24, respectively, for the outer islands). Chernichovsky and Meesook do not discuss what they think causes these results.
responses for 55 percent of the 286 possibilities (that is, 11 nutrients times 13 food group prices times 2 geographical areas). More than three-quarters of these responses are negative, but almost a quarter are positive, suggesting that increases in the prices of some foods induce substitution of other foods that are relatively rich in micronutrients (for example, vitamin C consumption is estimated to rise 5–6 percent in response to a 10 percent increase in rice prices). A comparison of these estimates with those already given for the 13 food groups suggests less inducement for change in nutrient consumption than for change in food consumption as food prices change, which seems plausible a priori since shifts among foods that have roughly similar nutrients do not change nutrient consumption much. Therefore, almost all of the micronutrient price responses are inelastic, and most are smaller than 0.5 in absolute magnitude. Nevertheless, for vitamins A and C, 12 estimated price elasticities are larger than 0.5 in magnitude: for vitamin A, responses are negative for prices of rice, wheat, potatoes, and the other food category but positive for prices of cassava and meat and poultry; for vitamin C, responses are negative for prices of wheat and the other food category but positive for rice and meat and poultry. Therefore, the effects of food price changes on micronutrients appear to be concentrated particularly on vitamin A and C.20

The rural Indonesian study in Pitt and Rosenzweig 1985 reports significant nutrient-price elasticities in 33 percent of the 90 possibilities (9 nutrients times 10 food group prices), 60 percent of which are negative. These estimates suggest less price responsiveness than those in the all-Indonesian study, with none of the estimated price elasticities being greater than 0.5 in absolute magnitude (though many price elasticities are greater than the income elasticities). They also do not suggest that vitamins A and C are particularly price responsive; to the contrary, vitamins A and C have the fewest significant estimated price elasticities among the 9 nutrients considered.

The rural Philippines study in Bouis 1991 reports significant nutrient-food price responses in 38 percent of the 16 possibilities (4 nutrients times 4 food prices), and all of the significant price elasticities are negative. The significant estimated price elasticities for the micronutrients, moreover, are relatively large in comparison with those already summarized: –0.35 for iron and –0.64 for vitamin C with respect to the corn price, –0.70 for vitamin A with respect to the sweet potato price, and –2.29 for vitamin A with respect to the rice price.

The Indian study in Behrman and Deolalikar 1990 reports price responses significantly above and below zero for 54 percent of the 28 possibilities (7 nutrients times 4 prices), and the majority of these responses are positive. Many of the implied elasticities are quite large in absolute magnitude, ranging from –11.0 for calcium consumed by women with respect to the milk price to 12.5 for thiamine consumed by men with respect to the milk price.

Thus the available estimates suggest that micronutrient responses to price changes are widespread and fairly substantial (at least in comparison with responses to income changes). But the few studies that are available raise some questions, such as why are there such differences between the two Indonesian studies? Specifically, for example, how important is the somewhat different aggregation of food groups? More generally, to what extent do food prices in these estimates represent homogeneous foods as opposed to different qualities of

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20For the other nine nutrients, there is only one estimated nutrient-price elasticity as large as 0.5 in absolute magnitude—a value of 0.81 for the iron-cassava price elasticity in Java.
food? Deaton (1988) has suggested that this issue affects the price elasticity estimates for food systems, but it has not been explored for micronutrient demand.

**HOW IMPORTANT ARE MICRONUTRIENTS IN MORBIDITY, PRODUCTIVITY, AND LEARNING?**

To an outsider, nutritionists and epidemiologists appear to have shifted over time their assessments of which nutrients are critical for improvements in health and productivity in developing countries. After a number of years in which experts seemed to view protein-energy malnutrition as the dominant nutrition problem in developing countries, there seems to be an increased recent emphasis on the possibly critical role of micronutrient deficiencies. Levin et al. (1991, 421), for example, state:

> Throughout the developing world high incidence of disease is associated with inadequate intake or absorption of micronutrients. Relatively minute quantities of each of the micronutrients are required for normal health status and well-being. If these nutrients are deficient, there are serious consequences for health, mental and physical. . . . It is generally thought that iron deficiency anemia is the most common nutritional deficiency in many developing countries, second only to protein-energy malnutrition (PEM).

