HEALTH AND NUTRIENT CONSUMPTION ACROSS AND WITHIN FARM HOUSEHOLDS

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Abstract—The conditions under which inferences can be made about the effects of changes in food prices and other interventions on the health status of individual family members from commonly-available household aggregate consumption data are assessed in the context of a multi-member household jointly producing farm output for sale and health. Data on farm households in Indonesia are used to obtain and compare estimates of how changes in commodity prices, health program service levels, and sources of drinking water alter household nutritional intake and the illness propensities of individuals, and how changes in the consumption of nutrients directly alter health.

I. Introduction

THE increased attention by the governments of many developing countries to the "basic needs" of their populations has motivated a number of econometric investigations into the nutritional consequences of food price interventions (Pinstrup-Anderson et al. (1976), Alderman and Timmer (1980), Pitt (1983), Strauss (1983)). Such studies have utilized data on household-level food consumption to estimate own and cross food price effects on nutrient intake by income class based on the conversion of foods into their nutrient components. This approach, necessitated in part by data constraints, has a number of problems which reduce the value of the estimates for policy. First, 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 nutrients is the view that they are an important set of inputs into the production of health. Yet none of the studies provide information on how the various nutrients map into observable health measures. Since, a priori, most food price changes are likely to alter the composition and level of nutrient intake, increasing the intake of some nutrients while reducing consumption of others, such estimates render nutrition-based policy conclusions about specific interventions difficult. Indeed, of the nine food prices considered by Pitt in Bangladesh, variations in seven had both positive and negative effects on the intake of the nine nutrients considered.[1]

A second shortcoming of existing studies of food price effects on household nutrient consumption is that the role of other health-related factors in consumption choices is ignored. If health and food consumption are nonseparable arguments in the household utility function, costs and availability of health inputs and environmental health factors, as well as food prices, may affect nutrient intake. To the extent that households that have greater access to health services or live in less sanitary environments also face higher or lower food costs (e.g., rural versus urban or suburban areas), cross-sectional estimates of food price effects that ignore the health infrastructure may lead to misleading conclusions about the consequences of food price interventions.

Finally, existing studies of the determinants of household-level nutrient consumption provide no information on how a change in the aggregate diet of a household affects the nutritional intake or status of individuals. If interest in aggregate (family level) consumption or overall nutritional "availability" in low-income households is mainly derived from concern about the nutrition or health status of members of such households, understanding how household aggregates map into the well-being and health of individuals, and how the household distributes its resources among its members, is critical. Indeed, there is evidence from both developing and developed countries that the intrahousehold distribution of resources is not equal across family members (Behrman et al., 1982; Rosenzweig and Schultz, 1982).

In this paper we consider how a change in a particular food or other price faced by a household affects nutrient consumption and the health of individual family members and assess the conditions under which inferences can be drawn about the health status of individual family members

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[1] This result pertains to uncompensated price elasticities for households whose food expenditures were greater than those of 75% of all households. For households in the 90th percentile, six of nine price elasticities had non-identical signs across the nine nutrients.

from information in commonly-available household aggregate consumption data. Unique data on farm households in Indonesia containing individual health and household food consumption information are used to obtain and compare estimates of (1) how changes in commodity prices and health program interventions alter (a) household nutritional intake and (b) the health status of individuals, and (2) how changes in the consumption of nutrients directly alter health.

II. The Model

We extend the conventional one-person farm household framework (Barnum and Squire, 1979) by incorporating (a) a health production "sector," (b) joint (non-separable) determination of production, consumption and health decisions and (c) multiple household members. The household, consisting of T individuals, maximizes the utility function

$$U = U(H, L, C_K, Z) \qquad U' > 0,\ U'' < 0 \quad (1)$$

where H, L, Z are, respectively, $1 \times T$ vectors of the health status H^i, leisure L^i, and consumption of non-foods Z^i for every family member i. C_K is an $n \times T$ matrix of the n foods consumed by each of the T family members. Health of the household members as well as food enter directly into the utility function because good health is desirable in itself and because foods are consumed for reasons other than their nutritional value.

The household maximizes (1) subject to several technology constraints. Central to the model is the biological health production function for each member i:

$$H^i = H(N^i, Y^i, G, x^i, \mu^i), \qquad (2)$$

where N^i is a $1 \times l$ vector of nutrients consumed by i which depend on his/her consumption of foods C_K^i, where $N_t^i = N_t^i(C_K^i)$, $t = 1 \cdots l$, Y^i is a vector of non-food health inputs which do not provide utility directly (medical services), G represents household resources which affect health (water, sanitation facilities) and the x^i are vectors of health-relevant personal characteristics of i that are observable (age, sex). The μ^i term represents the exogenous health endowment of the individual and environmental influences which affect health but cannot be influenced by the household. The health production function (2) thus depicts how health is directly affected by nutrient consumption, non-food health inputs and by factors beyond the household's or individual's control, the health environment.

