Nutrients: Impacts and Determinants

Jere R. Behrman, Anil B. Deolalikar, and Barbara L. Wolfe

Understanding the determinants of nutrient intake and the influence of nutrition on performance is critical in designing policies to alleviate hunger and malnutrition. A series of studies undertaken by the authors, which are synthesized here, analyzes the influence of prices, income, and women's schooling on the nutrient intake of those in developing countries and the effect of nutrition on health, productivity, wages, and fertility. These studies suggest that the impact of food price increases may be strong, particularly among those with the lowest incomes, that the growth of income may be less likely to improve nutrient intake than has been suggested by others, and that women's schooling is important in improving nutrition. These studies also indicate that nutrition exerts a positive influence on wages, productivity, and fertility. Our limited knowledge of the role and determinants of nutrition is reflected in the finding of unduly strong effects of seasonality on price-nutrition relations and the lack of a direct association between nutrition and health.

The nutrition of poor populations is of substantial interest because of the widespread and plausible presumption that better nutrition improves the welfare of individuals in such populations. Nutrition also is of interest because of the common conjecture that better nutrition improves productivity. A series of our studies have analyzed the relations between nutrition and health, labor productivity, and fertility and the relations between prices, income, women's schooling, and nutrition intake. Here we synthesize the results of these studies and address some of the puzzles and policy implications that have arisen.¹

I. Data

In our studies on which we report below, we use three data sets, which are briefly summarized here.

¹ The interested reader is referred to the full studies for details and further elaboration. We only are summarizing our studies here, and are not surveying the literature more generally. For such a survey, see Behrman and Deolalikar (1988a).

Jere R. Behrman is a professor of economics at the University of Pennsylvania. Anil B. Deolalikar is a visiting associate professor of economics at Harvard University. Barbara L. Wolfe is an associate professor of economics and preventive medicine at the University of Wisconsin-Madison. They thank the Population Council Research Program on Fertility Determinants, funded by the U.S. Agency for International Development, the U.S. National Science Foundation, and the U.S. National Institutes of Health for research support for the underlying studies.

©1988 The International Bank for Reconstruction and Development / THE WORLD BANK.
Rural South Indian Data

The International Crops Research Institute for the Semi-Arid Tropics Village Level Studies (ICRISAT VLS) data panel have been collected from 240 households in six carefully selected “typical” villages in three different agroclimatic zones in two states in the semi-arid tropics (SAT) region of India over the 1975–84 period. Within each village ten households are randomly selected representatives of agricultural labor and non-landholding households and another thirty are a random sample of cultivating households stratified by size of landholding. For the 1976–77 and 1977–78 crop years special nutritional surveys were undertaken, from which individual nutrient intakes during the previous twenty-four hours and anthropometric health indicators were recorded by nutritionists and medical doctors. For three of the ICRISAT villages (one each from each agroclimatic zone), expenditure data also are available for these two crop years. Total food expenditure data were obtained by valuing each self-produced and consumed food at its average village price and adding this to market expenditures on that food. We use the expenditure, nutrition, and health data for three villages for these two crop years for the study in Behrman and Deolalikar (1987b). For the other studies we use the nutrition and health data from all six villages.

The special nutritional surveys provide information on nine of the most crucial nutrient intake measures: calories, proteins, calcium, iron, carotene, thiamine, riboflavin, niacin, and ascorbic acid. Nutrient values for the foods studied were calculated by applying Indian nutrient/food conversion factors from Gopalan, Sastry, and Balasubramarian (1971) to 120 foods for which direct observations on individual consumption were made in the nutrient surveys. These foods encompass the total food consumption for the rural Indians under study. The number of foods is large in comparison with the six to eight more aggregate food groups typically used at the estimation stage of indirect expenditure-system-based estimates of nutrient elasticities.

Examination of these data (see Behrman 1988b, 1988c, and Behrman and Deolalikar 1987d, 1988b) suggests that this sample generally is malnourished in comparison with Indian standards, particularly for carotene and ascorbic acid—in which cases less than half the Indian standards are met at the sample means. Less than three-quarters of the Indian standards also are met at the sample means for calcium and riboflavin. Only for proteins, iron, and thiamine among these nine nutrients are the sample averages above Indian standards. The coefficients of variations for these nutrient intakes are relatively large for carotene and riboflavin, both with values greater than 0.90, indicating substantial fluctuations in consumption across households. The variations across households are relatively small (below 0.40), however, for calories, proteins, niacin, and iron.

Anthropometric data on weight, arm circumference, triceps skinfold thickness, and height were collected as indicators of an individual’s health. These
data subsequently were standardized for weight and height by age-specific standards for higher-income groups in Hyderabad as determined by the National Institute of Nutrition (and which are at about the fiftieth percentile of the widely used Harvard standards) and for weight-for-height, arm circumference and triceps skinfold thickness by international standards in Jelliffe (1966).