A few studies of household behavior provide some information on this topic. Pitt and Rosenzweig (1985), in the same study on rural Indonesia referred to above, estimate production function relations for the incidence of illness across households, first without, and then with, control for the endogenous choice of nutrients consumed. Without control for the endogenous choices of nutrients by households, their estimates indicate that micronutrients and calories have small negative, but insignificant, effects on the incidence of illness. With control for the endogenous choices of nutrients, in contrast, calories, calcium, and vitamin C have much larger (in absolute value) and significantly negative effects on the incidence of illness; protein, carbohydrates, and fat have significantly positive effects, whereas iron, phosphorus, and vitamin A have insignificant effects. A comparison between these two estimates raises the possibility that the failure to consider the choice dimensions of household consumption decisions might lead to fundamental misunderstandings of the effects of micronutrients on morbidity, as estimated from household survey data. Interestingly, the Pitt and Rosenzweig study, while it supports the assertion of Levin et al. that micronutrients might be important, points to different micronutrients (that is, calcium and vitamin C) than are emphasized in Levin et al. and finds insignificant effects for two of the micronutrients emphasized (iron and vitamin A; this study presents no evidence for the third emphasized micronutrient, iodine). However, the results in this study, while provocative, must be qualified, because they depend on the maintained assumption that the instruments used to control for the choice of nutrients are predetermined (that is, independent of the disturbance term), which may not be the case if there are choice household inputs into health production that are not observed in this study (so that the instrumented values of the nutrients may represent, in part, such inputs).

A number of socioeconomic survey and experimental studies that attempt to investigate the impact of nutrition on labor productivity and on learning in schools are reviewed in
This evidence suggests possible important effects of micronutrients. But many of the results in this literature must be qualified as well, because it is not clear that the studies effectively control for household behavior regarding nutrient and other choices, including changes in such behavior induced by participating in experimental studies. In cases in which there are efforts to control for such choices, it is not clear that the procedures used lead to good estimates. For example, Behrman and Lavy (1995) show that failure to control for household allocations of nutrients and other health-related inputs may result in either upward or downward biases in the estimated effect of nutritional status. Then, they estimate cognitive achievement production functions for Ghanaian children aged 10–17 (1) with no control for the choice dimensions of nutritional status (as measured by anthropometric indicators), (2) with control, using, as first-stage instruments, community prices and governmental programs, and (3) with control for unobserved household and community factors, using information on intrafamily variance among siblings ("within-sibling" estimators). The estimates in scenario 2 suggest much larger effects of nutritional status than do those in scenario 1, but the effects evaporate in scenario 3. These results are consistent with the possibility that the effort to control for the choice aspect of household behavior by using price and program instruments leads to a considerably biased coefficient estimate of the nutritional status variable, because the instruments represent, in substantial part, unobserved variables allocated by the households, such as parental time devoted to helping children learn.

Thus, although much evidence suggests some important effects of micronutrients, consideration of the nature of household behavior and its implications for such estimates suggests that further explorations with more careful consideration of the modeling/estimation problems would be valuable to assess how robust the current state of knowledge is regarding various effects of micronutrients.

WHAT IS THE NATURE OF INTRAHOUSEHOLD ALLOCATIONS OF MICRONUTRIENTS?

Most of the evidence on household nutrient demand relations relates to calories, because emphasis has been greatest on PEM. This literature can be divided into three categories:

1. A number of studies characterize the distribution of calories among household members, relative to their "needs" or "requirements." The most common claims are that nutrients are allocated in households, if anything, to favor males and older children—particularly in parts of South and Southeast Asia and North Africa, but not in Sub-Saharan Africa. Explicit attention to micronutrients is relatively rare. One exception is Bouis's 1991 study for the rural south Philippines, in which he notes that iron intakes are about the same for males and females, which implies that iron adequacy is much lower for females, since iron requirements are about 80 percent higher for females than for males (and, therefore, that reallocation of iron intakes...
toward females within households would have a large positive impact), and (2) vitamins A and C are “reasonably equitably distributed across types of household members, although parents consume more vitamin A than their children” (p. 27). Another exception is for the sample collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) from rural south India. For this sample, Behrman and Deolalikar (1990) calculate the proportion of the total variance in age-sex standardized nutrient intakes relative to requirements across individuals within a household to be from 15 percent for riboflavin to 48 percent for calcium (thiamine, niacin, calories, protein, and iron, in that order, fall in between). Also for this case, Behrman (1988b) reports that the standardized seasonal mean requirements satisfied do not differ significantly between boys and girls for calories, carotene, riboflavin, vitamin C, and calcium.

2. A few studies go beyond such characterizations by attempting to estimate critical relations underlying household behavior, under the assumption that households have a unified objective function. Behrman (1988a, 1988b) has estimated the parameters of a household objective function defined over nutritional status of boys versus girls (so the objective function looks, in general terms, like that in Figure 4, with girls’ nutritional status on the horizontal axis and boys’ nutritional status on the vertical axis), using individual anthropometric and nutrient intake data from rural south India. The nutrient intakes include calories, carotene, riboflavin, vitamin C, and calcium (because these are the nutrients that Ryan et al. 1984 claim are critical for this population). The estimates suggest that in the surplus season households show considerable inequality aversion (that is, indifference curves are relatively sharply curved) and no preference related to gender or birth order (that is, indifference curves are symmetrical around the 45-degree ray from the origin). In the lean season households have an interest in productivity rather than in equality and have a preference for boys and older children. This study, however, does not control for the endogenous choice of nutrients consumed, which, in this case, results in estimation biases toward equity (or away from productivity). Another study for the same data set suggests that demand elasticities do not differ significantly among the nutrient demands for men, women, girls, and boys, but price elasticities tend to be larger in absolute values for nutrient intakes for females than for males—so nutrient intakes are subject to greater variability for females than for males (Behrman and Deolalikar 1990). A study for rural Bangladesh integrates the demand for calories with the use of calories in rural labor activities (Pitt, Rosenzweig, and Hassan 1990). This study finds that females (at least those over 10 years of age) receive fewer calories relative to their requirements than males; this result is reported by a number of other studies of intrahousehold calorie distributions in South Asia. However, the study also finds that, given the gender division of tasks, energy demands are relatively higher for adult males, so that adult males actually are “taxed” more at the margin than are adult females, because they shift more net calories (net of energy used in work) to other household members.

