Open access • Journal Article • DOI:10.1086/261375

Does Better Nutrition Raise Farm Productivity — Source link

John Strauss

Published on: 01 Apr 1986 - Journal of Political Economy (The University of Chicago Press)

Topics: Sierra leone and Efficiency wage

Strauss, John

Working Paper

Does Better Nutrition Raise Farm Productivity?

Center Discussion Paper, No. 457

Provided in Cooperation with:
Yale University, Economic Growth Center (EGC)

Suggested Citation: Strauss, John (1984) : Does Better Nutrition Raise Farm Productivity?, Center Discussion Paper, No. 457, Yale University, Economic Growth Center, New Haven, CT

This Version is available at:
http://hdl.handle.net/10419/160381

ECONOMIC GROWTH CENTER

YALE UNIVERSITY

P.O. Box 1987, Yale Station
27 Hillhouse Avenue
New Haven, Connecticut 06520

CENTER DISCUSSION PAPER NO. 457

DOES BETTER NUTRITION RAISE FARM PRODUCTIVITY?

John Strauss

May 1984

Abstract

Does Better Nutrition Raise Farm Productivity?

John Strauss

Household-level data from Sierra Leone are used to test whether higher caloric intake enhances family farm labor productivity. This is the notion behind the efficiency wages hypothesis, which has found only weak empirical support. A farm production function is estimated, accounting for the simultaneity in input and calorie choice. An agricultural household model is used to develop a proper set of instruments, which include prices, household characteristics, and farm characteristics. The latter two sets of instruments are later dropped to explore the robustness of the results to different specifications of exogeneity. A variety of ways are explored in which calories might enter the production function, the results being quite robust to these. The exercise shows a highly significant effect of caloric intake on labor productivity, providing the first solid support of the nutritional-productivity hypothesis.

DOES BETTER NUTRITION RAISE FARM PRODUCTIVITY?*

1. Introduction

The potential interrelationships between labor productivity and nutrition (or more generally, health) have been the focus of economists' interests for some years. The idea that higher market and/or farm productivity should help to determine nutritional status is an old one. Recently there has been an increase in work exploring this relation, including Pitt (1983), and Strauss (1982, 1984a). The reverse relation, that better nutrition (health) may improve labor productivity has spawned an important theoretical literature, the efficiency wages hypothesis, on the possible labor market consequences.[1] The empirical research on the efficiency wages hypothesis has been indirect, and has found mildly negative evidence (see Binswanger and Rosenzweig, 1984, for a useful survey). The empirical evidence on the underlying nutritional (health) labor productivity hypothesis has also been weak, most of it focusing on the productivity of plantation workers. Attempts to test for and quantify the relationship between nutrition and labor productivity for family farms have been nonexistent, despite the overwhelming importance of family farms in developing country agriculture. Indeed Bliss and Stern (1978, p. 390) conclude in their survey on the efficiency wages hypothesis "... We should not be dogmatic. We suggest, however, that an attempt to tease something out of the data, which is much more delicate than the crude production function, with all the problems attendant to that simple exercise, will not be justified..."

This paper reports an attempt to test and quantify the effects of current nutritional status (annual caloric intake) on annual farm production, and hence

---

*The author gratefully acknowledges the very helpful comments of David Feeny, Mark Rosenzweig, T. Paul Schultz and Victor Smith, as well as from seminar participants at the University of Minnesota and Yale.

labor productivity, using farm household level data from Sierra Leone. A farm household model (see Strauss 1984b, for a survey) is developed and used to specify appropriate instruments for both caloric intake and variable farm inputs, which are then used to estimate a farm production function. The results show a highly significant and sizable effect of caloric intake on farm output, even after accounting for its endogeneity, as well as the endogeneity of variable farm inputs. Moreover both the significance and size of the calorie effects are reasonably robust to the ways in which calories enter the production function; to different assumptions concerning the substitutability of family and hired labor; and to assumptions concerning the exogeneity of farm and household assets.

2. Review of Some Empirical Studies

Earlier empirical studies investigating nutrition (health) — labor productivity links have focused on individual workers, usually on plantations. Experimental studies using a low and a high calorie diet supplement have been conducted on Guatemalen sugarcane cutters (Immink and Viteri, 1981 a, b; Immink, Viteri and Helms, 1982), and on Kenyan road construction workers (Wolgemuth et. al., 1982). These studies measured average labor productivity, finding either weak or no effects of energy supplementation on labor productivity.

In a non-experimental study, Baldwin and Weisbrod (1974) and then Weisbrod and Helminiak (1977) investigated the effects of disease on the weekly earnings, daily wages, and weekly labor supply of plantation workers on St. Lucia. They found some evidence of a negative relation between daily wages and schistosomiasis for male workers, but conclude that "...parasitic infection appears to cause few statistically significant adverse effects on agricultural labor productivity...[2]

The strength of these experimental and non-experimental studies lies in their relatively good data on individual disease incidence, caloric intake or stature. The experimental studies suffer from not controlling, either in the experimental design or in the statistical analysis, for important economic variables such as food prices, wage rates and farm profits. Individuals will vary their consumption of foods and nonfoods at home in response to a diet supplementation at work (the experimental studies all report this to occur). Individuals also presumably vary their labor supply to equalize marginal returns to different activities. If higher productivity is not rewarded with a comensurately higher wage, the increased energy intake may be used on farm on home production activities. If assignment to experimental groups is not randomized on variables capturing opportunity costs the labor supply results will be confounded. Moreover there may be intrafamily substitution in food consumption, resulting in higher intakes for other family members. None of these effects are captured by the experiments, and all are potential reasons why only very weak effects are found.

An additional weakness of the experimental studies is that non labor inputs are not controlled for, the productivity data used being average labor productivity. Most fundamentally perhaps, both the nonexperimental studies and the statistical analyses which use only baseline data from the experiments suffer because the direction of causation is unclear; more productive (less sick) workers may earn more, hence eat more (have less disease).[3] Likewise, the labor supply results are potentially marred by not controlling for selectivity bias, the possibility that extremely sick (malnourished) workers may not work at all, hence not be in the sample.

To measure the impact of nutrition (health) on labor productivity one should explicitly account for the level of other inputs, as is done in a production function. To account for simultaneity in nutritional status, and perhaps other inputs, instrumental variables are needed. Such variables can only be determined from a theoretical model. One such model which is well suited for this purpose is the agricultural household model.

Pitt and Rosenzweig (1984) use an agricultural household model to explore effects of illness on farm profits and labor supply, but not on the farm production function, for a set of Indonesian households. They find no statistically significant effects of family illness on profits, but do find such an effect of illness on male labor supply. The absence of an effect of family illness on farm profits need not imply that it does not affect farm production. If family and hired labor were perfect substitutes and households faced a fixed wage, then the demand for healthy labor can be met by hiring or selling more labor at that constant wage. Consequently the farm production function might show an effect, but farm profits would not.

3. Model

Farm households produce some of the commodities which they consume. In modeling their behavior the interrelationships between consumption and production need to be accounted for. This is the essence of agricultural household models. Such models have a general structure of maximizing a household utility function subject to farm production function, time, and budget constraints. There are differences between models which result from different assumptions regarding the existence and competitiveness of markets, or from corner solutions for commodities which are both consumed and produced (see Strauss, 1984b). Here it will be assumed that perfectly competitive markets for all commodities exist, and that food consumption out of home production and out of market purchases are perfect substitutes. Family and hired labor will, however, be allowed to be imperfect substitutes.