Most of the ICRISAT data that we use also are measured separately for the lean season (when food supplies are relatively limited) and for the surplus season (when they are relatively abundant). For further details concerning the ICRISAT VLS data, see Binswanger and Jodha (1978) and Ryan, Bidinger, Rao, and Pushpama (1984).

Nicaraguan Data on the Social and Economic Status of Women

These data are from a cross-section, area-stratified random sample of about 4,000 women aged 15-45 that we collected in 1977-78. For a subsample of about 500 women, we collected sibling data by interviewing the sister closest in age. Nutrient indicators in this data set are household calories and proteins consumed, each standardized for the demographic composition of the household. The mean calorie intake is 62 percent of international standards and that for proteins is 136 percent. Health indicators include anthropometric measures (that is, height, weight, and bicep circumference) for children under six, infant and child mortality rates, and for women, self-reported disease experience and days too ill to work in a recent period. For further details, see Behrman and Wolfe (1984a, 1984b, 1984c, 1987a, 1987b, forthcoming) and Wolfe and Behrman (1982, 1983, 1984, 1986, 1987, 1988).

International Data on Nutrient Intakes, Food Expenditures, Income, and Prices

These data include thirty-seven food expenditure categories, prices, and income for thirty-four countries in 1975 and for sixty countries in 1980 (which gives sixty-seven countries in total, for some of which there are two observations, including forty-seven developing countries), all based on careful purchasing-power-parity price comparisons in the International Price Comparison (IPC) project by Kravis, Heston, and Summers (1982). For our use below we link these data to the per capita caloric consumption given in FAO (1981).

II. The Impact of Nutrients

There is little point in studying the relation between changes in income and prices and their effects on nutrient intake unless nutrient intake is desirable in itself or is related to health, labor productivity, fertility, or other attributes of interest. Thus in this section we summarize the results of studies that examine the relation between nutrient intake and health, agricultural labor productivity, wages, and fertility.
Health

The conventional assumption is that increased nutrient intake improves health. We have estimated health production functions with current nutrient inputs for boys, girls, men, and women in rural South India and for children and women in Nicaragua in Behrman and Deolalikar (1988b), Behrman and Wolfe (1987a), and Wolfe and Behrman (1982, 1984, 1986, 1987, 1988). These estimates generally do not indicate a significant impact of the current nutrient intake on the health indicators. This surprising result may reflect one or more of the following factors: (1) increased nutrient intakes partly go to increase productivity rather than to improve indicators of health, but such nutrient use is not well controlled in the health-production function estimates (evidence consistent with this possibility is presented below); (2) within limits, human metabolism adjusts in response to nutrient intakes, with little impact on health indicators (as Sukhatme 1982 and Payne 1987 seem to argue); (3) there is tremendous intrapersonal variation in nutrient intakes over time as emphasized by Sukhatme (1982) and Srinivasan (1981) so that the current nutrition intakes are very poor proxies for the medium- or longer-run nutrient intakes of relevance for the health indicators used; (4) the instruments used to control for simultaneity are inadequate; and (5) the anthropometric and self-reported health indicators used are poor proxies for the true health status.

While we think that the first possibility is part of the explanation, we do not have a means of exploring the other possibilities. Panel data over longer periods of time would permit better exploration of the second and third possibilities. Most cross-sectional socioeconomic data sets are not likely to permit much consideration of the third possibility unless they include appropriate clinical measurements, which currently are very rare in integrated socioeconomic data sets. The instruments that we use have but limited price variation for the Indian data and only community characteristics (not market prices) for the Nicaraguan data. The limited instruments may obscure the true effect. Pitt and Rosenzweig (1985), for example, also only find a significant impact of nutrients on health (as represented by the negative of illness) in their study of Indonesian farm households when they use instrumented variables for nutrients. Their estimates also do not support conventional assumptions. They indicate a negative significant effect of three nutrients (calories, calcium, and vitamin C) on illness (which is consistent with the common presumption), but positive significant effects or insignificant effects on illness for their other six nutrients (positive for protein, fat, and carbohydrates; insignificant for phosphorous, iron, and vitamin A).

But we find it surprising that the nutrient impact on health is not sufficiently robust to be apparent even in (possibly biased) ordinary least squares (OLS) estimates. Conceivably, households allocate nutrients sufficiently to favor those inherently less well endowed so that ordinary least squares estimates are downward biased to the point that they make true positive effects of nutrients on
health appear to be insignificant. However, existing estimates of intrahousehold allocations indicate, if anything, nutrient allocations that reinforce (particularly in the lean season) rather than compensate for unobserved individual robustness (see Behrman 1988a, 1988b, 1988c). Finally, while our health indicators are hardly perfect, the anthropometric measures are widely thought to relate to important dimensions of health, and we explicitly have dealt with some possible measurement errors by using a latent variable representation for health in Behrman and Deolalikar (1988b), Behrman and Wolfe (1987a), and Wolfe and Behrman (1984, 1988). Thus, we are left with a puzzle regarding the lack of a statistically significant impact of nutrition on health.