3. A third set of studies attempts to investigate whether who has control over resources affects the allocation of household resources toward nutrients or toward inputs into nutritional status, perhaps of particular household members. Perhaps the most
prominent of these studies have been on Brazil, with results indicating that if mothers have greater command over resources, if anything, nutrient intakes and nutritional status of children (and particularly of girls) are better (Thomas 1990, 1993, 1994). Related studies claim that, in some cases, children have better nutritional status in female-headed households—for example, low-income Kenyan households (Kennedy and Rogers 1993). In others, the evidence is more mixed; for example, in Jamaica food shares do not differ by gender of household head but female-headed households have a more nutritious food mix (Louat, Grosh, and van der Gaag 1993). All of the studies in this genre, however, have a major problem. The experiment that the analyst would like to perform is to increase randomly resources of some individuals or to assign headship randomly and see if such resource or headship assignments made a difference. But the social science survey data that have been used for such studies have used resource measures such as wages or income from assets (perhaps gained from past wages) or actual household headships, so it seems unlikely that the resource/headship variables are predetermined in the statistical sense. Instead, it may well be the case, for example, that women with more resources or who are household heads are more productive or independent than other women and that the resource/headship variables are proxies for these or other qualities, not only for resources or headship per se.

Thus, current knowledge of what determines intrahousehold distribution of nutrients, and particularly of micronutrients, is very limited.

ARE INFORMATION PROBLEMS CRITICAL IN DETERMINING MICRONUTRIENT CONSUMPTION?

Is schooling important for obtaining or processing information? In a world in which market options, technological options, and health and nutritional knowledge all are changing rapidly, the capacity for acquiring and processing information becomes ever more important. If there are information imperfections, moreover, as argued earlier, there may be an important reason for policy interventions and subsidies, from an efficiency perspective, because information is not likely to be distributed efficiently by unhindered markets. For example, Levin (1986) has calculated high benefit-cost ratios for anemia reduction: ranges of 7 to 71 for fortification and 6 to 54 for supplementation in Indonesia, Kenya, and Mexico. Even if these estimates are good (see Behrman 1993 for a critique), then, from an efficiency perspective, Levin’s advocacy of public financing of antianemia programs does not make sense, since the gains from greater productivity are largely private. But there may be good reasons to subsidize information about such potential gains because of the public-good dimensions of information. If the potential beneficiaries are persuaded that the gains are indeed in the range that Levin claims, then once they are aware of them, it would seem that they would quickly adopt fortification and supplementation, since they probably have no other investment alternatives with benefit-cost ratios as high as 6 or 7 to 1, to say nothing of 54 or 71 to 1.

Knowledge about the role of information in micronutrient demand, however, is limited. Schooling is widely thought to improve information gathering and processing capabilities.

\[22\text{[T]he financing of antianemia programs will probably require government sponsorship . . . Programs will have a solid financial base only if they are publicly financed} \] (Levin 1986, 237).
However, adult schooling has no significant effect on the micronutrient demand relations for Indonesia and the Philippines described earlier (Pitt and Rosenzweig 1985; Bouis 1991), nor does an index of nutritional knowledge have a significant impact in the Philippine case. Nevertheless, Bouis (1991, ii–iii) suggests that in the Philippine case there would be definite gains from educational and extension programs regarding vitamins A and C (which are concentrated in relatively cheap vegetables, but about which he claims consumers are unaware), though probably not for iron (for which sources are diverse and expensive). Also, Behrman and Wolfe (1984a) report significant positive effects of women's schooling on Nicaraguan household demand for calories, protein, iron, and vitamin A, with implied elasticities in the range of 0.07 to 0.19—higher for each nutrient than their estimated income elasticities.