The utility function can be written as

$$U(X_F^c, X_N^c, X_L^c, Z) \tag{1}$$

where $X_F^c \equiv$ household consumption of food[4], $X_N^c \equiv$ household consumption of nonfoods, $X_L^c \equiv$ household consumption of leisure, and $Z \equiv$ household assets such as size, age and sex composition, and education, all for the moment being considered as fixed. Since the caloric consumption which potentially matters is at the individual level, a model explaining food consumption of individuals would be better. One could move towards such a model by indexing the household consumption variables by individuals. Since the available data are at the household level, however, this will not be pursued.

The farm production function can be written as:

$$X_F = F(L_F^e, L_H^e, V, K, A) \tag{1a}$$

where $X_F \equiv$ production of foods, $L_F^e \equiv$ effective family labor, $L_H^e \equiv$ effective hired labor, $V \equiv$ non-labor variable inputs, $K \equiv$ physical capital, and $A \equiv$ land acreage.

Effective labor, both family and hired, is a function of calorie intake (or health) at the individual level, and hours worked. It is the inflow of calories during the current year which is hypothesized to affect annual effective labor. No attempt is made to measure effects of deficiencies that occured long ago, a stock effect, though to the extent that current and past intakes are correlated the joint effects are being captured. In specifying effective labor the efficiency wages literature is followed (Bliss and Stern, 1978a,b) by making effective labor the product of labor hours and a function relating efficiency per hour worked to caloric intake:[5]

$$L_F^e = h(k_F X_F^c) L_F \qquad (1b)$$

$$L_H^e = h(k_H Y_F^c) L_H \qquad (1c)$$

where $L_F \equiv$ hours of family farm labor, $L_H \equiv$ hours of hired farm labor, $Y_F^c \equiv$ household food consumption of hired labor, and $k_i \equiv$ a factor converting household family (F) or hired (H) labor annual food consumption into calories per laborer per day. These conversion rates have two components: a conversion of annual household food consumption into average daily household caloric availability, and a conversion of household calories into a per laborer equivalent. The rates may differ between family and hired labor because either of the two components may differ.

The efficiency per hour worked function, $h(\cdot)$, is often hypothesized to have a portion which is increasing at an increasing rate followed by a portion increasing at a decreasing rate. It can begin at the origin or from a positive caloric intake.[6] Figure 1 provides an illustration.

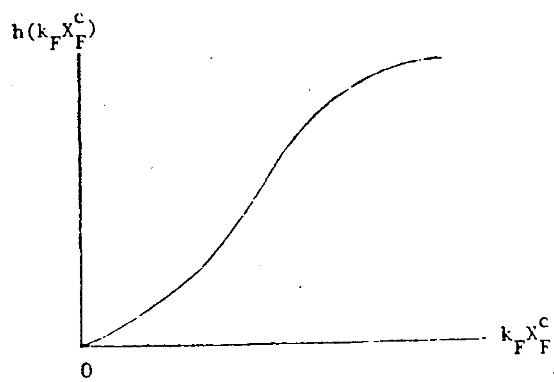

Figure 1

The household time constraint simply equates total non-sick time available to farm work plus off-farm work plus leisure. Following Grossman (1972) total non-sick time available is allowed to be a function of average individual-level caloric intake (health):

$$T(k_F X_F^c) = L_F + L_0 + X_L^c \tag{1d}$$

where $T(\cdot) \equiv$ total non-sick household time available, $T' \geq 0$; and $L_0 \equiv$ hours of off-farm labor.

Finally the budget constraint may be written as the value sum of agricultural production sold, family labor sold and any exogenous income equals the value sum of purchased farm inputs and nonfoods consumption.

$$p_F(X_F - X_F^c) + p_{FL}L_o + E = p_N X_N^c + p_{HL}L_H + p_V V \tag{1e}$$

where the p_i's are prices with $F \equiv$ foods, $FL \equiv$ family labor, $N \equiv$ nonfoods, $HL \equiv$ hired labor, $V \equiv$ non-labor variable inputs, and $E \equiv$ exogenous income. The budget constraint can be combined with the time constraint and be rewritten in standard farm-household form as

$$(p_F X_F - p_{FL}L_F - p_{HL}L_H - p_V V) + p_{FL}\, T(k_F X_F^c) + E = p_F X_F^c + p_N X_N^c + p_{FL} X_L^c \tag{1e'}$$

In this form of the model it is wages per clock hour of family labor, not per efficiency hour, which are assumed to be fixed to the household. The latter could easily be incorporated by substituting a wage function for the constant hourly wages, but that is not done here.[7] Hired labor is treated as homogenous within a region with its food consumption assumed to be exogenous to the hirer. This is a very different assumption than is usually made in the efficiency wages literature, but exogenous hired labor food consumption corresponds much better to a non-labor surplus situation in which labor contracts are daily. The effective labor per hour worked function may not respond much to highly transitory (i.e. daily) changes in food intake, because body weight can absorb those so long as they are short run. Even if there were some short run response there may be important externalities to the employer raising the wage above market levels, since the worker may not work for the same employer on subsequent days.

First order conditions appear in equations (2a)-(2g). Interior solutions are assumed for family labor sold out and hired labor.

$$\frac{\partial U}{\partial X_F^c} - \lambda p_F \left(1 - L_F \frac{\partial F}{\partial L_F^e} \frac{dh}{dX_F^c} - \frac{p_{FL}}{p_F} \frac{dT}{dX_F^c}\right) = 0 \qquad (2a)$$

$$\frac{\partial U}{\partial X_N^c} - \lambda p_N = 0 \qquad (2b)$$

$$\frac{\partial U}{\partial X_L^c} - \lambda p_{FL} = 0 \qquad (2c)$$

$$p_F X_F - p_{FL} L_F - p_{HL} L_H - p_V V + p_{FL} T(k_F X_F^c) + E - p_F X_F^c - p_N X_N^c - p_{FL} X_L^c = 0 \qquad (2d)$$

$$-\lambda \left(p_{FL} - p_F \frac{\partial F}{\partial L_F^e} h(k_F X_F^c)\right) = 0 \qquad (2e)$$

$$-\lambda \left(p_{HL} - p_F \frac{\partial F}{\partial L_H^e} h(k_H Y_F^c)\right) = 0 \qquad (2f)$$

$$-\lambda \left(p_V - p_F \frac{\partial F}{\partial V}\right) = 0 \qquad (2g)$$

The conditions are standard. Only for family and hired labor and food consumption are there any non-standard terms. The labor first order conditions equate wages per hour to the marginal value product of an hour of labor. Dividing through by the number of efficiency units per worker hour, h(·), yields the wage per efficiency hour, $P_{FL}/h(k_F X_F^c)$, for family labor, which is equated to the marginal value product of an efficiency unit of family labor $P_F \frac{\partial F}{\partial L_F^e}$. For food consumption, the farm productivity effect is equivalent to a proportionate decrease in the price of food of $L_F \frac{\partial F}{\partial L_f^e} \frac{dh}{dX_F^c} + \frac{P_{FL}}{P_F} \frac{dT}{dX_F^c}$, which is the marginal product of food consumption in raising farm output plus its marginal product in raising time available for work and leisure. Thus a substitution of foods for both nonfood and leisure will be encouraged.

