Bulletin Number 84-1

April 1984

ECONOMIC DEVELOPMENT CENTER

AGRICULTURAL PRICES, FOOD CONSUMPTION AND THE HEALTH AND PRODUCTIVITY OF FARMERS

Mark M. Pitt
Mark R. Rosenzweig

ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Agricultural and Applied Economics, St. Paul

UNIVERSITY OF MINNESOTA

Agricultural Prices, Food Consumption and the Health and Productivity of Farmers

Mark M. Pitt and Mark R. Rosenzweig
University of Minnesota

November 14, 1983

Revised March 1984

This paper utilizes existing household survey data from Indonesia to analyze the effects of food price changes and health program interventions on the health, nutritional status and profits of farm households. Many policies adopted by developing and developed countries serve to alter the price structure faced by consumers and food producers. Such macro price-intervention strategies as tariffs, support prices, ceilings, export taxes and exchange-rate policies directly alter relative prices and thus alter the distribution of income and dietary patterns of the population. Food aid programs, depending on the manner in which they are implemented, also may affect the price structure of foods. In addition, agricultural development policies which are crop-specific by design or by consequence and all projects which enhance employment opportunities affect the relative prices of not only foods but also of non-food resources supplied by family members to children -- parental time, breastmilk.

Despite the well-recognized potential importance of the nutritional consequences of most programs and policies, there is little empirical evidence on the linkages between price changes, food intake and nutritional well-being. A major impediment to the acquisition of this knowledge has been the lack of data. While a number of localized case-studies have emerged, the smallness of the samples, the lack of price variability, and the non-comparability of sample-designs and analysis makes it difficult to draw defensible inferences or generalities from such information (Martin, (1983). Recently, household data sets from developing countries have become available which have permitted estimates of the relationship between relative food prices and household food consumption patterns (Pitt, 1983, Strauss, 1982). While such studies provide for the first time theoretically-based estimates of aggregate household food consumption by disaggregated food groups from national probability samples, they do not yield any information on the health consequences of the observed alterations in nutritional intake for individuals or on the income or productivity changes arising from alterations in food consumption and in health status.

To the extent that food consumption is only one direct determinant of health and the rules by which households distribute their resources among their members is unknown, estimates of household-level consumption effects of food price and programmatic interventions do not necessarily provide sufficient information on the health consequences of such initiatives. The health of the population may also depend on the cost or availability of medical services, on the sanitation conditions of the environment and, in the case of children, on the availability of parental care. To the extent that programs which are designed to directly alter the health status of populations may compete for donor funds with food-oriented projects and aid programs, it is useful to assess from comparable data both the relative effects of food price changes and of health program interventions on health or nutritional status.

In this paper, we extend the now conventional model of the producer cum consumer farm household model by incorporating a household health production sector in which the household produced-good, health, can both affect the production of farm output and provide direct additional utility to the household. In Section I, we discuss the model, focusing on how changes in farmer's nutritional or health levels differentially affect farm profits, full income and earnings. Particular attention is paid to the issue of the separability of the three household sectors and the role of input and output markets. The effects of food pricing policies and health programs on food consumption, health and productivity are also addressed.

Section II of the paper is concerned with how the household distributes its resources among its members and extends the traditional one-person consumer-producer model to include multiple members. The model is used to show how misleading inferences can be drawn about the nutritional or health levels of household members from observations on household-level consumption that are provided in most survey data.

In Section III we use farm household data from an Indonesian national probability sample to estimate the effects of the short-term illness of farmers and their spouses on farm profits and labor supply, the effects of changes in eleven food-group prices, health programs and farm profits on the probability and severity of illness of farmers and farmer spouses, and the effects of alterations in food consumption on household health levels. Section IV contains a summary of our findings and a discussion of future research needs.

I. Determinants and Consequences of Changes in Health in Farm Households

1. Consumption, Farm Production and Health Production

To understand health determination and the consequences of changes in health or nutritional levels in the farm sector it is necessary to specify: 1) the processes (technology) by which health is produced, 2) the way in which health is valued by the producer-household, 3) the effects of changes in health on household constraints, 4) the mechanisms by which changes in health directly affect farm production, and 5) the efficiency of input and output markets.

To illustrate how these relationships involving the market environment, health, production and consumption influence the appropriate methods of estimating health determinants and health effects as well as policy conclusions, we consider first the simplest model of the farm "household", in which the farm commodity is produced with one input, labor, there is one adult member, the farmer, and the farmer's health is also produced. The farmer derives utility from his/her level of health, H, from the consumption of the produced "food" commodity X (at level X^c) and purchased food commodity Y, and from leisure l, such that

(1) $U = U(H, X^c, Y, l)$.

The level of health is assumed to be influenced by the levels of X^c and Y consumed, a health input Z (which yields no direct utility), the farmer's work time l_f and by environmental factors and the individual's health endowment, summarized by μ, beyond the control of the household; i.e.,

(2) $H = h(X^c, Y, Z, l_f) + \mu \quad h_1, h_2, h_3, > 0; h_4 < 0.$

Expression (2) is the health production function, which depicts how changes in food consumption, work, time, health goods (medical services, etc.), and the environment affect the farmer's health. Just as with conventional firm or farm production functions, the technology embodied in (2) may change over time and may be known more or less precisely by different households.

The farm output production function is conventional, except that it also describes how the farmer's health may affect production; i.e.,

(3) $X = \Gamma(L; H)$,

where L = farm labor input, defined below. The level of health may affect the productivity of farm inputs ($\partial^2X/\partial L\partial H>0$) but may have no direct productivity effect. That is, the health of the farmer may affect his/her ability to utilize (supervise, allocate) resources. The level of health might also directly affect the "quality" of the labor input supplied by the farmer. That is, the "effective" labor units L_f the farmer supplies might be both a function of his/her health and time worked, i.e.,

(4) $L_f = \Theta(l_f, H) \quad \Theta_1 > 0, \Theta_2 > 0$

If labor time can be hired in the market at a wage rate per unit of time W and each unit of <u>hired</u> labor time provides σ efficiency units of labor, then the labor input L in efficiency units is $L_f + \sigma L_H$, where L_H is hired labor time. The price of an efficiency unit is thus $\omega = W/\sigma$ and labor costs of production on the farm are $L\omega$. We note that W (or ω) may be determined according to the "efficiency" wage models of Leibenstein (1957), Mirrlees (1975) or Stiglitz (1976), or be the result of standard supply/demand equilibrium. The critical assumption, discussed below, is that hired and farmer labor are perfect substitutes in farm production and the supply of hired labor to an individual farm is perfectly elastic at the "market"(efficiency) wage.

(1972)

As in Grossman's/pioneering work on health production, an increase in the farmer's health may also increase the number of "healthy days" available to him/her for leisure l or work l_f; i.e.,

(5) $l_f + l = \Omega(H), \quad \Omega' > 0$

The income constraint of the household is thus

(6) $p_x X^c + p_y Y + p_z Z = \pi + \omega L_f = \pi + \omega\ \Theta(\Omega(H) - l,\ H) = I$

where p_x, p_y, p_z are the market prices of X, Y, and Z; ω is the market wage rate, I is income, and $\pi = p_x X - \omega L$ = profits.

2. Separability and The Effects of Farmer's Health on Farm Profits and Farm Income

As described, changes in the health status of the farmer can affect income by altering 1) the farmer's available time Ω, 2) his or her managerial abilities, and/or 3) the productivity of his/her work time. We now discuss more precisely the effects of changes in the farmer's health on potential output or income, farm profits, and actual family income, given that the world consists of "households" which maximize the utility function described by (1), subject to the constraints and structural relations (2) through (6). Note that since health is an endogenous choice variable in the model it is necessary to distinguish the exogenous component of health (μ) from that part influenced by behavior (consumption choices and thus tastes) in order to draw causal conclusions from relationships between observed health and other variables. We will thus examine how changes in μ -- the health environment or endowment -- which is exogenous to the farmer but possibly maniputable by policy -- affect these various components and concepts of incomes. To further simplify, we will for the time being ignore the managerial effect of health. The utility-maximizing (necessary) first-order conditions for the optimal quantities of the consumption and household production "inputs" X^c, Y, Z and 1 and the farm production input L are:

(7) $U_{x^c} + U_H h_{x^c} = \lambda[p_x - \omega h_{x^c}(\Theta, \Omega' + \Theta_2)]$,

(8) $U_Y + U_H h_Y = \lambda[p_y - \omega h_y(\Theta, \Omega' + \Theta_2)]$,

(9) $U_H h_z = \lambda[p_z - \omega h_z(\Theta, \Omega' + \Theta_2)]$,

(10) $U_1 + U_1 h_1 + \lambda\omega[\Theta_1 - h_2(\Theta_1 \; \Omega' + \Theta_2)]$,

(11) $P_x \Gamma_L = \omega$

where λ = Lagrangean multiplier.