**Agricultural Labor Productivity**

The basic problem in identifying the impact of nutrition on agricultural productivity is controlling for the possible simultaneous impact of labor productivity on nutrition through income. While a number of efforts have been made to estimate the impact of nutrients on productivity (see Behrman and Deolalikar 1987 forthcoming-a or Strauss 1986 for references), to our knowledge, only the studies by Strauss (1986) and by Sahm and Alderman (forthcoming) have used simultaneous estimates to avoid simultaneity biases.

We present simultaneous fixed-effects estimates of a Cobb-Douglas farm production function for the rural South Indian sample with calories, weight-for-height, farm labor, hired labor, bullock power, fertilizer, and cropped area in Deolalikar (1988). We use weight-for-height because it presumably reflects past nutrient intakes, which should be considered in measuring the impact of nutrition on productivity. Because of large intraindividual (intertemporal) variations in calorie requirements of the human body (for example, see Sukhatme 1982), current calorie intake may be a poor proxy for energy available for work effort or activities other than basal metabolism. Therefore it may not be surprising that the coefficient estimate of calories is not significant. The coefficient estimate of weight-for-height is significantly positive and substantial—indicating an elasticity of farm output with respect to weight-for-height of approximately 2. If weight-for-height is a good indicator of short-run nutritional status, as is widely claimed in the nutrition literature, these estimates indicate a strong impact of short-run nutritional status on labor productivity. However such an interpretation must be qualified due to our failure to find a significant association between current nutrition and anthropometric indicators of health, as is discussed above.

2. This is the only study in this genre of which we are aware that controls for unobserved fixed effects.

3. Within the range of the sample experience, there is not evidence of changing elasticities. But this result should not be generalized too far out of the sample experience (for example, to conclude that obese pygmies would be particularly productive).
Wages

The same simultaneity problem exists, of course, in determining the impact of nutrients on wages. For the rural South Indian data, simultaneous estimates with fixed effects estimates for annual data indicate an elasticity of wages with respect to weight-for-height of 0.3 to 0.7 in Deolalikar (1988), though that with respect to calories is not significant. The results suggest a large and significant impact of nutritional status—although not of caloric intake—on wages (again with the qualification above that weight-for-height represents nutritional status). The wage results are thus similar to the production function results. Finally there is no evidence of differential effects for men versus women with the annual data.

In Behrman and Deolalikar (forthcoming-a) we further explore the nutritional impact on wages in rural South India with simultaneous estimates for the peak and slack labor demand seasons. We consider the two seasons separately because of the considerable emphasis by a number of recent authors on the importance of seasonality (for example, Chambers 1982; Chambers, Longhurst, and Pacey 1981; Sahn forthcoming; and Schofield 1974). The estimates suggest that calories have a significant impact on wages with an elasticity of 0.3 in the peak season and that weight-for-height has a significant impact in both seasons, but with a larger elasticity in the slack season (0.7) than in the lean season (0.4). This pattern may be due to the difference in tasks between the seasons. Tasks normally performed in the peak season, such as harvesting, threshing, ploughing, and transplanting, may require greater sustained human energy expenditure than slack-season tasks, but may not require innate strength (which is associated with greater weight-for-height) to the same extent as in the slack season. In fact, small size may be a distinct advantage in certain peak-season tasks such as harvesting and transplanting. Finally, apparently due to the gender division of seasonal tasks, the impact of nutrition is evident only for males, but not for females.4

Our results thus indicate significant support for the "wage efficiency hypothesis" (see Bliss and Stern 1978; Leibenstein 1957; Mazumdar 1959; and Stiglitz 1976) for males within the rural semiarid tropics Indian context, with significant differences between the peak and slack seasons. Among adult males, consumption has an immediate impact on productivity through energy availabilities in the peak labor season and a possible longer-run impact through health status. This implies that policies that improve males’ health and nutrition improve productivity within this context. It also means that households rationally might allocate somewhat more food relative to minimum requirements to adult males than to others than would be the case were there no impact on productivity. There is the further implication that male wages should be treated as endogenous in analysis of the determinants of other outcomes such as in-

4. Sahn and Alderman (forthcoming) report a similar gender differential for the impact of nutrients on wages in rural Sri Lanka.
vestment in children or in physical assets. Given labor force division by gender and the nutrition and health variation appearing in the sample, however, such results do not carry over to women.

Fertility

Whether nutrition affects fertility is a subject of some controversy. Bonnegaarts (1980) and Menken, Trussell, and Watkins (1981) review previous studies and conclude that there is not evidence of a biological link except for quite malnourished populations. But there still may be behavioral links if better nutrition is associated, for example, with more frequent intercourse.

