Chapter 14

HEALTH AND NUTRITION

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Contents

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1. Introduction

Health and nutrition are important as ends in themselves and often are emphasized as critical components of basic needs in developing countries. In addition they may be channels through which productivity and distributional goals of developing societies may be pursued effectively if, as is often hypothesized, the productivity of low-income persons in work and in human–capital formation is positively affected by health and nutrition status.

Cross-country comparisons of standard data suggest that on the average health and nutrition in the developing world falls considerably short of that in the developed world (Table 14.1).[1] The differences in means across countries in 1983 were considerable: in the other low-income countries (i.e. excluding China and India) life expectancies at birth were 50 and 52 years for males and females, as compared with 72 and 79 in industrial market economies; for the same two country groups infant mortality rates were 115 versus 10 per 1000 inhabitants; per physician were 17,990 versus 554, and daily calorie supplies were 2118 versus 3400. The proportion of the population with access to safe water in 1975, moreover, was less than a third for the low-income countries.

On the other hand, the changes in such indices in recent decades in the developing countries have been enormous, and in many cases the absolute gaps between the developing countries and developed countries have been reduced. Between 1960 and 1983, for example, life expectancies at birth for males increased by 16 years for low-income countries, 10 years for middle-income countries and 14 years for high-income oil exporters, as compared with only four years for industrial market economies and one year for East European nonmarket economies. Thus, while significant gaps remain in health and nutritional status across country groups defined by their level of development, by a number of indices such gaps have been reduced more rapidly in recent decades than has been the reduction in gaps, for example, in per capita income.[2]

[1] Of course the interpretation of averages must be qualified since health and nutrition attainment may depend critically on the shapes of the distributions of key variables; we return to distributional questions below. There also are some critical measurement issues which we discuss below in Section 3.

[2] However, one should be careful about extrapolating the past relative gains into the future for at least two reasons. First, for some such measures, there has been an advantage to being a relative latecomer. But closing the last 10 percent of the gap may be much more difficult than closing the first 10 percent since the transfer to latecomers of new techniques (e.g. public health measures) typically focuses on higher productivity techniques initially. Second, the last columns of Table 14.1 suggest a decline in relative shares of health and nutrition-related expenditures at least in central government budgets. The declines in the shares of health expenditures are large enough so that absolute health expenditures also have declined despite growth in overall governmental budgets, though private health expenditures may have increased and other related government expenditures (e.g. housing, community amenities, social security and welfare) increased.

Table 14.1
Indicators of recent levels and changes in health and nutrition and in related percentage shares of government expenditures[a]

	Life expectancy in years at birth				Mortality rates per 1000				Population per				Daily caloric supply per capita (1982)	
	Male		Female		Infant (age < 1)		Child (1–4)		Physician		Nursing person			
	1960	1983	1960	1983	1960	1983	1960	1983	1960	1980	1960	1980	Total	% of requirement
Low-income economies	42	58	41	60	165	75	27	9	12088	5556	7226	4564	2408	105
China and India	42	61	41	63	165	61	26	6	7019	1858	6734	3279	2503	109
Other low-income	42	50	43	52	163	115	31	18	37092	17990	9759	8697	2118	93
Middle-income economies	49	59	52	63	126	75	23	9	17257	5995	3838	1945	2661	114
Lower middle income	44	55	47	59	144	87	29	11	28478	7555	4697	2292	2495	109
Upper middle income	55	63	58	68	101	59	15	5	2532	2018	2752	995	2880	119
High-income oil exporters	43	57	45	60	175	90	44	11	14738	1360	4996	836	3271	...
Industrial market economies	68	72	73	79	29	10	2	(·)	816	554	470	180	3400	133
East European nonmarket Economies	65	66	72	74	38	30	3	1	683	345	358	130	3419	133

Percentage of population with access to safe water	% of central government expenditure			
	Health		Housing, community amenities, social security, welfare[b]	
1975	1972	1982	1972	1982
31	6.1	3.0	3.8	5.0
...	...	...	...	...
29	6.1	4.0	3.8	6.0
52	6.5	4.7	20.2	17.7
...	4.5	3.7	4.9	6.8
...	7.0	5.1	24.2	21.0
88	5.6	5.5	12.5	9.1
...	9.9	11.7	36.8	40.4

[a]*Source*: World Bank (1982, Table 22; 1984, Tables 23, 24, 26; 1985; Tables 23, 24, 26).

[b]According to the World Bank (1985, p. 241): "Housing and community amenities and social security and welfare covers (1) public expenditure on housing, such as income-related schemes; on provision and support of housing and slum clearance activities; on community development; and on sanitary services; and (2) public expenditure for compensation to the sick and temporarily disabled for loss of income; payments to the elderly, the permanently disabled, and the unemployed; and for family maternity, and child allowances. The second category also includes the cost of welfare services such as care of the aged, the disabled, and children, as well as the cost of general administration, regulation, and research associated with social security and welfare services."

In recent years economists have directed increasing attention towards exploring the determinants of and the impact of health and nutrition in the development process. Some progress has been made in our understanding of a number of important issues, but substantial lacunae remain in our knowledge about health and nutrition and development. Important issues concern the extent of health and nutrition problems, the determinants of health and nutrient status, the impact of health and nutrition on incomes and other outcomes, and appropriate policy design.

The measurements issues about the extent of health and nutrition problems in some cases precede and in some are intertwined with the economic analysis. To what extent are the standard indices (such as in Table 14.1) useful for characterizing health and nutrition well-being? To what extent are these misleading because of confusion between inputs and outputs, ambiguity between curative and preventive health measures, failure to recognize the endogeneity of health status and health inputs, intra- and interpersonal variability in health and nutrient standards, and individual economic and psychological adaptability?

The determination of health status and nutrition is largely by individuals and the households in which they reside given their resources and the prices that they face, both broadly defined. Important questions about this process include: What is the production process that determines health status? What are the lags? How do biology, behavior, and environment interact? What is the nature of complementarities and substitution in this production process? How important are nutrient and other purchased (or produced) inputs? How important is education (especially of women) and, if it is important, what is it representing? How critical are various dimensions of the household and community environment? How responsive are nutrition and health status to changes in prices that households face and in resources that households have? To what extent are there interhousehold variations in these responses depending on relative or absolute income? Will income increases associated with development result in substantial increases in health and nutrition? To what extent are there intrahousehold variations in such responses depending on age and gender? Are seasonal variations critical? How well do the relevant prices reflect the true social costs of resources used for nutrition and health inputs? In what cases are there significant externalities with respect to the production of these inputs? What are the expected returns to private versus social and to preventive versus curvature health inputs?

The possible impact of nutrition and health status on other outcomes also raises a number of questions. To what extent is improved nutrition reflected in greater metabolism, greater energy expenditure or better ongoing health? Are there important own-farm, labor market and schooling productivity effects of nutrition and health? What is the impact of nutrition and health of adults and of their children on fertility?

Finally, based on as good answers to these questions as possible given information and research costs, what are the implications for policies? To what extent do externalities or distributional concerns warrant governmental subsidies to certain health and nutrition inputs? What do the patterns of price and income demand elasticities across different health and nutrition inputs and among various population groups imply about policy design? To what types of governmental health and nutrition investments are the social returns likely to be highest?

In this chapter we review a number of these issues regarding health and nutrition in developing countries and available studies on the determinants of health and nutrition and on their impact on productivity in developing countries. We consider first a theoretical framework and some issues pertaining to the empirical representation of health and nutrition. We then survey existing studies on both health and nutrition determinants and on their productivity impact and conclude with some discussion of policy issues and directions for future research.

2. Theoretical framework

A theoretical framework for the determinants of health and nutrition and their possible productivity impacts is essential in order to analyze these variables in an organized manner and to be able to interpret empirical studies. Since most of the studies that we review below in Section 4 focus on demand determinants and since most macro studies appeal to micro rationales for their specifications, we begin with micro production function and demand considerations. We then more briefly consider the supply side and macro relations.

2.1. Micro considerations: Household production functions and reduced-form demands for health and nutrients

The proximate determinants of an individual's health and nutrition usually are decisions made by the individual or by the household in which he or she lives – given assets, prices, and community endowments (some of which may be determined in part by governmental actions). Therefore a natural starting point is the determination of individual health and nutrition at the household level (some individuals, of course, live in single-person households). Since many individuals in developing countries live in consumption units for which the production–consumption separability conditions (which are required to permit consideration of income generation and demand for consumption goods and services as a two-stage process as in most studies) are not satisfied because of incomplete markets or because of productivity effects of health and nutrition input consumption, we consider the case of a household-firm decision-making unit. The most analyzed such unit is the household-farm model considered by Lau, Lin and Yotopoulos (1978), Barnum and Squire (1979), Singh, Squire and Strauss (1986) and others, but similar considerations may be important for nonagricultural family enterprises in services and industry, particularly in the informal sector. The situation in which separability is an appropriate assumption can be considered to be a special case of this model in which the prices, assets, and endowments that affect the income-generation side alone can be replaced by predetermined income in the health and nutrient demand relations. If the nature of one's occupation and one's productivity directly interact with one's health and nutrition, however, the separable case may not be as common as often is assumed.

We structure our presentation of this model "as if" the household maximizes a single preference function subject to a set of constraints.[3] For simplicity, we also consider a one-period model under certainty. Of course the period may be long, so long lags such as the impact of some occupational choices on health [say, such as analyzed by Bartel and Taubman (1979) for the United States] can fit within this framework. Uncertainty is pervasive in the real world with regard to many long-run health effects of a myriad of choices, from diet to occupation to residential location. Within a simple neoclassical household model the impact of the introduction of uncertainty given risk aversion, ceteris paribus, would be that people would tend to shy away from more uncertain outcomes as compared with

[3]This assumption bothers some who think it is a misleading abstraction of the bargaining and negotiations that actually occur in the household [e.g. Folbre (1983, 1986), Jones (1983)] and that instead bargaining models should be used, such as developed by Manser and Brown (1980) and McElroy and Horney (1981). For most purposes given generally available data (though not including questions of household formation and dissolution) and for virtually all purposes of this review, the alternative bargaining model has no different implications for empirical specification since the same structural and reduced-form relations for health and nutrition result [e.g. Rosenzweig and Schultz (1984)]. The interpretation of some variables, however, might differ to the extent that such variables reflect the bargaining power of different household members instead of the productivity of their human capital. One potential contribution to our understanding would be to collect data that permitted the empirical distinction between maximization of a joint utility function and a bargaining framework and to test empirically how important the difference is. For example, one could explore if it made a difference in the reduced-form demand relations to (from) whom in the household extra income were given (taken away). However, such income would have to be distributed randomly and *not* be associated with human capital directly or indirectly (e.g. through the number of children) in order to be able to identify from cross-sectional data between bargaining models with their emphasis on bargaining strength emanating from the income controlled by an individual and the shadow prices associated with human capital that are emphasized in neoclassical household models with an unified utility function. Therefore, for instance, analysis that assumes that women with higher wages have more bargaining power as in some of the studies reviewed by Folbre (1986) does *not* provide support for the bargaining models relative to the unified utility function model since higher wages change the opportunity cost of women's time. Jones' (1983) study is another example of the identification difficulty. She argues that evidence of allocative inefficiency within households supports the bargaining model interpretation since such inefficiency might reflect bargaining strategies by household members. But there also is considerable evidence that is consistent with the possibility that allocative inefficiencies reflect human capital inadequacies, as is reviewed in Schultz (1975).

more certain ones – the more so the greater their risk aversion. The impact of uncertainty on decisions pertaining to health and nutrition indeed might be an interesting one to explore. But we are unaware of any efforts to do so to date in the economic development literature on health and nutrition, so we abstract from uncertainty in what follows.

We turn now to an algebraic statement of the one-period, household-firm model with constrained maximization of a joint utility function. We emphasize, however, that the objective of the general form of the model that we present is not necessarily to derive a priori testable predictions of household responses to exogenous shocks. The model is far too complicated for such exercises. Testable predictions can be derived only if one is willing to simplify the assumptions in the model considerably and probably unrealistically. Instead, our objective in presenting the general model is to distinguish the endogenous variables from the exogenous ones under our assumptions, to guide the choice of right-side variables in estimated production and demand relations, to indicate what instruments should be used for endogenous variables in estimating structural relations, and to suggest what variables may be missing from estimated relations in the literature. In other words, our basic purpose is to indicate how the available empirical estimates of health, nutrition, mortality and health-care determinants and of the impact of health, mortality and nutrition on labor productivity and on fertility fit into a household decision-making framework.

2.1.1. Household preference functions

Assume that the household has a preference function:

$$U = U\left(H^i, C^{\mathrm{p}}, C^i, T_{\mathrm{L}}^i, E^{i|\mathrm{c}}, S; \xi\right), \quad i = 1, \ldots, I, \tag{1}$$

where

- H^i is the health of household member i,
- C^i is the consumption of household member i, with the superscript p referring to household pure public goods,
- T_{L}^i is the leisure time of household member i,
- $E^{i|\mathrm{c}}$ is the education of household child i,
- S is the number of surviving children,
- ξ are taste norms, and
- I is the number of individuals in the household.

(All of these variables and others defined below may be vectors with multiple dimensions.)

Utility is presumed to depend on the health of each of the household individuals, with a negative impact of poor health and mortality.[4] Pure public goods consumption and private consumption and leisure[5] of each household member have positive impact. An individual's health may affect critically the extent of enjoyment of both consumption and leisure, so sensible explicit forms of the utility function include interactions of health with consumption and with leisure. The education of each child is included because of possible altrustic interests of the parents, concern about the child's expected prospects as an adult which may affect the parents' material well-being in their old age, or as a proxy for the child's future consumption or utility in a multiperiod model.[6] The number of surviving children is presumed to improve parental welfare (perhaps with diminishing returns) whether for altrustic, insurance, or other reasons. The utility function, finally, is conditional on norms. Most economists assume that these norms are exogenous, though some have considered the implications of intergenerational or intragenerational endogenous norms [e.g. Easterlin, Pollak and Wachter (1980)]. If norms are endogenous, empirical identification of structural effects and private welfare analysis both are much more difficult than if norms are exogenous. If parental schooling affects these norms, for example, it becomes very difficult to identify possible productivity effects of parental schooling on health and nutrition in reduced-form health and nutrition demand functions (see below). And whether schooling has a productivity or a norm impact may make a great deal of difference in making positive or normative conclusions about policy impacts.

The preference function in (1) is maximized subject to two sets of constraints, given assets and prices.

The first set of constraints is a set of production functions. These production functions, in turn, can be subdivided into three categories: ones that produce health and nutrition, ones in which health and nutrition affect other outcomes, and ones in which health and nutrition do not enter. We discuss the first two of these categories.

2.1.2. Production functions determining health, mortality and nutrient intakes

The *health* of the *i*th individual is produced by a number of choices relating to the consumption and time use of that individual, the education of that individual

[4] The utility function generally has arguments of living household members, but mortality may enter because, for example, infant and child mortality may reduce the utility of surviving household members. Also see footnote 9 below.

[5] We make the standard assumptions that nonleisure time (i.e. time working) is not differentiated with respect to its impact on utility. A more complicated formulation with the nature of work time having a direct impact on utility would not add to the analysis of existing studies.

[6] Though schooling may not be a very good proxy if parents also transfer assets to their children or if endowments (genetic and otherwise) are important in determining child quality. See Behrman (1987a).

and of the key person(s) in the household making and implementing health-related decisions, and the individual and household endowments:

$$H^i = H\left(N^i, C^i, C^{\mathrm{p}}, I, E^i, E^{\mathrm{m}}, T_{\mathrm{L}}^i, T_{\mathrm{H}}^i, T_{\mathrm{H}}^{\mathrm{m}}, \eta^i, \Omega\right), \tag{2}$$

where

N^i is the nutrient intake of the ith individual,
E^i is the education of the ith individual (with the superscript m referring to the person – often the mother or wife – who makes critical health-related decisions and implements them within the household),
T_{H}^i is the time of the ith individual devoted to health-related procedures,
η^i is the endowment of the ith individual (e.g. genetic make-up),
Ω is the endowment of the household/firm (e.g. the general environment), and the other variables are defined above.

Nutrient intakes (N^i) are emphasized because of their presumed importance in health determination. For most individuals in developing countries, it is assumed that the health impacts of N^i are positive, though too great quantities can have negative effects on health. The production function often is treated as if it encompasses fixed nutrient standards (given age and gender), though the validity of this assumption has been questioned increasingly recently (see Section 3.2). Other consumption items (C^i, C^{p}) include goods and services with a range of direct effects on health (e.g. medicine, cigarettes, driving vehicles). The household size (I) is included to represent possible scale and congestion effects. The individual's time use is included because the nature of his or her occupation (not included explicitly above), the extent of leisure time (T_{L}^i) and the time devoted to health-related activities (T_{H}^i) may have strong health effects.[7] The time use of the individual and the nature of occupational and other activities, for instance, affect energy use and thus the health impact of given levels of nutrients intakes. The individual's education (E^i) and that of the key person in the household concerned with health-related decisions and implementation (hereafter referred to as the mother), may affect health through affecting the choice of health practices, through better information and through affecting the effectiveness of the use of given health-related inputs (e.g. more-educated cooks may prepare food in more nutritious ways, more-educated mothers may be more likely to know about oral

[7] O'Connell and Mwabu (1986), for example, develop an interesting model in which rural (or, perhaps better, informal sector) workers allocate less time to health maintenance and are less healthy as a result than urban (formal sector) workers because of greater possibilities for productive activities for low-health workers in the former sector and, thus, higher opportunity costs for taking time from work for health maintenance for such workers.

We also note that some time uses (e.g. sleeping, exercise) may affect both leisure and health, as could be accommodated in this framework with a much larger vector for different time users. However, little is lost for the general level of our discussion if we ignore the complexities of such possibilities, so we continue to do so.

rehydration procedures).[8] The last two variables, the individual's endowments (η^i) and the household endowment (Ω), differ from the other variables in that they are presumed not be choice variables of the household during the period being modeled. Examples, respectively, would be the individual's age, initial health and genetic make-up, and the natural environment of the household – though the latter could be modified by migration. While the general health production function in (2) captures most of the factors emphasized in the economic literature on health determinants, it is important to realize that our knowledge of the technical relations determining health and the nature of interactions and lags is quite primitive.

The *mortality* function for the ith individual is related intimately to his or her health, with mortality (M^i) resulting if health falls below some critical level (H^*):[9]

$$M^i = M(H^i - H^*), \quad i = 1, \ldots, I. \tag{3}$$

The *nutrient* intake of the ith individual (N^i) depends upon the food intake of that individual (C^i, with nonfood components having zero weights), perhaps as modified by the skills (E^{m}) and time input ($T^{\mathrm{m}}_{\mathrm{H}}$) of the food preparer, and the household/firm environment (Ω):

$$N^i = N\left(C^i, E^{\mathrm{m}}, T^{\mathrm{m}}_{\mathrm{H}}, \Omega\right). \tag{4}$$

The last three terms may modify the nutrients obtained from given food intakes since such nutrients depend on the methods of food storage and preparation. Note that N^i refers to nutrient intakes, and *not* to nutritional outcomes like weight which we argue in Section 3.2 logically are indicators of health status (H^i).

Numerous estimates exist of the health and mortality production functions (see Section 4). Four important considerations in evaluating such estimates are: First, many of the right-hand-side variables are determined simultaneously with health and mortality by the household. However, in many existing studies the right-hand-side variables are treated as exogenous, with simultaneity biases resulting. For example, if individuals with a greater unobserved (to social scientists) propensity towards illness are relatively sick despite their greater tendency to use

[8] The impact of education, of course, may interact with time and goods allocated to health-related activities.