While on a priori grounds, therefore, better information might have important positive effects through lessening micronutrient deficiencies and there might be important efficiency reasons for public policies to subsidize the provision of such information, very little, systematically, is known about the effectiveness of such information programs. Moreover, some of what is commonly accepted does not appear to be based on careful systematic knowledge. Perhaps the most important example is the widespread belief that there is overwhelming evidence that women's education causes improvements in the health and nutrition of household members, in part, through increasing the women's capacity for acquiring and processing information. While there is much evidence that women's schooling is associated with good outcomes, including better health and nutrition, most studies implicitly assume that women's schooling was distributed randomly, rather than systematically to females with greater abilities, greater motivation, better family background, and other advantages. That is, most studies of the impact of women's schooling assume that adult schooling is predetermined in the sense defined earlier, so it is not associated with unobserved abilities, motivation, childhood training regarding health and nutrition habits, and other factors that are in the disturbance terms of the relations being estimated for the determination of health and nutrition. On the basis of casual observation and of simple models of human capital investment, this widespread assumption seems to be untenable. Moreover, almost all of the studies of the effect of schooling on health and nutrition use years of schooling to represent this effect; this measure may not be a good indicator of the effect of schooling if there are variations in schooling quality, as other research suggests. Since few systematic studies explore the effect of women's (or men's) schooling with sensitivity to either the possible correlation of schooling with attributes such as ability, motivation, and family background or to possible school quality variations, the gains in understanding how schooling works from more systematic studies may be substantial.23

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23There are recent studies that address some of these questions for outcomes other than micronutrients. A series of studies on Nicaragua, for example, uses adult sibling data to control for the common childhood background of sisters (for example, Behrman and Wolfe 1984b, 1987a, 1987b, 1989; Wolfe and Behrman 1987). These studies find that the estimated effect of schooling on some outcomes (for example, income, child health, and fertility) is much less when common childhood background is controlled (suggesting that schooling is representing, in part, unobserved abilities and motivations related to childhood background). Controlling for childhood background does not, however, significantly change the estimated effect of schooling on household calorie consumption or the women's own health. Also, several recent studies suggest that cognitive achievement, produced in substantial part by time in school and school quality, better explains variations in labor market wages in Ghana, Kenya, Pakistan, and Tanzania than the usually used years of schooling (for example, Boissiere, Knight, and Sabot 1985; Glewwe 1992, 1996; Alderman et al. 1996).
WHAT IS THE NATURE OF DYNAMIC AND LONGER-RUN DETERMINANTS AND EFFECTS OF MICRONUTRIENTS?

There is little literature on dynamic aspects of the impact of nutrients in general, and what there is tends to focus on calories once again. For example, there is a small literature on whether children experience catch-up growth after suffering nutritional insults, but with diverse results. To illustrate, Martorell, Rivera, and Kaplowitz (1989) claim that Guatemalan children show no catch-up growth. But Behrman, Deolalikar, and Lavy (1994) find, for Indian and Philippine data, that estimates suggest limited catch-up growth in terms of anthropometric indicators if there is no control for heterogeneity across children in unobserved growth determinants (such as genetic makeup), but that catch-up is estimated to be complete after one season with such controls. These results again suggest that unobserved factors and related estimation methods may significantly affect understanding of important nutritional issues. Another example of a dynamic approach is the Behrman, Foster, and Rosenzweig (1996) estimation of the impact of income on calories across stages of agricultural production in Pakistan. This study shows how being careful about the timing of calorie consumption and of predetermined income components when estimating income effects can make a considerable difference in estimates, if mechanisms for transferring resources across production stages are limited and particularly if calorie consumption has productivity effects that are revealed only by waiting until harvests. To the author's knowledge, however, no such studies have been undertaken for micronutrients.
4. SUGGESTED RESEARCH ON HOUSEHOLD BEHAVIOR AND MICRONUTRIENTS

Household behavior has an important effect on the micronutrient intake of household members. The available information about household behavior and micronutrients, however, contains many gaps, a number of which have been indicated. Moreover, the nature of household behavior, particularly in light of variables that are not observed in data sets, makes it difficult to tease out causal relations rather than just associations. Nevertheless, research based on suitable data and using systematic integrated modeling/estimation approaches could be very informative regarding household behavior and micronutrients and could help fill some of the gaps noted previously. Since such research must be data-driven, this section sketches out some possibilities for further research based on three categories of data.

FURTHER ANALYSIS OF EXISTING DATA

Further analysis of existing data may offer insights both because some important topics have not been analyzed with existing data sets and because some of the estimation approaches in existing analysis have not been sufficiently systematic due to the nature of household behavior. Such further analysis is likely to be relatively cost-effective, moreover, because there is not a huge data collection start-up cost. For the same reason, such analysis could be undertaken relatively quickly and for a number of different locations in the developing world.  

Several suggestions for such analysis appear here, but others could be developed on the basis of the discussion in the previous sections:

1. The importance of the distinction between micronutrient intakes by household members and micronutrients available to the household has not been investigated, as it could be, with the data for Bukidnon Province in the Philippines gathered by researchers at the International Food Policy Research Institute (IFPRI) or the ICRISAT rural south Indian data. This distinction may be more or less important for micronutrients than for calories and may vary among micronutrients, since foods transferred from richer households to members of poorer households are likely to be primarily basic staples with a different micronutrient composition from the foods consumed by