The farm production technology is described by

$$Q_j = Q_j(F_j, F_j^o, X_j, A_j, k_j, H, u) \qquad j = 1 \ldots m \quad (3)$$

where Q_j = farm production of j^{th} crop, F_j is a $1 \times T$ vector of on-farm family labor, F_j^o = hired agricultural labor, X_j = vector of non-labor variable farm inputs, A_j = land under cultivation for crop j, k_j = capital used in production of the j^{th} crop, u = exogenous productivity characteristics of the environment. Note that the health of family members may affect farm productivity.

If each household member allocates his/her time to household and market activities and receives a wage rate W^i in the labor market, maximization of (1) subject to (2), (3) and the usual full income constraint yields, for each household, $n \times T$ reduced form demand equations for the foods allocated to each household member, $l \times T$ person-specific nutrient demand equations and T reduced form health equations, all of the form:[2]

$$\lambda^i = \psi_\lambda(P, P_z, P_y, G, W, W^o, K, P_x, x, u, \mu, V) \qquad (4)$$

where λ^i is the health status, H^i, food C_K^i or nutrient consumption N_t^i of individual i, P is a $1 \times n$ vector of food prices, P_z = price of non-foods Z, P_y = the price vector of non-food health inputs, W is a $1 \times T$ vector of market wages, W^o = price of hired labor services, K = total (household) agricultural capital stock, P_x = price vector of non-labor farm inputs, x and μ are vectors of the characteristics of all family members and V is non-earnings income.

Food consumption and health are thus functions of *all* goods prices (P, P_y, P_z) and of the characteristics of all family members (x); comprehensive price information is important for understanding the determinants of both food consumption and health. Moreover, for farm households, prices of farm inputs and the agricultural environment u also condition the demand for foods, health inputs and health. In the special case

[2] An individual's health may also influence the wage rate he or she receives, as depicted in Pitt and Rosenzweig (1984) and Deolalikar (1984). We treat the (head's) wage as endogenous in our estimates below because of this possibility.

commonly assumed in the estimation of farm household models (Lau, Lin, and Yotopoulos, 1978; Barnum and Squire, 1979) in which household and farm-allocative decisions are separable, input prices affect household decisions only via their effect on farm profits. In that case farm profits can replace the set of input prices in equation (4) as one exogenous component of income, and food price effects (whether or not the foods are also produced) are interpretable as in the standard (non-farm) model. When consumption and farm production decisions are not separable, due to absent or imperfect markets for farm inputs, however, profits are jointly determined along with the consumption set.

No prior studies of farm household expenditure systems have provided estimates of the individual-specific commodity (nutrient) demand or health equations (4); rather the estimating equations aggregate foods over all household members (e.g., Pitt, 1983; Strauss, 1983). Since the price structure pertaining to commodities is the same for each household member i, such aggregation is permissible (Hicks composite good theorem) and the usual restrictions of demand theory (symmetry, negative own compensated price effects) apply to the household aggregations. However, little can be inferred from theory or aggregated food consumption estimates about how a food price change facing a household affects the food consumption of the *individual* members of that household or about the health impact of food price changes.[3] The theoretical ambiguity with respect to the effects of a particular food price change on the level and composition of nutrient or food consumption at the household-level, arising from theoretically-unsigned cross price effects, is well known. With respect to the effects of food price changes on the health status of individual family members, however, additional ambiguities arise because of lack of information on how the household distributes food (nutrients) or other resources to each household member i in response to a food price change (equation (4)) and on how foods or nutrients affect health for each individual (equation (2)).

With measures of health for individuals, however, estimates of the health reduced-form equations may be obtained, given suitable price variability. Such reduced-form estimates yield information on how changes in the price of foods, medical services and other goods result in changes in health or nutritional status. Reduced-form health estimates obtained for different members of the same family also allow a test of whether family members, identified by observable traits x^i, are viewed as identical by the household, since in that case 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. However, if that technology is linear in foods or nutrients, with aggregate, household-level information on food or nutrient consumption and the individual health measures, the (linear) health technology parameters can be estimated without any assumptions about how households distribute resources among their members.

III. The Data and Estimation Procedures

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), provides information for a national probability sample of farm households on itemized weekly household consumption expenditures, water sources, land ownership, farm profits and, for each household member, information on the incidence and severity of illness in the seven-day period preceding the survey, 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

[3] Predictions can be made with respect to the effects of *person-specific* price changes (e.g., wage rates) on person-specific consumption or leisure, as in household labor supply studies and in Rosenzweig and Schultz (1982). All individuals within a household face the same food price change, however. Parameterization of the household's utility function (1) and the individual-specific production functions (2), and specification of the relationships among the observed characteristics of individuals x and the preference and technological parameters might also permit inferences about individual-specific consumption from aggregate household data. However, closed form solutions from household models incorporating reasonably flexible functional forms for both preferences and the household health technology are difficult to obtain. Complexity is increased if household size and structure are endogenous.

on health program availability, sources of water and attributes of the nonfarm labor market.

We selected a sample of farm households having both a head (always male in the data) and spouse and estimate the health effects of variations in prices, income and programs for these two family members. While tests of within-family equality in health price effects are thus restricted to only this subset of family members, information on health/food consumption relationships are obtained using information on the illness incidence among all household members, as discussed below. The number of sample households used in the analysis is 2,347.[4]

Wages for the head (male in all sample households) were computed based on wage equations estimated from a sample of all household members aged ten years and above, stratified by sex and corrected for selectivity bias.[5] The least squares correction for selectivity bias was applied (Olsen, 1980). Variables measuring land ownership and irrigation were used to identify the selectivity correction in the wage equations. To achieve identification of the health equations using predicted wages, kabupaten-specific measures of industrial capital and manufacturing workers per-capita, derived from a 1978 survey of manufacturing establishments, were included as regressors in the individual wage equations.