We present indirect evidence in Behrman and Wolfe (1984b, 1987a) that is consistent with such a possibility. In the 1984 study, fertility determinant relations are shown to differ in the Nicaraguan sample for couples classified by biological fecundity characteristics including nutrient intakes. In the 1987 study, using a system of reduced-form equations, we find that a rise in income for the Nicaraguan sample is associated simultaneously with significantly increased nutrition, contraceptive use, and fertility. Both studies find that improved nutrition is associated with increases in fertility at least for subgroups of the population.

Thus we have found some evidence of nutrient impact on labor productivity and perhaps on fertility, though not directly on health indicators. For these reasons, in addition to the widespread interest in nutrient intakes themselves, it is useful to ask what determines nutrient intakes.

III. PRICE, INCOME, WOMEN’S SCHOOLING, AND NUTRIENT INTAKES

In the standard reduced-form demand equations for nutrients, the determinants are prices, income, and predetermined household assets, the most emphasized of which is women’s schooling. We consider each in turn.

Price Effects

The predominant view seems to be that increases in food prices probably worsen the nutrient intakes of the poor. Before we turn to our estimates of price effects, therefore, it is useful to ask what are the possible price effects of food price changes on nutrition.

Clearly, given common economic assumptions about price response, an increase in the price of a food will tend to drive consumption out of that good and into its substitutes, which could decrease nutrient intake. There are several conditions, however, in which nutrient intakes would not necessarily decline.

5. Conceptually there is a possibility of a positive effect if the food in question is a Giffin good and its food-to-nutrient conversion factor is sufficiently large so that the coefficient of the income term is negative (see Behrman and Deolalikar 1988 forthcoming-b). Empirically this is sufficiently unlikely that it safely can be ignored, and we do so here and below without further qualification.
First, if the food subject to a price rise is nutritionally inferior to its substitutes, then movement out of it and into other foods may improve nutrition.\textsuperscript{6} Second, if demand for a food is almost infinitely price elastic and foods are nutritionally similar, consumers would be able to move between substitutes in response to a price rise with almost no loss of real welfare, income, or nutrition. Third, if consumers are compensated for the loss in real income (that is, if only pure substitution occurs) and if goods are similar nutritionally, the price rise will have no deleterious nutritional impact. Some structural adjustment programs, for instance, include both removal of food price subsidies and some wage increase to offset increased prices.

Fourth, if the household produces and consumes a food subject to a producer and consumer price increase, a positive effect on the consumption of the food and nutrient is induced through the production income effect. This effect will be stronger: (i) the larger the impact of income on nutrient intake; (ii) the larger the share of the product in income; (iii) the greater the supply response of that product and the less the reduction in supplies of substitutes (which may depend on given production and investment gestation periods); and (iv) the smaller the share of production that is consumed by the household instead of being sold.\textsuperscript{7} Therefore it is possible that a farm household that produces some of the foods that it consumes has a positive nutrient response to food price changes once this income effect is incorporated.

Finally, an increase in the price of a farm product that the household does not consume operates directly through income, with an expected positive impact on nutrient demands. This assumes the normal positive income elasticity of demand. Conversely, a price rise in a production input would have a direct negative income and nutrient effect.

What happens in a particular case, of course, is an empirical question. In Behrman and Deolalikar (1988b) we present estimates of the price elasticities of annual nutrient intakes for boys, girls, men, and women in rural South India. Four characteristics of these estimates merit emphasis. (1) The absolute magnitudes of these elasticities are substantial, larger than unitary except for the price of sorghum response for nutrients for girls. Rises in food prices may thus generally be expected to result in substantial nutritional effects. (2) Of the four basic foods studied, the nutrient intake responses to price changes for millet, rice, and pulses are positive, however, reflecting relatively extensive substitution with other items with high food-to-nutrient conversion factors. Nutrient intakes tend to improve when the prices of these commodities rise. (3) The direct nutrient intake responses to the price of sorghum, the basic staple, is negative. Because many of these households are very large producers of sorghum, however, when the effect on income is included, the total impact

\textsuperscript{6} Welfare, however, will worsen because nonnutrient characteristics of foods are important, a topic to which we return below.

\textsuperscript{7} This is related to the debate about the price elasticity of the marketed surplus in the 1960s, see Krishna (1962) and Behrman (1966), or Strauss (1984) for a more recent updating and further extensions.
of a change of the sorghum price on nutrients for producers is positive. (4) For girls' nutrient intake, we found smaller adjustments in response to changes in the sorghum price and larger adjustments in response to other price changes. Therefore nutrient intakes for girls are treated within the households as "necessities" with respect to sorghum and as relative "luxuries" with respect to other foods. That nutrient intake is adjusted less for girls when the price of basic staples changes and more when prices of other foods change does not in itself indicate that girls are favored or disfavored. Behrman (1988b) gives estimates of parents' preferences that indicate that boys are favored over girls in the lean season when food is scarce.