[9] T.N. Srinivasan has suggested that, if the survival of every household member is crucial, the mortality consideration can be represented directly in the utility function by letting the marginal utility of H^i go to minus infinity as H^i approaches H^*, with no need for a separate mortality function. We acknowledge the spirit of such a possibility, though letting the marginal utility go to minus infinity may be extreme. However, we choose to consider mortality explicitly because much of the empirical work in the area of health and nutrition has been on mortality determinants.

health-related inputs, the failure to control for simultaneously determined health inputs in the estimation of the health production function may bias downward the estimated health impact of such inputs.[10] Exogenous variables, such as the market prices discussed below, should be used with simultaneous estimation techniques to avoid simultaneity biases. Second, there are a number of variables on the right-hand-side of these relations that often are not observed, e.g. time use and endowments. If these variables are correlated with the included variables, omitted variable bias may be widespread. If households with better unobserved endowments tend to have more-educated mothers, for example, the estimated impact of mother's education in health and mortality is upward biased.[11] Third, the relations may differ for different types of individuals in the same household and the distribution of inputs among and individuals may not be uniform. Therefore estimates based on household averages may be misleading. If, for example, marginal nutrient increases are consumed primarily by prime-age adult males (either because of power relations within the household or because of high productivity returns), then average household nutrient demand relations are not very informative about what happens to nutrient intakes, say, for prime-age males or infant girls if household income increases. Fourth, the above productions functions are presented for simplicity in a one-period framework. But in empirical applications the nature of lagged responses may be critical for understanding long gestations and expectational formation. If lagged responses in health to nutrients, to illustrate, are not well represented, empirical estimates may understate the health impact of better nutrition.

There are not many econometric studies of the nutrient production function in relation (4). Instead, in most empirical work this relation is reduced to a weighted average of food intakes by using standard nutrient/food conversion factors, thus supressing all but the food components of C^i. This procedure means that nutrient intakes are measured with error that is systematically associated with the last three variables in (4). To the extent that this error is randomly associated with nutrient intakes, if nutrients are right-hand-side variables as in the estimation of health production functions, the impact of nutrients is likely to be underestimated, and the direct health impact of variables such as the mother's education, her time spent in health-related activities, and the household endowment overestimated.

[10] There also may be biases in the estimates of other parameters, but it is difficult to make any general statement about the magnitude and direction of such biases. See any standard econometrics text.

[11] Any correlation between the omitted variables and included predetermined variables (e.g. schooling in many studies) also means that the variations in the residuals are biased estimates of the variations in the unobserved variables. Thus, unobserved exogenous impacts of, say, endowments *cannot* be identified with the estimated structural residuals, as proposed in various studies [e.g. Rosenzweig and Schultz (1983b)], unless the unobserved variables *truly* are uncorrelated with right-hand-side variables.

2.1.3. *Production functions with health and nutrients as inputs*

Health and nutrient effects on labor productivity and on fertility are frequently postulated. Two types of relevant labor market or income-generation production functions are particularly important. The *wage* (P_L^i) of the ith individual reflects a maximizing choice given the individual's characteristics and the labor market characteristics (or community endowments):

$$P_L^i = P_L(H^i, N^i, E^i, \eta, \theta), \tag{5}$$

where

- θ refers to community characteristics, including – but not limited to – labor market conditions,
- P_L^i is the wage of the ith individual, and all other variables are defined above.

The *household firm/farm production function* depends upon the characteristics of all individuals in the household who work on these activities, capital stock (K, including land), intermediate inputs (A), hired labor (L^*) used in the production process and the household/firm environment (Ω):

$$Y^h = Y(H^i, N^i, E^i, T_F^i, \eta^i, K, A, L^*, \Omega), \quad i = 1, \ldots, I, \tag{6}$$

where

- Y^h is the household firm/farm product,
- K is the capital stock (including land) used in the firm/farm production process, part of which may be owned by the household (K^h) and the rest of which may be rented (K^*),
- T_F^i is the time of the ith household member spent on household firm/farm production,
- A are the intermediate inputs used in firm/farm production,
- L^* is the effective hired labor used in firm/farm production, and all other variables have been defined above.

Health and nutrition enter into both of these relations in the hypothesis of Leibenstein (1957), Mazumdar (1959), Stiglitz (1976), Bliss and Stern (1978) and others that better health and nutrition may increase labor productivity. Better nutrition may work indirectly through improving health status, but also may permit greater productivity through greater energy expenditure without altering on-going health status, so it is included as a separate variable.

Health and nutrition also may enter into the production function for *births* (B):

$$B^{mf} = B(H^m, H^f, N^m, N^f, \eta^m, \eta^f, C_C, E^m, E^f, \xi), \tag{7}$$

where C_C is contraceptive use or other birth control efforts, and the superscripts m and f refer to the mother and to the father.

Births are determined by the health, nutrition, and endowments of the parents because such characteristics may affect both fecundity and frequency of intercourse. Taste norms also may affect the latter. For a given frequency of intercourse, the extent of conscious birth-control efforts affects the probability of conception, though the success of such birth-control efforts may depend on the education of the users. Births, like mortalities, affect household utility by changing family size.

For the estimation of the impact of health and nutrition in these production functions, the implications are similar to those above: health and nutrition and other endogenous variables should be treated as simultaneously determined to avoid simultaneity bias since health and nutrition well may be greater due to higher income if productivity is greater. Omitted variable bias due to unobserved endowments may be a problem with the result, for example, that greater productivity wrongly may be attributed to better health if better health is associated with unobserved endowments such as abilities that increase productivity.[12] Aggregation of the household level may be misleading if, for example, marginal nutrients are concentrated among workers (or vice versa). Lags may be critical for understading real-world relations.

2.1.4. Full-income constraint

The second set of constraints are the time and income constraints that can be combined into a full-income constraint:[13]

$$\sum P_{\mathrm{L}}^{i} T_{\mathrm{W}}^{i} + R + P_{Y} Y^{\mathrm{h}} - PA - P_{\mathrm{L}}^{*} L^{*} - \sum P_{\mathrm{L}}^{i} T_{\mathrm{F}}^{i} - \mathrm{d} K^{h} - rK^{*} + \sum T^{i} P_{\mathrm{L}}^{i}$$
$$= P_{\mathrm{C}} C + P_{\mathrm{F}} C_{\mathrm{F}} + \sum_{i=1}^{I_{\mathrm{C}}} P_{\mathrm{E}} E^{i}$$
$$+ \sum P_{\mathrm{L}}^{i} \left(T^{i} - T_{\mathrm{F}}^{i} - T_{\mathrm{W}}^{i} - T_{\mathrm{H}}^{i} - T_{\mathrm{E}}^{i} \right), \tag{8}$$

where

- r is the rental rate on hired capital,
- d is the depreciation rate on capital,
- T^{i} is total time of the ith individual,
- T_{W}^{i} is the labor-market work time of the ith individual,
- T_{E}^{i} is the school time of the ith child,
- R is transfers minus taxes (assumed to be lump-sum for simplicity), and
- P_{j} refers to different prices.

[12]And once again, structural residuals may not be good representations of unobserved endowments if such endowments are correlated with observed variables such as schooling as often would seem plausible.

[13]Since the model is a one-period model, for simplicity we ignore savings and investment.

2.1.5. Reduced-form demand relations

Under the assumption that the underlying functions have desirable properties so that an internal maximum is obtained,[14] the constrained maximization of preferences leads to a set of reduced-form demand functions. The left-hand-side variables are all of the endogenous variables in the system for the household. The right-hand-side variables are all of the exogenous (to the household) prices, endowments, transfers minus taxes, and predetermined wealth:[15]

$$Z = f(V), \tag{9}$$

where

$$Z = \left(H^i, N^i, C^i, C^i_{\mathrm{B}}, C_{\mathrm{F}}, P^i_{\mathrm{L}}, T_{\mathrm{H}}, Y^h, T^i_{\mathrm{L}}, T^i_{\mathrm{W}}, T^{i|c}_{\mathrm{E}}, L^*, A, E^{i|c}, B, M\right),$$

and

$$V = \left(P_{\mathrm{C}}, P_{\mathrm{F}}, P_{\mathrm{E}}, P^*_{\mathrm{L}}, P_{\mathrm{A}}, P_{\mathrm{Y}}, r, P_K, E^{i|a}, \eta^i, \Omega, \theta, \xi, R, K^h, \sum, d\right).$$

Estimation of the reduced-form relations usually does not provide much information about the structural coefficients in (2)–(7), but it does provide a consistent framework within which to examine the impact of changes in market prices, endowments, and policies on the health- and nutrition-related consumption of different types of individuals. Estimates of such reduced-form demand relations for health, nutrition and other health-related inputs are fairly common (see Sections 4.1 and 4.2).

Several characteristics of these reduced forms merit emphasis. First, all of the exogenous prices – for all consumption goods, birth control, education, hired labor and capital, intermediate inputs and the firm/farm product – enter into the determination of each of the endogenous variables. Thus, health, for example, depends inter alia on the prices of all consumption goods and services and of all farm/firm products and inputs, not just on food and direct health-related input prices. Only if markets are sufficiently complete and if household members' firm/farm labor productivities and wages are independent of household consumption choices can the separability between production and consumption be invoked to obtain standard demand functions; in this case net income can replace all the production-related prices and assets, though of course all of the

[14] In some cases this may be a strong assumption since corner solutions with, say, zero values of certain health-related inputs may occur, which complicates estimation.

[15] We write the reduced-form relations as being dependent on predetermined tastes as is standard practice among most economists. If tastes are endogenous [e.g. Easterlin, Pollak and Wachter (1980)], identification of productivity versus taste effects becomes difficult.

consumption prices and household production related assets remain. Empirically, of course, it is difficult, if not impossible, to include the full range of relevant prices. Omitted variable biases possibly result. For example, if farm/firm product prices are high and are positively associated with food prices but excluded from the estimation, the estimated impact of food prices on nutrient intake and on health may be biased towards zero. Second, if wages are endogenous as is posited in (5), they do *not* enter into the reduced forms as right-hand-side variables. In such a case individual wages *cannot* be used to represent the predetermined opportunity cost of time as Rosenzweig (1985) and others have suggested.[16] Third, *all* of the predetermined assets enter into *all* of the reduced-form relations. The endowments of the adults and the production assets of the firm/farm, for example, have an effect on the health and nutrient intakes of children in the household. Moreover, a number of the components of the endowments – for instance genetic dimensions of η^i and some environmental dimensions of Ω and θ – usually are not observed in socioeconomic data sets. Their exclusion may cause omitted variable bias in microestimates of health and nutrition reduced-form determinants if they are correlated with observed variables, which often may be the case, for example, for education of adults. Note that tastes may be just another form of endowments in this regard. Fourth, governmental policies affect health and nutrition primarily through prices, community endowments, and income transfers. Policies acting through prices include free or subsidized provision of health services, but also any other policies that affect *any* of the prices on the right-hand-side of (9), such as fertilizer subsidies or import tariffs and quotas. Policies may alter community endowments through public work programs and malaria and other disease control; to the extent that individuals can change the relevant community endowments through migration, however, these endowments are endogenous. Income transfer policies, of course, work through changing the budget constraint. Fifth, private firms and farms also alter the environment in which the household operates, most notably through the labor market, but also through other markets and through the community endowments. Technical choices made by such entities affect the wage and occupational choices of households and the environment in which the household members live and work, all with feedback on the health and nutrition of individuals in the household. The impact of Union Carbide on Bhopal, both before and after the 1984 disaster, provides a vivid example. Sixth, different individuals in the same household may be affected differently by an exogenous change in prices or endowments. Therefore analysis at the household level of

[16] If wages are endogenous, moreover, their reduced-form determinants include *all* prices and *all* predetermined assets (i.e. everything in V), which means that these variables *cannot* be used to identify labor force participation determinants and possible selectivity as in the widely used Heckman (1976) procedure (except for functional form differences, which seems a weak reed on which to base identification).

aggregation may not be very informative about what happens, for example, to infant girls. On the other hand, successful targeting of nutrients or other health-related inputs to particular individuals may be very difficult if resources are fungible within the household. Seventh, in empirical applications, once again, correct specification of lag structures may be important both because of gestation periods and because of expectational formation. For an example of the latter, investment in children's health may be of interest in part because of expected labor market returns when the children become adults. If so, some representation of the expected returns needs to be included among the right-hand-side variables in the reduced-form relations. Eighth, different groups of households may have different reduced-form relations because the constraints are not well represented in the reduced forms. For example, consider the situation in which all households receive a subsidized food ration that they *cannot* resell in the open market.[17] Then the households can be classified into three groups: those who buy their entire food ration and more in the open market, those who buy just the rationed amount, and those who buy only a part of their ration. If there is a small increase in the rationed commodity, the first household type has just an income effect, the second buys just the extra ration, and the third is unaffected. Thus, the same change in the exogenous ration produces different responses in these three household groups because of the preclusion against resale of the rationed food. Either the resale preclusion need be included in the reduced-form relations explicitly, or relations of the three household groups need to be estimated separately. Ninth, if enough structure is imposed on the underlying structural relations, there may be restrictions on the reduced-form coefficients.

2.1.6. *Quasi-reduced forms*

In addition to empirical estimates of production functions which determine health and nutrition and in which health and nutrition are determinants of other outcomes and of reduced-form demand relations for health and nutrition, there are many estimates of quasi-reduced forms in which health or nutrition is posited to be determined by some inputs from the structural production function (e.g. health-related inputs like innoculations or good water) and some variables from reduced-form demand relations (e.g. income). Such quasi-reduced forms would seem to be of limited interest because they generally neither reveal all of the structural parameters nor the total impact of exogenous changes. If they are to be estimated, however, the simultaneity of right-hand-side endogenous variables should be controlled in the estimation. Also, as in the estimates of production function and of reduced-form demand relations, omitted variable bias, aggregation and correct specification of lags may be problems.

[17] We thank T.N. Srinivasan for this example.

2.2. Supply considerations

Household or individual demand for health, nutrients and other health-related inputs are aggregated to obtain total market demand. On the other side of markets for health-related inputs are supplies. There are not special considerations on the supply side except that certain market failures may be more common for health-related inputs than for many other goods and services and there may be more of a tendency to attempt to use governmental policies in such markets to pursue distributional goals than in many other markets. Market failures may be more common because of the extensive public good element in some health inputs (e.g. control of contagious diseases) and the difficulty in privatizing the returns to information about health practices (e.g. about oral rehydration techniques). Internal efficiencies may be relatively difficult to obtain in the production of certain health-related inputs because of information problems (e.g. about the quality of drugs), and because of governmental regulations adopted ostensibly to maintain quality or for distributional purposes. Distributional concerns are reflected in the subsidization of health-related inputs such as food or noncontagious curative medicine for which there are not obvious market failures. The provision of many drugs may be affected by patients, limited information about technology, the behavior of multinational companies, and developing country policies regarding such companies. Only recently has there been almost any effort to clarify systematically to what extent a particular health-related input has purely private returns and the efficiency versus distributional motives for various policies [e.g. de Ferranti (1985), Jimenez (1984, 1986)].

2.3. Macro or aggregate considerations

At a very general level, most the macro demand or production function considerations are obtained basically by aggregating over the micro factors considered for individuals and households. Four important observations, however, need to be made about this aggregation.

First, distribution of income or wealth may make a great deal of difference for health and nutrition. Sen (1981a, 1981b), for instance, highlights this point in his discussion of nutrition and real purchasing power (or what he calls entitlements). Given the concentration of inadequate health and nutrition in the left-hand tail of the income distribution, analysis of averages over large groups may be misleading. In such analysis, in fact, some variables such as literacy rates may in part be proxies for distribution rather than only representing their purported effects.

Second, some variables that are exogenous to households may be endogenous at a more aggregate level. An example may be the nature of community endowments and prices in so far as they are affected by governmental policies, which in turn depend on total income of the society.

Third, the more aggregate analysis has at least one advantage in that random errors tend to average out. However, systematic errors which the micro discussion suggests may be important (e.g. due to unobserved endowments) still may cause problems.

Fourth, some aggregate relations appear to be aggregate representations of production functions or reduced-form demand relations, but others appear to be market reduced forms in which both demand and supply factors are combined. Satisfactory interpretation of such relations is difficult.

3. Measurement and estimation problems in health and nutrition relations

There are basic definition and related measurement problems regarding health and nutrition that underlie some of the ambiguities and controversies in the literature and in policy formation. There also are problems with empirical representations of the relevant prices, health-related inputs, and assets for the relations discussed in the previous section. Finally, several major econometric problems are ubiquitous in empirical studies attempting to relate health, nutrition, and socioeconomic variables. We now review some of these issues.

3.1. Measurement of health status

Health status in relations (2), (3), (5), (6), (7), and (9) above is not directly observed. Representation of health status in micro empirical studies generally is by: (i) clinical measures of bodily attributes; (ii) anthropometric measures of height, weight, triceps skinfold thickness, arm circumference, etc.; (iii) respondent-reported disease symptoms, mortality histories, and general health evaluation; and (iv) reports on incapacity for undertaking normal respondent activities. These measures differ significantly in regard to their costs and the extent of measurement error. They also may refer to different dimensions of health status, rather than a unidimensional construct; if so, measurement errors may be dependent on the dimension of health status that is relevant for a particular study.

The four categories of health status measurement indicated above are in order of decreasing data collection costs for most developing countries. Rarely do socioeconomic data sets of any size have health-status measures of the first type due in part to the collection costs. Anthropometric measures are somewhat more common, but still relatively rare due in part to collection costs. More common are the self-reports (or reports on other individuals, such as children) in the last two categories, for which the collection costs are about the same as for other respondent-reported socioeconomic census or survey data. Though collecting some sort of measures of health status seems to be increasingly common in socioeconomic data collection efforts, in many – probably the majority of existing socioeconomic data sets – no, or virtually no representation of health status is included. Conversely in many health-oriented data sets, information on socioeconomic variables that is needed to estimated reduced-form demand or structural production function relations usually is not present. Tradeoffs obviously exist among sample size, data completeness, sample variance and accuracy, but many existing data sets do not seem to have a good balance from the point of view of analyzing health and nutrition and development.

Measurement errors in some narrow sense probably tend to be less for the first two categories in which outsiders take "scientific-objective" readings. However, social scientists, out of ignorance or out of naive admiration for "more scientific" disciplines, quite possibly overstate the accuracy of such measurements. Measurement error is unavoidable even for clinical readings and anthropometric measurements. Moreover, the relation between accurately measured bodily attributes and health status of the sort that affects an individual's welfare [i.e. enters into the utility function in relation (1)] probably is less tight than often presumed, and may be culturally determined [e.g. Low (1984)]. Furthermore, the anthropometric measures and some of the other measures of bodily attributes often are interpretable as indicators of health status only with comparison to some reference group, though this is not the case for exploring some productivity effects of health. But such comparisons raise basic questions about the appropriate standards that are akin to those discussed below with regard to nutritional status. Some studies use gender–age standards defined from the sample data themselves, which permits relative comparisons within the sample, but not an indication of absolute health status relative to other populations. Other studies use as standards the sample statistics from supposedly healthy populations, such as healthy individuals in United States, though there has been a tendency in recent years to develop standards for populations more similar to those under study. But the use of standards such as those based on U.S. samples raises the question of whether people may not be, in Seckler's (1982) terms, "small but healthy".[18] Why should, for example, North American or Northern European height and weight distributions indicate desirable standards for Africans, South Asians, or Latin Americans? Of course, the use of such reference standards may overstate health problems in the developing countries, which practice may or may not be misleading regarding the analysis of the determinants of health status as in

[18]Which raises another question about the possible detrimental effects of the situation which led (at least the survivors) to be small, even if perhaps healthy. For a critical survey of the "small but healthy" hypothesis, see McGuire and Austin (1986).

relation (2) or the impact of health status on various outcomes as in relations (5) and (6). If, for example, the reference used were always exactly 130 percent of the appropriate standard, this would not cause biases in estimates of elasticities from relations such as (2), (5), and (6). On the other hand, if the difference between the standards used and the appropriate standards varies systematically with gender or age and if other observed characteristics in relations such as (2), (5), and (7) are associated systematically with gender or age, the coefficients of such characteristics could be biased by the standardization procedure. Moreover, for relations exploring the impact of health such as (6), even if the standardization error is random across gender and age categories, it tends to bias the estimated impact of health towards zero as in the classical errors-in-variable model. Finally, independent of what standards are used, there is a question for multivariate regression analysis (as opposed to simple characterizations of health status) of whether the marginal relations between such indicators and true health status is constant over the range of observations as is assumed in much such analysis. That is to say, is someone at 150 percent of the weight standard twice as well off as someone at 75 percent of the standard? Often – such as with respect to weight – the answer to this question would seem to be negative.