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24 Some Annapolis workshop participants (see foreword) seemed to think that existing data are likely to be inadequate because of random errors in recall data for foods (perhaps, in part, because of the level of aggregation used for reported foods). For some micronutrients, it was suggested that as many as 20 to 25 daily observations (scattered over the year) for an individual would be required to obtain a sufficiently accurate measurement of that individual's micronutrient intakes (particularly for micronutrients that are obtained from a few foods eaten irregularly in a context with strong seasonality). While it may require a number of observations on disaggregated food consumption to obtain an accurate assessment of an individual's micronutrient intakes, however, it does not necessarily require many observations on disaggregated foods in a 24-hour recall to obtain good estimates of the determinants or effects of micronutrients in regression analysis. In an investigation of the determinants of micronutrients, micronutrients are the dependent variables in the regressions, and, as is well known, random measurement error in the dependent variable, while reducing the "explained" variance or $R^2$, does not affect the coefficient estimates of interest. In an investigation of the impact of micronutrients on various outcomes, instrumental variables should be used because of the endogenous choice aspect of those nutrients, and such procedures also eliminate the random measurement error problem (which, otherwise, would bias the coefficient estimates toward zero). Therefore, existing (or new) data sets can be very useful for analysis, even if the nutrient intake indicators have large random measurement errors.
members of richer households. It would be useful to learn how estimated demand relations for micronutrients differ, depending on this distinction, since this would help interpret estimates that can be made from data sources such as expenditure surveys, in which only nutrients available to the household can be calculated.

2. The importance of dynamic considerations in understanding the determinants and effects of micronutrients in light of imperfect mechanisms for transferring resources across time and possible productivity effects of micronutrients has not been investigated, even though recent research suggests that such an approach makes a considerable difference in understanding determinants and effects of calorie demand. The IFPRI Pakistan data could be used to investigate these considerations for micronutrients.

3. The interrelations—in both directions of causality—over time between cognitive achievement and micronutrients have not been investigated. The IFPRI Pakistan data could be used to explore both how micronutrient consumption affects subsequent cognitive achievement and how cognitive achievement affects subsequent micronutrient demands.

4. There are claims that encouraging home gardening is an effective way to increase micronutrient consumption. Available studies have tended to take home gardening as predetermined in estimating its effect on micronutrient consumption. But households that have elected to cultivate home gardens may be those that have particularly strong interest in or knowledge of possible benefits from the micronutrients available from such gardens. Therefore, home gardening may not be predetermined in the statistical sense, and the estimated effects of home gardens may include not only the effect of such gardens but also the effect of micronutrient knowledge and interests. A number of existing data sets, including the Philippine, Indian, and Pakistan data already mentioned, could be used to explore the effects of home gardens (or of own-farm production of certain crops) on micronutrient consumption while treating the behavior of having a home garden as a choice of households.

5. The estimated effects of prices on micronutrient demand vary considerably from sample to sample and in some cases are substantial. Obtaining better estimates of the price effects, including controls for unobserved quality differentials, would be useful in improving understanding of the determinants of micronutrient consumption. With several existing samples, it would be possible to see to what extent control for differences in average food qualities across communities affected the nature of the estimated price response in micronutrient demand, but such estimates have not yet been undertaken.

6. There are a number of estimates of the effects of calorie consumption on wages and farm productivity, but no evidence regarding the effects of micronutrients on wages and farm productivity with control for household behavior regarding food consumption, nor of the role of imperfect information in determining the rewards of better nutrition. Again, several data sets would permit such investigations.
ADDITION OF FURTHER ROUNDS OF COLLECTION TO EXISTING DATA SETS

Building on existing data sets offers at least four advantages. First, the existing information from an earlier period permits the investigation of the longer-run effects of micronutrients (say, over a decade) without having to wait 10 years for the data to be available. Such data sets could be used, for example, to investigate the effects of micronutrients consumed by small children on a range of outcomes (for example, cognitive achievement and anthropometrics) when they became teenagers. Second, much is already known from previous studies about the behavior and conditions of households in these data sets, and this knowledge would help researchers frame better questions for future studies. Third, such longitudinal information can be used to control for unobserved fixed individual and household effects, such as inherent robustness and abilities, that would cause biases if there were not controls. Fourth, if there have been important changes since the earlier data were collected, such as the introduction of new crop varieties or changes in government programs, the earlier data can serve as a baseline and permit better evaluation of such changes.

If the project is to build upon previous data sets, however, it would be desirable to collect in the new data rounds more extensive information about the determinants of micronutrient demands and about the possible effects of micronutrients. Examples—some of which are in some data sets—include information about knowledge of micronutrients, individual food intakes, more careful assessment of food transfers, more careful assessment of health (possibly including blood, urine, and stool samples; clinical signs of micronutrient deficiencies; and more information on morbidity), cognitive achievement, and more information on the health-related environment (for example, water quality) and health-related facilities (for example, quality indicators and timing of major changes). Researchers may also find opportunities to conduct and evaluate experiments on, for instance, alternative means of providing new information on products or micronutrients. Finally, using existing household samples that were started some time ago may raise problems related to the splitting up of households, attrition, and nonrepresentativeness. Therefore, it is important to follow up the components of split households, attempt to locate migrants, and perhaps supplement the ongoing sample to generate a representative cross section.