A further consideration of possible importance, as noted above, is seasonality. To the extent that changes in the availability of foods are reflected in their prices, seasonality does not necessarily affect the parameters in nutrient reduced-form demand equations. But there are several reasons why the relations between nutrition and price may vary across seasons, including changes in (1) caloric or other nutrient use (during plowing and harvesting); (2) environmental conditions; (3) the importance of caloric intake, for example, at low as compared with higher nutrient intake, so that the health production function is not homothetic; (4) metabolisms across seasons; and (5) production function parameters due, for instance, to changes in spoilage and/or transport problems. Moreover, if income is hard to store across seasons in kind or in financial assets due to high interest or inflation rates, high storage losses, and/or imperfect credit markets, seasonal production income effects may cause the price parameters in the nutrient demand equations to vary seasonally.

In Behrman and Deolalikar (forthcoming-b) we present estimates of seasonal differentials in price elasticities (including income effects) for the rural South Indian sample. In the lean season, the price elasticities are systematically about 1.5 times less than in the surplus season. If these estimates truly capture seasonal effects, then these effects are quite substantial and our annual estimates (Behrman and Deolalikar 1988b) are the average of lower (more negative) estimates for the lean season and more positive estimates for the surplus season. The differences are large enough to surprise us, however, and to leave us somewhat puzzled as to exactly what underlies the seasonal differences. We understand that storage problems, for example, are not likely to be so important for the basic foods in this semiarid tropical area as to account for such strong seasonal patterns.

A final factor in the extent of price elasticity, related to the discussion in the next section, is income level. Several empirical studies surveyed by Alderman (1986) show a larger nutrient response to prices for lower income consumers. This point is explained below with reference to figure 3.

Income Effects

The conventional wisdom seems to be that nutrient intakes improve substantially with income increases. The World Bank's World Development Report 1981 (World Bank 1981, p. 59) articulates this view forcefully:
There is now a wide measure of agreement on several broad propositions. . . . 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.

Such a view is consistent with numerous estimates that indicate food expenditure elasticities with respect to income of the order of magnitude of 0.7 to 0.9 for poor people as in standard Engel curve analysis if food composition does not change systematically with income in a way so that nutrients do not increase almost proportionally to food expenditure.

Despite the possible importance of the last qualification, we were surprised when we estimated direct nutrient elasticities with respect to income for Managua with the Nicaraguan data and obtained significant, but very small effects—about 0.1 at the sample means (Wolfe and Behrman 1983). When we extended the sample to the whole country and included many poorer households (Behrman and Wolfe 1984a), we tested the hypothesis that the nutrient elasticities might be an inverse function of per capita income (as have others; for example, see Pinstrup-Andersen and Caicedo 1978; Timmer and Alderman 1979; and Murty and Radhakrishna 1981) so that our small estimates for the relatively high per capita income capital city might be consistent with much higher elasticities for the poorer inhabitants elsewhere. We found a statistically significant inverse association between nutrient elasticities with respect to income and per capita income. Nevertheless, the estimated nutrient income elasticities remained quite low. We therefore conjectured that when income increases for fairly poor people and they increase their food expenditures almost proportionally, at the margin they concentrate on food attributes other than nutrients—taste, appearance, odor, degree of processing, variety, status—that are not necessarily highly positively correlated with nutritive value (also see Shah 1983). As a result, nutrient intake elasticities are quite low even if food expenditure elasticities are high.

The increasing attention to several studies that were published in the early 1980s—Murty and Radhakrishna (1981), Pitt (1983) and Strauss (1982)—led us to further exploration of the question of the magnitude of nutrient income elasticities. Rather than directly estimate nutrient demand relations, these studies first carefully estimate food expenditure systems for a relatively small number of food groups. They then estimate the nutrient elasticities by the weighted average of the food expenditure elasticities, with standard food-to-nutrient conversion factors as the weights. The results are food and nutrient expenditure elasticities with respect to income of the order of magnitude of 0.7 to 0.9.