Conditions (7) and (8) and (10) indicate how changes in the consumption of the food items as well as in leisure time augment utility both directly and indirectly, by changing the level of health, and also influence income indirectly by altering the efficiency of the farmer's labor time and the time available for leisure or work. Despite the interdependence between the farmer's consumption and his labor productivity, however, the level of the farm (labor) input L is independent of the farmer's consumption and leisure choices. Expression (11) is the profit maximization condition for the use of the farm labor input; farm production and consumption allocations are thus separable. The reason is that, whatever the endogenously-determined efficiency per unit of time supplied by the farmer to farm production and whatever the quantity of time he or she supplies, labor time (and efficiency units) can be hired at constant cost per unit to perfectly substitute for changes in the farmer's labor supply. Thus, farm profits will be independent of the farmer's health status when market substitutes are easily available for his labor input, measured in efficiency units or time. Conversely, only if such substitution is imperfect will consumption decisions and health affect production decisions and farm productivity. If, for example, the farmer's health affects his management performance and the market for management is absent or imperfect, then the separability between production and health will be broken.

The independence of farm profits and farmer's health in the perfect (input and output) market case does not imply that potential income or household income is not affected by changes in the health environment. We can define the household's potential or "full" income $F(H^*)$ in the perfect market (separable) case, for a given health level H^*, as the sum of the profit-maximizing level of profits π (independent of H^*) and labor income when the farmer works full time (all available time = $\Omega(H^*)$), i.e.,

$$(12)\quad F(H^*) = \pi + \omega\,\Theta(\Omega\,(H^*),\, H^*)$$

The effect of a small change, $d\mu$, in the health environment on full income is thus:

$$(13)\quad \frac{dF(H^*)}{d\mu} = \omega\,(\Theta_1\Omega' + \Theta_2\,)\,\frac{dH}{d\mu} > 0$$

Since second-order conditions constrain $dH/d\mu > 0$, increases in health always increase full income, by altering the (potential) time available for work and by augmenting efficiency per unit of labor time. Even though the farmer's *profits* are unaffected by the healthiness of his/her environment, potential output to society is affected (hired labor time can be released for use in other productive pursuits).

While full or potential income rises when the farmer's health environment improves, even in the separable case no prediction can be made from the model with respect to how actual or realized income will change in response to changes in μ , since realized income depends on labor time supplied:

$$\frac{dI(H^*)}{d\mu} = \omega\left(\theta_1 \frac{dl_f}{d\mu} + \theta_2 \frac{dH}{d\mu}\right) \tag{14}$$

The effect of μ on the level of the farmer's work time cannot be predicted because it depends on the properties of the unknown utility function as well as on the characteristics of the health production and efficiency labor functions. *Thus, changes in farm profits, actual or realized income and potential income in response to changes in health will generally not be identical*. Indeed, if health were purely a consumption good, had no effects on time availability or on labor efficiency, farmer's income (via labor supply) would be likely to change when the healthiness of the environment changes but output and full or potential income would not.

It is clear that the "effect" of health on farm profits, which depends on the nature of input (and output) markets, or on income, which depends in part on the labor-leisure choices of the household, is not an appropriate measure of the societal costs (or benefits) from changes in the health environment. In the absence of direct measures of efficiency units of labor, measures of health, of labor time and all farm inputs could be used in a production function analysis to discern how farm output changes, given labor time, in response to changes in health. (Of course, this approach, i.e., holding all inputs constant, would not capture any effects of health on the allocative ability of the farmer.) Additionally, if illness fully prevents any work effort, then the cost of illness is simply lost earnings. The value of marginal changes in lost work days from severe (fully constraining) illness however, while relatively easy to measure, will understate the total returns from investments in health when health also affects worker efficiency.

Finally, it can be easily demonstrated that the absence of markets for any of the consumed commodities or inputs in health production, which lead to own production of those factors, also breaks down the separability of farm production and consumption, as hired resources are diverted from the "cash" crop to produce non-marketable commodities. Farm profits will thus be affected by the farmer's health even if input markets are "perfect," although in the latter case, production of the cash crop will be efficient.

3. Food Prices and Health Programs: The Exogenous Determinants of Health

The reduced-form consumption demand equations for the foods, other health inputs and leisure, conditional on farm profits, derived from the model incorporating health production are:

$$X^c, Y, Z, 1 = D^i(P_x, P_y, P_z, \omega, \Pi, \mu) \qquad i = X^c, Y, Z, 1 \tag{15}$$

These conditional demand equations have all the usual properties of demand equations derived from models without household (health) production. Thus, own compensated price effects are negative, cross compensated price effects are symmetric, etc. However, the functional form of these demand equations depends on (or implies) the characteristics of both the household utility function (1) and the household production technology embodied in (2). Thus, the assumption that the utility function is Stone-Geary, ELES or Cobb-Douglas, for example, does not under most circumstances result in the usual demand system parameterizations derived from these specific functional forms, since the system will depend as well on the household technology. In most cases, no exact closed-form solutions for the demand equations in (15) can be obtained from explicit parameterizations of the preference orderings and technology of the household. One special case where this is possible, considered in Rosenzweig and Schultz (1983), is when the Cobb-Douglas form characterizes both the utility and household production sector. Conversely, *ad hoc* specification of the reduced form consumption demand equations does not generally allow retrieval of either the underlying technological or utility parameters. *Household health production and consumption are never separable, unlike* consumption and farm production with perfect input and output markets, because there is no market for the produced good, in this case, health.

While the consumption demand equations derived from the household production model, as noted, do contain all the predictions of conventional utility maximizing models, the parallel reduced form demand equation for health, in (16), does not have any predictive content:

$$H = D^H(P_x, P_y, P_z, \omega, \Pi, \mu) \tag{16}$$

To see why, consider the effects of a change in the price of the food good X, P_x, on the household's health:

$$\frac{dH}{dP_x} = h_{x^c}\frac{dX^c}{dP_x} + h_y\frac{dY}{dP_x} + h_z\frac{dZ}{dP_x} + h_{l_f}\frac{dl}{dP_x} \tag{17}$$

Even if all inputs including the food good X in the health production function have positive marginal products, contribute to improving health, it can be seen from (17) that a rise in the price of X or of any food good may increase or decrease health. The reason is that a change in any one price of food also (generally) affects the consumption of other foods and leisure (cross price effects are non-zero) in directions which cannot be predicted. In (17) for example, while dX^c/dP_x is likely to be negative, consumption of the Y good and the Z-input may increase (if Y and health are gross substitutes for X in consumption) and health may improve. For example, governmentally-subsidized technological improvements in cash crops, such as wheat, which result in higher relative prices for non-internationally traded items, such as some vegetables, could lower or raise health levels even if farm profits are unaltered and vegetables are "healthier" than bread (consumption of butter, rich in vitamin A and a likely complement to bread, might increase).

The net effect of a food price change on health will thus depend on the magnitudes and signs of the own and cross price effects in consumption and on the relative magnitudes of the marginal productivities of the inputs in the health production function. That is, food price effects on health depend on both the properties of the health production technology and the underlying preference orderings of the household for foods and other health-related goods. As a consequence, conclusions about the health impact of various food policies, which alter the relative prices of foods and other goods, cannot be known *a priori* without estimates of the health reduced-form equation (16) or estimates of both the consumption (food and other health inputs) demand system (15) and the health technology, from (2).

Finally, the composition and nutrient level of the household diet reflects not only relative food costs and the constraints of income but also the cost or availability of health services P_Z and the healthiness of the environment μ. Moreover, just as a change in one food price may reduce or increase health levels because of theoretically ambiguous substitution among foods of different health marginal productivities (nutritiousness), the health effects of interventions which alter the cost of pure health inputs will be augmented or diminished by substitutions in health production and consumption. Thus, reductions in health service costs may induce a change in diet towards less nutritious (but more tasty?) foods, if nutritious foods and health services are substitutes in health production and such foods and health are substitutes in consumption. Similarly, programs aimed at improving the health environment (cleaner sources of water) will alter the composition of demand and the demand for health services in ways which may reinforce or attenuate the health effects of such interventions. Estimates of the health reduced form equation provide information about the joint health effects of food policies and health programs which reflect these household allocationsof resources.