To maintain tractability, the 112 separate expenditure items detailed in the SUSENAS were aggregated into 13 commodity groups based on their nutrient homogeneity: 11 foods plus an aggregate of tobacco/betel and tobacco/spice mixtures (which are "chewed" and smoked, respectively) 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. Price indices are computed 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 11 food commodities were converted into nine nutrients (calories, proteins, fats, carbohydrates, calcium, phosphorous, iron and vitamins A and C) based on the nutrient coefficients specific to foods grown in Indonesia (Direktorat Gizi, Departemen Kesehatan RI, 1981).

The absence of complete data on non-food prices (other than fuel or tobacco) means that we must impose the assumption that foods and non-foods other than health are separable in (1). However, 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, or public lavatory to reflect the cost of medical services and the health environment. Data sources for all the areal variables are described in Pitt and Rosenzweig (1984). A table listing the characteristics and definitions of all variables used in obtaining the estimates presented below is available from the authors.

While a principal advantage of the SUSENAS data set is the availability of individual-specific illness information, the measures of health provided have two significant shortcomings. First, the shortness of the reference period (one week) means that illness will be an infrequent event and thus an insensitive indicator of health or nutritional status; indeed only 3.4% of household heads and 2.7% of their wives report having had an illness in the reference week.[6] Second, illness is self-reported and thus may vary in the sample not only because of differences in individual-specific consumption and heterogeneity in biological endowments (μ in the model) but also because of differences in subjective "sensitivity" to illness symptoms and in propensities to report them. While village-level food prices and the presence of health programs are unlikely to be correlated with the individual-specific unobservables, the associations between personal attributes (age, education, sex) and re-

[4] Less than 5% of households did not have both a head and spouse; to test for the equality of individual-specific reduced-form health equations across other family members (e.g., boys vs. girls), would have required severe sample selection and reductions in sample size.

[5] While over 50% of all farm heads reported a market wage during the survey period, less than 20% of farm wives worked off the farm and less than 10% of children participated in the wage labor market. Selectivity-corrected wife's wage effects were not statistically significant in any of the estimated equations. All specifications reported thus include only the (predicted) head's wage. The wage and selectivity correction estimates are reported in Pitt and Rosenzweig (1984).

[6] Respondents evidently reported that they were ill only if the illness symptoms were relatively severe. Two-stage least squares estimates indicated that farm heads with an illness worked a statistically significant 50 hours per week less than farm heads not reporting any illness.

ported illness may reflect in part such heterogeneity.

IV. Results: Price and Environmental Effects on Nutrition and Health

A. Determinants of Per-Capita Household Nutrient Consumption

Estimation of the effects of food prices and the health infrastructure on per-capita farm household consumption requires attention to two issues—the separability of production and consumption and heterogeneity across households in family composition. With respect to the former, Wu/Hausman (1974, 1978) tests, as well as structural estimates of the effects of the farmer's health on farm profits, reported in Pitt and Rosenzweig (1984), could not reject the production/consumption separability hypothesis, evidently because of reasonably well-functioning factor markets in Indonesia. Consequently, farm profits are treated as an exogenous variable in the set of nutrient demand equations.

One of the implications of the multi-member household model is that per-capita aggregate household consumption will depend on the set of characteristics x of family members.[7] Accordingly, we include among the profit, price and health environment regressors the sex composition (proportion male), mean age and the mean of the squared age of household members, as well as the education and ages of the head and head's wife and the head's wage rate. While almost all studies of household demand systems treat household composition as exogenous (Pollak and Wales, 1981), many studies have also shown that the number of children in a family is endogenously related to both measures of family resources and to health and family planning programs (Rosenzweig and Wolpin, 1982). In our data, the mean age of households is significantly related to the set of food price, wage rate and infrastructural variables (F-test, 0.01 level) and the Wu/Hausman test rejects the hypothesis, in all nutrient equations, that the age variables are orthogonal to the nutrient consumption residuals. Accordingly, all nutrient demand equations are conditioned on the age and sex composition variables and are estimated using two-stage least squares (2SLS), with mean age and mean age squared treated as endogenous variables. The proportion of villages in the relevant kabupaten with family planning clinics and/or maternity hospitals are the identifying instruments.[8]

Tables 1 and 2 report the reduced-form estimates for the nine nutrients. Table 1 displays the matrix of uncompensated price, wage and farm profit elasticity estimates; table 2 provides the estimates of the effects of the health infrastructure and family characteristic variables. F-tests applied to each of the nine equations indicate that for all nutrients the sets of prices, the water-source and the family composition variables are all statistically significantly related to per-capita nutrient consumption at at least the 0.05 level of significance. Neither the hospital nor health clinic variables attained statistical significance except in the case of the consumption of fats, however.