But evidence exists to show that as income rises, households buy more expensive foods so that food expenditures increase, but the nutrient content of these foods does not necessarily increase proportionately. Thus the food expenditure-to-nutrient conversion factor increases with income, and this occurs even in the relatively poor South Asian developing economies (see, among others,
In Behrman and Deolalikar (1987d) we demonstrate formally how application of constant food-to-nutrient conversion factors at a high level of aggregation overstates nutrient elasticities with respect to income if the price paid per nutrient increases as income increases. From the rural South Indian sample we estimate nutrient elasticities with respect to income both (i) indirectly by estimating food expenditure income elasticities for six major food groups and applying constant food-to-nutrient conversion factors at that level of aggregation and (ii) directly by estimating nutrient reduced-form demand equations with the food-to-nutrient conversion factors applied for 120 disaggregated food groups. The indirect approach yields nutrient elasticities with respect to income of 0.8 (a little higher if there is control for fixed effects)—the same order of magnitude as those estimated by Murty and Radhakrishna (1981), Pitt (1983), and Strauss (1982). The direct approach gives estimates that for most nutrients are not significantly nonzero and are 0.3 or smaller. In Behrman and Deolalikar (1987b) we present similar estimates for calorie elasticities with respect to income from the international sample. For countries with annual per capita incomes of $1,000 1975 U.S. dollars or lower, the indirect estimates imply elasticities of almost 1.0, but the direct estimates imply elasticities of 0.1 to 0.2. For the same countries the elasticity of the price paid per calorie with respect to income is 1.3 to 2.6. Thus the high level of aggregation of foods in the indirect approach seems to result in a substantial overstatement of the true nutrient elasticities with respect to income.

As suggested above, we conjecture that this occurs because other food attributes are important at the margin in food consumption decisions even for fairly poor people and these attributes are not highly correlated with nutrients in marginal food choices. With most social economic data sets such a conjecture is difficult to test directly because most of the food attributes are not observed. We can observe one such attribute in many such data sets, however: the variety of foods consumed. In Behrman and Deolalikar (1988a, 1988c) we conjecture that the demand for food variety increases with income. At low incomes calories are obtained primarily from low-cost sources, but at higher incomes multiple sources are used for a wide range of relative prices. This result may arise from the dictates of survival or from the shape of the preference map above the survival level. We consider the two possibilities in turn.

First, the existence of a nutrient subsistence constraint may result in a zero nutrient elasticity with respect to income and a strong taste for variety at very low incomes at and a little above minimum subsistence levels. Figure 1 illus-

8. In both sets of estimates the possible simultaneity of income and total expenditure is controlled by using simultaneous estimators with agricultural prices and predetermined assets as identifying instruments.

9. For clarity we include only the dimension under discussion in each of the figures below, but any two or all three might coexist in consumer preferences.

10. We thank T. N. Srinivasan, who suggested to us the possible relevance of a nutrient subsistence constraint, though we (not he) are responsible for any errors in interpretation of this possibility.
Figure 1. *An Effective Nutrient Subsistent Constraint*

Note: NN' is nutrient constraint; dashed lines show preference curves if no nutrient contraints were present.

trates this possibility. There is an effective nutrient constraint (NN') below which one cannot survive, so at very low incomes preferences effectively collapse along NN' under the assumption that survival is preferred lexicographically over food variety. For this reason we draw with dashed lines the segments of the preference curves that would exist only if there were no subsistence constraint. At the minimum subsistence level of income represented by the budget constraint, BB', and given the price ratio represented by the slope of BB', N units of food 1 and no units of 2 are consumed: no other available combination would secure survival. If there were no subsistence constraint, the combination of foods at C would have been selected. Thus some desire for food variety is suppressed in order to subsist. As income increases and the budget line moves out, initially all extra income is used to purchase food variety by shifting at the margin from food 1 to food 2, so the food composition choices move down along NN', which implies a zero elasticity of nutrient intakes with respect to income. Expenditure of all marginal income on variety (and not on nutrients) continues until income increases sufficiently so that the
Budget linetangency with the preference curve (given relative prices) is on the subsistence constraint (at D). With further income increases, the subsistence constraint no longer is binding, and consumption of both foods is expanded, so the nutrient elasticity with respect to income becomes positive.

Second, at income levels above the nutrient subsistence constraint, preferences may favor variety over nutrition as income grows. This result may be generated by a curvature of the Engel curve away from a low-cost source of nutrition as income grows, or by decreased substitution among foods, in response to price changes, at higher incomes. The former is shown by fig. 2, in which, at the price for which the income-consumption curve, $U_1$ is drawn, food 1 is assumed to be the low-cost source of nutrition; at high income levels expenditure is more evenly allocated between the two foods than at low income levels. The latter possibility is shown in fig. 3, in which at higher income levels the price elasticity of substitution between the foods is less than at low income levels, a pattern found in empirical studies surveyed by Alderman (1986).