Strong candidates for inclusion of future rounds of data include the existing IFPRI Bukidnon Philippines data, the ICRISAT south Indian data, and the IFPRI Pakistan data. While these data sets will not necessarily span a period during which centers of the Consultative Group on International Agricultural Research (CGIAR) introduced important technological changes related to micronutrients, they will span periods covering important market and technological changes that may have substantially influenced micronutrient deficiencies and the effects of such deficiencies through changing use of income and time. The author is not aware of good examples of existing data sets in Africa and Latin America, but researchers should search to be sure that there are not such opportunities.

COLLECTION OF NEW DATA SETS

An important benefit of establishing new data sets is that the populations to be surveyed can be selected to provide insights about important micronutrient issues that relate to the particular interests of cooperating CGIAR centers, including the introduction of new plant and
animal varieties. But it is important to establish the samples and the baseline data early in the project so there will be time to collect and analyze several rounds of data within the scope of the project. Desirable data would include the types collected by some of the existing data sets emphasized earlier, with the extensions also noted earlier.

All three of these data possibilities should be pursued, since each has certain advantages and each would help fill the considerable gaps in our knowledge about the determinants and effects of micronutrient consumption. If such a mixed data strategy is followed and if systematic attention is paid to the implications of household behavior in the analysis of these data, the project should add significantly to the body of knowledge concerning the determinants and effects of micronutrients in human populations in developing countries.


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COMMENTARY
Beatrice Lorge Rogers

Jere Behrman provides a thorough treatment of the issues related to understanding the demand for micronutrients. My comments follow the organization of his paper, dealing with (1) determinants of demand for micronutrients; (2) appropriate policy levers to improve micronutrient nutrition; and (3) future research.

DETERMINANTS OF DEMAND FOR MICRONUTRIENTS

As Behrman observes, micronutrients are not perceptible the way calories are. Generalizable predictions about the relationship between calories and such determinants as income and food prices can be made because, functionally, food is calories, and the distribution of protein consumption tends to follow that of calories. This is not true of micronutrients; they are not observable in food, and their effects on health, growth, cognition, and productivity are subtle and occur with enough of a lag so that consumers are unlikely to perceive them. Hungry people seek more calories, but micronutrient-deficient people are not directly aware of the relationship between their diets and the way they feel.

It is generally true that at very low income levels, diets consist primarily of basic staples, and that, as incomes rise, diets become more varied. A varied diet, containing more animal products, fruits, and vegetables, is likely to be richer in most or all micronutrients than one in which the bulk of calories is provided by one or two staples. The income elasticity of demand for household calories drops off at fairly low income levels (Alderman 1986), as households use additional income to improve the quality as well as the quantity of the foods they consume. (In this case, quality refers to consumer aspects such as taste and prestige, not necessarily nutrient density.) The income elasticity of demand for overall nutritional quality is thus likely to continue to be higher at greater income levels than the demand for calories. But because micronutrients are less perceptible than the macronutrients that directly satisfy hunger, the income elasticity of micronutrient consumption is much less predictable once the perceived needs of the household have been met. In some cases, the “higher-quality” food is less nutritious (as the examples of polished rice and Coca-Cola demonstrate), so that income increments may be positive for some nutrients in some settings, but negative for others.

Micronutrients are distributed very unevenly among foods. As consumers substitute one staple grain for another in response to relative price changes, the macronutrients provided are likely to be similar, but the micronutrient content may vary greatly. Consider, for example, choosing between a leafy green vegetable and onions as a condiment for rice or millet: they may serve identical roles in the diet, but one is rich in vitamin A and the other is not. Also, one food may typically be prepared with quite different complements from another, so that a change in consumption of the staple implies dietary changes in other foods as well. Using the same example, if rice is typically prepared with onions but millet is prepared with green vegetables, then changing the choice of staple implies nutritionally significant changes in other, apparently unrelated, foods. Thus, even aside from the important issue of variations in methods of measurement and choice of variable discussed in the paper, the apparently inconsistent data on income elasticities of demand for individual micronutrients cited by
Behrman should not be surprising, simply because of variations in the consumption patterns associated with individual foods in various settings.

Predicting the effects of price and income changes on micronutrient consumption requires understanding which foods are substitutes and complements in the local diet, so that individual food substitutions, not those of aggregated food groups, can be analyzed for their effect on the availability of specific micronutrients. The effects on micronutrient consumption of relative price changes (and income changes) cannot be generalized across places, nor across nutrients, since patterns of substitution and complementarity, and perceptions of quality vary from place to place. Reliable prediction requires highly disaggregated, country-specific food consumption data, collected in terms of quantity, not expenditure amount (because expenditure combines information on quality with that on quantity).