It is clear from equation (2e) that farm input choices now depend on food consumption. The model is not, then, separable between farm production and consumption decisions. Separability would imply that farm input and output choices are, in effect, made independently of consumption choices, but affect those choices through profits. Now production depends upon consumption choices through the wage per efficiency hour. Likewise consumption choices depend on production decisions through the shadow price of food, $P_F(1 - L_F \frac{\partial F}{\partial L_F^e} \frac{dh}{dX_F^c} - \frac{P_{FL}}{P_F} \frac{dT}{dX_F^c})$, as well as through farm profits. However, conditional on the level of h(·) being fixed, equations (2e)-(2g) may be solved independently for variable input, hence output, levels. Thus there exists a profit function conditional on the level of h(·) (hence on X_F^c). The h(·) function will enter this conditional profit function through the efficiency wage rates for family and hired labor (e.g. $p_{FL}/h(k_F X_F^c)$ for family labor). The conditional profit function will obey all the standard properties of profit functions when one treats the efficiency wage rates rather than the hourly wage rates as the appropriate ones. This means that profit functions, or input demand and output supply functions, can be estimated so long as the endogeneity of X_F^C is accounted for. Furthermore, this conditional profit function will equal the unconditional profit function when is evaluated at its optimum. On the demand side, a similar argument applies. There will be an expenditure function conditional on h(·) and on T(·), which can be related to the unconditional expenditure function. This fact can be used to specify a labor supply equation, conditional on h(·) and T(·), which will be consistent with this agricultural household model.

For the purpose of estimating the farm production function, equation (1a), the agricultural household model provides a set of variables which may be taken as exogenous to the household, hence which are candidate instrumental variables. These variables can be classed in three groups: prices, farm assets and household assets.[8] Prices include both prices of consumption commodities and variable farm inputs. Household assets include demographic variables.

4. The Data and Study Setting

The data are from a cross-section survey of households in rural Sierra Leone taken during the 1974-75 cropping year (May-April). Sierra Leone was divided into eight geographical regions chosen to conform with agro-climatic zones, and those were used to stratify the sample. Within these regions, three enumeration areas were randomly picked and households sampled within these. Households were visited twice in each week to obtain information on production, sales, and labor use, among other variables. Half the households were visited twice during one week per month to obtain market purchase information.

The data set contains much detail on outputs, family and hired labor use (there is not much use of other variable inputs), capital stock, land use, and household characteristics. It also provides estimates at the household level of food consumption from both market purchases and home production of 196 different foods (see Appendix for details of variable construction). From these data estimates of household caloric availability have been constructed using food composition tables. This data set also has regional price data with sufficient variation to have supported estimation of a moderately large (seven commodity groups) complete demand system (Strauss, 1982). It is then a good data set with which to estimate farm household level production functions, including a measure of caloric availability, having good data on outputs and inputs as well as data on the type of instrumental variables required for estimation.

The major weaknesses in the data are the absence of other measures of nutritional status, especially anthropometric or clinical measures, and the absence of individual level data on caloric intake. Anthropometric and clinical variables would be useful to distinguish different possible effects on productivity of long term (chronic) and short term (acute) deficiencies. Ideally the dietary information one would like would be that on actual intake for individuals.

The measure available in the Sierra Leone data is of availability, not intake. The two may differ systematically, especially if food waste is positively related to income levels. However intake data are difficult to obtain accurately. Recall methods have potential inaccuracies, and if the data come from one or two interviews they risk being unrepresentative of average annual intake. The Sierra Leone data were collected throughout the year, twice weekly for production related variables, and twice during one week per month for the market purchase information. It is not clear then whether more measurement error is introduced by using annual household availability data or non-annual individual intake data. Clearly, though, one would like individual level data if it were annual. Since such data are not available, the household level calorie variable has to be converted into an average per family worker.

Two methods are used to make this conversion, to see how robust the results are. At one extreme one could assume that food is shared equally among family members, by dividing household availability by household size. This seems unreasonable though, so another assumption used will be that individual food consumption is proportional to approximate caloric requirements for moderately active persons of a given age and sex. This allows adults to get a higher share than under the equal distribution assumption, though perhaps not as high as they in fact receive.[9] The per consumer equivalent conversion is a scalar multiple of expressing total household caloric intake expressed as a ratio of total household requirements, the scalar being the daily caloric requirement for adult males.[10]

Two points are worth bearing in mind when considering the potential adequacy of the caloric availability data. First, in a cross section it seems plausible that differences (especially large ones) in per consumer equivalent caloric availability will reflect a corresponding difference in nutritional status across households. Second, when using an instrumental variable for calorie availability in estimation, the errors in variables problem will be corrected if the instruments are uncorrelated with the measurement error. It is reasonable to believe that may be the case for this problem.

Caloric data for hired laborers are not directly available. However, labor markets in rural Sierra Leone during the survey period were characterized by reciprocal arrangements. Most families in a region contributed some labor during the year to work on their neighbors' farms, which was then reciprocated (Spencer and Byerlee, 1977). Moreover hired labor is often in groups. Consequently it may not be unreasonable to suppose that there is a regional average caloric level for hired laborers, that is homogeneous hired laborers. Since workers who hire themselves out are identified in the data, this average can be calculated as a weighted average of per consumer equivalent (or per capita) daily caloric availability of all households in a region. The weights used are the proportion of total regional hours hired out that come from each household. This reduces the weighted average caloric intake for hired laborers beneath the simple average because poorer households tend to provide a proportionately greater amount of labor sold out, partly because they tend to be larger households.

Sierra Leone is characterized by active rural labor markets (see Spencer and Byerlee, p. 25-45, for details). As mentioned, much hiring is reciprocal, payment being either in cash or in kind (including meals). Payment in meals could reflect a recognition of nutritional-productivity effects but it is also consistent with other hypotheses, such as economizing on travel time to and from fields.[11] Most hired laborers, roughly 87%, are paid by the day. Payment by task is not the norm, being confined to male laborers engaging in brushing, tree felling or swamp digging, all heavy labor activities. Analysis of variance of wage rates showed wages (including in kind payments) to vary by season, by sex, and by region, but not by job performed (Spencer and Byerlee, p. 41). Thus if better fed workers worked at more demanding tasks, which were paid better, this did not show up in the data. This picture of the labor market is consistent both with daily wages being constant after age, sex, region and season are accounted for, and with the long-run food consumption of hired laborers being exogenous to the hirer.

5. Empirical Specification and Identification

The agricultural production function estimated is a Cobb-Douglas function with effective family labor, effective hired labor, capital and land as inputs (see Appendix for variable definitions).[12] The production elasticities are allowed to vary by the percent of cultivated land which is upland. This is an attempt to capture differences in land quality between swamps and uplands. It may also capture some output composition effects since swamps tend to produce rice in pure stands while uplands tend to be in mixed cropping sytems (Spencer and Byerlee, p. 18). This specification gives rise to the estimating equation

$$\log X_F = \beta_1 + (\beta_2 + \beta_3 U)\ (\log L_F + \log h(k_F X_F^c)) + (\beta_4 + \beta_5 U)(\log L_H + \log h(k_H Y_F^c)) + (\beta_6 + \beta_7 U)\log K + (\beta_8 + \beta_9 U)\log A + \beta_{10} U + \varepsilon \qquad (3)$$

where $U \equiv$ upland as a percent of cultivated acreage, the β's are parameters and ε is an iid error term with zero mean and constant variance.