In table 1, in common with other studies of nutrient demand systems, generally no food price unambiguously affects nutrient demand in one direction. The one exception here is the price of milk, for which all nutrient price elasticities are negative and all but one (fats) are statistically significant. While this result would appear to suggest that milk price supports, a pervasive policy, might be harmful to health, as noted, the health effects of changes in any food price will depend on the relative magnitudes of the price effects on the individual nutrients and on the relative importance of the different nutrients in the production of health. These latter relationships are estimated below.

[7] Estimates by Pitt (1983) of food and nutrient price elasticities in Bangladesh were obtained in the absence of information on household composition.

[8] The per-capita nutrient consumption (and health) equations estimated are assumed to be linear approximations to the relevant reduced form equations. Estimates of equations specified in terms of the underlying preference and technology parameters would require not only closed form solutions for demand equations from a fully parameterized model but also attention to the existence of multiple "corner solutions" among households in foods consumed. Solution to these issues lies outside the scope of this paper, and have not been addressed in prior studies. Estimates of the (linear) health technology parameters are reported below. We have also ignored the possibility of household economies of scale (e.g., in food preparation); thus family size does not appear as an endogenous right-hand side variable in the specification of the health production function.

TABLE 1.—2SLS ESTIMATES OF PER-CAPITA HOUSEHOLD NUTRIENT PRICE AND FARM PROFIT ELASTICITIES

	Calories	Protein	Fat	Carbohydrates	Calcium	Phosphorous	Iron	Vitamin A	Vitamin C
Price of:									
grains	0.0781	−0.129	0.0916	0.105	0.350	−0.125	0.167	0.128	0.348
	(0.81)	(1.29)	(0.75)	(1.03)	(2.82)	(1.36)	(1.55)	(0.75)	(2.17)
tubers	−0.0284	0.101	0.116	−0.0612	−0.0452	0.0662	0.0374	0.00748	−0.00295
	(1.28)	(4.37)	(4.12)	(2.23)	(1.58)	(3.12)	(1.51)	(0.19)	(0.08)
fish	0.0451	−0.113	−0.182	0.0895	−0.228	−0.0379	−0.0727	−0.0368	0.00769
	(1.27)	(3.05)	(4.03)	(2.39)	(4.96)	(1.11)	(1.82)	(0.58)	(0.13)
meat	−0.122	−0.102	0.00402	−0.139	−0.137	−0.0938	−0.105	0.0517	−0.101
	(1.94)	(1.55)	(0.05)	(2.10)	(1.70)	(1.56)	(1.49)	(0.46)	(0.96)
milk	−0.0968	−0.0788	−0.0375	−0.107	−0.0971	−0.0864	−0.125	−0.180	−0.222
	(2.75)	(2.16)	(0.84)	(2.88)	(2.14)	(2.57)	(3.18)	(2.90)	(3.78)
vegetables	−0.00068	0.00226	0.0340	−0.00916	−0.104	0.0152	−0.0685	−0.197	−0.207
	(0.03)	(0.93)	(1.15)	(0.38)	(3.47)	(0.69)	(2.63)	(4.80)	(5.34)
legumes	−0.0561	−0.0323	0.0609	−0.0733	−0.0596	−0.0377	−0.140	−0.155	−0.0480
	(0.90)	(0.50)	(0.78)	(1.13)	(0.75)	(0.64)	(2.03)	(1.46)	(0.47)
fruits	0.0470	0.0294	0.0727	0.0457	0.0487	0.0293	0.0604	0.0113	−0.0645
	(2.11)	(1.27)	(2.57)	(1.96)	(1.70)	(1.38)	(2.42)	(0.29)	(1.74)
sugar	0.109	0.0698	−0.109	0.138	0.0528	0.0725	−0.109	−0.229	−0.132
	(0.95)	(0.58)	(0.75)	(1.14)	(0.35)	(0.66)	(0.84)	(1.20)	(0.69)
veg. oils	0.00838	−0.0644	−0.378	0.0631	0.00241	−0.0322	−0.0604	−0.123	−0.0795
	(0.17)	(1.24)	(5.96)	(1.20)	(0.04)	(0.67)	(1.08)	(1.39)	(0.95)
tobacco/ betel	−0.0449	−0.0325	−0.0256	−0.0475	0.0343	−0.0524	0.0369	−0.0736	0.0245
	(1.10)	(0.77)	(0.49)	(1.11)	(0.65)	(1.35)	(0.81)	(0.10)	(0.36)
fuels	0.0206	0.0290	0.0189	0.0197	0.00322	0.0226	0.0361	0.0000	0.0203
	(2.19)	(2.96)	(1.58)	(1.99)	(0.26)	(2.51)	(3.42)	(0.00)	(1.29)
head's wage	0.192	0.240	0.341	0.170	0.365	0.223	0.159	0.317	0.257
	(2.65)	(3.19)	(3.71)	(2.23)	(3.91)	(3.23)	(1.96)	(2.48)	(2.13)
Profit	0.00731	0.0122	0.0198	0.00668	0.0168	0.00980	0.0179	0.0245	0.0274
	(3.39)	(4.69)	(6.27)	(2.55)	(5.22)	(4.11)	(6.43)	(5.56)	(6.61)

Note: Asymptotic t-values are in parentheses.