Respondents' reports are subject to better known (among social scientists, at least) measurement errors due to incorrect self-diagnosis of health status and to recall error. Such diagnoses may be conditioned, for example, by education, as is suggested by the results presented by Wolfe and Behrman (1984). They also are in part culturally determined as emphasized by Low (1984). What is "normal" or "good" health in the Sahael might not be normal or good in Korea. Moreover, within a given culture, some of these responses are likely to be conditioned by socioeconomic status. Whether one is healthy enough to perform normal duties, for example, is likely to be endogenous, so that an individual with a given objective health status is more likely to try to perform his or her normal activities if he or she is from a poorer household than if he or she is from a richer household due to diminishing marginal utility of consumption goods in the utility function of relation (1). If so, such respondent reports understate the extent of health problems among the poor, understate the health improvements that occur with income gains, and probably cause biases in estimates of both the determinants and impact of health.

The existence of all of these problems with the micro representations of health status leads to caution for the researcher and for the user of the research results. Since such health status measures are inherently imperfect, it also suggests the advantages of using a multiplicity of them to represent health status in empirical analysis. Wolfe and Behrman (1984, 1986b), Behrman and Wolfe (1987), and Behrman and Deolalikar (1987d) are recent examples in which this strategy has been followed in analysis of health in developing economies by using a latent variable representation of health status with a number of imperfect indicators.

Their results suggest that the latent variable representation of health status may lead to a different understanding of the determinants of, and role of, health than do many of the frequently used anthropometric and respondent-reported health indicators of health status in isolation. Their results, of course, are conditional on their overall model specifications and the health indicators available to them, so further explorations along these lines with different health indicators for different populations might be valuable.

For aggregate studies the basic indicators of health status that have been used are life expectancies (particularly at birth) and mortality rates (particularly for infants and children). These data are constructed from census and survey micro data and standard demographic procedures. While the health status that enters into relations such as (1), (2), (5), (6), and (9) above is likely to be related positively with life expectancy and negatively with mortality rates, the relationships are hardly likely to be perfect. For given life expectancies it is easy to conceive of very different health statuses prevailing due to very different morbidity experiences. It would be of value to explore the associations between these aggregate indicators of health status utilized for aggregate analysis and micro indicators such as those discussed above. We are unware of such explorations.

3.2. Measurement of nutrient intakes and nutritional status

There are issues and ambiguity on several levels about what is meant by nutritional status.

On one level there seems to be confusion between using nutritional status on one hand to refer to nutrient intakes as we have done in relations (2), (4), and (9) and as do Reutlinger and Selowsky (1976), Srinivasan (1981), and many others and – on the other hand – to refer to health outcomes that are thought to be related closely to nutrient intakes, particularly anthropometric measures, as do Horton (1984) and many nutritionists. If indeed there are many non-nutrient determinants of health status as we posit in relation (2) – such as water supply, individual and household endowments, community endowments, time devoted to health-related activities, health-care inputs related to preventative and curative medicine, education – then the latter usage seems misleading to us. Why should some of a multitude of inputs in the production of health status be characterized as representing such health status? Though it is simply a matter of definition, therefore, we think it clearer to use nutritional status in the former way to refer to nutrient inputs and we use the term in this way in what follows. To attempt to increase clarity, however, we use "nutrient intake" or "nutrients" instead of "nutritional status".

A second possible measurement problem has to do with the use of fixed conversion factors for food with heterogeneous nutrient qualities. If there is substantial heterogeneity in nutrient quality among foods defined as narrowly as "rice", as appears to be the case, then the use of fixed nutrient to food conversion factors may lead to substantial misrepresentation of the impact of changed income on nutrient intakes. Shah (1983) and Behrman and Wolfe (1984a), for example, conjecture that nutrient elasticities with respect to income calculated by applying fixed conversion factors to food elasticities may overstate substantially true nutrient elasticities since, for marginal food expenditures, other food attributes – taste, appearance, status value, degree of processing – may be much more important than nutrients.[19] Behrman and Deolalikar (1987c, 1987e) provide estimates consistent with this conjecture for a relatively poor sample from rural south India and for an international cross-section sample (see Section 4.2 below).

A third possible nutrient measurement problem is that certain critical data are available only on, or at least used only on, an aggregate level. Most striking in this regard are the studies such as those by Reutlinger and Selowsky (1976) and Berg (1981) that characterize malnutrition for large groups of people based on a comparison of their *average* nutrient intakes with *average* nutrient requirements. Such studies ignore the fact that there are distributions of nutrient intakes and requirements so that when the mean intake meets (or falls short of) the nutrient standard, there are likely to be substantial numbers of individuals above and below that standard. Clearly, such a procedure misrepresents whether or not many members of a given developing country group meet the nutrient requirements. While there obviously is such a problem with aggregate data for nations, regions, or other large groups, it also may be a problem for many microdata sets. Such data often are based on total household intakes of nutrients, but there appears to be substantial intrahousehold variations in nutrient intakes in the relatively few data sets that have such measures [see Behrman and Deolalikar (1987d), Behrman (1987a, 1987c, 1988), Horton (1984) and the references therein]. Of course the data on individual nutrient intakes probably is subject to considerable measurement error, which may be systematically associated with characteristics such as age or the education of the respondent. If so, such data may not reflect true nutrient distribution patterns within households.

More contentious are problems in defining nutritional "norms", "requirements" or "standards", and therefore "malnutrition". Such definitions are important in assessing the nature and extent of malnutrition in the developing world and in analyzing the determinants of, and the impact of, nutrition. Payne and Culter (1984) distinguish between two paradigms for nutrient requirements.

The first is the "establishment" or the "genetic potential model" in which the body is self-regulating and self-optimizing, the optimal diet depends on inherent

[19] Which is one reason that the foods consumed, and not the nutrients consumed, are included in the preference function in relation (1).

genetic characteristics that differ among individuals, the "optimal" diet for given genetic characteristics can be determined from the diet of those whose food choices effectively are unconstrained in well-fed populations, and malnutrition can be measured in a straightforward manner by shortcomings in comparison with such "optimal" diets. Estimates of calorie deficiencies based on this approach have suggested massive malnourishment in the developing world.

The second paradigm is the "individual adaptability model" emphasized by Payne (1975), Sukhatme (1977, 1982), Sukhatme and Margen (1978), Srinivasan (1981, 1985) and Seckler (1980, 1982) in which individuals adapt to their environment, with differences among individuals in the extent to which they are able to adjust in response to environmental stresses and in the efficiency with which they convert nutrient intakes to energy (partly due to genetic differences, but also due to the accumulative effects of past adjustments), with substantial interpersonal and intrapersonal variations, with productivity dependent on nutrition as well as vice versa, and with no fixed optimal levels. Adaptation includes shorter-run adjustment to variations over time in energy intakes and expenditures around unchanging means (homeostatis) and longer-run adjustments to changes in the means through changes in body weight.[20] Within this paradigm, the term "nutrient requirements" has a much less precise meaning than with the genetic potential paradigm since there is no true optimal. Certainly the nutrient intakes of healthy whites in industrialized countries, the standard used in many studies, do not provide an obvious reference standard. Moreover, there is the implication that malnutrition estimates based on the genetic potential paradigm are likely to be substantially overstated because of their failure to recognize individual adaptability.

Empirical evidence to discriminate between the two paradigms is very limited. Increasingly those such as Sukhatme, Srinivasan, Payne, and Seckler interpret the evidence to point to individual adaptations to the nutritional situation, though in many cases sample sizes are quite small, not obviously representative, and the evidence seems limited. If such adaptations do occur within limits, they raise questions about the use of international standards for characterizing the extent of malnutrition and, as Srinivasan has emphasized, the identification of what segments in a population are malnourished. They also raise questions about the extent of malnutrition in developing countries. Sukhatme (1977), for example, estimates that the estimated incidence of poverty in India declines from 50 to 25 percent in urban areas and from 40 to 15 percent in rural areas if allowance is made for variations in individual calorie requirements instead of using a poverty line based on average calorie requirements, but his estimates are not unchal-

[20] Sometimes there also appears to be an even longer-run genetic adaptation to environmental changes in this literature, but this possibility is emphasized less and seems to be relatively speculative.

lenged.[21] Parallel to the discussion above about standardizing health status indicators for age and gender, such standardization may or may not cause biases in our understanding of the impact of nutrients in relations such as (2) and in the determinants of nutrient intakes in relations such as (4) and (9).

3.3. Measurement of non-nutrient health-related inputs

We include in the health production function of relation (2) a number of non-nutrient health determinants. These may range from individual preventative and curvative inputs, such as innoculations and formal medical care, to household public goods inputs, such as shelter and water supply, to the community environment regarding matters such as control of contagious diseases and parasites and availability of formal medical care facilities. Empirical representations of these inputs also range broadly. Two points seem useful to emphasize about these measures.

First, like nutrient intakes, these are *inputs* into the health production process in relation (2), not measures of health status itself, though sometimes they are interpreted to represent health status. Care should be taken not to misidentify such inputs as indicators of health outputs. Examples exist in which factors such as education increase the use of such inputs, but do not measurably improve health status [e.g. Wolfe and Behrman (1984)].

[21] There is a large literature which seeks to establish poverty lines and measure the incidence of poverty on the basis of minimum cost diets that satisfy calorie requirements [Dandekar and Rath (1971), Bardhan and Srinivasan (1974)]. Greer and Thorbecke (1986) have proposed a new way of establishing a food poverty line which takes into account regional food preferences and prices, and have applied this methodology to study the incidence of poverty in Kenya. In a paper that we received as we were completing the final version of this chapter, Kakwani (1986a) reviews much of the literature on measuring undernutrition, develops a new class of undernutrition measures that incorporates the extent of undernourishment (and not just whether an individual is undernourished), explores what can be said about the ranking of populations according to the degree of undernutrition if the distribution of calorie requirement is completely unknown, develops upper and lower bounds on the head-count measure of undernutrition if only the mean requirement is known and the distribution of requirements is assumed to be uniform or normal, criticizes the Sukhatme procedure for defining undernutrition to be nutrition intakes less than two standard deviations below the mean requirements, and presents empirical estimates for India that suggest much broader malnutrition than do Sukhatme's estimates primarily because Sukhatme ranked households by expenditures rather than by calories, Sukhatme focuses on households rather than on individuals (even though the more poorly nourished households tend to be larger), and Sukhatme uses an arbitrary threshold for undernourishment. Neither Kakwani nor Sukhatme, however, deal satisfactory with the empirical difficulty of ascertaining undernourishment or malnutrition from cross-sectional data if there is considerable intrapersonal variability, as Sukhatme and Srinivasan, among others, maintain. In such a case, just because an individual has low nutritional intakes during the sample period does not mean that he or she is poorly nourished due to persistent nutrient shortages.

Second, such inputs are in part culturally and economically determined [e.g. see Low (1984)]. Within a particular society, care must be taken in empirical analysis to consider an appropriate range of such inputs, and not just those that are identified with public health measures or curative medicine in industrialized countries.

3.4. Measurement of prices, health-related inputs, and assets

For the most part, the conceptual bases for the measurement of the prices, health-related inputs and assets that are included on the right-hand side of relations such as (2)–(7) and (9) are fairly clear, and probably clearer than the conceptual bases for health and nutrient measures. However, problems of empirical representation still often are severe for these variables. As a result, measurement error (both random and systematic) and omitted variable biases abound.

The empirical problems for prices are of several types. First, samples with interesting health and nutrition data generally do not include empirical representations of the full range of consumption and firm/farm production prices in relation (9). As a result, the impact of unobserved prices may be picked up in the estimated coefficients of observed variables, prices and otherwise. Second, usually if there are observations on prices, the observations are limited to market prices, and do not include important time costs that have to be incurred in travel and in waiting for relevant goods and services. This may be a particularly severe problem for emergency health services because such services must be obtained at the time of health emergencies. In contrast, for more routinized health inputs and other goods and services, trips for purchases may be combined with other market (and nonmarket) activities so the marginal nonmarket costs may not be so large, though queuing costs for formal nonemergency medical services often seem to be considerable. Third, available frequently used proxies for prices may be quite imperfect. For example, hospital beds and formal medical care personnel per capita may be very poor proxies for the prices of preventative and minor aliment curative care that may be critical in the health production process, though such variables may serve adequately for prices for curative care for more severe illnesses.

For health-related inputs and assets, the problems are similar. For health-related inputs, for example, time inputs often are not observed well. The difficulties in measuring or controlling for some assets – in particular individual genetic endowments, moreover, are quite severe with most data sets. Sibling data, particularly on twins, may be attractive for this purpose for use as in Behrman, Hrubec, Taubman and Wales (1980), Behrman and Wolfe (1986, 1987) and Wolfe and Behrman (1987).

3.5. Estimation problems

Our catalog of possible estimation problems is *not* meant to lead to despair about the possibility of learning anything systematic about health, nutrition, and development. These problems are hardly unique to the study of health and nutrition. Applied work in the social sciences almost always has such problems to various degrees. The art of undertaking good applied studies is to control for the most probable difficulties, see what difference they make, and to replicate studies to see how robust they are. In considering any particular study, however, it is important to be aware of the range of possible problems and to try to judge how important is each. It is for this reason that we have reviewed these problems before turning to reviews of specific studies.

First, simultaneity occurs quite often in health and nutrition studies. For example, while estimating health production functions which relate, say, anthropometric measures to nutrient intake, many studies do not recognize that the latter is subject to individual choice and likely to be endogenous. Since individuals presumably decide on nutrient intake to improve health outcomes, the disturbance term in the health production function (which might include the effects of unanticipated shocks, omitted variables, or heterogeneity) is transmitted to the nutrient demand relation. The correlation between nutrient intake and the disturbance term means that OLS estimates of the health production function are biased. Unfortunately, it is not always easy to identify the direction of the bias [Maddala (1977)].

Unfortunately, many studies propose solutions for simultaneity that are purely empirical and not guided by economic theory. Theory suggests, for example, that the reduced-form nutrient demand equation in the above example has prices and certain (exogenous) individual/household characteristics as its arguments. These should be used as instruments since they are likely to be correlated with nutrient demand, yet uncorrelated with the disturbance term in the health production function. If more than one right-hand-side variable is endogenous, then all of the appropriate reduced-form exogenous variables should be used as instruments for each such variable. Instead, many investigators make what appear to be arbitrary restrictions by precluding from the relevant set of instruments different exogenous variables for each endogenous variable.

A second econometric problem that is endemic in empirical studies on health and nutrition is the classical errors-in-variables problem. Data on health and nutrition are typically collected over short reference periods (24 hours to a week), and are often based on self-reported rather than clinically-observed symptoms. For example, one rarely has data on effective nutrient intake, which is the correct variable to include in a health production function. What most consumption surveys manage to obtain are data on food availability. Only if the cooked food is weighed as it is about to be eaten could one obtain a measure of intake, and the intervention of such measurements itself may cause data distortions. Thus, there is likely to be substantial measurement error in health and nutrition-related variables. If health/nutrition variables are right-hand-side variables, this causes bias (towards zero if the measurement errors are random) in the estimates of the effect of health/nutrition on other variables, such as productivity or wages. If these variables are dependent variables, random measurement error leads to imprecise parameter estimates. To make matters worse, the measurement error is not always random. For instance, the accuracy of reporting illness symptoms or food intake is likely to be positively related to the education of the household head or the food preparer.

One solution, used in very few empirical studies, is to explicitly model true health and nutrient consumption status as latent (or unobserved) variables, for which are observed imperfect indicators like anthropometric measures, self-reported illnesses, and nutrient availability.

A third common problem has to do with omitted variables. The genetic endowments of an individual are unobserved but important factors in most health and nutrition relations. The exclusion can cause widespread omitted variables bias in parameter estimates. Consider the case of a health production function that does not control for such unobserved effects. Since genetically better-endowed individuals are likely to utilize more nutrients, the unobserved excluded variable in this case is positively correlated with the included nutrient intake variables. As a result, the estimated elasticities of health outcomes with respect to nutrient intakes are likely to be overstated if unobserved genetic effects are not controlled.

A fourth common problem is related to sample selectivity. This arises because there may be selection rules which determine the presence of healthy or unhealthy persons in a sample. The extremely unhealthy – those for whom nutrient intake produced no positive health outcome – do not live to be enumerated in a sample. Consequently, in a health production function, for example, the estimated effect of nutrient intake on health outcomes is upward biased since those individuals for whom the estimated effect was too low to insure survival are not in the sample.

A fifth problem pertains to the specification of appropriate lags for adjustments and for expectation formation. Most theory is static and provides no guidance regarding such lags. Yet in the real world they may be critical. Estimation of the impact of nutrition on health with current data on each, for example, may miss most of the effects if in fact they are lagged considerably.

A sixth problem is that aggregation to the household level may produce misleading results for individual welfare. A small nutrition response of the household to food price increases may hide widely different responses of individual members; for instance, children or women in the household may face the brunt of price increases, while adult males might be relatively protected. It is, therefore, important, wherever possible, to disaggregate the analysis beyond the level of the household.

Finally, most of the micro empirical studies reviewed below account for a limited proportion of the observed variance in the variables of interest. This is particularly the case for the studies on individual and household health determinants. Few of these studies are consistent with more than 10 percent of the interindividual or interhousehold variation in health status even after including individual and family background variables and health-care related prices. The limited explanatory power of such studies, highlights once more the problems involved in measuring and modeling health status; it is a variable which is very imperfectly observed and whose dependence on food and nutrient intake as well as on family background variables is too complicated and dynamic to be estimated well with cross-sectional data. The studies on nutrient and food consumption demand have somewhat greater explanatory power, with typical R^2's of 0.3–0.4. The studies on health/nutritional consequences have a range of explanatory powers; when multi-input agricultural production functions are estimated, a large portion of the cross-sectional variation in farm output or productivity is explained, but those studies that attempt to explain variations in economic outcomes only with health and/or nutrition variables have very low explanatory power.

However, it should be emphasized that important information *may* be obtainable about the magnitudes of critical responses, such as to prices or to policies, from relations that may be consistent with a limited portion of the variance in the outcome of interest. The critical question is not what is the proportion of explained variance, but whether there are biases in the relevant estimates due to specification errors, simultaneity or omitted variables.