Two specifications are reported for the efficiency per hours worked function, one having one parameter, and one having two. The one parameter funcion is a log-reciprocal function.

$$\log h = \gamma_0 - \gamma_1 / k_F X_F^c \qquad (4a)$$

This function maps out a sigmoid shape for h, starting from the origin and converging asymptotically to a maximum at e^{γ_0}. The two parameter function reported is a simple quadratic

$$h = \alpha_o + \alpha_1 k_F X_F^c + \alpha_2 (k_F X_F^c)^2 \qquad (4b)$$

This allows for a range of negative productivity effects, for high enough food intake. It does not allow for both convex and concave portions, but it is likely that observed values would be on the concave portion of the curve, since that is the more relevant economic region.[13] A cubic function was estimated but showed very little statistical improvement over the quadratic and so is not reported.[14]

The coefficients for all the h(·) function specifications were normalized so that h(·) equals one at the sample mean value of $k_F X_F^c$. For the log-reciprocal specification the normalized h(·) function is

$$\log h = - \gamma^* (\overline{k_F X_F^c} / k_F X_F^c - 1) \qquad (5a)$$

and for the quadratic specification it is

$$h = 1 + \alpha_1^* (k_F X_F^c / \overline{k_F X_F^c} - 1) + \alpha_2^* ((k_F X_F^c / \overline{k_F X_F^c})^2 - 1) \qquad (5b)$$

These normalizations have the further advantage that h(·) equals one if the calorie coefficients are zero, so the usual agricultural production function is a special case of the one hypothesized here.

For hired labor caloric intake two approaches are taken. The first uses the per consumer equivalent (or per capita) regional weighted average described in Section 4. The second assumes that hired labor caloric intake equals the sample mean family labor caloric intake. In this case the normalized h(·) for hired labor is one, so effective hired labor time simply equals hours of hired labor.[15]

The restriction (which is tested) that the production elasticities are identical for hours of family labor and for the effective family labor per hour function (likewise for hired labor) introduces nonlinearities into the parameters. The quadratic specification for h(·) introduces further nonlinearities in parameters, as well as in variables. However, even though the production function is linear in variables for the log-reciprocal specification, the other equations of the system derived from the model will be highly nonlinear in both variables and parameters, so a linear in variables reduced form cannot be solved. Under the circumstances both identification and estimation have to be considered in the context of nonlinear simultaneous equations. In this case the nonlinearities aid in identifying the production function.

The basic set of instrumental variables used appears in Table A.1, along with their summary statistics. They are grouped into four components: prices, caloric intake of hired labor (and functional transformations thereof), farm assets and household assets/characteristics. The last two groups are arguably endogenous if there exist unobservable household characteristics, such as management skills, which persist over time, hence which may be correlated with asset accumulation. This notion will be tested by dropping groups of these possibly suspect instruments and seeing how robust the results are.

A brief discussion is called for concerning the inclusion of prices for individual foods into the instrument set, given that the model aggregates food. The identification issue can be most easily seen in the context of a linear model. Suppose the Cobb-Douglas production function has added to it the calories variable, where calories equals the sum of individual food consumption, each weighted by a conversion factor, into daily calories per consumer equivalent. Each food added by disaggregation contributes a linear coefficient restriction, because in this model it is nutrients (e.g. calories) which potentially increase productivity, not consumption of a particular food. In other words, the production function coefficients for nutrients provided by each food are constrained to be equal.[16]

6. Empirical Results

Table 1 shows estimates for the production function, equation (3). Except for the first column, for which the effective labor per hours worked function is omitted, all estimation uses nonlinear two stage least squares (see Amemiya, 1983).[17] The first column gives a two-stage least squares estimate of the Cobb-Douglas function when no calorie variable is included, the family and hired labor variables being treated endogenously. The second column reports results for a quadratic $h(\cdot)$, equation (5b), while the fourth column does the same for the log-reciprocal specification. The coefficients on calories in the effective labor function are highly significant in both the quadratic and log-reciprocal specification. The third (quadratic (2)) and fifth (log-reciprocal (2)) columns repeat the estimation after dropping the insignificant upland and land-upland interaction variables. The nonlinear, two-stage least squares analog of the likelihood ratio test,[18] gives test statistics of .66 and .27 for the quadratic and log-reciprocal specifications respectively. Those statistics, which test the joint significance of the upland and land-upland variables, are asymptotically distributed as chi-squared variables with two degrees of freedom. They are thus very insignificant.

All the coefficients in both the quadratic (2) and log-reciprocal (2) specifications are significant at the .1 level and all but one coefficient in each equation is significant at the .05 level. The calorie coefficients remain highly significant.

Column six repeats the quadratic (2)specification when hired labor caloric intake is assumed to equal the sample mean family intake (see page). The calorie coefficients remain highly significant and the coefficient magnitudes change imperceptibly.[19] Column seven shows the results when the quadratic (2) specification is rerun using daily calories per capita rather than per consumer equivalent. Again the calorie variables are highly significant with little change in magnitude.

It is certainly possible that the calorie variables are picking up the effects of other human capital type variables. For this sample, data are available for years of English and Islamic education of the household head, and for his/her age. The education variables show very little variation, most people having none. Regressions were repeated entering both types of education into the family effective labor function as well as age and age squared. The coefficients of these human capital variables are completely insignificant, while the calorie coefficient(s) remain highly significant. The remaining coefficients are quite close in magnitude to those reported in Table 1.

The fact that only a very crude proxy, percent upland, is available for land quality could also bias upwards the calorie coefficients. Another variable, related to land quality, was available, the average age of bush on fallowed land. To the extent that better quality land is cultivated more extensively, one would expect that less time in fallow would be allowed, so that a lower average age of bush would result. However, when this variable was entered linearly into an effective land function, similar to the effective labor function, equation (5b), its coefficient was insignificant, and once again the other coefficients didn't change very much.

Table 2 reports output elasticities and marginal products for per consumer equivalent family calorie intake and for standard farm inputs, derived from the quadratic (2) and log-reciprocal (2) specifications. Both specifications show roughly constant returns to scale. Interestingly, the 2SLS estimates without the effective labor function, column one, imply a returns to scale of .8. The largest change in output elasticities comes for family labor, which drops to .42. Apparently, holding other inputs constant, households demanding more family labor have a lower per consumer equivalent caloric intake, which biases family labor's coefficients downwards.

The marginal products of family and hired labor are almost identical in the quadratic specification, and not significantly different in the log-reciprocal specification. Both are very close to the sample mean real wage, which is .29.

Family caloric intake has a sizable, statistically significant, output elasticity ranging from .18 for the log-reciprocal specification to .34 for the quadratic. The sample mean elasticity of the effective labor function with respect to calories per consumer equivalent is .58 for the quadratic specification and .27 for the log-reciprocal.

For the quadratic specification, the effective labor function reaches a peak at a daily per consumer equivalent intake of 5175 calories, thereafter calories having a negative impact on effective labor. The corresponding value of h(·) is 1.2. Roughly 12 percent of the sample (15 households), have an estimated daily per consumer equivalent caloric intake above this level. The h(·) function for the log-reciprocal specification reaches a peak at 1.3 (by construction there is no negatively sloped portion). The inflection point of h(·) occurs at 413 calories per consumer equivalent daily. Thus the convex portion of h(·) seems to be irrelevant empirically, and this is substantiated by the insignificance of a cubic specification over a quadratic one.