In Behrman and Deolalikar (1988c) we test for the factors relevant above the

Figure 2. *Preferences Exhibiting Greater Taste for Variety (Greater Centrality) as Income Increases*
Figure 3. Preferences Exhibiting Greater Taste for Food Variety (Greater Curvature) as Income Increases

We find that as per capita income grows, preference curves change from about the Cobb-Douglas form (that is, being relatively price responsive) for a per capita income of $500 to significantly closer to the L-shaped case (being rela-

11. We do not test the nutrient subsistence constraint possibility because the specification of such constraints would be very difficult given heterogeneity across individuals at the level which would represent subsistence nutrient intake (see Behrman and Deolalikar 1988a). Our average country data, nevertheless, may reflect in part the impact of nutrient subsistence constraints on the poorest members of society, particularly in lower per capita income countries. That the taste for variety is estimated to be significant for middle and higher per capita incomes, however, suggests that our estimates do not reflect only nutrient subsistence constraints.
tively unresponsive to price and showing strong preference for variety) for per capita annual income of $2,800 (the sample mean). We also find significantly increasing centrality of preferences as income increases from low to middle income levels. These results are consistent with our hypothesis that an increasing taste for variety related to both preference curvature and centrality as income increases is an important factor underlying low nutrient elasticities with respect to income.

What are the implications of our estimates of low income elasticities of nutrient demand? First, the statement above from the *World Development Report 1981* and similar statements by others may overstate substantially the impact of income increases on nutrient intakes of poor people. Second, possibly the poor do not increase their nutrition much with income increases because they do not understand the relation between nutrients and other food attributes. If so, and if undernourishment and malnourishment are of social concern, it may be desirable for governments to improve dissemination of nutritional information. Third, if to the contrary, marginal nutrient choices of these poor people are reasonably well-informed choices, it would seem that these people do not perceive themselves to be as poorly nourished as do many outside observers or they would weigh nutrient content more heavily in their marginal food choices. In this sense such results are consistent with the claim of Sukhatme (1982), Srinivasan (1981), Seckler (1980), Payne (1987), and others that nutritional shortages in developing countries often are exaggerated and misunderstood by conventional estimation procedures.

*Women's Schooling*

In addition to prices and income, reduced-form demand equations for nutrients (or for other household consumption) should include all predetermined household assets and endowments. The most commonly emphasized of these, women's schooling, has been claimed to influence a range of nonmarket outcomes, nutrition among them. At the same time there have been a number of studies using special data or estimation techniques that suggest that in standard estimates schooling is representing in substantial part unobserved attitudes and abilities related to childhood family background (for example, Behrman and Taubman 1976; Behrman, Hrubec, Taubman, and Wales 1980; Behrman and Wolfe 1984c, 1987b; Horton 1988; Olneck 1977; Taubman 1977; Wolfe and Behrman 1984, 1986).

Conventional multivariate estimates of the impact of women's schooling on nutrient intakes show mixed results for different samples. We find no significant positive effects for the rural South Indian sample in Behrman and Deolalikar (1988b), but a significant impact (with an elasticity of 0.1 to 0.2) for the Nicaraguan data in Wolfe and Behrman (1983) and Behrman and Wolfe (1984a). The latter estimates, however, may be subject to the criticism noted above, that possible omitted variables bias the results and cause an upward estimate of the impact of mother's schooling. It is difficult to accurately observe and measure the range of women's endowments such as ability, motivation,
and knowledge. Therefore, if such endowments are not controlled, the impact of women's schooling may be overstated since schooling partially is serving as a proxy for the endowments.

The Nicaraguan adult sister subsample permits control for such endowments insofar as they are related to childhood family background shared by the sisters. By subtracting the nutrient demand relation for one sister from the same relation for the other sister, we obtain an expression for the difference in nutrient intakes between their households as dependent on the differences in their respective schooling, their household's incomes, their endowments, and other factors. But to the extent that they have common endowments due to a shared childhood family background, the difference in those endowments is zero. Thus, this procedure effectively controls for unobserved characteristics that originate in their shared childhood background.

In a number of contexts, such a procedure results in much lower estimated impact of schooling than do standard estimates. The striking result in this case, however, is that mother's schooling remains at least as important a determinant of household nutrition as in the standard estimates. For this sample at least, the impact of mother's schooling on household nutrition apparently is substantial and quite robust (Behrman and Wolfe 1987a, forthcoming; and Wolfe and Behrman 1987, 1988).

IV. Conclusions

Several insights and some puzzles regarding the effect of nutrition in poor populations and the determinants of nutrient intakes arise from our studies. Since these findings are based primarily on special micro data sets (though cross-country international data are used in some cases) there is a question of how much they can be generalized to other populations. Since generalization is an empirical question, they indicate the need for further exploration of several issues using data for other societies.

We do not find a significant positive impact of nutrition on health status. This enigma suggests a major gap in our understanding of the nutrition-health nexus, perhaps because of lags in the process, inadequate control for nutrient uses, variability in nutrient intakes and in metabolism for individuals over time, or poor data. More research in this area may have a high payoff, and more extended data (longitudinal and clinical, time use) than are available in most socioeconomic data sets would be useful for such research.