4. Empirical studies of determinants of health and nutrition in developing countries

4.1. Determinants of health

Two broad categories of studies of health determinants are of particular interest: those attempting to estimate the reduced-form demand for health outcomes [H^i in eq. (9)] and health-care goods [C_{H}^i in eq. (9)] and those attempting to estimate the underlying health production function [eq. (2)]. Unfortunately, few researchers maintain clearly the distinction between the two. Most studies estimate hybrid demand–production functions or quasi-reduced forms for health. Not surprisingly, interpretation of the results from such studies is difficult.

4.1.1. Demand functions for health outcomes and health-care utilization

There are relatively few studies on health and health-care demand, at least compared to the number of health production function studies. Moreover, since most of the demand studies are based on cross-sectional data, few of them explicitly include market prices as explanatory variables. For the most part, they include household characteristics, income, and availability of health care, the latter, of course, being interpretable as the price of health services.

Among the micro studies, Blau (1984) estimates a demand function for age-standardized height using 1977–78 data on children under five years of age in Nicaragua. He includes the mother's age, education, urban origin, other income, and predicted formal and informal sector wage rates (corrected for selection bias) as independent variables. Blau's rationale for separating the two types of wage rates is that female informal-sector jobs in developing countries may be consistent with own childcare in a way that formal-sector jobs are not, since childcare often can be combined with informal-sector jobs. If this is indeed the case, the substitution effect of the mother's formal-sector wage rate on child health should be negative and that of the informal-sector wage rate should be zero. After allowing for a positive income effect, the gross impact on child health of the informal-sector wage rate should be greater in magnitude than that of the formal-sector wage rate. Blau's results, however, indicate the opposite: he finds the mother's (predicted) formal-sector wage rate to have a significant *positive* effect on child health and the informal-sector wage rate not to have any significant effect.

Akin et al. (1985) study the determinants of a household's decision to use medical services and its choice of a medical practitioner (i.e. whether public, private, or traditional), applying multiple-choice logit models for adults and children to data on 1903 households from 100 barangays in the Philippines. An extensive set of price variables for each of the four types of medical facilities, including the cash price of using the facility, the transport time and cost in reaching the facility, and the drug costs involved, are included as explanatory variables in the demand functions for health services. In addition, variables such as whether the sickness is covered by insurance; the value of household assets; gender, education, and urban location of the patient; and the severity of the illness are included in the demand equations. The authors obtain an almost total lack of statistical significance of any of the economic (price, time) variables. Since the pecuniary and nonpecuniary costs of consuming medical care are not trivial in the sample, results which show that these costs are not significant determinants of practitioner choice are very surprising.

Unfortunately, Akin et al. include the demand for health outcomes (namely, the severity of illness) as an explanatory variable in their demand for health-care utilization, without treating it as an endogenous variable. Indeed, they find that it is the most important (and only significant) determinant of practitioner choice. While this result is perfectly logical (since there is likely to be a segmentation in the facilities available for treating particular types of illnesses, with severe illnesses being treated in large public facilities and minor complaints by traditional medicine men), the fact that individuals have a choice of allowing their illnesses to become severe introduces a bias in the price effects estimated by Akin et al. Indeed, it could well be the case that health-care prices do matter in determining the demand for health-care utilization and practitioner choice by influencing the degree to which individuals ignore their initial symptoms and allow their illnesses to become severe.

Birdsall and Chuhan (1986) also estimate a multiple logit system for the demand for type of curative health services in Mali. Unlike Akin et al., they find significant effects of a number of dimensions of prices – i.e. distance and quality measures. They do not explore, however, whether there are price effects on health status as opposed to the demand for health inputs.

Merrick (1985) uses infant mortality as a proxy for health outcomes in his analysis of the effect of piped water supply in Brazil on the demand for health outcomes. Although he formulates the mortality determination process in a multi-equation framework (with husband's education influencing household income; husband's and wife's education, household income, and community water *availability* influencing the household *utilization* of piped water; and husband's and wife's education, household income, and piped water utilization affecting child mortality), he estimates the system by OLS methods, arguing for recursivity among the three relations. However, he also presents reduced-form estimates of mortality (which are preferable to the OLS-estimated structural estimates); these suggest that, while piped water supply has a negative impact on infant mortality, the effect of parental education on mortality is much greater.

One study that includes a very comprehensive list of community-level infrastructural variables, most of which can be interpreted as health-care price variables, in explaining the household demand for health outcomes is that by Rosenzweig and Schultz (1982a). They use a 4 percent sample of the 1973 population census for Colombia to study the joint determinants of fertility and child mortality. Among the independent variables included in their mortality equation are the woman's age and schooling and the per capita number of hospital beds and clinics, family planning expenditures per capita, transportation time to the capital city, average daily temperature and temperature squared, price of food, and the average schooling of women aged 15 and above in the region of residence. Additionally, all the community-level variables, with the exception of the price of food and the regional schooling variable, are interacted with the woman's schooling. Separate equations are estimated for each five-year age group of women residing in rural and urban areas.

Rosenzweig and Schultz find that, in the urban areas, child mortality in families with less-educated mothers is strongly affected by public health and family planning programs. They thus conclude that "...urban public health institutions are substitutes for the health care knowledge and the management capacity that an educated mother brings to her family" [Rosenzweig and Schultz (1982a, pp. 58–59)]. They also find that, in the urban areas, clinics are a more cost-effective means of lowering child mortality than are hospitals. For the rural sector, however, they find little effect of health and family planning programs on child mortality. They attribute the lack of these effects to the greater dispersion of health and family planning programs in rural areas. In both urban and rural areas, finally, Rosenzweig and Schultz observe a strong negative effect of maternal education on child mortality.

The Rosenzweig and Schultz study is an example of a study that is relatively consistent with the model we have presented in Section 2.1. They treat health outcomes and fertility as jointly determined choice variables by households, and do not include any endogenous variables in their reduced-form demand relations. However, while the health infrastructure variables they include are exogenous to an individual household's fertility and mortality decisions, they may be endogenous with respect to the fertility and mortality experiences of a community. It is possible, and indeed very often the case, that governments choose to locate hospitals and family planning clinics in communities that have high mortality and fertility rates. In such a situation it would not be surprising to find no, or even negative, cross-sectional association between household mortality patterns and the presence of health programs, as Rosenzweig and Schultz do. It would be incorrect, however, to interpret this result as reflecting the inefficacy of governmental health programs. Moreover, they do not control for unobserved household and individual endowments, which might cause a substantial upward bias in the estimated health input of maternal education (see below).

Most of the above studies are not sensitive to intrahousehold variations in health and the differential response of the health of different members within a household to prices and income. Most studies also are not sensitive to the fact that a large proportion of households in many less-developed countries are farm households, and, as such, the omission of farm input prices and farm assets from the health demand functions is tantamount to making very restrictive assumptions about product and labor markets and about the lack of links between health and nutrient inputs on one hand and productivity on the other (see Section 2). Two recent studies that incorporate both these concerns are Pitt and Rosenzweig (1985) and Behrman and Deolalikar (1987d).

Using data on 2347 farm households from Indonesia, Pitt and Rosenzweig have estimated separate health outcome demand (or, as they call it, "illness demand") functions for husbands and wives. These functions have as arguments prices of thirteen consumption goods (foods and nonfoods); source of drinking water; availability of hospitals, family-planning clinics, public lavatories, and clinics; owned land; farm profits; and the age and education of the husband and the wife.[22] Using ordered probit equations, the authors find relatively few significant determinants of health. The authors attribute the lack of precise estimates to the definition of illness in the survey: it was self-reported (and hence subject to differences in subjective sensitivity to illness symptoms and in propensities to report them, see Section 3.1) and it was recorded over a short reference period of only one week.

Using panel data on rural south Indian households and utilizing a much wider and probably more reliable (than used by Pitt and Rosenzweig) set of health status indicators, Behrman and Deolalikar (1987d) estimate joint reduced-form health and nutrient consumption status relations which allow for differing price and income responses by different household members (namely, adult males, adult females, male children, and female children) and which control for individual-specific fixed effects. Like Behrman and Wolfe (1987) and Wolfe and Behrman (1984, 1986b), they use a latent variable representation of unobserved health status, for which they have three observed (but imperfect) indicators: (age–gender) standardized arm circumference, triceps fatfold, and weight-for-height. They find three of the six prices (namely, of rice, milk, and male labor) to have significant positive effects on health status, even with a control for income. However, they find neither a significant income effect nor significant differences in price or income responses across household members.

The positive (income constant) price effects on health status may be surprising prima facie. However, they are consistent with strong cross-price substitution effects in the underlying food demand equations toward foods with high nutrient-to-food conversion factors (see the discussion on price impacts in Section 4.2). This means that if the price of, say, milk increases, a sufficiently large increase in the demand for other foods and thereby in nutrient intake and health status is induced so that the direct deterioration in health status resulting from reduced milk consumption is more than offset by the induced increases in nutrient consumption of other high-nutrient foods.

Horton (1984) also analyzes the demand for individual health outcomes by using data on approximately 2000 predominantly rural children aged 15 or less from the Philippines. To correct for heterogeneous tastes (particularly with respect to child quality and quantity) across households, Horton explores the differences in weight-for-height and height-for-age among children *within a single family* in terms of differences in their age, gender, and birth order. She also allows some household-specific variables to enter her health demand function indirectly by specifying that the coefficient on birth order depends on maternal

[22] The authors treat farm profits as an exogenous variables since a Wu–Hausman specification test could not reject the production/consumption separability hypothesis.

education and total household expenditure per capita. Her results suggest that birth order has a significant adverse effect on both height-for-age and weight-for-height (such that later-born children have poorer health than earlier-born children), but that maternal education significantly weakens these adverse effects of birth order.

While differencing across individuals within a family is an attractive method for resolving the twin problems of heterogeneity across households and endogeneity of right-hand-side variables (which Horton has in her birth order variable), it purges observed household-specific and community variables such as prices and wealth as well from the health demand function. This is unfortunate since the impact of such variables on health is of policy interest. Behrman and Wolfe (1986) and Wolfe and Behrman (1987) also estimate intrafamilial deviation estimates for health and nutrition demand relations for a Nicaraguan sample, but, since their sample includes adult sisters (including half siblings), many of whom live apart from each other, they are able, unlike Horton, to retain crude price (proxied by population size of the community of residence) and income variables in their demand equations and are able to control for common unobserved childhood background characteristics of the mothers in estimates of the impact of maternal schooling. They find that, without the deviation control, mother's schooling apparently has widespread positive health and nutrition effects. But once there is a control for unobserved family-origin endowments, the impact of female schooling on female health (proxied by the number of days ill and the presence of parasitic diseases), child health (proxied by standardized height, weight, and biceps circumference), and infant mortality is not significant, although the impact on calorie and protein intake is. Their results, thus, raise doubts about standard estimates without control for unobserved mother's childhood–family background characteristics that claim to find strong positive health effects of women's schooling. They also find that mother's schooling has a significant negative effect on length of breastfeeding. Income effects are not significant in any equation, while population size (proxying food prices) has a significant negative effect on nutrition and on breastfeeding.

A somewhat different approach to intrahousehold allocation is taken by Behrman (1987c, 1988). He adopts a specific form of the preference function in relation (1) and estimates two critical parameters of these preferences from data on the distribution of individual nutrient intakes and of individual health outcomes for sibling children in rural south India. The estimation is from first-order conditions which have the advantage, conditional on the functional forms specified, that unobserved child endowments (such as inherent robustness) do not appear explicitly. The first parameter is the extent of parental inequality aversion, which indicates to what extent there is a tradeoff between distribution and productivity in the allocation of nutrients. The estimates suggest that there is a tradeoff, with significant concern about inequality, but parents act as if they are closer to pure investors in the lean season when food is relatively scarce than when food is more available. The second parameter is the extent of unequal concern, that is the extent that the preference function weights equal health outcomes differently for different children. The estimates suggest that larger weights are placed on health outcomes for boys and for older children, particularly by lower caste households, in the lean season. Thus, when food is scarcest, intrahousehold allocation of nutrients more closely follows a pure investment strategy and leaves the more vulnerable children in the household, particularly younger girls, more at risk.

The final study we review which analyzes intrahousehold variations in health outcomes is the Rosenzweig and Schultz (1982b) analysis of the determinants of male–female differentials in child survival rates in rural India using both household and district level data. They argue that the male–female survival differential depends upon the relative returns to male and female labor, since the latter determines parental investments in male and female children. They use predicted employment rates of men and women as proxies for the economic returns to male and female labor, arguing that wage rates may not accurately reflect the shadow value of time because cultural factors such as religion and caste may prevent women from equalizing market and household marginal products. Their results are interesting: in both the household as well as the district-level samples, they find predicted female employment rates to be a significant (and negative) determinant of the male–female child survival differential. Predicted male employment rates are not significant in either sample. They thus conclude that children who are likely to be more economically productive adults receive a greater share of family resources and therefore have a greater propensity to survive.

The health demand studies reviewed above that incorporate prices have found few significant price effects in the demand for health outcomes and, in some cases, health-care utilization. This either means that prices are in fact largely irrelevant in explaining interhousehold variations in health status or that prices may matter but empirical studies have not been able to find significant price effects owing to the use of faulty methodologies or improper data. We tend to be drawn to the latter view because evidence of price responsiveness seems pervasive in other contexts and because of the limitation in the existing studies of health determination. The results of many of the studies can be discounted because they ignore probable simultaneity in right-hand-side choice variables. Almost all studies use poor proxies for health status, use inappropriate prices, and ignore the long lag with which prices may influence health in the real world. True health status may be poorly measured by reported illness or by anthropometric measures used in these empirical studies, though very limited effects are found even in the studies which try to account for the measurement problems regarding health status with multiple indicators in a latent variable framework. However, the Rosenzweig–Schultz (1982b) results for India suggest that prices different from those usually considered by most studies, namely, those related to expected labor market returns rather than food or other direct health related input prices, may be more important in determining health.[23] Finally, since health status, especially of adults, is a *cumulative* outcome of events over a long period of time, it may be poorly explained by *current* prices and income/wealth, which most studies use as explanatory variables. This suggests the need for collecting historical/retrospective data on individuals and households, confining studies on the demand for health outcomes to infants and young children for whom the lag between current and cumulative factors may not be large, or devising methods using limited lags from which the impact of longer lags can be deduced.[24]

4.1.2. Health and mortality production functions

Health production functions are much more susceptible to simultaneous-equations bias than are health demand functions because many right-hand-side variables (namely, variable inputs) are subject to individual/household choice. Unfortunately, a large majority of studies do not treat such inputs as endogenous.

There are two types of production functions that have been estimated widely: the first is the mortality production function M^i [eq. (3)], which has as its input the discrepancy between the health status, H^i, of an individual and the critical (minimum) level of health H^* (with the latter generally not represented directly). The second is the morbidity/anthropometric production function H^i [eq. (2)], which has as its inputs nutrient intakes and health-related consumption goods, among other variables. Studies of the mortality production function have been largely clinical in nature, while health production function studies have been based on social survey data.

There is a large scientific literature on the relationship between clinical measures of malnutrition (e.g. stunting and wasting) and morbidity on the one hand and mortality on the other. A few of the large number of studies that establish a link between anthropometric measures and mortality are Bairagi (1981), Chen et al. (1980), Kielmann and McCord (1978), Sommer and Lowenstein (1975), and Trowbridge and Sommer (1981). Martorell and Ho (1984)

[23] However Behrman (1988) reports that the addition of Rosenzweig and Schultz-type expected labor market returns to health to his preference model does not swamp nor dominate the role of preferences in exploring intrahousehold allocations of nutrients between boys and girls in rural south India.

[24] For example, conditional on particular functional forms for adjustment processes and price expectational formation, long-run responses might be deduced without long lags in the data by formulations parallel to those used for stock/flow considerations in tree crop and other capital investments [e.g. Bateman (1965), Behrman (1968)].

provide a good survey of this literature. They conclude (p. 61) that

> ...the studies reviewed here all show that severely malnourished children (i.e., those with very low anthropometric readings) have greatly increased mortality risks relative to normal children. Children with mild and moderate malnutrition (i.e., those with lower-than-average anthropometric readings) also showed increased mortality risks... Arm circumference was found to be an excellent predictor of mortality by all authors who included this measure.

Black (1984), Bradley and Keymer (1984), and Foster (1984), among others, show that morbidity, particularly in the form of parasitic and immunizable diseases (such as diarrhea, tetanus, and measles), significantly increases the risk of mortality among children and infants.

The link between nutrient and other health-related intakes and anthropometry or morbidity has been explored by two distinct types of studies. On the one hand, there are experimental studies, such as those based on the INCAP project in Guatemala (conducted between 1969 and 1971) and the Narangwal project in Punjab, India (conducted between 1968 and 1973), which have attempted to analyze the effect of nutritional supplementation programs by comparing the morbidity of individuals in villages benefiting from such programs to those in control villages not having such programs (Martorell and Ho). Using the INCAP data, Clark (1981), for example, found that the physical growth of infants (weight gain up to 12 months) was associated significantly ceteris paribus with the number of calories of atole (a high-protein–high-calorie supplementary diet introduced in one of the villages) consumed and length of breastfeeding. Using the Narangwal project data, Taylor et al. (1978) found that (controlling for factors such as age, gender, caste, season, and number and composition of siblings) children in villages receiving nutritional care, whether alone or in combination with medical care, had the highest weights and heights, those in medical care villages the next highest, and those in control villages the lowest. Chernichovsky and Kielmann (1977) used two-stage least squares with the same data as Taylor et al. to measure the impact of calorie intake on the weight of children aged 6–36 months. They found a significant positive effect of calories on weight after controlling for age and gender.

Another set of studies try to relate nutrient intakes, including breastfeeding, to anthropometric measures of physical growth and to infant mortality, using nonexperimental household survey data. Magnani et al. (1985), for example, analyze the determinants of child weight (treated as a dichotomous variable, with a value of one if the child weighs 75 percent or more of the age–gender standardized weight and zero otherwise) with a sample of 1500 children aged 1–59 months in the Philippines. Using OLS (and not logit or probit, which would be more appropriate given the dichotomous nature of the dependent variable), they find that breastfeeding ceteris paribus reduces significantly the probability of the child weighing less than 75 percent of the standardized weight. However, since breastfeeding is not treated as a choice variable in their analysis, their results are likely to be biased. Indeed, their results may simply reflect the fact that underweight children may receive priority in breastfeeding from their mothers or that the sickest children or mothers may be least able to breastfeed.

DaVanzo and Habicht (1984) exploit the panel nature of their Malaysian data by estimating a fixed-effects logit model for infant mortality. They find that decreases in the durations of both supplemented and unsupplemented breastfeeding led to an increase in infant mortality between 1956–60 and 1971–75. However, increases in maternal education and in piped water availability (particularly for women who did not breastfeed) resulted in large (and offsetting) declines in infant mortality over the same period. By estimating the model in first differences, DaVanzo and Habicht purge their estimates of unobserved household-specific health management and taste effects. However, they do not treat duration of breastfeeding as a choice variable, thus making their estimates susceptible to simultaneous-equations bias.

Similarly, Wolfe and Behrman (1987) control for unobserved family endowments by estimating child health (proxied by standardized weight, height, and arm circumference) and infant mortality production functions in intrafamily deviations for the Nicaraguan adult sister sample mentioned in the previous section. Their standard estimates (i.e. using individual data in the standard manner) suggest a strong positive impact of women's schooling on child health, though not a significant effect of calories and breastfeeding.[25] When they control for unobserved childhood-background related characteristics of the mothers through adult sister deviation estimates, however, the impact of mother's schooling no longer is significant. This suggests that in the standard estimates mother's schooling is only a proxy for her unobserved characteristics. Only the negative effect of duration of breastfeeding on child weight is significant at the 15 percent level in the deviation estimates.