Similar concerns apply to the determinants of allocation within households. Even if patterns of discrimination and preferential treatment can be identified for a given setting, the implications for micronutrient consumption may not be obvious, as the preferred foods may not be the most micronutrient-dense. Generally, households allocate food equitably to individuals when supplies are plentiful and favor particular individuals in times of scarcity, but the effects on individual consumption of particular micronutrients are unpredictable. A study in India, for example, found that preferential treatment given to boys meant that they received milk in the limited quantities available, while girls consumed the grain staple (Levinson 1974). Presumably, the boys' intakes of calcium and vitamin B6 were relatively high, but it was the girls who obtained adequate calories. Again, disaggregated and location-specific analysis is required.

POLICY LEVERS FOR IMPROVING MICRONUTRIENT NUTRITION

Behrman argues that public intervention to raise micronutrient consumption (through food price subsidies, publicly provided fortification, or provision of supplements, among other means) may not be justifiable if the gains from adequate nutrition are entirely private, that is, captured by the individuals who gain in productivity and earning capacity as a result of their improved nutrition. He suggests that providing information on the importance of micronutrients (and, presumably, on how to obtain them) should be adequate to achieve the socially optimum level of micronutrient consumption, as consumers can then make informed choices consistent with their own preferences.

This argument requires some qualification. Treating micronutrient inadequacy as a health problem meriting public intervention is justified by the fact that many countries provide public support in the form of income maintenance programs or other transfers to poor people who are unable to support themselves. Even if there are no publicly provided transfers, there are social costs (which exceed the private costs and which affect other people) of having a significant population incapable of supporting itself. While the gains from improved productivity may be entirely private, there may be public costs associated with individuals' inability to provide for themselves (which means that the public gains from improved private productivity are in the form of costs and expenditures forgone). The same reasoning applies to the link between micronutrient inadequacy and morbidity. If public expenditures support health care and if nutrient inadequacy results in higher rates of morbidity, then improving micronutrient consumption again may have public benefit.
Providing full information may not be enough to accomplish the social goal of improving micronutrient malnutrition. First, the household members deciding whether to obtain and how to allocate micronutrients may not be those who expect to capture the benefits of the enhanced productivity of other members. (This is analogous at the household level to the problem of externalities in markets.) Even with full information, adult household members may make purchase and allocation decisions that are not consistent with the entirely private interests of other members.

Further, the private gains from enhanced productivity are not assured, but represent an altered statistical probability of such gains. The evidence cited by Behrman suggests, for example, that micronutrient adequacy affects piecework and own-account returns to labor more than wage work (Foster and Rosenzweig 1993, 1994); decisions about nutrient consumption and allocation within the household are thus made in the presence of considerable uncertainty. And people's judgment of risk is notoriously inaccurate: people tend to overestimate the likelihood of dramatic and catastrophic risks and underestimate the likelihood (and consequences) of more ordinary risks in deciding to alter their behavior (Lowrance 1976). So, simply educating people about the importance of micronutrient nutrition is likely to be insufficient to change their behavior. (Not to mention that demonstrating productivity gains from micronutrient nutritional status has required some fairly sophisticated data analysis; it is not obvious that a consumer household would fully understand or unquestioningly accept the results of this research communicated in the form of nutrition education.)

This is not to argue against the idea of targeted, promotional nutrition education campaigns to promote consumption of micronutrients known to be inadequate in the diet. Social marketing does work, if it is designed carefully in consideration of the time, resource, and cultural constraints on current consumption behavior (Achterberg 1992). But social marketing is a more interventionist approach than the more neutral (and generally less effective) provision of information.

The paper provides a thorough treatment of the evidence regarding alternative policy levers, including education and incomes, and discusses the difficulties in accurately estimating the likely effects of each, given the problems of simultaneous determination of input and outcome. It does not seek to address the programmatic issues involved in developing a micronutrient-focused intervention, but a few general points may be worth making.

Any intervention that seeks to change consumption behavior needs to consider not just the cost, but also the time and task allocation implications. For example, there are places where vitamin-rich vegetables are cheap and available year-round (Bouis 1991), and it appears a simple matter to suggest that households buy or gather these foods to enrich the diet. Before such a recommendation is made, one must know whether the preparation of these foods is more time-consuming than what is currently eaten, and whether it requires more fuel. Are there implications for the timing of tasks? For example, do these foods spoil quickly so that purchases need to be made more frequently, or prepared food consumed over fewer days? These are fairly simple questions to answer if, in fact, they are asked.

Both fortification and plant breeding for micronutrient content seek to change the nature of the food supply so that it supplies more nutrients without requiring behavior change on the part of consumers. Obviously, cost is one issue: people may be unwilling to spend more on what appears (in their terms) to be a perfect substitute for a less expensive food. But organoleptic properties of the foods must be fully acceptable. If a new food looks or tastes
funny, households will strongly resist consuming it in spite of any amount of education about its health value. (This is a concern for foods fortified with, or bred for, beta carotene content, for example, because of the color it imparts.) Some consumption patterns are flexible, but others are not, and it helps if both price signals and educational messages are pushing in the same direction. (An example from the United States is the long-term trend toward consumption of chicken and away from red meat, cited by nutrition educators as a success story and by economists as simply a demonstration of cross-price elasticity of demand.)