12. Bishop (1976) and Griliches (1979) have argued that the differenced estimates are more subject to measurement error due to the differencing involved, and thus are more biased toward zero. Their point is valid if measurement errors across siblings are not very correlated, but the bias may be upward in differenced estimates relative to standard estimates if the measurement errors are highly correlated across siblings (Behrman 1984). Behrman and Birdsall (1983, 1985) suggest that using years of schooling alone to measure the effect of schooling in another Latin American sample may result in important biases due to school quality differentials. But the measurement error due to the failure to incorporate school quality is likely to be highly correlated among sibs since they often attended the same schools and therefore had schooling of very similar or identical quality.
Our positive results provide evidence of the positive effect of improved nutrition on agricultural labor productivity and human fertility. The labor productivity effect supports the "wage efficiency hypothesis" with at least some nutritional improvements resulting in greater productivity. The impact on fertility means that in the development process there may be some initial fertility increases despite increased contraceptive use, other things being equal, as suggested by Easterlin and Crimmins (1985).

Four important points about the determinants of nutrient intakes are suggested by our studies. First, due to food compositional changes at the margin, income increases are likely to have less impact on nutritional intake demand than claimed by the World Bank (1981) and others. This may be due to imperfect information about the relation among nutrition and other food attributes; if so, public support for dissemination of such information may have a high return in the form of better nutrition. Second, if marginal nutrient choices are basically informed choices, then apparently poor people such as those in the rural South Indian sample may not perceive themselves to be so undernourished and malnourished as do many outsiders, thus supporting the revisionist view of nutrition.

Third, the impact of increased prices on nutrition may be substantial, particularly for poor people, if price elasticities are higher at lower income levels as we have estimated. It may be positive for some basic food prices, however, because of high substitution toward more nutritive foods and positive due to possible income effects from production for those who grow those foods. Such a result brings into question the predominant assumption that low prices for basic nutrients necessarily improve nutritional intakes for poorer members of society. Carefully designed price policy, however, based on estimates of the nutrient responses to prices of particular foods may be an effective way to affect nutrition intakes if that is deemed an important policy goal. Such policy, however, requires good information about the relevant price elasticities in order to be effective. Moreover, raising food prices to increase agricultural production may create substantial unintended declines in nutritional effects if policy design is not sensitive to the nature of possibly large nutrient demand price elasticities. The estimated magnitude of the seasonal differences in the nutrient elasticities with respect to prices is also unexpectedly high, which raises questions about the possible need for special policies to improve the transfer of resources across seasons or other special seasonal interventions. Fourth, the impact of women's education on nutrition in some contexts appears to be substantial and robust. Thus the argument that women's education may have some strong nonmarket returns is supported in the case of nutrition. This result buttresses advocacy for increased investment in women's education, other things being equal. Given the long gestation period for this effect to be obtained from formal education, the question arises whether direct nutrition education of adult women might have a higher payoff.

Thus the set of studies that we have undertaken has shed some light on the impacts of and the determinants of nutrition in developing countries while
suggesting a number of areas for further research. At the same time they indicate the complexity of the determinants of nutrition and of nutritional impacts, so that seemingly straightforward policies unfortunately may not always have the intended effects.

References


———. Forthcoming-b. “Seasonal Demands for Nutrient Intakes and Health Status in Rural South India.” In David E. Sahn, ed., *Causes and Implications of Seasonal


household Allocation of Resources in the Philippines." Economic Development and


Kravis, Irving, Alan Heston, and Robert Summers. 1982. World Product and Income:
International Comparisons of Real Gross Product. Baltimore: Johns Hopkins Univer-
sity Press.

Krishna, Raj. 1962. "A Note on the Elasticity of the Marketable Surplus of a Subsis-
tence Crop." Indian Journal of Agricultural Economics 17 (July-September): 79–
84.

York: Wiley.


An Evaluation of the Evidence." Journal of Interdisciplinary History 11, no. 3 (Wint-

and Demand Patterns in a Low-Income Country." In Robert E. Kalman and J.
Martinez, eds., Computer Applications in Food Production and Agricultural Engi-
neering. Amsterdam: North-Holland.

Olneck, Michael R. 1977. "On the Use of Sibling Data to Estimate the Effects of
Family Background, Cognitive Skills, and Schooling: Results from the Kalamazoo
Brothers Study." In Taubman (1977, 125–62).

and Malnutrition." In David E. Sahn, ed., Causes and Implications of Seasonal
Research Institute.

Income Distribution on Food Demand and Human Nutrition." American Journal of

Pitt, Mark M. 1983. "Food Preferences and Nutrition in Rural Bangladesh." Review of

across and within Farm Households." Review of Economics and Statistics 67, no. 2
(May): 212–23.

for Food Policy." In K. T. Achaya, ed., Interfaces between Agriculture, Nutrition,
and Food Science. Tokyo, Japan: United Nations University.

Individual Diets and Nutritional Status in Six Villages of South India. Hyderabad,
India: ICRISAT.

Sahn, David E., ed. Forthcoming. Causes and Implications of Seasonal Variability in