In contrast, Khan (1983) attempts to correct for simultaneity in estimating the impact of *average* household per-capita calore intake on individual standardized height and of height on the number of sickdays for a sample of Bangladeshi individuals. However, his bases for identification seem to make so little sense that it is not clear whether his simultaneous equations estimates are any better than OLS. He finds calorie intake to be a statistically significant determinant of height for three demographic groups, and height to be an important negative determinant of the number of sickdays for males and females over 19 and females aged 5–14. Blau (1984), on the other hand, develops his estimation model, including

[25] Their standard estimates use ordinary least squares procedures. However, they report that when they use simultaneous estimates for calories and length of breastfeeding, women's schooling has even less estimated impact on child health than in the ordinary least squares estimates, apparently because it is highly correlated with the instrumented estimates for calories and length of breastfeeding.

his choice of instruments and identification restrictions, from a well-specified theoretical framework for a sample of Nicaraguan children under 5 years of age. He uses food prices and the woman's characteristics as instruments (with arbitrary exclusions to identify the effects of breastfeeding duration (which he finds to be significantly positive) and *average* food expenditure per adult equivalent (which he observes to be insignificant) on the standardized height of children.

Pitt and Rosezweig (1985) estimate a health production function with the same Indonesian data used to estimate health demand functions reviewed earlier. Since only aggregate household nutrient (but individual illness) data are available to them, they regress the average incidence of illness in a household on the average per capita household consumption of nine nutrients (treated endogenously) as well as on the exogenous) source of drinking water and the age and schooling of the husband and the wife. Prices of food and nonfood items and access to infrastructural facilities (such as hospitals, drinking water, etc.) serve as instruments, though the identifying restrictions are arbitrary. In their instrumental-variable Tobit equation, five of the nine nutrients have statistically significant coefficients, whereas in the single-equation Tobit equation (which they also present) none of the coefficients is significant at the 5 percent level. Furthermore, in the former, the consumption of several nutrients, including protein, fat, and carbohydrates, is observed to have a negative (and significant) impact on health.

One problem with all the above studies is that they use average nutrient intakes based on aggregate household nutrition data. If the intrafamily distribution of food is unequal [as suggested by the studies by Behrman (1987c, 1988), Behrman and Deolalikar (1987d), and Horton (1984) reviewed above], the health or illness of a family member may be poorly related to the average level of nutrient intake in the household even in the presence of a strong positive association between nutrient intakes and health for each individual member. Wolfe and Behrman (1987) avoid this problem by utilizing information on different individuals within a family. They estimate a latent variable simultaneous equations system including health production functions for women and their children, using Nicaraguan data. Standardized height, weight, and biceps circumference are used as the observed indicators for child health, while the number of days too ill to work and the presence of parasitic diseases, medically preventable diseases, and therapeutically treatable diseases are used as the observed indicators for female health. Medical-care usage (which is represented by the age–standardized number of injections received by the child, the term of the mother's first pregnancy-related medical examination, and coverage in social security schemes), household nutrition (represented by standardized intakes of calories and protein by the family and by household ownership of a refrigerator), and water and sanitation facilities (represented by the absence of indoor toilets and baths) are included as endogenous inputs. Household income, the mother's initial endowments (represented by her own mother's schooling, her urban upbringing, mother present in adolescence, father present in adolescence, and number of siblings), and community endowments (represented by population, population density, number of hospital beds per 1000 inhabitants, and the literacy rate) are some of the instruments used to identify the parameters of the production function. Wolfe and Behrman's results are somewhat discouraging for standard analyses: they find that medical-care usage, nutrition and mother's schooling appear to have significant positive effects on child health and community endowments appear to have significant positive effects on mother's health *if* mother's childhood–family related endowments are excluded a priori, but that all of these coefficients become insignificant if mother's childhood–family related endowments are included. Similar results are presented in Behrman and Wolfe (1987) for child health with adult sibling deviation control for mother's unobserved endowments. They interpret such endowments to include health-related abilities, knowledge and habits and prior health status all of which relate to usually unobserved (and therefore uncontrolled) dimensions of childhood–family environment. Thus, the standard results about the positive health impact of nutrition, water and sanitation, maternal schooling and community endowments may be misleading due to the failure to control for maternal endowments.

The lack of a strong association between nutrient intakes and health outcomes may not be very surprising, especially in the case of adults. In most surveys, data on nutrient intakes are collected over a short reference period. Health, on the other hand, is a cumulative outcome of nutrient intakes ingested over a much longer period of time. Moreover, as discussed above in Section 3.2, intraperson variations in nutrient intakes apparently are considerable. Only in the case of infants and young children is the lag between the nutrient intakes and health outcomes likely to be short and the cross-sectional mapping between them significant. No wonder then that studies by Clark (1981), Taylor et al. (1978), Chernichovsky and Kielmann (1977), Magnani et al. (1985), DaVanzo and Habicht (1984), and Blau (1984), which estimate health production functions for infants and young children, find significant positive associations between nutrient intakes/breastfeeding and health outcomes. Even for infants and small children, however, the relation between nutrient intakes and health is not always robust with control for unobserved characteristics [e.g. Behrman and Wolfe (1987), Wolfe and Behrman (1987)].

There is perhaps another reason for the poor association between nutrient intakes and health outcomes for older children and adults. Increased nutrient intakes may be reflected in increased metabolism or work effort rather than in the types of health outcomes commonly observed and reported in surveys (see Sections 3.2 and 5.1).

Yet another important factor is that these studies generally omit the time usage or work effort of individuals in the health production function. In so far as part of the nutrients consumed contribute to increased work effort and that effort is not controlled in the health production function estimate, the coefficient of the impact of the remaining nutrients (i.e. those not absorbed by the work effort) is biased downwards. To the extent that individual metabolic responds to nutrient intakes as Sukhatme (1982) and others have argued (see Section 3.2), the failure to control for endogenous metabolic adjustments also causes a downward bias in the estimated impact of nutrition on health.

At any rate, the true human health production function is a complex relationship that cannot be captured easily by regression analysis based on single-period, cross-sectional nutrient intake, anthropometric, morbidity and endowments data. Individual-specific immunity, either acquired or inherited, may have an important bearing on the conversion of nutrients into health. The lag between ingestion of nutrients and the production of health also is likely to be complex and probably needs to be modeled as a dynamic process. In addition, while diseases (health outcomes) are determined by the level of nutrient intakes, they also influence the utilization of nutrients. For instance, episodes of severe diarrhea during infancy can affect adversely the production of a child's height from given levels of nutrients [Heller and Drake (1979), Barlow (1979)]. Most health production function studies have not been sufficiently sensitive to these problems.

4.1.3. Cross-country studies of health demand

Some studies, namely Preston (1980, 1983), Wheeler (1980), and Horton et al. (1985), have analyzed the determinants of health at the cross-country level. Preston (1980), for instance, explores the determinants of life expectancy using cross-country data for 1940 and 1970. He finds that per capita income and adult literacy are highly significant determinants of life expectancy for both periods. Furthermore, the coefficients of the life expectancy equations are very similar for the two periods. However, an additional variable that he includes to measure the extent of malnutrition in a country – namely, the excess of average daily calorie availability per capita over 1500 – is not significant for either period.

To assess the contribution of increases in per capita GDP, literacy, and calorie availability to the increase in life expectancy between 1940 and 1970, Preston calculates what life expectancy would have been for individual less-developed countries if no structural changes had occurred in the relationship between life expectancy and socioeconomic development. The difference between actual life expectancy in 1970 and that predicted if 1940 relations had continued to prevail in 1970 indicates the amount of change in life expectancy attributable to structural shifts in the life expectancy equation. He finds that approximately half of the total gain in life expectancy during the 30 years was unrelated to changes in per capita income, literacy, and calorie availability.

A problem with Preston's study is that prices and endowments are not included in the relation; if they are associated with income or literacy (as a priori seems plausible), the coefficient estimates for the included variables are biased because they are representing in part the excluded ones. Quite possibly, for example, the coefficient estimates for both income and literacy are biased upwards because they capture in part the effect of excluded endowments that also increase in the development process. However, when, for a smaller sample of countries for which data are available for both 1940 and 1970, Preston estimates the life expectancy equation in first differences, his results are largely unchanged. Since first differencing purges his estimates of unobserved country-specific fixed effects (including at least some cross-country differences in the measurement and definition of life expectancy), it means that the omitted variables problem was not severe for such fixed effects (though no insight is provided regarding variables that change over time) even in Preston's levels equation for life expectancy.

Since the measures of per capita GDP used above are based on international exchange rates, which are subject to many distortions, Preston (1983) re-estimates the relationship between life expectancy and income using the International Comparisons Project (ICP) measures of per capita GDP, which are based on purchasing power parities of various currencies. Estimating the life expectancy equation (in levels) for 1965–69 and 1975–79 with both measures of income (and with literacy rate and excess calories availability as control variables), he finds that the coefficient of income in the ICP-based regressions is 50 percent larger than that in the other regressions.

Using a sample of 54 countries, Wheeler (1980) estimates a simultaneous-equations model of the relationship between percentage changes in life expectancy between 1960 and 1970 and percentage changes over the same period in per capita GDP, adult literacy, per capita calorie availability, population per doctor, and population per nurse. The first three (namely, changes in GDP, literacy, and calorie availability) are treated as endogenous variables in the model, with the 1960 levels of per capita calorie availability and literacy, the 1960–70 percentage change in primary school enrollment, and the 1960–70 percentage changes in (physical) capital and labor input serving as instruments. All explanatory variables also are interacted with the level of life expectancy in 1960 (which is assumed to be exogenous). The fit of the model is generally poor and all coefficients are estimated imprecisely. Only the percentage change in the adult literacy rate has a significant positive (but declining with the initial level of life expectancy) impact on percentage changes in life expectancy. The intercept term is statistically significant and indicates an exogenous increase in life expectancy of 9.6 percent between 1960 and 1970.

Wheeler's analysis suffers from arbitrariness – in the specification of equations, in the choice of which variables are endogenous and which exogenous, and in his identification restrictions. Unlike Preston, Wheeler claims to estimate a full model of income, health, and nutrition determination. Yet none of his equations is derived from an economic model of health or nutrition behavior. For example, there is no price of food in his calorie availability or life expectancy equation. Change in the *quantity* of labor input in the production function is treated as exogenous at the same time as changes in the *quality* of that input (namely, life expectancy, calorie availability, and literacy) are treated as endogenous. Similarly, per capita GDP is treated as an endogenous variable, but infrastructural variables like population per nurse and doctor are treated as exogenous, though it is not clear why it is more important to treat GDP as endogenous than to treat health expenditures and infrastructure as endogenous.

Horton et al. (1985) estimate a demand relation for infant mortality from pooled cross-country (34 LDCs) and time-series (1966–81) data. The innovation of this study is the inclusion of the "price of cheap calories", namely, the average of ICP-adjusted, open-market/controlled retail prices of rice, maize, wheat, millet, and sorghum from FAO series. Estimating separate demand equations for each country, the authors find that nine of the 34 countries have negative and significant income elasticities of infant mortality, while six have positive and significant price elasticities. Seven countries have the "wrong" signs (positive and significant) for income elasticities and eight have the "wrong" signs (negative and significant) for price elasticities (but see the discussion on price effects in Section 4.2). The country-by-country results thus are ambiguous and permit no broad generalizations.

This brings us to a general discussion about the merits and demerits of estimating health demand relations derived from household and individual behavior with cross-country data. The assumption that is maintained in such analysis is that a country corresponds to a "representative consumer". Even if one is willing to avoid attaching any behavioral interpretations to cross-country analysis, there are still serious estimation problems. The use of average data, however, may be misleading if distribution is important and differs across countries. Few variables, furthermore, are exogenous at a national level. Those that are (such as international prices) have limited cross-country variability, and therefore are not very useful in single cross-section regression analysis. The variables that most cross-country studies on health demand have treated as exogenous – viz. infrastructure facilities, per capita GDP, food prices – very often reflect choices of national health (and other) policy makers. Finally, the per capita GDP of a country may serve as a proxy for a much larger number of variables than the average income of its residents; it is highly collinear with urbanization, literacy, health (and other) infrastructure, and many other variables. A positive association between health and per capita GDP thus tells us very little about the specific determinants of health.

4.2. *Determinants of nutrients*

As in the case of health, there are two ways of looking at the determinants of nutrient consumption: the demand for nutrients [N^i in eq. (9) in Section 2.1] and the production of nutrients [N^i in eq. (4)]. In the first, prices, income, and given endowments are presumed to determine the nutrient intakes of an individual, while in the second, better nutrient intakes are determined by the food consumption of the individual and the education and time of the household food preparer. In both functions, individual-specific unobserved variables, e.g. metabolism rates in the former case, may play an important role.

4.2.1. Nutrient demand

Virtually all the studies that have analyzed the determination of nutrient intakes are demand relations. Most have either followed the approach of (i) estimating food demand/expenditure systems and then converting the price and income elasticities obtained from these to nutrient elasticities using fixed food–nutrient conversion facts [Strauss (1984), Pitt (1983), Pinstrup-Andersen et al. (1975), Pinstrup-Andersen and Caicedo (1978), Murty and Radhakrishna (1981)], or (ii) estimating directly the demand for nutrients as a function of food prices, household size, and income/expenditure [Wolfe and Behrman (1983, 1986b), Behrman and Wolfe (1984a, 1986), Ward and Sanders (1980), Timmer and Alderman (1979), Williamson-Gray (1982), Pitt and Rosenzweig (1985), Mateus (1985), Behrman and Deolalikar (1987a, 1987c, 1987d)].[26]

Estimates of the income/expenditure elasticities (hereafter referred to as income elasticities) for calories, which is included in most of the above studies, vary widely, from a low of 0.0–0.1 for Managua, Nicaragua [Wolfe and Behrman (1983)], rural south India [Behrman and Deolalikar (1987c)] and Indonesia [Pitt and Rosenzweig (1985)] to a high of 0.9 for rural Sierra Leone (Strauss). Estimates of the income elasticity of proteins, which are far fewer in number than calorie income elasticity estimates, also range from 0.0–0.1 for small children and infants in rural India [Levinson (1974)] and households in Indonesia (Pitt and Rosenzweig) to 0.6–0.8 for rural Bangladesh (Pitt).

Furthermore, most studies that analyze the relationship between the income elasticity of nutrient demand and income have found it to be negative [Timmer and Alderman, Pinstrup-Andersen and Caicedo, Williamson-Gray, Mateus, Behrman and Wolfe (1984), but not Behrman and Deolalikar (1987c) nor Strauss]; such an inverse association between the income elasticity of nutrients and the level of income is consistent with the possibility that income changes play an important role in the marginal determination of nutrients at very low incomes but not at high ones. The most dramatic evidence of this is provided by Mateus (1985), who estimates income elasticities of both calories and protein of 1.2 for

[26] Pitt suggests that the expenditure system route is superior, but does not explain why he thinks this. But to us his apparent reasoning suggests the characterization that we give below in the text.

low-income Moroccan households, of 0.5 for average-income households, and of −0.15 for high-income households.

Behrman and Deolalikar (1987c) argue that calorie (more generally, nutrient) income elasticities which are derived from aggregate food demand equations tend to be overestimates, since households switch purchases among disaggregated foods to higher priced, but nutritionally not necessarily much better, foods with increasing income. Since foods are typically aggregated into broad groups in the estimation of demand/expenditure systems, the problem is one of the commodity aggregation and the possible dependence of group price indices on income levels. Using 1970–71 data from the Indian National Sample Survey, Radhakrishna (1984) calculates that the average cost of calories from each of six broadly-defined food groups increases consistently with total expenditure for both rural and urban households. Pitt also observes this in his sample for Bangladesh. He reports that the 25th percentile household spent 22 percent more per gram of protein, 15 percent more per calorie, and as much as 44 percent more per milligram of iron than did the 90th percentile household. Finally, Williamson-Gray estimates the income elasticity of the average price paid per calorie (which she treats as a proxy for food quality) to be 0.288 even for relatively malnourished households in her Brazilian sample.[27]

If the income elasticity of the average cost of a nutrient is indeed positive, the income elasticities of food demand tend to overstate the income elasticity of nutrients. Behrman and Deolalikar (1987c) show this by estimating expenditure elasticities of demand for six foods (namely, grains, sugar, pulses, vegetables, milk, and meat) and nine nutrients (namely, calories, protein, calcium, iron, carotene, thiamine, riboflavin, niacin, and ascorbic acid) for rural south India with OLS, OLS-IV, and fixed-effects estimation techniques. They find large and statistically significant expenditure elasticities of food demand for all foods (ranging from 0.4 to 3.5), but small (and sometimes even negative) and often not significant expenditure elasticities of nutrient demand (ranging from −0.3 to 0.8 but less than 0.4 for calories and proteins) across all model specifications.

The other determinants of nutrient demand explored by empirical studies include food prices. Strauss obtains negative food price effects on calories demand when he controls for farm profits in his sample of Sierra Leonean farm households. However, the majority of the food price elasticities turn positive when farm profits are allowed to vary (i.e. when it is recognized that food prices have a positive impact on farm profits and thereby on consumption). On the other hand, Pitt finds that, even after controlling for income, calorie demand in

[27]Of course, the difference in the *effective* price of a calorie obtained from low-priced grains and that obtained from high-priced grains may not be as large as we have emphasized, if the latter types of grains contain fewer stones and impurities (which need to be removed before consumption) than the former types. However, we believe that even the effective nutrient prices are likely to vary substantially because of taste, odor, status, and quality variations.

Bangladesh has positive elasticities with respect to the prices of five of the nine foods he considers – pulses, fish, mustard oil, onions, and spices. In their latent variable study, Behrman and Deolalikar (1987d) also find a large number of positive food price effects on the unobserved nutrient consumption status of all household members, even after controlling for income and individual-specific fixed effects. In fact, only the price of sorghum seems to affect nutrient consumption inversely in their study. Finally, Pitt and Rosenzweig also find a large number of positive price effects on nutrient demand for this sample of Indonesian farm households even with farm profits held constant. The only food price which has a consistently negative (profits-constant) effect on *all* nutrients is the price of milk.

There is thus a great deal of evidence on positive income-compensated food price effects on nutrient consumption. This reflects strong cross-price substitution effects among foods together with variations in nutrient-to-food conversion factors. Thus, when the price of, say, rice increases, a sufficiently large increase in the demand for other relatively nutritious foods and thereby in nutrient consumption may be induced to more than offset the direct decrease in nutrition resulting from reduced rice consumption.

The finding of frequent positive price elasticities for nutrients has important implications for policy. It suggests that certain food subsidies may not only fail in improving the nutritional status of the poor, but that they may actually worsen it.

A survey by Alderman (1984) of 15 nutrient demand studies notes that the majority of these, including the studies by Pitt and Strauss reviewed above, find that own-price elasticities of food demand decline in absolute values with income or expenditure. Sometimes the trend is pronounced, as in Williamson-Gray who observes a compensated own-price elasticity of cereals demand of -0.74 for the poor, -0.16 for the middle, and not significantly different from zero for the rich in Brazil. A few studies, namely Williamson-Gray and Timmer and Alderman, also observe an inverse relationship between the absolute value of *cross*-price elasticities and the level of income or expenditure. There is thus compelling evidence that the poor are more responsive – to income, own-prices, and cross-prices – than are the rich. This has important distributional implications for food subsidy and price policies.