II. The Multi-Person Household, Consumption Aggregation and Intrafamily Resource Allocation

An important element of unrealism in the model discussed so far is the assumption that the farm household consists of one person. While one-person "household" models are extensively used in the development literature (e.g. Barnum and Squire, 1979. Deolalikar, Chapter ; Iqbal, Chapter), analyses of labor supply in developed countries (Ashenfelter and Heckman, 1974; Schultz, 1980) have demonstrated the importance of the interaction between heterogenous members residing in the same household (husband and wife) as well as the differential intrahousehold responsiveness of spouses' labor supply to price and wage changes. Since almost all households in all developing societies consist of at least one adult female and one adult male and wage rates for males and females are not always in fixed proportion (see Rosenzweig, 1984, for evidence from India and Hansen, 1969, for evidence from Egypt), treatment of family members as one aggregate person or as a collection of identical individuals (Sen, 1966) facing a "unisex" wage would appear to be overly-simplistic at best. Moreover, in the area of health and nutrition, the well-documented differentials and variation in male and female infant survival rates across countries suggests that changes in income and prices may have significant distributional effects on the health of individuals within families, given that most households contain children and adults of both sexes.

The question of how a household distributes its available resources among its members is particularly important in the study of food price, food consumption, nutrition relationships, because most available household data sets are likely to provide information only on household consumption agrregates, given the expense of collecting individual-specific consumption data. To the extent that interest in aggregate (family level) consumption or overall nutritional "availability" in low-income households is mainly derived from concern about the nutrition, health status and/or productivity of members of such households, understanding how household aggregates map into the well-being and health of individuals is critical.

In this section we consider three related questions:

1. How does a change in a particular food or other price faced by a household affect the consumption and health of individual household members?
2. What inferences regarding the health of individual members of a household can be drawn from information on total household food consumption or nutritional availability?
3. Given data on the health of individual family members and the total household intake of food, what inferences can be made about the relationship between food intake and health, i.e., when can the health technology be retrieved given data on the health of individuals and household level input information?

We first generalize the model discussed in the previous section by adding n-1 family members, whose individual-specific vectors of consumption goods, leisure and health enter the household utiltiy function such that:

(18) $U = U(H^i, X^i, Y^i, l^i) \quad i = 1 \ldots n$

(19) $H^i = h^i(X^{ci}, Y^i, Z^i, l^i) + \mu^i$

(20) $L_f{}^i = \Theta^i(l_f^i, H^i)$

$$(21)\ X = \Gamma(L^i)$$

$$(22)\ P_z Z + P_x X^c + P_y Y = \pi + \sum_{i=1}^{n} \omega^i L_f^i$$

where $Z = \Sigma z^i$, $X^c = \Sigma X^{ci}$,, $Y = \Sigma Y^i$, $L^i = L_f^i + L_H^i$, and superscripts denote individuals. Note that the μ^i term includes both household-specific factors - the health environment - and individual-specific factors - the health endowment. As constructed, the model allows each person to have unique health and efficiency unit production functions and assumes that each type of person has an equivalent market substitute, at wage rate ω^i, in farm production. Thus the model retains its separability between the profit and consumption sections.

The first order condition, derived from maximization of (18) subject to(19) through(22) for the intrahousehold allocation of, say, good X between person j and person k, is:

$$(23)\qquad \frac{U_x{}^j + U_H{}^j h_x{}^j}{U_x{}^k + U_H{}^k h_x{}^k} = \frac{P_x - \omega^j h_x{}^j \theta_2^j}{P_x - \omega^k h_x{}^k \theta_2^k}$$

As can be seen from(23) the allocation of resources between members of the household will depend on 1) how the household values the health/consumption leisure of each member ($U_H{}^i$, $U_x{}^i$), 2) how the relationships between health and consumption (the health technology) and between productivity and health (Θ^i) differ among members and 3) how the pecuniary returns to investments in the health of individual family members (the ω^i) differ.

The reduced form demand equations for the multi-person model are

$$(24)\qquad \begin{matrix} X^{ci} \\ Y^i \\ Z^i \\ l^i \\ H^i \end{matrix} = R^{ji}\,(P_x, P_y, P_z, \pi, \omega, u) \quad j = X, Y, Z, l, H; \quad i = 1 \ldots n$$

where ω, μ are the household vectors of individual-specific wages and endowments containing the elements ω^i, μ^i, $i = 1 \ldots n$.

Comparing the single person model to its multiple-person counterpart, we see that each has the same number of exogenous food and input prices, while the number of endogenous consumption variables to be determined (solved for) in the multi-person model is greater by n-1 times the number of choice variables. As a consequence, no additional predictions can be made from the multi-person model regarding the effects of changes in the food and health input prices beyond those for foods and health inputs aggregated over individuals; i.e., own compensated price effects for X^c, Z, Y are negative , etc. Thus, no predictions can be derived from the multiperson model as to how changes in food prices alter the distribution of food consumption across members of the household without the imposition of a great deal of additional structure.

Because, however, there is a unique price of time ω_i corresponding to each individual in the model, the compensated effects of person-specific wage changes on the consumption of individual household members and thus on the intrahousehold allocation of foods can be discerned with little additional structure imposed. For example, a compensated increase in the wage of person type j can be shown to increase the allocation of food to person j and decrease the allocation of food to person k, if the health, food consumption and leisure of j and k are Hicksian substitutes. Thus, the household will tend to distribute more resources to persons with higher earnings capacities, as given by the market wage per labor efficiency unit, when the individual-specific "goods" in the household welfare function are substitutes. This feature of the multi-person household is exploited in Rosenzweig and

Schultz (1982) to show how differences in economic opportunities for women could account for the variation in male/female infant survival ratios across India.

To examine the relationships between the aggregate quantity of household consumption and the consumption and health of individual family members, we employ a simpler multiperson model in which there are only two persons. We also, for simplicity, ignore labor/leisure decisions and farm production. **The** household's utility thus depends on the health status H and consumption of food **good** X of each individual as well as on a jointly consumed good Y. The health of each individual depends in turn on his/her own consumption of the X good.

Thus,

(25) $U = U(H^1, H^2, X^1, X-X^1, Y)$

(26) $H^1 = h^1(X^1)$ $\quad h^i_{X^i} > 0,\ h^i_{X^iX^i} < 0$

(27) $H^2 = h^2(X-X^1)$

(28) $p_x X + p_x Y = I$

where $X^2 = X-X^1$ and I is total income, assumed exogenous.

To facilitate the comparison between aggregate household consumption X and person-specific consumption we treat the aggregate food X and the consumption of X by individual one, X^1, as control variables. Determination of X and X^1 obviously determines the consumption of X by person 2, X^2, in this two-person case. The necessary first order condition for the allocation of X between household members 1 and 2, the intrafamily allocation "rule", **given the optimal aggregate consumption of X, is**

(29) $U_{H^1} h^1_{X^1} + U_{X^1} = U_{H^2} h^2_{X^2} + U_{X^2}$;

i.e., allocate resources across family members to equate their marginal contributions to household welfare. These marginal values will depend on both the unique utility-generating traits of each individual and on individual-specific differences in the health technology.

The relevant first order conditions for the aggregate household consumption of X^2 and Y are given by:

$$(30)\quad U_{H^2} h^2_{x^2} + U_{x^2} = \lambda p_x$$

$$(31)\quad U_y = \lambda p_y$$

where λ is the Lagrangian multiplier.