At a daily per consumer equivalent intake of 1500 calories, which corresponds to the average for roughly the lower tercile of the sample, h(·) varies between .6 and .75 (for the quadratic and log-reciprocal specifications). Hence hourly efficiency of family labor is in the range of 60% to 75% of the efficiency of a family worker from a representative family. For 4500 calories, roughly the average intake of the upper tercile, the corresponding values of h(·) are 1.18 to 1.1.

The equations in Tables 1 and 2 all use farm and household capital stocks as instrumental variables. If there exist time persistent household effects which are unobserved and which are correlated with these asset variables, then the earlier estimates would be inconsistent. Such household effects, or heterogeneity, might include managerial ability. Even without this heterogeneity the household size and number of adults variables could possibly be endogenous since households with higher incomes might attract more family members to live with them. Since extended families are important in Sierra Leone this should be considered.

Table 3 reports reestimates of the quadratic (2) and log-reciprocal (2) specifications from Table 1, while systematically dropping groups of instruments. The first specification, columns one and four, drops the household asset variables: size and the number of adults. The second specification, columns two and five, drops the farm asset variables: capital, land and their interactions with percent upland. The percent of land which is upland is retained in the instrument set on the ground that it is largely a geographical variable which can be considered exogenous to the household. The third specification, columns three and six, drops both household and farm asset variables. In both the second and third specifications wage squared is added to the instrument set.[20] A fourth specification dropped hired labor caloric intake as an instrument in addition to the others. The results from that are very close to the third specification, however.

Dropping the two sets of instruments changes the results somewhat, but not in important respects. While the statistical differences between coefficients in different specifications are not tested here,[21] two points can be noted. First, the calorie coefficient remains significant for the log-reciprocal specification under all three combinations of omitted instruments. Second, the magnitude of the coefficient changes by only a little. For the quadratic specification, while the individual calorie coefficients lose their significance when the farm asset instruments are dropped, they remain highly significant jointly. The Wald test statistics of 11.0 and 10.3 (chi-square variables with 2 degrees of freedom) for the quadratic (2) and (3)specifications respectively are significant at less than the .01 level. While the magnitudes of the calorie coefficients change for the quadratic $h(\cdot)$ function, the elasticity of $h(\cdot)$ with respect to family calories does not change much, rising to from .58 to .65 when both farm and household assets are dropped (quadratic (3)).[22] The output elasticity of family labor, however, rises to .8 under this specification, so the output elasticity of family calories rises to .52 from .34. The land coefficient becomes insignificant and its magnitude drops considerably for both quadratic and log-reciprocal specifications when the farm asset instruments are omitted. Apparently the remaining instruments predict little of the variation in land input, as evidenced by the large drop in R^2. The hired labor and capital output elasticities change only by a small amount. Clearly, then, even after allowing for possible endogeneity of farm and household assets, family calorie intake remains a significant and important determinant of farm output.

7. Implications

Statistical and economic significance are, of course, completely different concepts, the latter being the important one. Ideally one would like to know roughly the social returns to various investments in better nutrition. Examining alternative investment strategies, for instance between programs targeted to particular groups or more general policies such as pricing policies, is outside the scope of the paper. What can be done is to derive some illustrative figures on some potential consequence of better nutrition which are generally ignored.

The major conclusion from these empirical results is that current nutritional status of farm laborers as measured by annual caloric availability increases farm output, holding other inputs constant. The relevant policy response is the unconditional supply function. While this cannot be solved for in closed form, a supply function conditional on family calorie consumption can be derived from the first order conditions, equations (2a)-(2g), and from the Cobb-Douglas production function. Its form for the specifications from Table 1 is

$$\log X_F = \frac{1}{1-\mu}\beta_1 + \frac{\mu}{1-\mu}\log p_F - \frac{\eta_{FL}}{1-\mu}\log (p_{FL}/(\eta_{FL}h(k_F X_F^c))] \qquad (6)$$

$$- \frac{\eta_{HL}}{1-\mu}\log [p_{HL}/(\eta_{HL}h(k_H Y_F^c))] + \frac{\eta_k}{1-\mu}\log K$$

$$+ \frac{\eta_A}{1-\mu}\log A$$

where the η_i's are output elasticities, the i's having been previously defined, $\mu \equiv$ the sum o. the variable input (family and hire labor) output elasticities, and β_1 is the constant term. At the sample mean, an exogenous increase in per consumer equivalent family calorie intake has a supply elasticity of 1.1 using the quadratic (2) estimates from Table 1, and .6 using the log-reciprocal (2) estimates.[23] These estimates vary by level of caloric intake since $d\ln h/d\ln k_F X_F^C$ varies, being higher at lower intakes. Thus for a family with a daily per consumer equivalent intake of only 1500 calories, which corresponds to the average for roughly the lower tercile of this sample, the conditional supply elasticity with respect to calories is 1.5 for the quadratic specification and 1.2 for the log-reciprocal. With a per consumer equivalent intake of 4500, the average for roughly the upper tercile, the calorie supply elasticities are .6 and .4 respectively for the quadratic and log-reciprocal specifications. These elasticities compare with sample mean output price elasticity, holding calorie consumption constant, of 2.2. Thus exogenous increases in calorie consumption would seem to have an important effect on output supply. Moreover the effect may be understated since no allocative effects from better nutrition have been modeled here. Of course exogenous (to the household) increases in calorie consumption are not going to come from government programs or policies. The unconditional supply function is thus more relevant for policy, but to obtain that the response function of calorie intake to exogenous variables would have to be derived. That is outside the scope of this paper. However it is clear that prices or investments in land clearing or new technologies will have an additional impact, through calories, on output supply. For instance, Strauss (1984a) suggests that higher farm output prices will tend to raise calorie consumption, especially for poorer households. While those results did not account for a nutritional-productivity relationship, which casts doubt upon them, to the extent they hold up they suggest even greater potency for output price in raising output supply. Likewise for investments in new capital or technologies. To the extent that calorie intake responds strongly to wage increases, as suggested by Strauss (1984a), the decreasing effect on output of an induced increase in wages will be mitigated.

A different effect may be seen by looking at the first order condition for food consumption, equation (2a). Ignoring the effect of higher caloric intake on total non-sick time available to the household, T, an increase in per consumer equivalent calorie intake is equivalent to a proportionate reduction in the effective price of food. Taking rice, the staple food in Sierra Leone, as an example, a percentage increase in kilograms of rice consumption will reduce the sample mean effective price of rice by 44% using the quadratic h(·) results or by 22% using the log-reciprocal results.[24] Again those percentages vary by level of caloric intake, being in the range of 72% to nearly 100% for an intake of 1500 daily calories per consumer equivalent, and from 15% to 18% at 4500 calories. Now clearly these magnitudes seem large, especially for the poorer households. The point is not that they are likely to have pinpoint accuracy, but they may well reflect an order of magnitude effect. Given the reasonable robustness of these empirical results these effects should not be dismissed.