TABLE 2.—2SLS ESTIMATES OF HEALTH PROGRAM, WATER SOURCE, SCHOOLING ATTAINMENT AND AGE STRUCTURE EFFECTS ON PER-CAPITA HOUSEHOLD NUTRITION CONSUMPTION

	Calories	Protein	Fat	Carbohydrates	Calcium	Phosphorous	Iron	Vitamin A	Vitamin C
Hospitals ($\times 10^3$)	−9.18	0.234	0.356	−3.29	−0.210	1.08	0.00197	47.0	1.12
	(0.53)	(0.59)	(1.47)	(0.90)	(0.07)	(0.15)	(0.02)	(0.80)	(1.10)
Clinics ($\times 10^3$)	−27.9	0.649	0.903	−9.49	9.36	−0.0903	0.138	−15.5	0.268
	(0.96)	(0.97)	(2.23)	(1.55)	(1.83)	(0.01)	(0.78)	(0.16)	(0.16)
Lavatories	−4.12	−0.508	−0.298	0.225	1.91	−8.49	0.0522	22.9	0.974
($\times 10^3$)	(0.53)	(2.82)	(2.73)	(0.14)	(1.39)	(2.62)	(1.11)	(0.86)	(2.11)
Well or pump	−10.7	0.113	0.0732	−2.94	−1.58	0.768	0.0437	−1.38	0.154
($\times 10^3$)	(2.60)	(1.19)	(1.27)	(3.37)	(2.17)	(0.45)	(1.75)	(0.10)	(0.63)
River ($\times 10^3$)	−12.3	0.0189	−0.0108	−3.08	−2.51	−0.620	−0.0808	−19.7	−0.0310
	(2.00)	(0.13)	(0.13)	(2.37)	(2.31)	(0.24)	(2.17)	(0.94)	(0.09)
Head's education	−11.6	−0.0895	−0.000761	−2.77	−1.43	−3.10	0.0373	28.0	0.560
($\times 10^2$)	(1.25)	(0.42)	(0.01)	(1.41)	(0.87)	(0.81)	(0.66)	(0.88)	(1.02)
Wife's education	−19.2	0.0628	0.297	−5.26	−0.363	−4.12	0.0193	10.9	1.32
($\times 10^2$)	(1.40)	(0.20)	(1.55)	(1.82)	(0.15)	(0.73)	(0.23)	(0.23)	(1.63)
Head's age	−19.0	−0.310	−0.142	−4.11	−3.76	−6.77	−0.0957	−70.7	0.789
($\times 10^2$)	(2.02)	(1.43)	(1.08)	(2.07)	(2.26)	(1.74)	(1.68)	(2.20)	(1.42)
Wife's age	−1.68	−0.0239	−0.0896	−0.290	−2.88	−0.927	−0.0544	−1.15	−1.27
($\times 10^2$)	(0.11)	(0.67)	(0.42)	(0.09)	(1.06)	(0.14)	(0.58)	(2.19)	(1.40)
Mean household	−90.0	−1.76	−0.106	−19.7	−0.350	−34.6	−0.0702	4.63	5.11
age ($\times 10^2$)[a]	(1.24)	(1.05)	(0.10)	(1.28)	(0.03)	(1.15)	(0.16)	(1.89)	(1.19)
Mean household	1.01	0.0310	0.00659	0.348	0.127	0.628	0.00414	−2.54	−0.0273
age^2 ($\times 10^2$)[a]	(2.52)	(2.10)	(0.74)	(2.58)	(1.18)	(2.37)	(1.07)	(1.16)	(0.72)
Proportion males	87.2	1.63	1.85	16.1	12.6	40.5	0.0609	5.73	6.57
($\times 10^2$)	(0.75)	(0.61)	(1.15)	(0.66)	(0.62)	(0.84)	(0.09)	(1.45)	(0.96)

Note: Asymptotic t-values are in parentheses.
[a] Endogenous variable.

A few other patterns are evident in table 1. Generally, a rise in the price of a food that is intensive in a nutrient will result in a decline in the consumption of that nutrient. Thus, increases in the price of tubers significantly reduce the per-capita consumption of carbohydrates, increases in the prices of meat, milk and fish reduce household protein consumption, increases in the prices of fruits and vegetables reduce the consumption of vitamin C, and increases in legumes and vegetable prices lower per-capita vitamin A consumption in the household. Farm profit and wage elasticities are positive and statistically significant in all nutrient demand equations; however, the profit elasticity estimates are quite low and significantly lower than the wage elasticities.[9] The small nutrient farm profit elasticities may be due to the aggregation of foods, if most of the dietary response occurs within food categories. The estimates may also suggest, however, that food consumption responds to income changes mainly as a result of shifts in preference for non-nutrient qualities of foods (Behrman and Wolfe, 1984) and that such shifts can occur with little change in nutrient composition. Finally, fuel and nutrient consumption appear to be substitutes, as an increase in fuel prices appears to induce a rise in the per-capita consumption of all nutrients.