We now consider how member one's health status, H^1 changes when there is an exogenous change in the total amount of X, the commodity affecting health, consumed by the household. That is, we wish to know how a change in the availability of total or per capita X, x = X/2, alters X^1 (and X^2) and thus the individual health levels of 1 and 2. Using rationing theory (Tobin and Houthakker, 1950-51) and assuming that the exogenous change in the aggregate consumption of X occurs at the optimal level, as given by expressions (30) and (31), we know that dX^1/dx is just $(dX^1/dp_x)/dx/dp_x)$, the ratio of the compensated effects of a change in the price of the X commodity on individual one's consumption of X and the compensated effect of a change in the price of X on the total or per capita consumption of X in the household. In the two-person model, when the utility function is strongly separable, the relationships between a change in per-capita X, x, and the consumption of X by person one is thus:

$$(32)\quad \frac{dX^1}{dx} = 2\left[\frac{U_{H^1H^1}(h^1_{x^1})^2 + U_{H^1}h^1_{xx} + U_{x^1x^1}}{U_{H^1H^2}(h^2_{x^2})^2 + U_{H^2}h^2_{xx} + U_{x^1x^1}} + 1\right]^{-1}$$

Only if the numerator and denominator of the first parenthetical term in(32) are equal will changes in per-capita X consumption and changes in the consumption of all individuals in the household be equal; a sufficient condition is that the health production functions among individuals be identical and the family consider all persons perfect substitutes for each other. In the absence of "blindness" to individual traits by households and perfect biological homogeniety across family members, however, little can be said a priori about how alterations in the per capita (or adult-equivalent) availability of food in the household affect any individuals' health status in that household, unless the intrafamily distributional rules are also known.

Lack of information on intrafamily allocations also means that little can be said about the magnitude of the change in average family health status when average family consumption changes, so long as individual food or nutrient consumption is not in fixed proportion to health. The effect of per-capita X on average health ($\Lambda = H/2$) in the model is

$$(33)\quad \frac{d\Lambda}{dx} = \left[h^{1}_{x^1}\frac{dX^1}{dx} + h^{2}_{x^2}\frac{dX^2}{dx}\right]\frac{1}{2},$$

which will depend on both the allocative rule dX^1/dx and on the properties of the health production fuctions. Expression (33) above shows that even if the individual-specific health functions are identical, as long as 1) health production functions exhibit diminishing returns in food and 2) allocations of X across individuals are not equal, then:

1. if the *relationship* between individual food consumption and health is known, knowledge of per-capita family food consumption will not yield the level of per capita-household health, since $d\Lambda/dx \neq \frac{1}{n} \sum_{i}^{n} h^{i}_{x^{i}}$;

2. if the *relationship* between individual food consumption and health (the health production function) is *not* known, it cannot be inferred from information on the health status of individuals and family per capita food consumption, since $dH^1/dx = h_{x^1}\, dX^1/dx \neq h_x 1$.

Conversely, only if the relationship between individual consumption and health is in fixed proportions, i.e., if $h_{x^1} = h_{x^2} = a$, then, independent of how the household distributes its resources:

1. if the consumption-health coefficients are known, the average health of the household can be inferred from knowledge only of per-capita household consumption, although individual-specific levels of health or nutritional status cannot be known;
2. if the health production coefficients are unknown, they can be inferred from information on the individual health levels of all family members and total family consumption, since, from (33), $\sum_{i}^{2} dH^i/dX = a \sum_{i}^{2} dX^i/dX = a$.

Given the difficulty of directly estimating the health production function due to the need for individual-specific consumption (intake) information, it may be preferable to instead estimate individual-specific reduced form health "demand" equations (such as (24)). While such reduced-form estimates do not provide information on how the consumption of food items directly affect health, they do yield information on how changes in the prices of foods, medical services and other goods result in changes in health or nutritional status. Since it is relatively more difficult for policy-makers to directly alter (dictate) how households allocate their resources than to manipulate prices or provide services, the health reduced forms may provide more policy-relevant information than will estimation of the health technology, as long as technology (and tastes) remain unchanged. The reduced form equations for health and other consumption items including leisure also can provide information on how changes in measurable aspects of the health environment alter health, health practices (inputs) and the supply of labor.

Finally, reduced-form health estimates obtained for different members of the same family also allow a test of whether family members can be (or are) considered to be identical, since under the null hypothesis of perfect intrafamily substitution and biological homogeniety all coefficients in the person-specific reduced forms will be equal across household members. Rejection of the null hypothesis, of course, does not reveal the underlying cause (biological/behavioral) of the observed differences in health responses to commonly-experienced price and income effects across members of the same family in the absence of direct estimates of the health technology.

III. Estimation of the Relationships Between Health, Food Prices, Farm Profits and Aggregate Food Consumption: Indonesia

1. Heterogeneity, Separability and Estimation Procedures

We will estimate the relationships between health and food prices, consumption and production using household-level data from an Indonesian national probability sample. These data, described in detail below, provide information on short-term illness, labor supply, and earnings for all household members, detailed food and other consumption data and farm profits at the household level, and food and other price data at the village level. The data thus enable the estimation of:

1. The effects of changes in farmer's and spouse's health on farm profits and on labor supply.
2. The effects of changes in food prices and health infrastructure on the health of the farmer and spouse, on the demand for household-level health inputs, and on differences in the illness incidence between farmer and spouse.
3. The effects of changes in the level and composition of individual food consumption, on individual health levels, under the fixed coefficient and homogeneity assumptions for the individual health production function.

The estimation procedures used to obtain these estimates as well as the appropriate specifications of the profit function and health reduced forms depend not only on whether the farm production and consumption (household production) sectors are separable, as noted, but also on the existence of variations among individuals or households in exogenous characteristics which are unobserved or unrecorded in the data; i.e., heterogeneity. It is now well-recognized (Mundlak, 1961) that heterogeneity in farmer's managerial capacities may lead to bias in least squares estimates of farm production functions, as farmers of different abilities may choose different input combinations and will obtain higher output from a given input mix. Accordingly, in estimating the effects of farmer's health on farm profits, a correlation between those unobserved farmer characteristics which, conditional on prices, augment profits and unobserved characteristics which increase health status (the μ) will also lead to bias in estimating the effects of health on profits, even if changes in profit levels do not influence the household's demand for health. Thus it is possible to find that health and profits are correlated, even if health does not "structurally" affect farm profits, solely because of heterogeneity bias. Since price changes are likely to be uncorrelated with farmer characteristics, health input prices (P_x in the model) are suitable instruments for estimating the direct, structural effect of farmer health on farm profits.

Estimation of the reduced form equations including farm profit by ordinary least squares will provide consistent estimates of food price and profit effects on health and other goods (as long as unmeasured aspects of μ are independent of prices or farm profits). However, if exogenous changes in the farmer's health or in μ affect profits (non-separability), profits and unobserved components of μ will be correlated and all reduced form equations that include farm profits will be subject to bias. It is thus important to test for separability prior to estimation or specification of the profit-inclusive reduced form equations.

Heterogeneity bias also potentially plagues estimates of household (or health) production functions: Households reside in different health environments and may have different, genetically-endowed propensities for ill health, as embodied in the μ or μ^i terms in the model. Some of these exogenous environmental conditions (e.g., water facilities) can be relatively easily measured; others, related to genetic endowments, almost never. Yet, the model suggests that food consumption choices and labor supply will respond to those environmental conditions (the μ) which also affect health, leading to bias when the health production function is estimated by least squares. Because, however, prices of all consumed goods, whether or not all of the goods strictly affect health, as well as prices of production inputs (labor) influence the choice of those commodities affecting health, such prices can serve as instruments to obtain consistent estimates of the parameters describing the production of health.

Households are also heterogeneous with respect to "tastes," which jointly influence the level of health "demanded" and produced by a household as well as household consumption patterns and labor/leisure choices. Accordingly, least squares associations between measures of health (as a regressor) and such household choices as labor supply and food consumption are contaminated by heterogeneity bias even when all markets are perfect. As noted above, the reduced-form effects of health changes (even stripped of heterogeneity bias) on behavioral outcomes , controlling for prices, combine (and confound) the underlying utility and technological/biological parameters. Given the stability of those parameters, they do, however, yield information on the consequences of (if not the social returns to) improvements in health.

Table 1 summarizes the expected types of relationships, and their signs, between health and farm profits and labor supply, when structural health estimates are obtained using proxies for health input prices as identifying instruments. While in some cases structural effects are signed, or known to be absent, heterogeneity leads to a theoretically unknown relationship between health, profits and labor supply in all cases.