By estimating nutrient demand equations at the household level, most studies lose the intrafamily distributional consequences of price and income changes. The study by Behrman and Deolalikar (1987d) is an exception, since it addresses the issue of differing price and income responses by different members within a household. They find that price-induced adjustments in nutrient consumption are not uniform across different household members. Female children are made to accept the greater nutritional burden of adjustment to unfavorable price movements (and, by the same token, receive the greater nutritional bonus in response to favorable price changes), while the other members' nutrient consumption is allowed to fluctuate much less. Their findings are consistent with other evidence from South Asia, such as that reported by Rosenzweig and Schultz (1982), Sen and Sengupta (1983), Behrman (1988), and Kakwani (1986b), showing sex bias in favor of boys and against girls in intrahousehold resource allocation.

Household size often is entered as a determinant of nutrient demand. Behrman and Wolfe (1984a) argue that not only the sign but the magnitude of the household size elasticity relative to the household income elasticity is important, since it reflects the extent of returns to scale with respect to household size. They as well as Ward and Sanders and Wolfe and Behrman (1983) obtain statistically significant negative effects of household size on nutrient demand. The estimates presented by all three studies imply considerable increasing returns to scale. A study by Iyengar et al. (1968) obtains economies of scale in the consumption of "necessities" like cereals and fuel-lighting but not in the consumption of "luxuries" like milk and clothing. However, all the above estimates are likely to be biased since fertility and hence household size are endogenous variables that are jointly determined along with nutritional status choices, but not treated as such in these studies. Therefore the estimated household size variable coefficients are likely to represent in part unobserved profertility determinants (e.g. tastes), which may be associated with less investment in nutrition – and this understates the returns to scale. Pitt and Rosenzweig do not include household size as a determinant of per capita nutrient intakes, but do include household composition (treated as an endogenous variable) and find it to be a significant determinant of per capita nutrient intakes. In particular, per capita consumption of calories, protein, carbohydrates, and phosphorous are all observed to increase with mean household age.

The model in Section 2.1 also suggests the inclusion of the education of the food preparer in the household in the nutrient demand equation. Ward and Sanders, and Pitt and Rosenzweig find no significant effect of women's schooling on household nutrient consumption, but Wolfe and Behrman (1983, 1986b, 1987) and Behrman and Wolfe (1984a, 1986, 1987) do. The latter group of studies find that Nicaraguan households in which women have more schooling tend to be significantly and substantially better nourished, ceteris paribus, particularly in regard to vitamin A, proteins, and calcium. Furthermore, they find that this effect persists even if there is adult sibling deviation control for unobserved childhood–background related characteristics of the woman, in sharp contrast to the estimated impact of women's schooling on health (Section 4.1).

One other determinant of nutritional status, which is not explicitly included in the household model sketched in Section 2.1 but which, according to authors in Chambers et al. (1981) is important in the rural areas of LDCs, is seasonality. In particular, the wet season in these countries is often the most difficult time of the year when shortages of food are coincident with high energy demand for agricultural activities. Food is at its scarcest and most expensive at this time of the year. Unfortunately, it is precisely at this time that exposure to infections and diseases, like diarrhea, malaria, cholera, and dengue fever, is also most common. The result is that morbidity and mortality, particularly infant mortality, are at their highest levels during the wet season.

There have been few attempts to systematically incorporate seasonality in the determination of nutrient demand. The only study we are aware of which attempts this is Behrman and Deolalikar (1987a). They estimate separate nutrient and health demand equations for individuals for the lean and the surplus seasons of the year in rural south India. They obtain significantly negative food price elasticities of calorie and protein demand for the lean season, but elasticities that are close to zero or even slightly positive in the surplus season. On the other hand, the wage elasticities of calorie and protein demand they estimate are significantly positive for the lean season, but much smaller for the surplus season. They conjecture that this pattern of estimates occurs because the farm households are net suppliers of food but net buyers of labor in the surplus season and net buyers of food but net sellers of labor in the lean season. As a result, an increase in food prices in the surplus season exerts a positive (negative) income effect on nutrient demand which mitigates or overwhelms the negative substitution effect.

Behrman and Deolalikar's explanation of these results rests on the assumption that farmers cannot store sufficiently food or food purchasing power from one season to another. Given that most of the foods they consider are cereals – rice, sorghum, millet – this assumption seems strong. If valid, there may be important implications in their results for seasonal price stabilization or storage policies. If not, there is a puzzle as to why they obtain such strong seasonal differences. One possibility that they do not discuss is that the parameters in the reduced-form relations change because of unobserved seasonal changes in the environment or because of seasonal changes in time usage that affect health through the health production function.

4.2.2. Household nutrient production functions

There is only one study of which we are aware that attempts to estimate the nutrient production function in eq. (4) of Section 2.1. This is a study by Ybañez-Gonzalo and Evenson (1978) for the Philippines. Most other empirical exercises reduce the household nutrient production function to a weighted average of food intakes by using standard nutrient/food conversion factors.[28]

[28]In a different sense some other studies estimate nutrient production functions which relate effective nutrient intakes to the indicators of individual nutrients. Behrman and Wolfe (1984a), for example, report estimates for a range of elasticities of substitution (from zero to infinity) among different nutrients; they find that their results are not very sensitive to a wide range of elasticities of substitution, though very low elasticities seem less empirically relevant. Behrman and Deolalikar (1987d) use a latent variable representation of nutrition and estimate the relative association of various observed nutrients with that latent variable, as is discussed above.

Ybañez-Gonzalo and Evenson estimate a Cobb–Douglas production function for household nutrient intakes, using calories, protein, vitamin A, and a weighted sum of the three nutrients as alternative measures of nutrient intake. The inputs in the production process are the value of raw food prepared and served to the household (valued at constant market prices), the time elapsing from the beginning to the end of meal preparation, an index of home capital (namely, the value of refrigerators, stoves, and cooking utensils), the work status of the mother, and the number of adult equivalents in the household.

The (OLS) estimated production function reveals a large production elasticity with respect to household size (0.54), a very small elasticity with respect to home capital (0.008), and medium-sized elasticities with respect to value of food and time inputs (0.26 and 0.23, respectively). The sum of all the output elasticities is not significantly different from one, indicating constant returns to scale in nutrient production. The authors explain the relatively large impact of household size on nutrient production by arguing that larger households have lower food wastage, a result which is consistent with the estimates of the impact of household size on nutrient demands discussed above.

While the Ybañez-Gonzalo and Evenson study is an interesting and innovative study, to us the point estimates – especially the high one for household size – seem puzzling. The estimation of the nutrient production function by OLS techniques, moreover, is a definite shortcoming. Since all the explanatory variables used in the study are subject to household choice, an estimation procedure that treats them as exogenous or predetermined may produce biased estimates. It is not clear why the authors do not use simultaneous estimation techniques since they appear to have data on prices which could serve as exogenous instruments. Another problem with their estimation of the nutrient production function is that the true dependent variable that should be used in the function – namely, the level of nutrients actually ingested given the amount and type of cooking done – is not observed. What is observed instead is the amount of nutrients *purchased* given standard food/nutrient conversions. The use of the latter as a proxy for the former is likely to exaggerate the responsiveness of nutrient production to food expenditures and to underestimate its responsiveness to cooking time and cooking methods.

4.2.3. Cross-country studies on nutrient demands

All of the problems we discussed earlier about using cross-country data to estimate health demand functions hold in the estimation of cross-country nutrient demand functions as well. However, the data problem may be even more serious for nutrients. Most cross-country studies of nutrient demand use as their dependent variable the average daily calorie availability per capita constructed from FAO food balance sheets. Since large components of the balance sheets are not known with any degree of precision (particularly, food wastage, change in stocks, and subsistence production), there are likely to be large errors in the per capita calorie availability variable. What is even more worrisome is that these errors are likely to be systematically related to the level of per capita GDP of a country. This probably results in exaggerated income elasticities of nutrient demand from cross-country estimates.

Wheeler (1980), Reutlinger (1984) and Horton et al. (1985) are among the studies that have analyzed the determinants of nutrient demand at the cross-country level. In the same simultaneous-equations model discussed in Section 4.1, Wheeler estimates percentage growth (over 1960–70) of per capita calorie availability as a function of per capita GDP growth (treated as an endogenous variable) and the interaction of percentage GDP growth and the level of per capita calorie availability in 1960. He finds a significant positive (but declining with the initial level of per capita calorie availability) effect of per capita GDP growth on the growth of per capita calories availability. The implied income elasticities of calorie availability are 0.27 at 70 percent average calorie adequacy (according to WHO standards) and almost zero at the 100 percent level.

Reutlinger has used annual data from 1970 to 1980 for a larger sample of 84 countries to estimate a similar equation. He estimates a log-linear equation in which the annual rate of growth of average calorie availability between 1970 and 1980 is a function of the annual growth rate of per capita real income, a food production index, a real food price index, and the urban share of the population. The elasticity of average calorie availability with respect to income is allowed to vary with the initial (1970) level of per capita income and average calorie availability as a percentage of the WHO-recommended calorie intake. Reutlinger's results suggest a significant positive food production, but an insignificant food price effect on average energy availability. The effect of real income on average energy availability is very strong, and the income elasticity is observed to decrease with the initial energy adequacy of the national diet and, surprisingly, to increase with initial per capita income. For a country with a per capita real income in 1970 of $1250, the estimated income elasticity of average energy intake is 0.22 with 90 percent initial energy adequacy of diet, 0.14 with 110 percent initial energy adequacy, and 0.06 with 110 percent initial energy adequacy.

Unlike Wheeler, Reutlinger does not treat per capita GDP as an endogenous variable in his analysis. It is also not clear why he includes the index of food production along with the index of real food prices in his demand function. The two variables are most likely strongly correlated, which may explain the nonsignificance of the price effect.

In the study cited in Section 4.1, Horton et al. also estimate a calorie demand equation using pooled cross-country and time-series data for 34 LDCs from 1966 to 1981. They include as arguments ICP-adjusted real per capita GDP and an index of the real cereal price. The income elasticity of calorie availability they obtain is not too dissimilar to Wheeler's and Reutlinger's estimates (0.16). However, unlike Reutlinger, they do find a significant but small (elasticity of 0.03) effect of cereal price on calorie availability. It is interesting to note that they obtain a positive effect of real cereal prices on calorie availability a la many of the microeconomic studies (Strauss, Pitt and Rosenzweig, and Behrman and Deolalikar).

When the calorie demand equation is estimated separately for each country (which is what an *F*-test for the equivalence of parameters across countries suggests), the cereal price elasticity of calories availability is negative and significant for six countries and positive and significant for eight countries. In virtually all cases, however, the magnitude of the elasticity is relatively small. What is surprising, however, is that the income elasticity of calorie demand is observed to be negative and significant in six countries (five of which are relatively well-off countries in Latin America). With the exception of Bangladesh, all the Asian countries they include have positive income elasticities of calorie demand (ranging from 0.2 to 0.6).

Despite their problems, there seems to be a consensus emerging out of the cross-country studies, namely, that the elasticity of calorie demand with respect to GDP is relatively small even for the poor countries. A cross-country study of a different nature by Behrman and Deolalikar (1987e) sheds light on one reason why this may be so; they find that consumers' demand for food variety increases rapidly with incomes. Using ICP and FAO data on 34 developed and developing countries, they estimate a system of demand equations for average calorie consumption, for the average price paid for calories and for variety in the food basket, which they proxy by the share in total real food consumption of the three, five, and eight largest items (out of a total of 37 detailed food groups in their data set) in the food budget and by the Hirschman–Herfindahl index of concentration (namely, the sum of squared food shares of 37 food groups). The independent variables in the demand equations include ICP-adjusted per capita GDP, per capita GDP-squared, and the relative prices of nine aggregated food groups. Only one price – that of breads and cereals – turns out to be significant (with a negative sign) across all variety equations. Both GDP and GDP-squared have significant effects on variety such that increased income levels are associated with greater, but at a diminishing rate, demand for variety in food consumption.

With the same data, Behrman and Deolalikar then proceed to estimate the curvature of the underlying preference function (which they assume to be CES in the quantities of the nine aggregated food groups). They find the elasticity of substitution between food groups to be significantly and inversely dependent on the level of per capita GDP; the estimated elasticity has a value of 0.10 at a per capita GDP level of \$500, of −0.43 at a level of \$2800, and of −0.83 at a level of \$4500. These results suggest that the indifference curves across food groups become significantly more curved as income increases – moving from a curvature between the linear and Cobb–Douglas cases to one between the Cobb–Douglas and the L-shaped cases within the sample. The increased curvature of the indifference curves in turn suggests that consumers demand more variety with increased incomes, and purchase more variety instead of just more calories.

Another cross-country analysis of dietary quality by Chandhri and Timmer (1986) uses the starchy staple ratio and the proportion of total proteins derived from animal protein as indicators of diet quality. They find that the (per capita) income elasticity of the starchy staple ratio is -0.39 (-0.64 for developed countries and -0.23 for less-developed countries) and that of the animal-total protein ratio is 0.52 (0.43 for DCs and 0.50 for LDCs).

5. Empirical studies of the impact of health and nutrition in developing countries

The model developed in Section 2.1 suggests that individual health and nutrition may have impacts on several outcomes. First, they may enter the wage (P_L^i) relation, as shown in eq. (5). Second, they may enter as inputs in the household firm/farm production function [Y^h in eq. (6)]. In a parallel way they may affect productivity in other activities, such as in schooling. Third, the health and nutritional status of parents also may enter into the production function for *births* [B in eq. (7)]. Finally, although the model treats the infant mortality and birth (fertility) decisions of households as jointly determined, there is a literature which attempts to analyze the impact of infant mortality on parental fertility.

5.1. Impact on labor productivity

5.1.1. Micro studies

The idea that, at low levels of income, there is a technically determined relationship between nutritional status or health and labor effort or productivity is not a new one. This hypothesis – often called the Efficiency Wage Hypothesis – has been discussed by Leibenstein (1957), Mazumdar (1959), Stiglitz (1976), and Bliss and Stern (1978), among others. Although the hypothesis has important implications for developing country labor markets and for the possibility of separability between production and consumption (which usually is assumed a priori), it has been subjected to little systematic empirical testing. We review only the major studies in this area, referring the reader interested in other studies to surveys by Gwatkin (1983), Barlow (1979), Strauss (1985), Srinivasan (1985), and Martorell and Arrayave (1984).

Using experimental data from the INCAP nutrition supplementation project, Immink and Viteri (1981) compare the gains in productivity (daily cane harvest) between two groups of otherwise similar Guatemalan sugar-cane workers: one receiving a high-energy supplementation and the other receiving a low-energy supplementation. They find that the productivity of both groups rose during the supplementation period, but that there is hardly any difference between the productivity gains of the two groups. Their results suggest that whatever additional energy expenditure that the supplementation permitted (energy supplementation was found to successfully raise the energy intake and expenditure of workers) was dissipated in heat or spent on activities other than enhancement of work productivity.

Immink and Viteri include in their regression of change in sugar-cane cut per day the daily energy intake of the worker as well as whether he was in the high-supplementation group. Since daily energy intake includes calories from the supplementation diet (which is exogenous) as well as from the worker's diet at home (which is endogenous), it is an inappropriate variable to include as an explanatory variable. In this case, the lack of significance they obtain for the total energy intake variable may simply reflect the fact that workers with high productivity (and thereby greater earnings, if they were paid on a piece rate) do not spend their additional earnings on food with high calorie content – a result consistent with the evidence presented in Section 4.2 above.

In the same vein, Wolgemuth et al. (1982) regress gains in labor productivity in road construction on total calorie intake from a supplementation diet and the number of days worked. Unlike Immink and Viteri, they randomly assign workers to treatment groups. Their results indicate a large positive (but only marginally significant) effect of calories (a calorie output elasticity of 0.5), but a negative and significant effect of labor supply. As Strauss (1985) has pointed out, since labor supply is subject to individual choice, their alleged negative effect of labor supply on productivity may simply reflect an income effect on labor supply – whereby workers with increased productivity (due to the diet supplementation) and therefore increased earnings (if the work was paid by piece rate) cut back on their labor supply. Wolgemuth et al. also present their productivity results without including labor supply. In this case, they still obtain a marginally significant effect of calorie intake on average productivity, which casts doubt on Strauss' conjecture.

Popkin (1978), Baldwin and Weisbrod (1974), and Weisbrod and Helminiak (1977) have attempted to link productivity to health indicators. Popkin regresses daily productivity of road construction workers in Bicol, Philippines, on their hemoglobin levels, while Baldwin and Weisbrod and Weisbrod and Helminiak regress daily and weekly earnings of plantation workers in St. Lucia on dichotomous variables indicating the presence of schistosomiasis (a parasitic infection endemic to the island). However, since health may be as much of a choice variable as nutrition (see Section 2.1 above), and is a cumulative outcome of past investments in nutrition and health, which presumably would be influenced by higher productivity and earnings, it is also inappropriate as an exogenous explanatory variable.

There are other studies that have attempted to correlate productivity with anthropometric indicators. Surveying such studies, Martorell and Arroyave (1984) conclude that body size (namely, weight, height, or weight-for-height) is an important determinant of productivity. Since most of the cited studies are based on simple correlations between simultaneously-determined variables, none of them offers definitive evidence of a productivity effect of body size. Ryan and Wallace (1986) estimate wage equations (corrected for selectivity bias) having height and weight as arguments, using the ICRISAT data from rural south India for a sample of rural labor participants. They find that weight-for-age has a significant positive effect on male but not on female wage rates. However, what is disturbing is the significant negative sign that they obtain on the coefficient of height-for-age in the male wage equation. No explanation is offered for this puzzling result. Indeed, it is very likely that their wage equation estimates are contaminated by simultaneous equations bias which arises because of the endogenous nature of the weight (and, to a smaller extent, height) variable.

The only studies of which we are aware that are sensitive to the endogeneity of the nutrition and health variables and which estimate technical production functions to relate labor productivity to nutrition and health are two studies by Strauss (1986) and Deolalikar (1988). Deolalikar analyzes the impact of individual health and nutritional status (namely, weight-for-height and energy intake) on individual market wage rates and on-farm labor productivity for a sample of agricultural households in semi-arid south India. Strauss estimates the effect of average (over the household) per adult consumer equivalent calorie intake on the productivity of on-farm family labor in Sierra Leonean agriculture. Both studies estimate agricultural production functions having hired labor and nonlabor inputs in addition to family labor inputs.

Strauss estimates a Cobb–Douglas production function for a sample of farm households practicing hoe agriculture in Sierra Leone. One of his inputs is "effective family labor", which is a nonlinear function of the number of actual on-farm family labor hours and the average availability of calories per consumer equivalent in the household. He finds effective family labor to be a statistically significant input in the agricultural production function, and effective family labor to increase significantly, albeit at a diminishing rate, with per consumer equivalent calorie availability within the household. He estimates the output elasticity of per consumer equivalent calorie availability to be 0.33 at the sample mean level of family calorie availability, 0.49 at a calorie availability of 1500 calories a day, and 0.12 at a calorie availability of 4500 calories a day. Beyond a daily per consumer equivalent intake of 5200 calories, calories have a negative impact on effective labor. The other results of interest are the estimated increase in the relative efficiency of an hour of labor with calorie intake (namely, labor consuming 1500 calories a day is 40 percent less and labor consuming 4500 calories a day is 20 percent more efficient than labor consuming 3000 calories a day). Since Strauss' results hold across a wide range of specifications, including dropping several variables (such as family size and farm assets) from the instrumental variable set, Strauss' finding of a link between agricultural labor productivity and calorie availability per consumer equivalent appears to be robust.