The estimates reported in table 2 indicate that while the household's principal source of drinking water significantly affects its choice of nutrients, for given prices, as in the case of food prices, no clear pattern of water source effects is evident. The household's age-composition also affects aggregate household nutrient consumption, with the relationships between nutritional intake and age displaying an inverted U-shape for calories, protein, carbohydrates and phosphorous. For the latter three nutrients, consumption appears to peak at age 28; while calorie consumption peaks at age 45. Consistent with the popularity in Indonesia of the infant dish *nasi tim*, a vegetable/rice combination, consumption of vitamin A appears to reach a maximum at age one. The result rejects the hypotheses, however, that the sex composition of the household or the educational attainment of the head or the head's wife affect the aggregate household diet.

[9] The farm profit elasticities were only slightly increased when profits were estimated using instrumental variables (with type of irrigation serving as an instrument) to eliminate any errors-in-variables bias.

B. Determinants of Illness among Farm Heads and Farm Wives

To ascertain whether the effects of food prices and the water source variables on household nutrient consumption levels are also significantly reflected in the health of family members, we utilize the survey information on illness for the farm head and his wife. 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 $y^i = X\beta + u^i$ $i = 1, \ldots, N$, where $N =$ number of individuals in sample, y^i is a latent variable, X is the set of household and individual-specific 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, reported in columns 2 and 3 in table 3, yield positive and statistically significant values for the parameter λ for both the head of household and his wife, confirming the ordered specification.

In contrast to the results from the aggregated household nutrient demand equations, many of the parameters of the sex-specific illness reduced forms for the two principal household members are imprecisely estimated. However, a likelihood ratio test indicates that the slope parameters in the equation for heads, but not for wives, are jointly different from zero at the 0.05 level of significance. Another important contrast with the nutrient price elasticity results is that a number of food prices emerge as important determinants of health. The estimates of table 3 indicate that the prices of grains, sugar, vegetables and vegetable oil are significantly related to illness incidence among farm heads, with the former two prices negatively related to illness and the latter positively related to illness. At the sample means, the estimates suggest that a 10% reduction in the prices of vegetables and vegetable oil will decrease the probability of illness by 4.2% and 9.3%, respectively, while similar proportional decreases in the prices of grains and sugars will increase the incidence of illness by 15% and 25%. Interestingly, despite the price of

TABLE 3.—MAXIMUM LIKELIHOOD POLYTOMOUS PROBIT AND FIXED EFFECT LOGIT ESTIMATES: INDIVIDUAL ILLNESS AND ILLNESS DISTRIBUTION (HEAD AND WIFE)

Variable/Estimation Procedure	Head Ill Ordered Probit	Wife Ill Ordered Probit	Head Ill/Wife Ill Fixed Effect Logit
Farm profits ($\times 10^{-5}$)	0.1000	−0.0000	0.756
	(0.97)	(1.10)	(1.54)
Owned land ($\times 10^{-2}$)	−0.00071	3.47	−0.0119
	(1.28)	(1.01)	(0.51)
Age, head ($\times 10^{-2}$)	0.499	0.876	0.00785
	(0.54)	(0.84)	(0.01)
Age, wife	0.00721	0.00299	0.00181
	(0.71)	(0.27)	(0.01)
Education, head	0.0603	0.02441	0.0965
	(2.20)	(0.84)	(0.90)
Education, wife	−0.0573	0.0347	−0.174
	(1.70)	(1.01)	(1.32)
Wage, head	−0.0741	−0.0701	−0.106
	(1.42)	(1.35)	(0.50)
Price of grain	−0.520	0.0687	−1.20
	(1.62)	(0.21)	(0.87)
Price of tubers	−0.0312	0.191	−0.909
	(0.14)	(0.94)	(1.03)
Price of fish	−0.0256	0.111	−0.444
	(0.49)	(2.40)	(2.01)
Price of meat	0.0164	0.0291	0.0478
	(0.55)	(0.97)	(0.40)
Price of milk	0.0162	−0.0227	0.162
	(0.81)	(0.97)	(1.78)
Price of vegetables	0.168	−0.0930	0.899
	(2.27)	(0.81)	(2.30)
Price of legumes	0.0866	0.0755	0.118
	(1.00)	(0.91)	(0.34)
Price of fruit	0.0821	0.118	−0.245
	(0.88)	(1.24)	(0.74)
Price of other foods	0.0187	0.00574	0.139
	(0.56)	(0.16)	(0.92)
Price of vegetable oil	0.0814	0.0194	−0.0163
	(1.67)	(0.40)	(0.08)
Price of sugar	−0.489	−0.172	−0.384
	(1.94)	(0.68)	(0.30)
Price of tobacco	0.185	−0.105	0.996
	(1.13)	(0.61)	(1.58)
Price of fuel	0.00216	−0.00278	−0.00129
	(0.28)	(0.34)	(0.36)
Well	0.112	−0.191	0.816
	(0.78)	(1.36)	(1.50)
River	0.189	−0.246	1.30
	(1.06)	(1.31)	(1.65)
Hospital	−0.0399	0.0679	0.581
	(0.06)	(0.11)	(0.23)
Clinic	1.73	−1.03	10.1
	(1.78)	(0.95)	(2.05)
Maternity hospitals	−0.867	−0.185	−1.86
	(1.26)	(0.27)	(0.75)
Family planning	−0.269	−0.582	1.30
	(0.84)	(1.77)	(0.93)
Public lavatories	−0.00006	0.00005	−0.900
	(0.37)	(6.25)	(0.76)
Households	−0.00013	0.00025	−0.00173
	(0.58)	(1.10)	(1.75)
Constant	−1.57	−2.40	0.334
	(1.87)	(2.83)	(0.09)
−2 ln likelihood	49.3	28.3	35.93
$\lambda > 0$, t-statistic	5.62	4.57	—