2. Results

1. Data

The household-level sample used to estimate the relationships between health and food prices, food consumption and production are from the April-June 1978 subround of the National Socio-Economic Survey of Indonesia (SUSENAS 1978) carried out by the Central Bureau of Statistics (Biro Pusat Statistik). This survey provides information on farm profits, itemized household consumption and expenditures, water sources, drinking water treatment, land ownership, cultivation, income and, for each household member, information on the incidence and severity of illness in the previous seven days as well as age, education, labor supply and wages. These data were augmented with local-area information on health program availability,

Table 1

Observed Associations Between Farmer's Health, Farm Profits and Labor Supply Under Perfect and Imperfect Labor Substitution in Production, by Type of Association

Dependent Variable and Type of Association With Health	Perfect Labor Substitution			Imperfect Labor Substitution		
	No Productivity Effect	Labor Efficiency Effect	Managerial Effect[†]	No Productivity Effect	Labor Efficiency Effect	Managerial Effect[†]
Profits						
Structural	None	None	Positive	Positive[*]	Positive[*]	Unknown
Heterogeneity	Possible	Possible	Possible	Possible	Possible	Possible
Labor Supply						
Structural	Positive[*]	Positive[*]	Unknown	Positive[*]	Positive[*]	Unknown
Heterogeneity	Possible	Possible	Possible	Possible	Possible	Possible

[*] If health and leisure are gross substitutes.

[†] Assumes no perfect complements for own management.

irrigation quality and attributes of the nonfarm labor market. The sample size for households cultivating land and having both a head and spouse present, used in the analysis, is 2347. Data sources for all the areal variables as well as sample characteristics and definitions of all variables used in obtaining the estimates below are found in the appendix.

Wages for the head (male in all sample households) and spouse were computed based on wage equations estimated from a sample of all household members aged 10 years and above, stratified by sex and corrected for selectivity bias. To maintain tractability, the 112 separate expenditure items detail in the SUSENAS were aggregated into thirteen commodity groups, eleven foods plus tobacco/betel and fuel. Consumption of the commodity aggregate tobacco/betel, which includes the use of sirih, an intoxicating quid consisting of betel leaf, areca nut, gambier and lime, may influence a respondent's perception of illness in addition to any actual effect. Therefore caution is required in interpreting its estimated effects on the respondent's reported health.

The principal shortcoming of the SUSENAS data is that it only provides information on short-term farm profits, labor supply and illness. The health status of family members is indicated by the occurrence of (self-reported) illness during the previous week; illness intensity is captured by information as to whether the illness required bed rest.

b. The Effects of Illness on Farm Profit and Farmer Labor Supply

We first determine whether the allocation of resources in farm production can be treated as separable from household health and consumption decisions by estimating a farm profit equation including the illness of the head of household and his wife. We tested first whether the illness variables were independent of the profit function residuals. The Wu statistic (3.00) was less than the critical value for (2,2500) degrees of freedom. Thus the profit function can be appropriatly estimated by OLS. The parameter estimates are presented in Table 2. Table 3 presents the results of our tests of the illness structural effects and heterogeneity bias. The hypothesis that the illness of the farmer or the farmer's spouse do not structurally influence farm profits cannot be rejected (F (2,2144) = 1.62). Thus we cannot reject the separability of farm production and consumption sectors.

The hypothesis that health is exogenous in the labor supply equation for the male head of household is, however, rejected (F (2,2144) = 7.16); leisure and the household production of health are not separable. Consistent with farm production-consumption sector separability, however, farm profits are exogenous to labor supply decisions by the farmer (F (1,2170) = 0.92). Instrumental variable estimates of the male labor supply equation are reported in the second column of Table 2, with health program variables used as instruments. As predicted in Table 1, we find that illness experienced by the farmer does significantly reduce his labor supply even though his illness does not reduce farm profits. The hypothesis of no illness structural effects on the amount of work performed by the male head is rejected at the .01 level of significance (X^2 (2) = 9.40). Thus, rural labor markets appear to be operating sufficiently smoothly in Indonesia such that market substitutes can be found for significant illness-induced reductions in the farmer's cultivation time which leave levels of production unaffected, at least in the short term.

Table 2

Estimates of the Effects of Illness on Farm Profits and Farmer Labor Supply

Variable/Estimation Method	Farm Profits $(\times 10^{-3})$ OLS	Male Labor Supply IV
Illness, head[a]	3.24 (0.37)[b]	-68.0 (1.80)[c]
Illness, wife[a]	-16.7 (1.71)	-69.7 (1.72)
Profits $(\times 10^{-3})$	-- --	-.0455 (6.34)
Owned Land	.0115 (9.32)	.00102 (2.55)
Age, head	.615 (2.01)	-.346 (3.24)
Age, wife	-.535 (1.59)	.222 (2.12)
Education, head	1.31 (1.64)	.150 (0.44)
Education, wife	-3.52 (0.37)	-.489 (1.56)
Wage, head	-1.93 (1.61)	-.205 (0.47)
Wage, wife	3.24 (0.18)	-1.90 (-0.30)
Price of grain	4.01 (0.39)	-7.29 (-1.94)
Price of tubers	16.6 (2.83)	3.37 (1.73)
Price of fish	3.21 (2.24)	.0335 (0.06)
Price of meat	.385 (0.44)	.230 (0.80)
Price of milk	-.445 (0.71)	.169 (0.85)

Table 2, Cont.

Price of vegetables	-8.55 (2.98)	.597 (0.58)
Price of legumes	3.43 (1.44)	.101 (0.12)
Price of fruit	1.09 (0.36)	1.07 (1.10)
Price of other foods	-.871 (0.91)	.483 (1.59)
Price of vegetable oil	.668 (0.48)	.424 (0.88)
Price of sugar	-6.79 (1.03)	-3.04 (1.30)
Price of tobacco/betel	-2.47 (0.51)	1.21 (0.78)
Price of fuel	-.136 (0.63)	-.0127 (0.19)
Irrigation-1	25.6 (3.06)	-- --
Irrigation-2	-16.0 (2.01)	-- --
Irrigation-3	-21.5 (1.72)	-- --
Intercept	-3.91 (0.18)	55.2 (8.40)
d.f.	2171	2171

---

[a] Endogenous variable in labor supply equation. See text.

[b] t-values in parentheses in column.

[c] Asymptotic t-values in parentheses in column.

Table 3

Test Statistics: Profit and Farmer Labor Supply Equations

Variable	Test Statistic (d.f.)	Profit Equation	Labor Supply Equation
Illness			
Structural Effect (Wald)	χ^2 (2)	3.00	9.40
Exogeneity (Wu)	F (2,2144)	1.56	7.16
Profits			
Structural Effect (Wald)	t (2319)	-	6.34
Exogeneity (Wu)	t (2319)	-	.958

The labor supply parameter estimates indicate that the illness of the husband and wife jointly and significantly reduce the head's labor supply, reflecting both the expected complementarity between health and leisure and intrafamily substitution of time in household production. The illness reported in the sample appears to strongly reduce labor supply, by almost 70 hours a week. The low incidence of illness (2.6 to 3.4 percent) combined with this result suggests that only severely debilitating illness is reported by the respondents; thus the illness variable may not be a sensitive indicator of actual health status. Of the other coefficients, in accord with prior studies of labor supply, increases in farm profits (which are exogenous to consumption decisions) reduce the farmer's total labor supply, reflecting the "normality" of leisure, while only the price of grain, of the food price variables, significantly affects labor supply decisions--for given farm profits, an increase in grain prices reduces the farmer's labor supply (grain consumption and the head's leisure are substitutes).

c. Determinants of Drinking Water Treatment and the Illness of Farm Heads and Farm Wives: Reduced Forms

The first column of Table 4 provides the reduced form probit maximum likelihood estimates of the determinants of whether the household boils its drinking water. The estimates indicate that higher farm profits, larger land holdings and higher educational attainment of farm wives tend to increase the propensity of households to take the precautionary step of boiling water prior to its consumption. Commodity prices are also important determinants of boiling behavior -- t-values for five of the price parameters (those for grains, meat, milk, tobacco and fuel) exceed 2.0 in absolute value. While we cannot, as noted, sign *a priori* the reduced form price effects without knowledge of the fundamental technological and utility parameters, it is probably not surprising that higher fuel prices

Table 4

Maximum Likelihood Probit, Polytomous Probit and Fixed Effect Logit Estimates: Reduced Form Household Input, Individual Illness, and Illness Distribution (Head and Wife) Equations