Since Deolalikar has data on the same farms for two years, he estimates a fixed-effects instrumental variable-estimated Cobb–Douglas farm production function in which effective family labor is a Cobb–Douglas function of the number of actual on-farm family labor hours and the weighted averages of calorie intake and weight-for-height of family farm workers. The weights used in averaging over family farm workers are the shares of total hours of on-farm family labor contributed by each family member. All inputs, including average energy intake and weight-for-height (but not cropped area, which is treated as a fixed factor of production), are treated as household choice variables, for which food prices are used as instruments. Although the relationship between productivity and the health/nutrition variables may be nonmonotonic, Deolalikar assumes a monotonic relationship by adopting a Cobb–Douglas functional form, since for the range of values of calorie intake and weight-for-height observed in his sample, he finds no evidence of nonmonotonicity.

Deolalikar argues that it is important to include both energy intake and weight-for-height in the agricultural production function since the two fulfill qualitatively different needs in agricultural operations. Weight-for-height is associated with endurance and innate strength (or horsepower), while calorie intake is associated with energy expenditure. Some agricultural tasks like harvesting or weeding require sustained periods of energy expenditure but relatively little strength, while others like ploughing require peak horsepower. His results show a significant positive effect of weight-for-height but not calorie intake on farm output. The output elasticity of weight-for-height is estimated to be as large as four, while that of calorie intake is not significantly different from zero.

Using the same data as Ryan and Wallace, Deolalikar also tests whether the greater marginal productivity of healthy and well-nourished workers holds in casual agricultural labor performed outside the family farm. He estimates a wage equation for workers participating in causal agricultural labor market in first differences, treating individual calorie intake and weight-for-height as endogenous variables (instrumented by food prices and the value of farm assets). The results show significant effects of both weight-for-height and calorie intake on wages, although the effect of calorie intake is barely significant at the 5 percent level. (Deolalikar pools observations on male and female participants in his estimation, since an F-test for the equality of parameters across separate male and female wage equations reveals no significant differences.)

Deolalikar's results appear to be convincing for two reasons. First, differencing does not reduce the coefficients of weight-for-height and calorie intake towards zero, as might be the case if there were substantial random measurement errors in these variables.[29] This attests to the good quality of the data, particularly on weight-for-height and calorie intake. Second, he obtains quite similar estimates of the effect of weight-for-height and calorie intake on *both* market wage rates and family farm output. Calorie intake has a small and marginally significant effect, while weight-for-height has a large significant effect, on both wages and farm output.

Deolalikar speculates that the strong observed effect of weight-for-height and the weak effect of calorie intake on agricultural productivity may be the result of greater adaptability of the human body to low energy intakes but lack of such adaptability to low levels of strength and endurance in performing strenuous tasks.

Behrman and Deolalikar (1987a) further explore the labor market effects of health and nutrition in the ICRISAT sample for rural south India by focusing on seasonality, within a simultaneous framework. They find that there are nutrient and health (weight-for-height) effects only for males, with the former more important in the peak season (when greater sustained energy expenditure is required for tasks like harvesting) and the latter more important in the slack season (when innate strength may be relatively important).

In a different type of analysis, Pitt and Rosenzweig (1986) relate farm profits and adult male labor supply to morbidity for a sample of farm households in Indonesia. They find no statistically significant effects of number of sickdays (which is treated as an endogenous choice variable) on farm profits, but do find a significant adverse effect on adult male labor supply. As the authors themselves point out, however, their results cannot be used to test the efficiency wage hypothesis, since the absence of an effect of illness on profits may reflect availability of an active labor market through which sick family labor can be replaced by healthy hired workers at a constant wage rate, not necessarily the absence of an effect of morbidity on labor productivity.

5.1.2. Cross-country studies

There have been several attempts to estimate the impact of health and nutrition on GDP at the cross-country level [see the survey by Gwatkin (1983)]. Among the better known studies is an early one by Malenbaum (1970) which uses data from 22 LDCs to estimate the impact of infant mortality and per capita availability of

[29] However if measurement errors are systematic and sufficiently correlated across observations on the right-hand-side variables being differenced, the downward bias in the estimated coefficients may be greater in estimates from the nondifferenced data than in those based on the differenced data [see Behrman (1984)].

physicians on the post-war change in agricultural output, holding constant the share of labor in agriculture, the use of commercial fertilizer, and the extent of illiteracy. Almost 80 percent of the variation in output change is consistent with the variation in the two health variables. However, because of serious problems of simultaneity, the study's results only reflect association, and cannot be interpreted comfortably to reflect causality.

In the same cross-country study reviewed in Sections 4.1 and 4.2, Wheeler (1980) estimates a GDP production function in which percentage change in GDP is a function of percentage changes in calorie availability, adult literacy, and life expectancy – all treated as endogenous variables – and percentage changes in labor and capital stock. Identification is achieved with variables like the initial (1960) levels of literacy, life expectancy, and calorie availability; primary school enrollment; population per nurse; and population per physician. Wheeler finds a significant positive effect of life expectancy and calorie availability on output, with elasticities of output for the two inputs of 1.7 and 2.7, respectively (compared to output elasticities of 0.2 for labor and capital). He thus concludes that better health and nutrition in a country significantly increase the growth of income.

Wheeler's results are somewhat dramatic and almost suspiciously large. One does not know if they are the consequence of using inappropriate and possibly endogenous instruments such as 1960 levels of literacy, life expectancy, and calorie availability, or whether they reflect true large effects of health and nutrition on income growth.

5.2. *Impact on schooling productivity*

Among children, health and nutrition may influence schooling productivity in much the same way as it affects labor productivity among adults. There are at least two studies that have tried to estimate this productivity effect and found it to be significant.

Moock and Leslie (1986) estimate schooling enrollment (demand) and grade attainment (productivity) equations for a sample of approximately 350 children from the terai (plains) region of Nepal. The former is estimated by the probit maximum likelihood method and the latter by OLS. Besides control variables such as sex, age, father's schooling, family land ownership and caste affiliation, they include the child's weight-for-age, height-for-age, and weight-for-height as explanatory variables in both equations. They find that a child's height-for-age significantly and positively influences not only the probability of his/her enrollment in school but also how far ahead he/she is in school (in terms of compiled grade) relative to other children of the same age.

Another study of over 3000 children from urban and rural areas in China by Jamison (1986) also finds a strong effect of height-for-age on grade attainment. Like Moock and Leslie, Jamison also finds height-for-age to be a much better predictor of schooling performance than weight-for-age or weight-for-height. Since height is a cumulative outcome of malnutrition over a period of time, the results suggest that chronic nutritional abuse – but not transitory fluctuations in nutrient intake – adversely affects schooling performance among children. Unfortunately, since both the studies use OLS methods to estimate their schooling productivity equations, one cannot rule out bias in their estimated schooling productivity impacts of health/nutrition. Better endowed children might do better in schooling and be better by health indicators, with no causal impact of the latter on the former. There is also likely to be selectivity bias in their estimates which will tend to exaggerate the productivity effects. The selectivity bias arises from the fact that schooling performance is observed only for those children who did not drop out of school. Since children who drop out are likely to be those that perform poorly, estimates that exclude such children will show an exaggerated effect of health/nutrition on performance. It is impossible to know from the material presented in these studies whether the Moock and Leslie and Jamison estimates would be rendered insignificant were they to control for health endogeneity and sample selection.

5.3. Impact of female nutrition on fertility

It has been argued by some researchers that nutrition is related to fertility through ovulation [Frisch (1978)]. According to Frisch, a critical minimum weight-for-height is required to maintain regular ovulation and menstruation; hence, ovulation ceases among women who are subject to chronic malnourishment and whose fat level falls below the critical level. Frisch maintains that this level is well above the starvation level. Hence, not only severe nutritional deprivation, but also any weight loss which reduces body fat reserves below the critical minimum, cause anovulatory cycles during which conception cannot occur.

Bongaarts (1980) and Menken et al. (1981) have systematically reviewed the evidence for a nutrition–fertility link and concluded that "... little support is provided for the existence of a significant link between food intake and childbearing in situations of chronic or endemic malnutrition" [Menken et al. (1981, p. 425)]. They find that, although there is evidence suggesting that the length of the childbearing span is reduced by chronic malnourishment (mainly through a postponement in menarche), in few societies is the age of marriage determined by menarche. Nutrition thus has little effect on fertility through this link.

Menken et al. also review the evidence and conclude that the length of postpartum amenorrhea, which is a proxy for the duration of postpartum anovulation – the period after a birth when there is no ovulation, is affected very slightly, if at all, by chronic malnourishment among women. Lunn et al. (1980) do report evidence that supplementing lactating women's diets decreases post partum fertility in the Gambia. However, the total evidence to date suggests that this effect, although perhaps significant in some cases, is miniscule on overall fertility.

Finally, the waiting time from the resumption of ovulation after a birth to the next live birth is even less variable than the duration of postpartum amenorrhea. No significant association between nutritional indicators and the waiting time to conception have been found by Bongaarts and Delgado (1979) for Guatemala and by Chowdhury (1978) for Bangladesh.

Menken et al., therefore, conclude that while "... when food supplies are so short as to cause starvation, there is little doubt that fertility is lowered [,] ... when malnourishment is chronic and nutritional intake is above starvation levels, it is not clear that fertility is affected by any physiological mechanism determined by nutritional status" [Menken et al. (1981, p. 439)]. They do not consider behavioral mechanisms, such as frequency of intercourse, that may affect fertility through the birth production function.

There, however, have been few attempts to estimate empirically the birth production function [eq. (7) of the model developed in Section 2.1]. Efforts to estimate such a function are likely to run into some of the same problems encountered by studies testing the nutrition–productivity link. The problems of reverse causality (whereby high fertility and very short birth intervals pose a health risk for the mother), endogeneity of nutrient intake and health status, and heterogeneity across individuals are likely to be serious in birth production function estimation. Wolfe and Behrman (1986b), however, present a set of reduced-form estimates for fertility, nutrition, and contraceptive use that are consistent with a possible nutrition–fertility link in that increased income causes increases in nutrition, fertility, and contraceptive use.

5.4. *Impact of infant mortality on fertility*

Improvements in health can influence fertility in another way, namely through a reduction in infant and child mortality. Historically, declines in birth rates have followed periods of mortality decline. This phenomenon, called the Demographic Transition, took place in Europe during the eighteenth and nineteenth centuries, and is evident in several countries of Latin America and Asia, where crude and age-standardized fertility rates have been falling since the mid-1960s – some two to three decades after the onset of large mortality declines.[30]

There are two mechanisms through which fertility is influenced by mortality: a *replacement* effect whereby a dead infant is replaced ex post by another birth, and a *hoarding* effect whereby parents respond ex ante to anticipated deaths by bearing more children. There is in addition a biological response of fertility to mortality as well. The survival of infants who need to be breastfed can lengthen the duration of postpartum amenorrhea and thereby delay subsequent births. However, according to Schultz (1978), if empirical estimates of the derivative of births with respect to deaths exceed 0.1 or at most 0.2, the excess is likely to reflect voluntary response of parents rather than biological factors.

Using four samples, three based on urban household surveys in 1964 in Rio de Janeiro, San Jose, and Mexico City, and one on a survey of rural households in India in 1970, Schultz regresses cumulative fertility of a woman on the number of deceased children (normalized for the number of births, the age pattern of fertility, and an appropriate life table) and a set of control variables (age, education, income, and urban origin). He finds that in all samples the level of fertility is positively associated with child mortality, although the derivative of births with respect to deaths varies widely from 0.8–1.4 in Rio de Janeiro, to 0.4–0.8 in San Jose, to 0.2–0.3 in Mexico City, and to 0.3–0.5 in rural India. To explain this wide variation in fertility responses to child mortality across populations, Schultz proposes a hypothesis, namely that

> ... couples react to their child mortalilty experience by changing their reproductive performance, to the extent that they are aware of a general downtrend in mortality in their segment of society.... Thus, individual reproductive responses to child mortality increase to fully compensating levels (i.e., the derivative of births to deaths is one) only in those populations where child survival has markedly improved [Schultz (1978, pp. 212–214)].

Studies by Williams (1977), Mauskopf and Wallace (1984) and Olsen (1983) have shown, however, that a strong effect of mortality on fertility cannot be inferred from a regression of household fertility data on child deaths because of a spurious correlation between micro mortality and fertility data. This occurs because families with more births tend to have more deaths simply because they have more children at risk. Furthermore, since infant mortality is a variable subject to household choice (and influenced by inputs such as breastfeeding, nutritional supplementation, and utilization of health-care services), the alleged strong effect of mortality on fertility simply may reflect the fact that higher

[30] Though recent studies suggest that neither in some European countries (e.g. France) nor in some developing countries has the Demographic Transition always followed the stereotypic pattern. See Birdsall, Chapter 12 in this Handbook, for an extensive discussion of fertility determinants and experience in the developing world.

fertility resulting in shorter birth intervals significantly increases the probability of infant deaths.

Using merged data on Colombian households and communities, Rosenzweig and Schultz (1982c) estimate fertility and child mortality demand functions conditional on each other. To identify the effect of child mortality on fertility, they use per captia community expenditure on family planning, arguing that these proxy contraceptive prices and can be excluded from the child mortality (but not the fertility) equation; since all of the exogenous variables enter into all the reduced-form relations for all of the endogenous variables, however, this identification appears arbitrary. Their results indicate a positive effect of child mortality on fertility among mothers at all ages. The implied response derivatives of births with respect to deaths results range from 0.14 to 0.44 for different age groups of women.

Olsen (1983) estimates the impact of infant mortality on fertility, using Malaysian household data and controlling for the spurious correlation between the two variables and for family-specific fixed effects. The Olsen paper is the most thorough attempt to distinguish between the replacement, hoarding, and biological effects of child deaths on births. Olsen finds that, when the biases of simple regression procedures are eliminated, one is still left with a sizeable replacement response of fertility to mortality of some 30–40 percent. Replacement due to hoarding accounts for 14 percent; the biological impact of a death via lactation adds another 12 percent to the rate of replacement; and direct behavioral replacement is between 5 and 15 percent.

Interval regressions performed by Olsen suggest that the behavioral response to a death is fairly immediate. Thus, children who die soon after birth are replaced to a greater extent than older children who die, which implies that "...apparently replacement is more complex than just a simple attempt to achieve a goal for live children" [Olsen (1983, p. 25)].

6. Empirical studies on supply considerations and related policies

There have been a number of studies that have attempted to analyze the impact of governmental programs and policies seeking to supply health and nutritional goods to target households. We now review such studies on food subsidies, subsidies for other health related inputs, and on the impact of macro adjustment programs on health and nutrition in developing countries.

6.1. Food subsidies

Food subsidies have been used widely in developing economies, and a number of major programs persist to date. Numerous studies of the impact of these programs have been considered over the years, with the earlier studies focusing relatively on the extent of disincentives created for domestic food productions. We review some of the more recent studies that have substantial focus on the nutritional impact of such programs.

Alderman and von Braun (1984) study the impact of the Egyptian food ration and subsidy system at the micro level using household survey data. Egypt has had a long history of implicity of explicitly subsidizing food, with the food subsidy bill accounting for 10–15 percent of the government's total expenditures since the mid-1970s. They find that over 90 percent of the households in urban and rural areas have ration cards and frequently buy rationed commodities. The sum of all income transfers[31] from all outlets directly controlled by the government (rations, cooperatives, bakeries, and governmental flour shops) is $36 per capita for urban consumers and $24 per capita for rural consumers (in 1981–82). Thus, the subsidies transferred through the government outlets favor the urban population. In fact, the urban bias of the subsidy system is even greater, since food pricing (although not directly linked to food subsidy) adversely affects rural residents who are producers of food. Taking this into account (as well as the fact that input subsidies and livestock protection are transfers *to* producers), the authors estimate that the average net production transfer to rural areas is actually negative (approximately −$4 per capita), indicating an implicit tax on the rural sector.

The authors also note that the use that consumers make of the rationing system depends inversely on the time required to acquire food at the governmental outlets. Urban consumers are willing to pay higher prices for open market goods when lines at cooperatives increase. Interestingly, there is not much difference in the willingness of low- and high-income consumers to wait in line, indicating the similar opportunity costs of time for all consumers and that queing may not be a very effective redistribution mechanism.

To increase the effectiveness of the food subsidy system while reducing its cost, Alderman and von Braun suggest elimination of subsidies in such products as frozen meat and chicken and refined (fine) flour and its products, which contribute little to the amount of protein and calories that households consume and which have high income and price elasticities of demand. Since these subsidies are regressive, their elimination would also have distributionally appealing effects.

Williamson-Gray's (1982) study of food subsidization policies in Brazil finds these to be inefficient in helping the poor improve their nutritional status. This is because the commodities whose prices are generally subsidized, namely wheat, liquid milk, beef, and vegetable oils, are consumed primarily by high-income and well-nourished households. Williamson-Gray argues that rice and cassava flour are the best commodities to subsidize from the point of view of increasing calorie

[31] Defined as {(border or world price − local transport costs) − reported purchase price} × quantity purchased.

consumption by calorie-deficit groups. A subsidy on wheat bread may in fact reduce the calorie consumption of the poor and malnourished as they might shift from high-calorie, low-status goods like rice and cassava flour to what bread. The study uses demand system parameters along with an analysis of the demand for food quality (proxied by the average price of a calorie consumed) to draw its conclusion. Williamson-Gray observes a high income elasticity of quality even among the poor and the malnourished. This implies that these (food subsidy) target groups would be quick to shift to high calorie-cost foods with the smallest increases in real income, a result consistent with the discussion in Section 4.2.

Trairatvorakul's (1984) investigation of alternative rice price policies in Thailand finds that, contrary to widely held beliefs, the net gains to the rural poor from *increases* in the price of rice are likely to be minimal, since many small farmers are subsistence oriented and one-fourth are actually net purchasers of rice. A rice price increase would create short-run hardships for many of the rural poor, while most of the gains would accrue instead to large commercial farms.

Thailand long used export controls to regulate the domestic price of rice. In effect, this meant a subsidy on domestic rice, since the domestic price of rice was lower than the international price. Using partial equilibrium models of paddy supply, labor demand and supply, and food consumption behavior, Trairatvorakul analyzes the effect of rice price changes on the calorie intake of consumers and paddy farmers, among other things. He finds that, while a rice price increase of 50 percent would reduce the percentage of rice growers living under a fixed poverty line from 33.7 to 26.5, it would *increase* the percentage of other (consumer) households in poverty from 16.4 to 19.9. The national average rate of poverty therefore would fall only slightly, from 26.0 percent to 23.6 percent. Disaggregating his analysis by expenditure deciles and by rural/urban origin, he finds that 37 percent of the net gains to the rural sector from a rice price increase of 10 percent are acquired by the richest three deciles, while the largest net relative losses to the urban sector are borne by the lower expenditure groups.

Edirisinghe's (1985) study of the food stamps scheme in Sri Lanka finds that it has primarily benefited the poor. The percentage of total calories derived from food stamps is 11 percent for the poorest quintile of households (in 1981–82) and 6 percent for the next poorest quintile. However, the average cost of supplying 100 calories via food stamps is estimated to be around 53 cents, while the cost of supplying that number of calories to the poorest 20 percent of the households is 38 cents. Since the average cost of providing a calorie increases with income, this implies that the cost of the food stamp scheme in Sri Lanka could be almost 30 percent lower if recipients were restricted to the poorest 20 percent of the population. Edirisinghe thus concludes that, while the food stamp scheme in Sri Lanka has been successful in helping the poor, its cost effectiveness can be increased with better targeting and lower leakage to households who do not need nutritional supplementation assistance from the state.