8. Conclusions

It is not clear from these results what drives the nutrition-productivity links. The analysis has proceeded on the assumption that current, annual caloric intake directly causes higher productivity. However, it is quite plausible that current calorie flows are correlated with accumulated stocks (such as measured by height). It is also possible that the effects may differ by labor type, for instance between male adults, female adults and children. Having individual-level data on anthropometric or clinical variables such as height for age and weight for height might help to get at these questions and would be a useful extension of these results. Estimating conditional profit and labor supply functions should also be quite useful. Most importantly, it would seem necessary to replicate these results using other data sets from a range of country income levels to explore how prevalent the nutritional-productivity links are.

In conclusion, it would appear that current nutritional status, in the form of caloric intake, does raise current farm labor productivity in rural Sierra Leone. The effect explored here is a pure worker effect, while the other involves both worker and allocative effects. To the extent that allocative effects of better nutrition are important the results have understated the impact of better nutrition on output supply.

Appendix: Variable Construction

Household-level estimates of food consumption were derived by adding consumption out of home production and market purchases for 196 different foods. The former estimates were derived by a residual approach: subtracting sales, wages in kind paid out (and seed use for rice, the major crop) from production, and adding wages in kind received. These were adjusted for processing to avoid doubling-counting, and for storage losses. Estimates, in kilograms, of food availability were converted into calorie availability by using FAO (1968) food composition tables for Africa.

An aggregate Divisia production price index was formed for each region, using the regional proportions of output value as weights. Regional level farmgate prices were also used in constructing total value of output by household. An aggregate quantity index of agricultural production was then formed by dividing total output value by the aggregate price index.

Price indices for goods consumed come from Strauss (1982). They were formed by the eight geographical regions. Annual sales prices were formed using the larger sample of 328 households for which reliable production and labor use data were available. Value of regional sales was divided by sales quantity for each of 195 commodities. Likewise, regional purchase prices were formed for 113 commodities. A concordance between commodities purchased and sold was established and a commodity price for each region was then formed by taking a weighted average of sales and purchase prices with region-specific weights being the share of total expenditure for a commodity coming from either purchases or home production. Commodities were then aggregated into six groups with regional values consumed being used as weights to form weighted prices. Regional wage is in terms of male equivalents.

Land is measured both as total land area cropped, in acres, and broken down by upland and swamp land areas. This reflects a widely perceived quality differential within Sierra Leone.

Capital is measured as the value of its flow. For variable capital, this represents no problem. However, variable capital for our sample is minuscule, mostly rice seed. Only very little fertilizer is used and a little machinery hired, but these were added to the total. However, since there are some values for variable capital, which is a flow, it was necessary to convert the stock of fixed capital into the equivalent flow in order to add the two.

Data on household characteristics were available for total size and age/sex composition by 0-5 years, 6-10 years, 11-15 years, 16-65 years, and over 65 years. In addition, data on years of English and Arabic education by the household head, age of household head, ethnic group (there are three major ones in our sample), and region of residence are available. Since ethnic groups tend to live in contiguous areas, this information is also regional in character (though not identical to the eight survey regions).

Family and hired farm labor demand includes work on all agricultural activities exclusive of processing agricultural products. Units are in terms of male equivalents with weights 1 for males over 15, .75 for females over 15, and .5 for children aged 10-15. The weights are derived from an analysis of variance of wage rates as reported by Spencer and Byerlee (1977).

The potential sample size for this study was 138 households, out of which 128 were used. The remaining ten households were primarily engaged in fishing or non-agricultural activities, and were thought to have substantially different production functions. Table A.1 provides summary statistics for the major variables.

Footnotes

1/ Leibenstein (1957) first formalized this hypothesis, which was further developed by Mirlees (1975), Rodgers (1975), and Stiglitz (1976). Bliss and Stern (1978a) provide an excellent survey as well as some extensions of the model to labor supply.

2/ Baldwin and Weisbrod, p. 432.

3/ Although the Immink and Viteri studies were experiments, their nutrition-productivity relationship was estimated with data from the pre-experimental period, and thus is subject to this bias.

4/ These household consumption variables could just as well be vectors, for instance of foods.

5/ For simplicity different types of family or hired labor, such as male adult and female adult, are aggregated. In principle each might have a different function relating efficiency per hour worked to caloric intake.

6/ A horizontal intercept at a positive caloric intake would correspond to the basal metabolic rate requirement: those calories needed to keep body weight constant when lying down and engaging in no activity. This abstracts, of course, from the difficulty that basal metabolic rates may vary randomly over time for the same individual (Sukhatme, 1977).

7/ This assumption, while perhaps counterintuitive, seems consistent with what limited labor market information exists (see page 13). Further research on effects of caloric intake on labor supply is planned in which this assumption will be more thoroughly examined. In any case use of this assumption won't effect the statistical results since average regional wages are used as instruments, and even if they are biased predictors of wages, they are still uncorrelated with the production function error term.

8/ At a later stage, as an alternative, farm and household assets will be considered as endogenous.

9/ The weights from FAO, 1957, are as follows:

	Age			
Sex	0–5	6–10	11–15	16+
Male	.2	.5	.75	1.0
Female	.2	.5	.7	.9

Data were unavailable to correct for differential requirements of pregnant or lactating women.

10/ Daily household requirements may be expressed as $\sum_{i=1}^{N} a_i M_i$, where a_i are the daily requirements for a particular age-sex group and M_i is the number of group members in the household. Dividing by the a_i for adult males yields the number of consumer equivalents. So long as the adult male a_i can be taken as constant across the male adult population it will be absorbed into the regression coefficient(s) for calories per consumer equivalent.

11/ When there is a midday meal it is eaten in the fields, with hired laborers sharing the family's food.

12/ A Cobb-Douglas specification in which family and hired labor are permitted to be perfect substitutes, but with different efficiency weights, was also tried. The results are substantially the same.

13/ If $\frac{dh}{dX_F^c}$ is rising and at a faster rate than $\frac{\partial F}{\partial L_F^e}$, the marginal product of effective family labor, is falling, then it is possible for second order conditions to be violated.

14/ Two other functional forms were tried for h: a log-log and an extended semi-log, $h = \theta_o + \theta_1 k_F X_F^c + \theta_2 k_F X_F^c \log (k_F X_F^c)$. The latter is a functional form sometimes used to estimate Engel curves. Minus the constant it is the Engel curve of the Almost Ideal Demand System (Deaton and Muellbauer, 1980).Results are available from the author upon request.

15/ A third approach was tried: treating the weighted average intake as measuring with error the true intake faced by an individual hirer. This was accomplished by treating hired labor caloric intake as endogenous. It is arguable that the instrumental variables used would be uncorrelated with any measurement error, giving consistent coefficient estimates. The results turn out to be almost identical to those which treat hired labor calorie intake as exogenous, and so are not reported. They are available upon request.

16/ Each food price is, of course, a valid instrument, but does not aid in identifying the production function since a consumption structural equation is also added to the system.

17/ The objective function minimized is $S=u'W(W'W)^{-1}W'u$, where u is a Tx1 vector of residuals (T being sample size), and W is a TxN matrix of instrumental variables such that N is greater than or equal to the number of independent parameters. The matrix W can be of different forms, including for instance cross products of instruments as well as the instruments themselves. In this case only the instruments were included. The Davidon-Fletcher-Powell algorithm as available in the Fair-Parke program (see Fair, 1984), was used to minimize the objective function.