	Household Boils Water	**Head Ill**	**Wife Ill**	**Head Ill/Wife Ill**
Variable	**Probit**	**Ordered Probit**	**Ordered Probit**	**Fixed Effect Logit**
Farm profits ($x10^{-5}$)	.211 (2.24)	.1000 (0.97)	-.0000 (1.10)	.756 (1.54)
Owned land ($x10^{-2}$)	.0106 (2.36)	-.00071 (1.28)	3.47 (1.01)	-.0119 (0.51)
Age, head ($x10^{-2}$)	.231 (0.26)	.499 (0.54)	.876 (0.84)	.00785 (0.01)
Age, wife	-.00267 (0.03)	.00721 (0.71)	.00299 (0.27)	.00181 (0.01)
Education, head	-.00489 (0.19)	.0603 (2.20)	.02441 (0.84)	.0965 (0.90)
Education, wife	.0861 (2.60)	-.0573 (1.70)	.0347 (1.01)	-.174 (1.32)
Wage, head	.0901 (1.67)	-.0741 (1.42)	-.0701 (1.35)	-.106 (0.50)
Wage, wife	.325 (0.41)	-.336 (0.44)	-.992 (1.30)	2.92 (0.94)
Price of grain	1.16 (3.85)	-.520 (1.62)	.0687 (0.21)	-1.20 (0.87)
Price of tubers	.262 (1.34)	-.0312 (0.14)	.191 (0.94)	-.909 (1.03)
Price of fish	-.0439 (0.98)	-.0256 (0.49)	.111 (2.40)	-.444 (2.01)
Price of meat	.0975 (3.69)	.0164 (0.55)	.0291 (0.97)	.0478 (0.40)
Price of milk	-.0374 (2.11)	.0162 (0.81)	-.0227 (0.97)	.162 (1.78)
Price of vegetables	-.00725 (0.07)	.168 (2.27)	-.0930 (0.81)	.899 (2.30)
Price of legumes	-.0360 (0.44)	.0866 (1.00)	.0755 (0.91)	.118 (0.34)
Price of fruit	-.0416 (0.42)	.0821 (0.88)	.118 (1.24)	-.245 (0.74)
Price of other foods	-.158 (0.13)	.0187 (0.56)	.00574 (0.16)	.139 (0.92)
Price of vegetable oil	.0873 (1.85)	.0814 (1.67)	.0194 (0.40)	-.0163 (0.08)
Price of sugar	-.231 (1.01)	-.489 (1.94)	-.172 (0.68)	-.384 (0.30)
Price of tobacco/betel	.393 (2.49)	.185 (1.13)	-.105 (0.61)	.996 (1.58)

Price of fuel	-.0152	.00216	-.00278	-.00129
	(2.50)	(0.28)	(0.34)	(0.36)
Well	.207	.112	-.191	.816
	(1.67)	(0.78)	(1.36)	(1.50)
River	.0149	.189	-.246	1.30
	(0.97)	(1.06)	(1.31)	(1.65)
Hospital	.261	-.0399	.0679	.581
	(0.45)	(0.06)	(0.11)	(0.23)
Clinic	4.09	1.73	-1.03	10.1
	(3.25)	(1.78)	(0.95)	(2.05)
Maternity hospitals	.826	-.867	-.185	-1.86
	(0.98)	(1.26)	(0.27)	(0.75)
Family planning	1.35	-.269	-.582	1.30
	(4.28)	(0.84)	(1.77)	(0.93)
Public lavoratories	.375	-.00006	.00005	-.900
	(1.36)	(0.37)	6.25	(0.76)
Households	-.000687	-.00013	.00025	-.00173
	(3.34)	(0.58)	(1.10)	(1.75)
Constant	-1.44	-1.57	-2.40	.334
	(1.81)	(1.87)	(2.83)	(0.09)
-2lnlikelihood	278.3	49.3	28.3	35.93
λ	-	5.62	4.57	-

---

[a] Asymptotic t-values in parentheses.

are significantly associated with unboiled drinking water in our sample, given that fuel is an important input in the production of this "intermediate" health input.

All of the health program variables are positively associated with water boiling, although only public health and family planning clinics have highly significant coefficients. These results suggest that such programs may provide information on health practices in addition to providng remedial services. The estimates also indicate that poorer qualities of water, that from wells and rivers rather than from springs and piped water systems, tend to increase the propensity to boil water.

There are three ordered categories for the illness dependent variables: not sick, sick but not sick in bed, and sick in bed. If the underlying model is

$$y_i = X_i\beta + u_i \qquad i = 1, \ldots, N$$

where y_i is a latent variable, X_i is the set of explanatory variables, β is a vector of parameters, and u_i is the residual, then an individual belongs to the first category if the latent variable is below some threshold, say

$$y_i < 0$$

in the second category if

$$0 < y_i < \lambda$$

and the third category if

$$y_i > \lambda.$$

Maximum likelihood estimates of this ordered probit model (columns 2 and 3 in Table 4) yield positive and statistically significant values for the parameter λ for both the head of household and his wife, confirming the ordered specification.

Many of the individual parameters of the two, sex-specific illness reduced forms are imprecisely estimated. However, a likelihood ratio test finds that all of the slope parameters in the equation for heads, but not for wives, are jointly different from zero at the .05 level of significance. The patterns of signs for commodity prices are quite different in the farm head and farm wife illness reduced forms. As noted, of course, it is not possible to infer to what extent these apparent differences represent differences in sex-specific health technologies and/or the nature of intra-household allocation rules.

Among the more precisely estimated parameters for heads of households, we find that the prices of grains and sugar are negatively related to illness while the prices of vegetables and vegetable oil are positively related to illness. While the popular notions that sugar is bad for health and vegetables are good for health conform to these results, we reiterate that such conclusions cannot be drawn from the reduced form. The estimates do imply that reductions in the relative prices of vegetables will increase health levels while subsidies to sugar, for given farm profits, will increase the incidence of illness. At the sample means, the estimates indicate that a ten percent reduction in the prices of vegetables and vegetable oil will decrease the probability of illness by 4.2 and 9.3 percent, respectively, while similar proportional decreases in the prices of grains and sugars will increase the incidence of illness by 15 and 25 percent.

For wives of heads, only the parameter on the price of fish among the 13 commodity prices is estimated with reasonable precision. This parameter indicates that high fish prices are associated with the illness of wives. The remainder of the parameters of these reduced forms are estimated with insufficient precision to warrant special note. It seems likely that this imprecision is a result of the very short period of time over which the occurrence of illness is recorded. Not only is illness in the last week a highly infrequent event in our sample, but it may also be a poor measure of long-term health status.

A rigorous test of the joint hypotheses that there is both perfect intrafamily substitution and identical health production functions across the farm head and his wife is carried out by estimating a model obtained by subtracting the wife's illness reduced form from that of her husband. As Chamberlain (1980) has shown, such a model is still a dichotomous logit relationship but with a redefined dependent variable. In our case, the dependent variable has the value of one if the husband is ill but the wife is not and the value zero if the wife is ill but the husband is not. Observations where both husband and wife are ill or not ill do not enter into the likelihood function; thus the sample size for these estimates is only 138 households. An advantage of this technique is that biases arising from the omission of household-specific, exogenous health factors are eliminated.

The logit maximum likelihood estimates of the fixed effect logit model are presented in the last column of Table 4. A likelihood-ratio test fails to reject (at the .05 level) the hypothesis that the set of slope parameters of the head's illness reduced-form is different from that of the wife's reduced-form ($X^2(29) = 35.93$). This is not surprising given that the set of wife illness coefficients was found not to be statistically significant in the full sample and given the small sample of households in which one (and only one) spouse is ill. Among the individual food prices, however, the prices of fish and vegetables have statistically different impacts on the differential incidence of illness of heads and wives. Higher fish prices tend to make wives relatively more ill and higher vegetable prices tend to make heads relatively more ill.

d. The Illness Production Function

As noted, we are unable to directly estimate individual-specific health production functions because individual-specific consumption data are not available. However, if we assume that the relationship between individual consumption and health is in fixed proportions and is the same for all individuals we can estimate the person-specific health production function, formed by summing the linear health production functions for all the individuals residing in the household, even if household resources are allocated differentially across individuals. Food and tobacco consumption levels in this "aggregated" linear household illness production function are now household totals; the intercept is represented by the total number of household members and the age variable is the sum of the ages of all household members. Possible differences in the individual male and female health production functions are permitted by including an intercept dummy variable for sex (male = 1, female = 0), which, in summing to an aggregated function, becomes the total number of male household members.

Also included in the production function specification are household "public good" inputs, household-level variables which are assumed to affect the health of all individual family members net of their own consumption of foods. These are the (endogenous) boil variable, which affects the drinking water of all household members, the water sources, and the schooling attainment of the head and wife. The latter are included to test if schooling improves health net of input levels; i.e., to test for schooling effects in household production which are analagous to "worker" or "efficiency" effects in farm production.