Note: Asymptotic t-values are in parentheses.

milk being unambiguously associated negatively and significantly with all nutrients, alterations in the price of milk do not appear to have significant effects on short-run illness. The two sets of results imply, among other hypotheses, that those nutrients most sensitive to milk price changes may be relatively unimportant in determining the types of illness reported in our data, a hypothesis tested in the next section.

To test the hypothesis that the illness probabilities of the head and his wife respond equally to price changes and to alterations in the health infrastructure, we subtract the wife's illness reduced form from that of her husband and estimate the resulting model using maximum likelihood logit. As Chamberlain (1980) has shown, such a model provides consistent estimates of, in our case, differences in the parameters across the two person-specific reduced forms. 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 3. A likelihood ratio test fails to reject (at the 0.05 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 ($\chi^2(29) = 35.93$). 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 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.

V. The Illness Production Function: Nutrient Intake and Illness Incidence

As noted, if the relationships between an individual's consumption of nutrients and health are linear, the aggregate household nutrition data and individual health information can be used to estimate the output coefficients of the person-specific health production functions, without any assumption about the allocation of household resources across individuals, by summing the linear health production functions for all the individuals residing in the household. 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—water sources and the schooling attainment of the head and wife—which may affect the health of all individual family members net of their own individual consumption of foods.

All variables except the public good inputs 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 (where there are no observations). The Tobit estimation procedure is therefore employed. Because of possible heterogeneity in health endowments, health perceptions, and in environmental factors that influence both consumption decisions and health (see equations (2) and (4)), which would bias these single-equation estimates, the health production function is estimated using two-stage Tobit, where the endogenous food and other inputs are first regressed on all of the exogenous price and program variables (Rosenzweig and Schultz, 1983). 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 4 presents both Tobit and two-stage-Tobit estimates of the linear household production function. Heterogeneity bias arising from differences in unobserved environmental and family health endowments evidently importantly contaminate the single stage estimates, as the differences between the magnitudes of the Tobit and the two-stage-Tobit estimates are quite striking. For example, the two-stage-Tobit estimate of the negative effect of calcium intake on illness incidence is almost ten times the size of that estimated using single-stage

TABLE 4.—MAXIMUM LIKELIHOOD TOBIT AND INSTRUMENTAL VARIABLES TOBIT ESTIMATES

Variable/Estimation Procedure	Tobit		IV-Tobit	
	Coefficient	Asymptotic t-value	Coefficient	Asymptotic t-value
Age[a]	−0.0119	2.29	−0.0796	3.32
Age^2 ($\times 10^{-2}$)[a]	0.0173	2.55	0.101	3.25
Calories ($\times 10^{-3}$)[a]	−0.0331	0.62	−0.923	3.25
Protein ($\times 10^{-2}$)[a]	0.0176	0.58	0.444	2.97
Fat ($\times 10^{-2}$)[a]	0.0284	0.62	0.806	3.26
Carbohydrates ($\times 10^{-2}$)[a]	0.0135	0.62	0.376	3.25
Calcium ($\times 10^{-4}$)[a]	−0.0504	1.15	−0.454	2.56
Phosphorous ($\times 10^{-4}$)[a]	−0.0146	0.15	−0.152	0.35
Iron ($\times 10^{-4}$)[a]	−0.0936	0.07	−4.14	0.79
Vitamin A ($\times 10^{-6}$)[a]	−0.0449	0.14	0.823	0.60
Vitamin C ($\times 10^{-3}$)[a]	0.00827	0.71	−0.146	2.51
Tobacco/betel ($\times 10^{-2}$)[a]	−0.0404	1.99	−0.184	1.94
Sex (male = 1)	−0.0457	0.54	−0.0248	0.29
Head's schooling	0.0152	2.69	0.0215	3.43
Wife's schooling	0.00130	0.20	−0.00158	0.22
Well	−0.0310	0.93	−0.0241	0.57
River	−0.0612	1.46	−0.0416	0.79
Constant	−0.270	3.08	0.578	1.39
− ln likelihood	716.2		711.6	

[a] Endogenous variable.

Tobit. Moreover, while the Tobit estimates indicate that vitamin C consumption has a small positive effect on illness, the two-stage estimates indicate that the consumption of vitamin C significantly reduces illness.

The consistent two-stage-Tobit estimates suggest that consumption of each of the vitamins and minerals reduces illness, with the exception of vitamin A (which is imprecisely estimated). In particular, *direct* dietary supplementation with calcium and vitamin C would appear effective in reducing illness—a 10% increase in the levels of calcium and vitamin C consumed would reduce the incidence (expected value) of illness by 21% and 17%, respectively, in Indonesian farm households. The results also suggest that, given nutrient consumption levels, males are *no* less likely to become ill than are females, while illness incidence declines with age up to age 38 and then increases.