18/ This test statistics is $\frac{1}{\sigma^2}(S_R-S_U)$, where σ is the regression standard error, S_U is the value of the objective function evaluated at the unrestricted estimates, and S_R is its value evaluated at the restricted estimates. See Gallant and Jorgenson (1979) for details.

19/ The fact that the function value drops reflects the hired calorie variable, and its square, being dropped from the instrument set. No statistical inferences should be drawn from this.

20/ Given the variable nonlinearities it is appropriate to add all cross products of instruments to the instrument set. Adding squares or cross products of prices other than for labor, however, made the matrix of cross products singular.

21/ A Hausman test is possible, but computing the covariance of the difference between the two sets of estimates (one with the full instrument set and one with a reduced set) is somewhat complicated because neither estimate is efficient within a class of estimators. While a best nonlinear two-stage least squares (BNL2S, see Amemiya, 1983) does exist in principle, it is difficult to compute in practice, and was not computed here.

22/ At the sample mean this elasticity equals $\alpha_1^* + 2\alpha_2^*$ (see equation (5b)), where α_1^* is the coefficient on calories and α_2^* the coefficient of its square.

23/ Of course this is purely illustrative since exogenous increases in food consumption are highly unlikely.

24/ This is calculated assuming a conversion of 3743 calories per kilogram of rice, converting this annual figure to a daily per consumer equivalent, and multiplying by the marginal product of family calories from Table 2.

Table 1

Agricultural Production Functions: Quadratic and Log-Reciprocal Effective Labor Functions[a]

Variable	None	Quadratic (1)	Quadratic (2)	Log-Reciprocal (1)	Log-Reciprocal (2)	Quadratic[d] (3)	Quadratic[e] (4)
		Effective Labor Function					
Constant	-4.21	.18	1.50	.32	1.20	1.76	1.60
	(-1.7)	(.1)	(1.4)	(.2)	(1.2)	(1.5)	(1.4)
Effective Labor Function[b]							
Calories		1.38	1.42			1.59	1.14
		(4.6)	(5.3)			(10.5)	(4.4)
Calories squared		-.42	-.42			-.49	-.30
		(-3.5)	(-3.5)			(-10.2)	(-4.3)
Calories reciprocal				.25	.27		
				(3.0)	(3.6)		
Family Labor[c]	1.61	1.13	.90	1.08	.95	.89	.87
	(4.6)	(4.1)	(5.0)	(5.0)	(5.8)	(4.9)	(4.5)
Family Labor x Upland[c]	-1.89	-.92	-.49	-.86	-.47	-.31	-.63
	(-3.4)	(-2.0)	(-1.9)	(-2.5)	(-1.8)	(-1.3)	(-2.2)
Hired Labor[c]	-.27	-.49	-.47	-.47	-.49	-.44	-.47
	(-.9)	(-1.8)	(-2.2)	(-2.0)	(-2.5)	(-2.2)	(-1.9)
Hired Labor x Upland[c]	.48	.99	.91	.98	.86	.62	1.11
	(.9)	(2.0)	(2.4)	(2.4)	(2.3)	(1.8)	(2.7)
Capital	.02	.26	.40	.32	.40	.34	.41
	(.1)	(1.3)	(2.7)	(1.9)	(3.0)	(1.8)	(2.4)
Capital x Upland	.004	-.42	-.58	-.45	-.53	-.52	-.63
	(.01)	(-1.6)	(-2.8)	(-2.0)	(-2.6)	(-2.2)	(-2.8)
Land	.2	.35	.27	.28	.25	.31	.29
	(.9)	(1.7)	(2.6)	(1.5)	(2.5)	(2.5)	(2.4)
Land x Upland	.2	-.13		-.06			
	(.6)	(-.5)		(-.2)			
Upland	11.69	2.46		2.11			
	(2.8)	(.9)		(1.1)			
Function Value	2.60[f]	2.60	2.95	3.24	3.38	2.55[f]	4.33
Regression standard error	.59	.53	.51	.51	.50	.56	.55
R^2	.35	.49	.52	.52	.54	.43	.44

[a] Asymptotic standard normal statistics in parentheses.

[b] Family labor calorie intake is endogenous. Hired labor calorie intake is exogenous unless otherwise indicated.

[c] Endogenous variable.

[d] Hired labor calorie intake treated as unknown. See page 16.

[e] Calories per person used instead of calories per consumer equivalent.

[f] [illegible]

Table 2

Output Elasticities and Marginal Products at Sample Mean:

Quadratic and Log-Reciprocal Specifications[a/]

Input	Output Elasticities		Marginal Products	
	Effective Labor Function			
	Quadratic	Log-Reciprocal	Quadratic	Log-Reciprocal
Family caloric intake	.34 (.11)	.18 (.06)	.20 (.06)	.10 (.03)
Family labor	.59 (.18)	.65 (.17)	.31 (.09)	.34 (.09)
Hired labor	.10 (.15)	.05 (.16)	.30 (.45)	.15 (.48)
Capital	.04 (.10)	.07 (.09)	2.75 (6.52)	4.81 (5.99)
Land	.27 (.11)	.25 (.10)	88.68 (36.13)	82.11 (32.84)

[a/]Asymptotic standard errors in parentheses . Computed from the quadratic (2) and log-reciprocal (2) specifications of Table 1.

Table 3

Agricultural Production Functions Dropping Farm and Household Assets as Instruments: Family and Hired Labor Imperfect Substitutes[a]

Variable	Quadratic (1)	Quadratic (2)	Quadratic (3)	Log-Reciprocal (1)	Log-Reciprocal (2)	Log-Reciprocal (3)
	Effective Labor Function					
Constant	1.52	.89	.43	.94	.86	.17
	(1.3)	(.6)	(.3)	(.8)	(.8)	(.1)
Effective Labor Function						
Calories	1.42[b]*	.81[b]*	.66[b]*			
	(5.1)	(1.2)	(.9)			
Calories squared	-.35[b]*	-.12[b]*	-.002[b]*			
	(-1.8)	(-.3)	(-.01)			
Calories reciprocal				.32[b]	.22[b]	.22[b]
				(3.2)	(2.7)	(2.8)
Family Labor	.96[b]	.82[b]	.93[b]	1.05[b]	.90[b]	1.09[b]
	(4.8)	(3.2)	(3.4)	(5.4)	(4.7)	(5.0)
Family Labor x Upland	-.38[b]	-.38[b]	-.21[b]	-.27[b]	-.41[b]	-.13[b]
	(-1.4)	(-.9)	(-.5)	(-.9)	(-1.2)	(-.3)
Hired Labor	-.60[b]	-.69[b]	-.75[b]	-.59[b]	-.57[b]	-.66[b]
	(-2.5)	(-2.2)	(-2.3)	(-2.6)	(-2.4)	(-2.6)
Hired Labor x Upland	.77[b]	1.47[b]	1.27[b]	.57[b]	1.13[b]	.77[b]
	(1.9)	(2.6)	(2.2)	(1.4)	(2.4)	(1.15)
Capital	.44	1.21[b]	1.23[b]	.39	.78[b]	.71[b]
	(2.9)	(2.5)	(2.6)	(2.6)	(2.4)	(2.0)
Capital x Upland	-.53	-1.82[b]	-1.84[b]	-.44	-1.15[b]	-1.12[b]
	(-2.5)	(-2.6)	(-2.6)	(-2.0)	(-2.2)	(-1.9)
Land	.31	.005[b]	-.06[b]	.29	.14[b]	.10[b]
	(2.9)	(.01)	(-.2)	(2.7)	(.8)	(.5)
Function Value	1.14	1.95	.21	.78	3.16	.81
Regression Standard Error	.53	.65	.66	.55	.54	.57
R^2	.49	.22	.20	.44	.47	.39
Instruments dropped:	HH size, no adults	Capital and Land. Wage squared added	Capital, land, HH size and no. adults. Wage squared added	HH size, no adults	Capital and land. Wage squared added	Capital, land, HH size, and adults. Wage squared added

[a] Asymptotic standard normal statistics in parentheses. Asterisk (*) denotes jointly significant at .01 level. Hired labor calories exogenous.