The issue of targeting and cost effectiveness in food subsidies is discussed in detail in two surveys by Pinstrup-Andersen (1985) and Mateus (1983). The cost effectiveness of food subsidies depends directly on the degree of targeting. Pinstrup-Andersen suggests that subsidies may be either limited to certain times of the year, e.g. the lean months when malnutrition is severe, or targeted to specific individuals or households on the basis of criteria such as income, residence (e.g. rural areas and urban slums), and extent of malnutrition. In reviewing various food subsidy projects, Mateus argues that the most efficient programs are the special intervention programs designed for the malnourished and most vulnerable groups: children and pregnant–lactating mothers. Targeting also can be achieved by requiring customers who desire to purchase subsidized foods to wait in long lines (since this would seem to discourage participation by higher income households having a high opportunity cost of time, though the Alderman and von Braun results just reviewed raise questions about this assumption for Egypt) and by offering lower quality foods that are generally undesirable to high-income groups. The success of targeting certain types of individuals within households, however, is quite limited by the fungibility of resources among household members. Food programs for children and pregnant and lactating women, for example, tend to result in considerable offsets in the food available to such individuals from the household.

According to Pinstrup-Andersen, the "best" commodities to be subsidized can be chosen on a number of criteria, including their availability, own-price elasticity, share in the budget of poor households, and the price per calorie supplied. Additionally, since many studies have shown large production disincentive effects of nutrition programs and food procurement policies [Mateus (1983, pp. 40–41)], the ideal candidates for subsidies might be commodities with low supply responses. Many so-called inferior cereals in developing countries – namely sorghum, millet, cassava – might qualify for subsidization based on the above criteria. However, as we noted earlier in this section, many countries subsidize such inappropriate commodities as frozen meat and fine flour (Egypt), beef, liquid milk, wheat, and vegetable oils (Brazil).

Finally, of the various systems via which food subsidy programs can be implemented, Mateus regards the food coupon system as less demanding as long as it uses the traditional wholesale and retail trade systems. Colombia and Sri Lanka are two of several countries that have had highly successful and cost-effective food coupon schemes.

Mateus also notes that there is a dramatic improvement in the benefit/cost ratio of nutrition programs combined with health delivery systems. The integration of health and nutrition programs often has resulted in 40–50 percent declines in infant mortality, at the same time allowing a reduction in costs since joint use of facilities capitalizes on fixed-cost investment, personnel, and management.

According to Pinstrúp-Andersen, foreign food aid is an attractive source of obtaining food for subsidy programs, since it greatly reduces governmental costs of the program. Procurement schemes that obtain food from producers at below-market prices are difficult to enforce and impose large economic costs on the agricultural sector. Of course, foreign food aid programs also can result in local production disincentives if the market in which the recipients participate is not segmented from the market for local producers.

Mateus and Pinstrup-Andersen argue somewhat convincingly that targeting of food subsidies can be used to shift income to poorer members of society who purchase their food (i.e. not for poor subsistence farmers). However, they do not consider whether other policies might be more effective in redistributing income, nor that income increases may not have much impact on nutrition (see Section 4.2).

All of the above studies on food subsidies are based on partial equilibrium models. In particular, they do not address the macroeconomic impacts of food subsidies, which, for many countries (e.g. Sri Lanka, Egypt, Morocco, and Sudan), have been considerable and probably quite negative. Studies addressing the non-nutrition impacts of food subsidies are reviewed in an excellent survey of the food subsidy literature by Horton and Taylor (1986). In general, however, studies focusing on the macroeconomic and general equilibrium dimensions of food subsidies are very few [with a few exceptions such as Taylor (1979) and Narayana et al. (1985)]. Because pressures have increased substantially in recent years to cut food and other health-related subsidies as part of overall macro stabilization programs, further macro work seems warranted.

6.2. Other health goods and services subsidies

De Ferranti (1985) discusses the policy options of providing and financing health goods and services in developing countries. Most such countries finance health care to a very large extent from public revenues. de Ferranti argues for a reorientation of such policies, with greater focus on having users bear a larger share of health-care costs through a combination of fees for services and fees for coverage. This should particularly be followed for nonreferred curative care, which accounts for the bulk of public health expenditures in developing countries. For preventive services, however, de Ferranti suggests zero or even negative fees, since "... for many of the major preventive services currently feasible on a large scale in developing countries – including immunization, oral rehydration therapy, antenatal and perinatal care, promotion of breast-feeding and improved weaning practices, and hypertension control – the facts and concepts that users need to know are simple and can be communicated to the target population easily and at reasonable cost" [de Ferranti (1985, p. 61)]. The real issue would not seem to be, however, whether costs are "reasonable", but whether there are externalities, large increasing returns to scale, or distributional reasons for such subsidies.

In a survey of pricing policy for health and education in developing countries, Jimenez (1986a) also concludes that the efficiency gains from user charges for selected types of health and education (i.e. those for which the benefits accrue primarily to the individuals concerned, such as hospital care) could be substantial, and that the impact of increased user charges need not be inequitable since

> the present distribution of subsidies tends to be highly skewed towards higher income groups who obtain greater access to more costly social services...even if they are uniformly free for all. Under these circumstances, the expansionary effect of fee increases for selected services (and, if possible, for selected individuals) may actually improve equity in the distribution of public resources [Jimenez (1986a, abstract)].

While both of these studies are suggestive of general guidelines for deciding to what extent, if any, health inputs should be subsidized due to externalities or returns to scale, they do not provide concrete estimates of the gains to be reaped in different specific situations.

6.3. Impact of macro adjustment policies on health and nutrition

Several studies associated with UNICEF [Jolly and Cornia (1984), UNICEF (1984)] have attempted to evaluate the impact of macroeconomic adjustment policies specifically on health and nutrition. These studies do not formalize explicitly the links between recession and/or economic adjustment and the health and nutrition of children. But they attempt to use secondary data to characterize some of the links relating to factors such as unemployment, the composition of governmental expenditures, and direct indicators of health and nutrition. They conclude that the negative impact of recessions and adjustment policies on health and nutrition are multiplied for the most vulnerable members of society. In a review of these studies, however, Preston (1986, p. 375) suggests that the appropriate conclusion from surveying these studies would seem to be – subject to conceptual and data difficulties – that the available evidence from these studies indicates "how much can be achieved even in the face of unusual economic adversity – surely good news for social policy...". Instead of such emphasis, however, the editors have a "penchant for stressing the negative trends...(a distinct minority) [which] receive the lion's share of the editors' attention in the introduction and summary". Thus, a set of studies that seem to lead to the conclusion of little, or at least unproven, systematic impact of recession and economic adjustment on health and nutrition, is summarized as finding that adjustment policy usually multiples negative recessionary impact on the poor and vulnerable.

Hicks and Kubisch (1983, 1984) analyze the impact of economic adjustment programs on social sector spending on less-developed country governments by examining the pattern of cuts in expenditure induced by such adjustment programs for all 37 LDCs that reported cuts in real government annual expenditures during 1972–80. They find that, contrary to popularly-held beliefs, on the average social expenditures were the *most* protected of social, defense and administration, production, infrastructure, and miscellaneous expenditures (somewhat more so in low- than in middle-income countries). Thus, the frequent assumption that social sectors are particularly vulnerable to cuts in governmental expenditures may be wrong – in fact, the opposite may be the case.

Behrman (1976b) reviews evidence from a number of macro and micro studies. He concludes that "...the effects [of economic adjustment policies on health and nutrition] *may* be very limited because of the limited effectiveness of macroeconomic policies, the lack of impact of policies on some of the poorest, and the adjustment and substitution capabilities of those of the poor whose real income and prices broadly-defined are altered negatively" [Behrman (1987b, pp. 32–33)].

7. Summary and conclusions

The studies on health and nutrition in developing economies to date have provided some insights, but they also raise a number of important questions and point to great lacunae in our knowledge. In this concluding section we first summarize the insights and then consider directions for future research.

7.1. *Summary of available studies*

Although there is substantial variation in the estimates, the extent of malnutrition and poor health in the developing world as measured by conventional standards is considerable. Consideration of the adaptability of the human body to its environment and the extent of inter- and intraperson variations leads to a less pessimistic characterization of the current situation and somewhat different identification of who is at risk. Nevertheless, large numbers of individuals in the developing world have lower nutritional input and health status than many would think desirable. Such inadequacies are likely to be exacerbated at times of unfavorable relative price movements for the poorer members of societies, such as during famines. Such a characterization is appropriate for the late 1980s despite very considerable absolute and relative gains in indicators of average nutrition and health status in developing countries – such as life expectancy – in recent decades. These gains have been larger in fact than the gains indicated by narrowly defined economic indicators. Of course the national averages hide a wide range of variances and, since the situation for the poorer may be particularly critical in determining average health and nutrition, countries that appear similar according to the per capita income averages have had widely different average nutrition and health status. The life expectancy at birth in 1983 of 69 years in Sri Lanka as compared to 38 years in Sierra Leone, though both have per capita income estimates of $330 for that year, provides a vivid example.[32]

Efforts to investigate the micro level determinants of health status or of health-care utilization, whether by estimating health production functions or reduced-form demand equations, have met with some, but fairly limited success. Some micro health production function estimates suggest that direct nutritional supplements improve child, but not adult, health. This contrast between the health production function results for children versus those for adults may not be surprising given the apparent relatively greater importance of nutrients in the child development stage and strong intraperson serial correlation in health status. For adults, nutrient increases seem to result in increased energy expenditures, in some cases associated with increased productivity. Reduced-form micro demand relations for both child and adult health find little evidence of responses to relative market prices, income, or wealth. The micro estimates, however, contrast sharply with the aggregate estimates of fairly strong associations between measures such as life expectancy and per capita real income or product. This contrast raises the question of whether the micro results are misleading because of measurement errors for health and/or income and specification errors regarding lags and time use, or whether in the macro estimates per capita income or product is representing not the purchasing power of individuals so much as the general level of development and associated public health measures that are not well represented in micro estimates. For a number of both the micro and the macro estimates, furthermore, standard estimates often indicate a substantial role for women's schooling, in some cases substituting for other inputs. In the one sample for which adult sibling deviations permit extensive control for the women's unobserved childhood background characteristics, however, the impact of women's schooling on health vanishes with such a control.

Studies of the reduced-form demand relations for nutrient intakes suggest some substantial price responses, not only for foods consumed, but also for agricultural products and inputs in the case of farm households. The substantial price responses mean that many policies and market developments may affect nutrition whether or not that is their intent. Policy-makers need to be sensitive to such possibilities in their policy design and implementation. The food price responses, moreover, are not always negative; in some cases, particularly for farm

[32] Bhalla (1984) and Bhalla and Glewwe (1986) discusses in some detail the Sri Lankan experience.

or rural labor households, the price elasticities for locally produced foods may be positive and considerable in magnitude. For such households, food price floors may improve nutrition more than the price subsidies that often are rationalized on such grounds. Of course, the same result is not likely to be true for the nonrural poor, but many of the poorest and most malnourished are in the rural areas. Another interesting characteristic of the price elasticities is a tendency for them to be larger for poorer households. Differential price elasticities across the income distribution presents some possibilities of price policies that favor the poor for distributional reasons without too great leakages to those who are better off. Allocation of nutrients within households, finally, seems to favor males and older children in absolute terms, but there is some interesting evidence for rural south India that adjustments to price changes are relatively smaller for girls than for other household members – suggesting that in this sense nutrients for girls are treated less as luxuries than are those for others.

Estimates of nutrient determinants indicate a wide range of income or expenditure elasticities. However, in a number of cases large expenditure elasticities result from aggregate (with respect to foods) estimates based on a priori assumptions that nutrient elasticities are identical to a weighted average of food elasticities at a high level of aggregation. But this assumption may be very misleading if the prices paid for nutrients vary positively with income, as appears to be the case. Comparison of directly estimated nutrient elasticities with food elasticities for rural south India, in fact, suggest that the former are much smaller than the latter. Apparently other food characteristics – taste, appearance, status value, degree of processing – are valued much more than nutrition at the margin even among individuals in this relatively poor population. Cross-country estimates also suggest that in part the low income elasticities of nutrients (as compared with those for food expenditures) reflect an increasing taste for food variety as income increases. If non-nutritive food characteristics are favored highly at the margin, then income increases and the general development process will not alleviate malnutrition nearly as much as the World Bank (1980), Srinivasan (1985), and others have claimed. On the other hand, the limited importance placed by individuals in such populations on increasing nutrient consumption at the margin (if they are making informed choices) raises doubts about whether they are so malnourished as conventional estimates suggest, and thus provides a different type of evidence consistent with the Sukhatme–Srinivasan–Seckler–Payne hypothesis about individual adaptability to nutrient availabilities and "small but healthy" people. Of course such evidence does not speak to the question, why are many people in some populations so small, nor does it allay the suspicion that the malnutrition experienced by many children in such populations is associated not only with small adults, but also with high infant and child mortality.

Beyond relative prices and perhaps income, some – but far from all – studies point to the possible importance of women's schooling, nutritional knowledge, and public health measures in improving nutrient consumption (particularly for children). The impact of women's schooling and nutrient knowledge may reflect that better-educated consumers make more nutritious food choices, ceteris paribus. The impact of women's schooling on nutrient consumption, in contrast to that on health, is robust to control for unobserved background characteristics in the one sample that permits such adult sibling control. Better public health services such as safer water may reflect the greater value of nutrients when such factors are present because of their complementarity with nutrients in the health production function. Of course women's schooling also may be playing such a role in addition to or instead of working only by improving information about nutrient qualities of different foods.

Nutrient intakes and health status both appear to affect positively agricultural productivity and labor market wages and possibly schooling productivity for some poor populations. Nutrient intakes might affect productivity without altering indicators of health status because nutrient changes may be transferred largely to energy expenditure changes, including some that are productivity related. Except in extreme cases, malnourishment does not seem to alter fertility. However, declines in infant mortality do seem broadly to reduce fertility. Therefore health and nutrition are not only important ends in themselves, but also may be important means through which productivity and population goals are affected.

Investigations on the supply side have focused on the impact of subsidy policies for food and, to a lesser extent, other health-related inputs. Such studies suggest that general food subsidies are not very effective in redistributing income to the poor, but that targeted food programs can be used to shift income to some segments of the poor that depend on market purchases for food. However, the small nutrient elasticities with respect to income imply that nutrient intakes do not improve substantially as a result of such subsidies. Recent studies of actual nutrition and other health-related input pricing policies suggest that in fact they often redistribute income *from* the poor and are not justified on the grounds of externalities, though subsidies for preventive measures for contagious diseases may be justifiable on the latter grounds.

Strong claims have been made by UNICEF and others about very negative multiplied effects of macroeconomic adjustment policies on health and nutrition. Careful examination of the relevant studies, however, suggests that the empirical basis for such a claim currently is quite weak. In fact the underlying studies seem to be characterized better as reflecting how well societies and people have adapted to minimize negative health and nutrition effects rather than the more negative interpretation given by UNICEF.

7.2. Directions for future research

Despite the growing number of studies of health and nutrition in developing countries, the lacunae in our knowledge remain substantial. Many of the questions raised in our introduction remain unanswered.

Major questions pertain to the measurement of nutrient input and health status, and thus the extent, incidence and determinants of nutrient and health inadequacies. The adaptability hypothesis discussed in Section 3.2, for instance, raises difficult questions about how can policy-makers or other analysts identify at a reasonable cost who is malnourished in a population. The failure to find much in the way of positive results regarding the determinants of health (particularly for adults), for another example, may be due to substantial measurement errors in representing health status. Frequently, respondent-reported disease data are used as indicators, though such reports are likely to be determined endogenously by characteristics like wealth. The gains of obtaining clinical-based health indicators, therefore, may be worth the added costs. Perhaps it would be cost effective to obtain such information not so much by expanding socioeconomic surveys to include clinical information on health, but by working with health professionals like epidemiologists and expanding their data collection efforts to include broader samples and more socioeconomic data, with sample designs to assure sufficient variance in critical price and asset variables. In the meantime, conclusions based on the types of data available to date have to be qualified because of their conditionality on quite imperfect health and nutrition indicators. More studies might explore fruitfully how robust are their results to alternatives such as latent variable specifications of health and nutrition as have been undertaken in several recent studies.

With respect to the determination of health, major questions remain. To what extent does the very limited success in estimating micro health production functions and reduced-form demand relations reflect data inadequacies regarding health measures, inappropriate lag structures, energy expenditure adaptations, or the failure to specify the influence of individual, household and community endowments? What are the nature of the biological processes involved, the extent of substitutabilities and complementarities in health production processes, the nature of lags, and the role of nutrition? How important is women's education in determining health? Is its often significant role in standard estimates reflective of increased productivity in using given health-related inputs, or is it primarily proxying for unobserved individual and household endowments as suggested by the one available adult–sibling deviation study? Are education and public health measures substituted broadly, as Rosenzweig and Schultz suggest for their Colombian study? More generally, what is the nature of substitution and complementarities in health production functions? How important are seasonal variations, particularly in rural areas? How can the very limited success in estimating micro health relations be reconciled with the fairly strong association between health and development across societies? What role does uncertainty play in the determination of health?

With respect to the determination of nutrient intakes, progress apparently has been greater, but questions remain. To what extent would more extensive specification of prices, assets and endowments change our current understanding? What is the nature of the intrahousehold allocation process? Is it better represented by a bargaining framework? If so, what difference does it make? How fungible are resources within the household? For instance, how much do school children benefit from food provided at school and to what extent is such food received at school offset by receiving less food at home? Likewise, there are questions about to what extent food subsidies, food stamps, or food rationing improve the nutrition of recipients, or only result in the increased purchase of other food characteristics or of nonfood goods and services? How fungible are resources across seasons? How much is nutrition likely to improve with income increases associated with the process of development? Do the Behrman–Deolalikar results about the relatively limited nutrient income elasticities hold for other societies? If so, what explains the international nutrient differences that are associated with development?

Recent systematic estimates suggest that in some low-income contexts, the impact of health and nutrition on farm and labor market productivity may be substantial. How can such results be reconciled with the a priori scepticism such as summarized in Rosenzweig (Chapter 15 in this Handbook)? Do the Deolalikar–Strauss results carry over to other societies? If so, what are the implications for productivity growth, understanding labor market structure, and for health and nutrition policy?

Of course, one major reason for being concerned with the determinants of health and nutrition is to provide a better basis for policy formation. What are the implications of the growing corpus of empirical work on health and nutrition for policy? Can the apparent greater price and income responsiveness of poorer members of society (at least for nutrients) be utilized in more effective policies? Is the relative optimism of Mateus (1983) and Pinstrup-Andersen (1985) about targeting food subsidies warranted? If income increases have little nutritional impact, might direct income transfers for distributional reasons be preferable to food subsidies? What is the nature and extent of externalities, returns to scale, imperfect information or distributional concerns that warrant nutrition and other health-related price subsidies? Are the de Ferranti (1985) and Jimenez (1986a) type distinctions between nonreferred curative care versus preventive care useful in making operational policy decisions about health subsidies? What would be the distributional and health impact of increasing user charges or of new insurance schemes on different types of health inputs in specific contexts? How is dissemination of new inputs and knowledge affected by governmental pricing and subsidy policies, information problems, and industrial structure? To what extent are such policies justified in particular circumstances by externalities, public-good characteristics, returns to scale and other types of market failures or by distributional objectives? To what extent do governmental policies cause inefficiencies in the provision of health-related inputs? Do macro adjustment policies have multiplied or mitigated health and nutrition consequences? Could better policy design and monitoring lessen the negative effects?

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