All variables are divided by the size of the family in order to eliminate the heteroscedasticity caused by differences in household size. As a consequence, the illness dependent variable, average illness incidence in the household,has a large concentration of observations at zero but also observations which may range up to a value of one (when there are no observations). The Tobit estimation procedure is therefore employed. Because of possible heterogeneity in health endowments and environmental factors, which would bias these single-equation estimates, the health production function is also estimated using two-stage Tobit, where the endogenous food and other inputs are first regressed on the prices and programs. While the two-stage Tobit estimates are consistent estimates of the (linear) production coefficients, the standard errors are not unbiased so that caution should be exercised in interpreting the two-stage results.

Table 5 presents both Tobit and two-stage-Tobit estimates of the linear household production function. As we have noted, heterogeneity bias arising from differences in health environments and endowments, and tastes, potentially contaminate the single stage estimates. The difference between the Tobit and two-stage-Tobit estimates is indeed quite striking. For example, the Tobit estimates indicate that fruit consumption is implausibly positively and significantly associated with household illness, while the two-stage estimates suggest that the reverse pattern is more likely the case.

The consistent two-stage-Tobit estimates indicate that six of eleven food commodities have negative production coefficients in the production of illness. Of these, three are statistically significant at at least the 10 percent level of significance (fish, fruit, vegetables). The tobacco/betel production coefficient is negative, suggesting its consumption reduces reported illness. However, as noted, the sirih (betel) component of this consumption aggregate is intoxicating and may distort perceptions of health status. Sugar consumption, on the other hand, appears to increase significantly the production of illness. (However, as noted, the standard errors of the two-stage-Tobit model are not unbiased). The (consistent) point estimates indicate that a 10 percent increase in vegetable, fruit and fish consumption reduces the probability of illness by 9.1, 3.4 and 5.6 percent respectively while a similar proportional increase in sugar intake increases this probability by 11.5 percent. The results also suggest that for any level of the specified health inputs, males are no less likely to become ill than are females, while illness incidence declines with age up to age 38 and then increases.

Of the household-level variables, the set of water source and water treatment variables are statistically significant. The educational level of the household head, but not the wife, is also statistically significant. As in the health reduced-forms, however, higher male educational attainment is associated with higher levels of reported illness incidence, perhaps reflecting a greater propensity by more-educated respondents to report

Table 5

Linear Household Illness Production Function

Variable/Estimation Technique	Two-Stage Tobit	Tobit
Grain consumption[a, b]	.193 (0.53)	-.0135 (0.10)
Tuber consumption[b]	-.453 (0.28)	-.129 (1.13)
Fish consumption[b]	-3.92 (2.96)	-.678 (1.58)
Meat consumption[b]	4.82 (1.01)	.133 (0.14)
Milk consumption[b]	19.5 (0.30)	2.63 (0.89)
Vegetable consumption[b]	-2.74 (2.21)	.199 (0.70)
Legume consumption[b]	2.21 (0.20)	.144 (0.21)
Fruit consumption[b]	-1.98 (1.77)	.408 (2.27)
Other food consumption[b]	-1.40 (0.19)	-2.20 (1.90)
Vegetable oil consumption[b]	-4.78 (0.18)	-.958 (0.39)
Sugar consumption[b]	14.5 (2.16)	.807 (0.79)
Tobacco/betel consumption[b]	-1.78 (1.72)	-.355 (1.75)
Hours of work[b]	-.00711 (1.14)	-.0059 (3.54)
Male	-.0213 (0.99)	-.0396 (0.47)
Age[b]	-.0904 (3.52)	-.0043 (0.76)
Age squared[b]	.00117 (3.53)	-.000085 (1.19)

Table 5, Cont.

Boil water[b]	-.314 (1.30)	-.0450 (0.48)
Well x boil[b]	.575 (1.82)	.0387 (0.32)
Well	-.566 (1.88)	-.0715 (0.62)
River x boil[b]	1.11 (2.86)	.167 (1.07)
River	-1.08 (2.93)	-.217 (1.44)
Education, head	.0165 (2.44)	.0138 (2.45)
Education, wife	-.00431 (0.53)	.0013 (0.19)
Intercept	1.22 (2.63)	-.240 (1.99)

---

[a] All consumption variables divided by 100 ($x10^{-3}$).

[b] Endogenous variables.

illness in response to given illness symptoms. While individual differences in illness reporting propensities may be uncorrelated with (village-level) prices and programs, personal characteristics may influence both objectively-measured health conditions and reporting errors.

4. Summary and Conclusion

There have recently been a number of studies focusing on the allocation of food nutrients across households and the response of household nutrient intake to changes in food prices and income. Since nutrient intake itself cannot be considered an argument in the utility function or even a good indicator of welfare, it seems likely that implicit in this focus on nutrient intake is the view that they are an important set of inputs into the production of health. This paper addresses the direct relationships between food (and other health input) prices, income and health. In doing so, we demonstrate that policy implications derived from studying how the level and distribution of a sub-set of health inputs (foods) changes with price subsidies or other interventions may be seriously flawed if the ultimate policy goal is improving the levels or distribution of health in the population and discuss the difficulties in assessing agricultural output or income losses associated with ill health.

The traditional model of the producer cum consumer farm household incorporating a household health production sector is used to demonstrate the difficulty in predicting the effects of policies on health or of the consequences of changes in health status. It is shown that theory offers no predictions for the signs of the effects of food price changes on health without complete knowledge of preferences and of the health technology. Moreover, the change in farm profits resulting from changes in health status is shown not to be a measure of the output loss resulting from illness but rather an indicator of the imperfection of markets and the substitutability of inputs in farm production. Indeed, no prediction can be made from the model with respect to how household income will change in response to changes in health status.

While in principle the health technology is estimable, estimation requires individual-specific information on health inputs consumed and instruments, such as prices. However, available household data sets are likely to provide information only on household consumption aggregates. Thus, we consider how household aggregates map into the well-being and health of individuals. It is found that, in general, no predictions can be derived as to how changes in prices or per-capita consumption affect the distribution of consumption across individuals, the health of individuals or even the average health of the household. However, if the health technology is linear and homogeneous across individuals, it is possible to estimate the relationship between household consumption and an individual's health.

Based on a sample survey of farm households from Indonesia, farm profit and labor supply equations and reduced form equations for one household health input, the boiling of drinking water, and for the illness of the (male) head of household and his wife were estimated. Exogenous regressors included the prices of 11 food groups, tobacco and fuel, wage rates for the head and his wife, education and measures of the availability of water and the health infrastructure.

Our estimates of the profit and labor supply equations suggested that while the illness of either spouse decreased significantly the amount of labor supplied by the farmer, there was little or no effect on farm profits exclusive of family opportunity costs. Further tests were consistent with the hypothesis that the substitution of hired labor for illness-induced lost family labor time was fully compensating, as the production and consumption sectors of the farm householdwere found to be separable due to evidently well-functioning input and output markets.

With respect to the determinants of health, the estimates also suggested that both the health environment and costs of inputs affect households' choices of precautionary health measures and that certain foods play particularly important roles in determining the short-term illness propensities of adult farm family members. In particular, households residing in areas with less sanitary sources of water and where fuel costs were low were found to be significantly more likely to boil their drinking water. The consumption of vegetables, fruit and fish were found to be significantly and negatively associated with the incidence of adult illness, while increased sugar consumption appeared to significantly increase the probability of illness. Alterations in the prices of foods were also found to significantly affect the illness probabilities of adult males, with reductions in the prices of vegetables and vegetable oil improving health and reductions in the price of sugar increasing illness incidence.

While our theoretical framework implies that changes in actual or realized income or farm profit associated with changes in health status are not good measures of either the output loss due to illness or of changes in the welfare of individuals, with appropriate data it may be possible to obtain at least boundary measures of health effects on output. One approach is to estimate a farm production function including the health status of family workers as an additional input, controlling for their labor input in units of time as well as other production factors. A second approach would involve estimating the relationship between (time) wages and health status, as implied by efficiency wage theories. Measurement of the productivity gains associated with investments in health is a neglected but important area of research which may be useful in the assessment of the full consequences of both agricultural and basic needs policies.

References

Ashenfelter, O. and J. Heckman, "The Estimation of Income and Substitution Effects in a Model of Family Labor Supply," Econometrica 42, November 1974.

Barnum, H. and L. Squire, "An Econometric Application of the Theory of the Farm Household," Journal of Development Economics 6, June 1979: 79-102.

Biro Pusat Statistik, Fasilitas Sosial Desa, 2 volumes, Jakarta: 1979, 1980.