[b] Endogenous variable.

Table A.1

Sample Summary Statistics

Endogenous Variables	Mean	Standard Deviation
Farm output quantity index[a]	2295.2	1844.4
Daily family calories per consumer equivalent	3061.	1811.4
Daily family calories per capita	2434.7	1610.9
Hours of family labor	3898.2	2122.
Hours of hired labor	816.5	620.8
Exogenous Variables		
Daily hired labor calories per consumer equivalent	2788.4	1242.7
Output price index[b]	.27	.06
Rice price index[b]	.24	.05
Root crop and other cereal price index[b]	.58	.46
Oils and fats price index[b]	.66	.16
Fish and animal product price index[b]	.56	.31
Miscellaneous foods price index[b]	.60	.19
Nonfoods price index[b]	.64	.09
Male adult wage[c]	.08	.03
Capital stock (in Leones)	34.4	31.6
Land cultivated (in acres)	6.8	4.5
Upland as % of land cultivated	.63	.37
Household size	6.3	3.7
Persons 11 years and older	4.4	2.2
Other Variables Not Used		
Number of consumer equivalents	4.7	2.4
Years of English education of household head	0.4	1.5
Years of Islamic education of household head	1.6	4.1
Age of household head	50.9	15.

a/ In kilograms.

b/ Leones per kilogram. For definitions of commodity groups see Table A.1 in Strauss (1982).

c/ Leones per hour.

References

Amemiya, Takeshi (1983). "Non-Linear Regression Models." In Z. Griliches and M. Intriligator eds., Handbook of Econometrics: Volume 1 (Amsterdam: North Holland).

Baldwin, Robert and Burton Weisbrod (1974). "Disease and Labor Productivity." Economic Development and Cultural Change, 22:414-435.

Binswanger, Hans and Mark Rosenzweig (1984). "Contractual Arrangements, Employment, and Wages in Rural Labor Markets: A Critical Review." In H. Binswanger and M. Rosenzweig eds., Contractual Arrangements, Employment and Wages in Rural Labor Markets in Asia. (New Haven: Yale University Press).

Bliss, Christopher and Nicholas Stern (1978a). "Productivity, Wages and Nutrition, Part I, The Theory," Journal of Development Economics, 5:331-362.

________ and ________ (1978b). "Productivity, Wages and Nutrition, Part II, Some Observations." Journal of Development Economics, 5: 363-398.

Deaton, Angus and John Muellbauer (1980). "An Almost Ideal Demand System." American Economic Review, 70:312-326.

Deolalikar, Anil and Wim Vijverberg (1983). "Heterogeneity of Family and Hired Labor in Agriculture." Economic Growth Center Discussion Paper 444, Yale University.

Fair, Ray (1984). Specification, Estimation, and Analysis of Macro-econometric Models. (Cambridge: University of Harvard Press).

Food and Agricultural Organization (1968). Food Composition Table for

Use in Africa, Rome.

_________(1957). "Calorie Requirements: Report of the Second Committee on Calorie Requirements." Nutritional Studies No. 15, Rome.

Gallant, Ronald and Dale Jorgenson (1979). "Statistical Inference For a System of Simultaneous, Non-Linear, Implicit Equations in the Context of Instrumental Variable Estimation." Journal of Econometrics, 11:275-302.

Grossman, Michael (1972) "On the Concept of Health Capital and Demand for Health." Journal of Political Economy, 80:223-255.

Immink, Maarten and Fernando Viteri (1981a). "Energy, Intake and Productivity of Guatemalan Sugarcane Cutters: An Empirical Test of the Efficiency Wages Hypothesis, Part I," Journal of Development Economics, 9:251-272.

_________ and _________ (1981b). "Energy Intake and Productivity of Guatemalan Sugarcane Cutters: An Empirical Test of the Efficiency Wages Hypothesis, Part II." Journal of Development Economics, 9:273-287.

_________ and _________ and Ronald Helms (1982). "Energy Intake Over Life Cycle and Human Capital Formation in Guatemalan Sugarcane Cutters." Economic Development and Cultural Change, 30:351-372.

Leibenstein, Harvey (1957). Economic Backwardness and Economic Growth. (New York: John Wiley & Sons).

Mirlees, James (1975). "A Pure Theory of Underdeveloped Economies." in L. Reynolds ed. Agriculture in Development Theory (New Haven: Yale University Press).

Pitt, Mark (1983). "Food Preferences and Nutrition in Rural Bangladesh."

Review of Economics and Statistics, 65:105-114.

_________ and Mark Rosenzweig (1984). "Agricultural Prices, Food Consumption and the Health and Productivity of Farmers." in I.J. Singh, L. Squire and J. Strauss eds., Agricultural Household Models: Extensions, Applications and Policy, World Bank: forthcoming.

Rodgers, Gerry (1975). "Nutritionally Based Wage Determination in the Low Income Labor Market." Oxford Economic Papers, 27:61-81.

Selowsky, Marcelo (1981). "Nutrition, Health and Education: The Economic Significance of Complementarities at an Early Age." Journal of Development Economics, 9:331-346.

_________ and Lance Taylor (1973). "The Economics of Malnourished Children: An Example of Disinvestment in Human Capital." Economic Development and Cultural Change, 22:17-30.

Spencer, Dunstan and Derek Byerlee (1977). "Small Farms in West Africa: A Descriptive Analysis of Employment, Incomes and Productivity in Sierra Leone." African Rural Economy Program, Working Paper 19, Michigan State University.

Stiglitz, Joseph (1976). "The Efficiency Wage Hypothesis, Surplus Labor, and the Distribution of Income in LDCs." Oxford Economic Papers, 28:185-207.

Strauss, John (1984a). "Joint Determination of Food Production and Consumption in Rural Sierra Leone: Application of a Household-Firm Model." Journal of Development Economics, 14:

_________ (1984b). "An Overview of Agricultural Household Models: Theory." Economic Growth Center Discussion Paper 450, Yale University.

_________ (1982). "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 11:327-353.

Sukhatme, P. V. (1977). "Malnutrition and Poverty." Ninth Lal Bahadur Shastri Memorial Lecture (New Delhi: Indian Agricultural Research Institute).

Weisbrod, Burton and Thomas Helminiak (1977). "Parasitic Diseases and Agricultural Labor Productivity." Economic Development and Cultural Change, 25:505-522.

Wolgemuth, J.; M. Latham; A. Hall; A. Chesher; and D. Crompton (1982). "Worker Productivity and the Nutritional Status of Kenyan Road Construction Laborers." American Journal of Clinical Nutrition, 36:68-78.