Increased calorie consumption also significantly reduces the incidence of illness; however, the net effect of calorie consumption depends on the sources of the calories, since calories must be jointly consumed (in different proportions) with fat, carbohydrates and protein and the estimates suggest that the latter have differential effects on illness. For example, 100 grams of milled rice in Indonesia provide 360 calories, 6.8 grams of protein and 79 grams of carbohydrate; 100 grams of fish provide 143 calories, 18 grams of protein but only 0.29 grams of carbohydrates.

To use the nutrient production coefficients to ascertain the effects of any food (real or conjectured) on illness, all that is needed is information on its per-unit nutrient content since for any food C_K with nutrient coefficients a_{tK} ($a_{tK} = dN_t/dC_K$),

$$\frac{\partial I}{\partial C_K} = \Sigma_t \gamma_t a_{tK}, \tag{5}$$

where I = illness, γ_t = estimated health production coefficients, and $\gamma_t = \beta_t$ (.145), where the β_t are the estimated Tobit coefficients in table 4 (14.5% of households contained at least one person reporting an illness). For example, the estimates indicate that a 100 gram increase in spinach consumption per month would reduce the probability of illness by 5.1%, while a similar increase in milled rice consumption would reduce illness by only 1.2%, due to the high vitamin C and low carbohydrate content of the former and the high carbohydrate-intensity of the latter. Similarly, a 100 gram increase in monthly sugar consumption would *increase* illness propensities by 8.1%, while an increase of 100 grams in egg consumption would reduce the incidence of illness by 1.4%.

The health production results thus conform to the popular notions that, among foods, vegetables are "healthy" while consumption of sugar is bad for health. Interestingly, these technological properties of vegetables and sugar were reflected in the reduced form price effects on health of table 3, as increases in the prices of these two foods increased and reduced, respectively, illness incidence among male farmers. The simple (since they ignore the cross-price effects evident in table 1) notions that alterations in the prices of healthy or unhealthy foods would significantly affect illness appear to be supported by the (male) health reduced form and the health production function estimates.

One noted anomaly in the results of tables 1 and 3 is that, while the household nutrient demand equation estimates showed that increases in the price of milk would significantly reduce the farm household's consumption of all nutrients, the health reduced forms indicated that alterations in the price of milk had no effect on the illness reported by farm heads or their wives. We can trace out the effects of the milk price change on illness using the estimated nutrient price elasticities of table 1 and the (two-stage) nutrient production function coefficients of table 4, which weight the price-induced nutrient reductions according to their health effects. These estimates indicate that if a household member were to change his or her monthly nutrient consumption in response to a 10% increase in the price of milk in accordance with the household-level estimates of table 1, he or she would be 0.84% *less* likely to be ill. The estimated nutrient-consumption effects of a milk price change, based on the household nutrient aggregates, thus yield misleading information about the "average" health effects of changes in milk prices, evidently because the magnitudes and composition of nutrient reduction associated with milk price increases induce little net negative effect on health.

Finally, of the household-level variables, neither the wife's schooling nor the set of water source variables appear to be statistically significant. As in the health reduced forms, however, the head's educational attainment is positively associated with levels of reported illness incidence, again evidently reflecting a greater propensity by the more educated respondents to report illness in response to given illness symptoms. The subjective nature of the illness variables may also be reflected in the tobacco/betel coefficients; increased "consumption" of the tobacco/betel combination appears to significantly decrease reports of illness.

VI. Conclusion

In this paper we have used data on farm households in Indonesia to estimate the relationships among food prices, household nutrient consumption, and the incidence of illness among adults in the context of a multi-member household producing both farm output for sale and health. Estimates of the complete nutrient price elasticity matrix for households were shown to be insufficient for deriving policy conclusions concerning food price interventions designed to improve health. In particular, consistent with prior studies, our results indicated that almost all food price alterations, downward or upward, result in absolute declines in one or more nutrients consumed by farm households. Moreover, even in cases in which a food price change, through subsidization or taxation, unambiguously raises all nutrient levels, the impact on health cannot be known without additional information on the relative magnitudes of the nutrient consumption changes and their impacts on measures of health or well-being among individuals. We found that, while a fall in the price of milk in Indonesia would significantly raise the household availability of all nutrients, variations in milk prices were unrelated to the actual incidence of illness among farm heads and their wives. Estimates of the effects of nutrient consumption on illness probabilities indicated that this result was a consequence of the particular compositional changes in nutrient availability associated with the milk price change. In contrast, our estimates of individual illness equations suggested that increases in the price of sugar and reductions in the prices of vegetables and vegetable oils would significantly lower the incidence of illness among farmers. Consistent with this finding, estimates of the direct relationships between illness incidence and nutrient consumption indicated that, for the measures of illness available in our data, vitamins and minerals were at least as important as calorie consumption in affecting short-term health. However, we could find little evidence that measures of health service availability or water sources had any effect on adult illness, although farm household dietary intake appeared to be sensitive to the source of household drinking water.

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