**FUTURE RESEARCH**

Regarding further analysis of existing data, care needs to be exercised if data sets contain only average prices and average nutrient content of a fairly aggregated set of foods (as, for example, some of the data sets mentioned by Behrman, which analyze average prices and demand elasticities for between 4 and 13 food groups). These data sets could be made more useful by incorporating some qualitative research (starting with literature review, to see if the information is available already) to determine what individual foods are included in each food group and what is known about their consumption patterns. Issues to be addressed would include seasonal variation in consumption; whether some individual foods (which are important micronutrient sources) are associated with higher-income consumption, and what the micronutrient implications are; and which foods are typically consumed together. Even if such information is not available at the household or individual level, general information on the specifics of the diet can be used to help interpret aggregate food consumption data. For example, a study in Morocco found that aggregate vegetable consumption was significantly higher in the summer season, yet vitamin A consumption was higher in the winter, because among the fewer vegetables consumed, carrots played a greater role (Benjelloun 1993). Individual consumption data would not have been necessary to determine which vegetables were available in winter and in summer.

Behrman raises the issue of error in estimating food consumption data. Most nutritionists agree that multiple recalls for a single individual are necessary to obtain accurate estimates of “usual” consumption, which can then be associated with that individual’s other characteristics, such as age, sex, birth order, education, and income (Gibson 1990; Willett 1990). Behrman suggests that multiple observations are not necessary, since stochastic error does not alter coefficient estimates. While this is clearly correct, there is still a trade-off between the accuracy of each individual observation and the number of observations needed to identify significant relationships. Errors affect both R-square and tests of significance; potentially important relationships may be discounted if large errors obscure their significance. And this problem may be especially true for the rather subtle effects of nutrient intake on outcomes such as productivity, morbidity, and cognitive performance.

Certainly, existing data sets known to measure intake with large errors (for example, because they collected only one 24-hour recall for each respondent) should not be discarded if the sample size is sufficient to draw reliable conclusions. But in implementation of new rounds or in new data collection efforts, it may be more cost-effective to strive for accuracy in measurement through multiple recalls (and other measurement techniques) than to expand the sample size for an equivalent power in the research design. This question is amenable to empirical investigation.
Some of the questions proposed for future research pose difficult problems of design, given the issues of simultaneous determination so well presented by Behrman. In some cases, we need to recognize that the problems may be intractable. (One cannot randomly assign members to female- or male-headed households, for instance! And whatever characteristics are used to develop an instrumental variable to control for self-selection, one could argue that there must be unobserved differences that account for it.) Using instrumental variables is often not a solution, because of the difficulty of finding instruments that are truly independent and that have a plausibly high level of accuracy in predicting the variable to be instrumented. These problems are probably best addressed by conducting primary research in which the design is experimental or quasi-experimental, when possible.

When studying the effects of micronutrient adequacy on morbidity, mortality, productivity, and cognitive performance, researchers should combine population-based studies that use modeling techniques such as instrumental variables with biomedical research to demonstrate the underlying mechanisms by which micronutrients might operate on these outcomes. These two streams of research are by no means substitutes but, rather, complements. Population-based studies point to important relationships to be investigated in the clinic or laboratory and determine whether the physiological impacts have measurable economic effects in the uncontrolled environment of the “real world.” Biomedical studies are important for interpreting the relationships observed in free-living populations. For example, the Pitt and Rosenzweig (1985) study cited by Behrman found that calories, calcium, and vitamin C intake reduce illness incidence, while carbohydrates, protein, and fat increase it, and vitamin A has no effect. These results are not consistent with previous research (on vitamin A, for example) and do not appear to make sense from a physiological point of view. If the observed relationships are not due to the physiological effects of nutrient intake, then they must be markers for some other set of variables associated with intake of the nutrient that affects the outcomes of interest.

The paper proposes two critical sets of questions for future research: what are the effects of micronutrient deficiency on individual outcomes, and what are the effects of various policy instruments on the incidence of micronutrient deficiency? A third, related set of studies might also be recommended. These would address alternative program approaches to resolving micronutrient deficiencies, assessing cost and effectiveness (including consideration of time frame and of ancillary benefits) in various contexts. Such studies would provide useful guidance for appropriate action in cases where micronutrient deficiency is identified as a public health problem, justifying intervention.

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The International Food Policy Research Institute was established in 1975 to identify and analyze alternative national and international strategies and policies for meeting food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. While the research effort is geared to the precise objective of contributing to the reduction of hunger and malnutrition, the factors involved are many and wide-ranging, requiring analysis of underlying processes and extending beyond a narrowly defined food sector. The Institute's research program reflects worldwide collaboration with governments and private and public institutions interested in increasing food production and improving the equity of its distribution. Research results are disseminated to policymakers, opinion formers, administrators, policy analysts, researchers, and others concerned with national and international food and agricultural policy.

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