Chamberlain, G., "Analysis of Covariance with Qualitative Data", Review of Economic Studies 47: 225-238.

Deolalikar, Anil B., "Savings and Investment Decisions Incorporated in a Model of an Agricultural Household: Empirical Result from an Indian District, 1983, (Ch. ___ of this volume).

Direktorat Jenderal Pertanian, Statistik Bahan Makanan Utama Di-Indonesia, Jakarta: 1973.

Grossman, M., "On the Concept of Health Capital and the Demand for Health," Journal of Political Economy 80, March/April 1972: 223-255.

Hansen, B., "Employment and Wages in Rural Egypt," American Economic Review 59, June 1969.

Iqbal, Farrukh, "The Demand and Supply of Funds among Agricultural Households," 1983, (Ch. ___ of this volume).

Leibenstein, H., Economic Backwardness and Economic Growth, New York: John Wiley and Sons, 1957.

Martin, Terrence H., "Nutritional Consequences of Agricultural Development Projects: A Survey of the Evidence," Washington: World Bank, mimeo.

Mirrlees, J. A., "A Pure Theory of Underdeveloped Economies," in L. G. Reynolds, ed., Agriculture in Development Theory, New Haven: Yale University Press, 1975.

Mundlak, Y., "Empirical Production Functions Free of Management Bias," Journal of Farm Economics 43, 1961: 44-56.

Olsen, R. J., "A Least Squares Correction for Selection Bias," Econometrica 48:7, 1980: 1815-1820.

Pitt, M. M., "Food Preferences and Nutrition in Rural Bangladesh," Review of Economics and Statistics 65, February 1983: 105-114.

Rosenzweig, M. R.,"Determinants of Wage Rates and Labor Supply Behavior in the Rural Sector of a Developing Country," in H. P. Binswanger and M. R. Rosenzweig, Contractural Arrangements, Employment and Wages in Rural Labor Markets in Asia, New Haven: Yale University Press, 1984.

Rosenzweig, M. R. and T. P. Schultz, "Market Opportunities, Genetic Endowments and Intra-Family Resource Distribution: Child Survival in Rural India," American Economic Review 72, September 1982: 803-815.

Rosenzweig, M. R. and T. P. Schultz, "Estimating a Household Production Function: Heterogeneity, the Demand for Health Inputs and their Effects on Birthweight," Journal of Political Economy 91, October 1983.

Schultz, T. P., "Estimating Labor Supply Functions for Married Women," in J. P. Smith, ed., Female Labor Supply, Princeton: Princeton University Press, 1980.

Stiglitz, J. E., "The Efficiency Wage Hypothesis, Surplus Labour, and the Distribution of Income in L.D.C.'s," Oxford Economic Papers, New Series, 1976: 185-207.

Strauss, J., "Determinants of Food Consumption in Rural Sierra Leone: Application of the Quadratic Expenditure System to the Consumption-Leisure Component of a Household-Firm Model," Journal of Development Economics 11:3, December 1983: 327-354.

Tobin, J. and H. S. Houthakker, "The Effects of Rationing on Demand Elasticities," Review of Economic Studies 18, 1950-51: 140-153.

Appendix

The household-level sample is from the April-June 1978 subround of the National Socio-Economic Survey of Indonesia (SUSENAS 1978) carried out by the Central Bureau of Statistics (Biro Pusat Statistik). This survey provides information on farm profits, itemized household consumption and expenditures, water sources, drinking water treatment, land ownership, cultivition, income and, for each household member, information on the incidence and severity of illness in the previous seven days as well as age, education, labor supply and wages. Also provided is information on the kabupaten (regency) of residence - there are 300 kabupatens in the sample - enabling the merging of local-area information on health program availability, irrigation quality and attributes of the nonfarm labor market.

Wages for the head (male in all sample households) and spouse were computed based on wage equations estimated from a sample of all household members aged 10 years and above, stratified by sex and corrected for selectivity bias. The least squares correction for selectivity bias was applied (Olsen, 1980). Variables measuring land ownership and marital status were used to identify the selectivity correction in the wage equations. To achieve identification of the health and profit equations using predicted wages, kabupaten-specific measures of industrial capital and manufacturing workers per capita, derived from the raw data tapes of a 1978 survey of manufacturing establishments (Survey Tahunan Perusahaan Industri 1978), were included as regressors in the individual wage equations.

The SUSENAS survey only provides information on short-term farm profits, labor supply and illness. Farm profit is calculated as the value of farm output during the previous three months less the value of purchased inputs, hired labor, and family farm labor, valued at the predicted wage rates. The health status of family members is indicated by the occurrence of (self-reported) illness during the previous week; illness intensity is captured by information as to whether the illness required bed rest.

To maintain tractability, the 112 separate expenditure items detailed in the SUSENAS were aggregated into thirteen commodity groups, eleven foods plus tobacco and fuel. A village is assumed to represent a distinct market and the average village price of every item is calculated as the average price of the commodity consumed by the sampled households in the village. All food prices are measured in rupiahs per kilogram and fuel prices in rupiah per British Thermal Unit. Price indices are formed by geometrically weighting component prices with the average budget shares of the relevant kabupaten. A quantity index for each commodity group is formed by dividing expenditure by this price index.

The household-level information was augmented with data on the proportion of rural villages in each kabupaten in which there was at least one hospital, public health clinic (PUSKESMAS), maternity hospital, family planning clinic, health personnel or public lavatory(Biro Pusat Statistik 1979, (1980).

Data on the quality of irrigation by kabupaten, a determinant of farm profits, were also merged in from a separate survey (Direktorat Jenderal Pertanian, 1973). Table A1 lists the sample characteristics and definitions of all variables used in obtaining the econometric estimates.

Table A1

Sample Characteristics

Endogenous Variables	Mean	S.D.
Farm Profits in Past 3 Months (rupiahs)	13860	75041
Illness in Past Week - Farmer	.0336	.180
Illness "in bed" in Past Week - Farmer		
Illness in Past Week - Farmer's Spouse	.0267	.161
Illness "in bed" in Past Week - Farmer's Spouse		
Hours Employed in Past Week - Farmer	37.3	17.81
Household Boils Drinking Water	.932	.252
Family Size	5.16	3.95
Grains[a]	1420	749
Tubers[a]	373	744
Fish[a]	166	199
Meat[a]	34.3	81.6
Milk[a]	6.64	22.0
Vegetables[a]	379	290
Legumes[a]	67.0	116
Fruit[a]	196	347
Other Foods[a]	96.1	83.4
Vegetable Oil[a]	31.3	34.1
Sugar[a]	93.8	88.0
Tobacco/betel[b]	237	382
Fuel[b]	282	383
Exogenous Variables - Household Characteristics		
Age of Farmer	42.6	12.2
Age of Farmer's Spouse	36.0	11.0
Years of Schooling - Farmer	3.71	3.10
Years of Schooling - Farmer's Spouse	2.58	2.79
Predicted Hourly Wage - Farmer (rupiah/hour)	103	59.1
Predicted Hourly Wage - Farmer's Spouse	4.30	3.04
Land Owned	1047	1401
Exogenous Variables - Village or Kabupaten Characteristics		
Grain[c]	1.28	.213
Tubers[c]	.493	.315
Fish[c]	3.41	1.22
Meat[c]	8.80	2.20
Milk[c]	7.65	2.72
Vegetables[c]	1.15	.652
Legumes[c]	2.24	.807
Fruit[c]	1.07	.582
Other Foods[c]	4.57	1.82
Vegetable Oil[c]	5.18	1.17
Sugar[c]	2.33	.288
Tobacco/betel[d]	1.22	.378
Fuel[d]	6.20	8.10

Water Sources:		
Well or Pump	.575	.494
River	.203	.402
Other - Rainfall, Spring	.778	
Proportion of Rural Villages in Kabupaten with:		
Hospitals	.237	.169
Public Health Clinics	.111	.0930
Maternity Hospitals	.147	.133
Family Planning Clinics	.503	.378
Public Lavatories	.486	.271
Health Personnel Services	.568	.225
Number of Households in Village	611	553
Proportion of Cultivated Acres in Kabupaten Irrigated:		
Controlled and Partially Controlled	.200	.214
Simple, with bunds	.261	.227
Run-off	.0380	.145
Dry Land	.499	

a. Quantity index, all components measured in 100 grams.

b. Quantity index.

c. Price index, all components in price per 10 grams.

d. Price index.