Part II. Economics and Human Capital Formation

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INTRODUCTION

Several theoretical models underlie the economic components of this study on the functional consequences of marginal malnutrition among agricultural workers in Guatemala. The first is a small body of economic literature that deals with the so-called efficiency-wage hypothesis (1). Home production models that treat households as both production and consumption units form a second theoretical underpinning for our work (2).

The efficiency-wage hypothesis per se is of little interest outside the economics community. However, one crucial component, the productivity-consumption relation, provides a conceptual model within which to analyse the relationship between energy intake and worker productivity of rural wage labourers. Briefly, the productivity-consumption relation states that the workers' work performance is directly dependent on their food intake or energy intake. Starting at a level of daily energy intake that covers basal metabolic energy requirements, it is postulated that productivity (measured as number of work units per day) will increase at first more than proportionally, and thereafter less than proportionally, with higher levels of energy intake. Rural employers will have an incentive to provide productive wage increases to their work force if they can internalize the productivity benefits. All of these wage increases are assumed to be spent on food for the worker. The wage increases will bring total wages up to a level at which the average wage cost per unit of work equals the marginal cost of work unit as employers maximize profits.

Economic models of household production and consumption behaviour have recently been developed, though empirical evidence is still scarce (2, 3). These models postulate that rural households engage in market production (wage employment, surplus farm production, small-scale cottage industries, etc.), home production (food processing and preparation, child care, home repairs, etc.), and/or leisure (playing soccer or cards, attending a movie, etc.). In all these activities one input is human energy. Improved nutritional (energy) intake represents human capital formation when productivity in market, home, and/or leisure activities increases as a result. The concept "human capital" refers to the productive capacity embodied in human beings and consists of both physical and mental abilities. Conceptually, it is similar to physical capital: (a) human capital is subject to deterioration and obsolescence and has a finite life; (b) it is created and augmented through investment (it requires resources to produce) in education, health, nutrition, etc.; (c) it can be rented out in the market-place and thus earn a return for its owner. Ownership of human capital, unlike that of physical capital, is not transferable (in the absence of slavery). Our data only allow us to consider human capital formation in male labourers engaged in market production.

Human capital formation in present members of the worker force may have intergenerational consequences. Higher productivity in market or home production is likely to translate into higher household income with beneficial effects on the food intake of the members of the workers' households, including children. This income effect may not be limited to improved food intake but may also result in increased expenditures on education and medical care, with further implications for human capital formation in children. Improved in leisure activities is likely to result in more intensive social interaction activities is likely to result in more intensive social interaction with further beneficial effects on workers' offspring.

Little direct empirical evidence related to the efficiency-wage hypothesis existed before our studies were conducted.

Other relevant findings were conflicting. Viteri's study with agricultural workers showed that long-term energy supplementation may have a positive effect on productivity (4). Short-term energy supplementation has been shown to have no, or only a very marginal, effect on rural worker's productivity in developing countries (5, 6). The work setting for the study we conducted with sugar-cane cutters closely approximated that assumed by the efficiency-wage hypothesis. By direct energy supplementation of the workers, we simulated the assumption that wage increases would be converted to additional energy intake.

Our approach in analysing the data has been guided by these conceptual considerations. The principal objective is to study the economic consequences of increased energy intake by economically active members of the rural work force. The economic consequences investigated are the effect on worker productivity and on human capital formation. Partial results of the analysis have been published elsewhere and are summarized here.

METHODS

The analysis related to the efficiency-wage hypothesis was carried out with data for the sugar-cane workers. The human capital analysis involves data from the study with the coffee pickers as well as from the sugar-cane workers. These samples of workers are described in part I, above.

Data Collection Procedures

Both company payroll records and direct field measurements were used to obtain the worker productivity data. Specially trained assistants who were former sugar-cane cutters maintained daily activity records and took specific work measurements in the field for small subsamples of workers. To reduce inter-observer errors, these workers were periodically standardized in taking work measurements. The following indicators of worker productivity were extracted from the data:

a. for coffee pickers
   - weight (kg) of coffee beans picked per day;
b. for sugar-cane cutters
   - weight (tons) of cane cut and loaded per day,
   - total work time per day,
   - number of days worked per week,
   - length of furrow cut per hour,
   - time needed to complete a standardized weeding task (non-harvest periods).

The following anthropometric measurements, as described in part I, were taken periodically: body weight, standing height, mid-upper arm circumference, calf circumference, and triceps skinfold. To minimize inter-examiner measurement errors, the same staff member took the same measurement(s) during all examinations. All personnel were carefully trained and standardized.

Dietary intake data were obtained by means of periodic one-day recall surveys. Quantities of foods consumed were estimated by weighing equivalent quantities during the interview. Daily energy intake of the workers was obtained by converting total food intake using a food composition table for Latin America (7).

Submaximal exercise tests were performed making use of a treadmill or bicycle ergometer. These tests have been extensively described in Åstrand and Rodahl (8). The principal indicators of physical working capacity that were estimated are: (a) oxygen uptake at a heart rate of 150 beats per minute ($\dot{V}O_2$ 150), and (b) oxygen uptake at an estimated maximal heart rate ($\dot{V}O_2$ MAX).

Data collection on the sugar-cane plantation was initiated in August 1973 with a population and housing census in the two study communities. All field activities, including data collection, were terminated in August 1977. The study at the coffee co-operative was initiated in August 1976 and terminated at the end of 1978.

Energy Supplementation Programme

After a period of baseline data collection, an energy supplementation programme was started in April 1974 among the sugar-cane workers. Supplementation took place continuously for a total of 28 months. The programme and its effect on the total energy intake of workers has previously been described in detail (9). Two supplements were distributed free of change. The high-energy supplement consisted of a bottled, orange-flavoured drink and contained 350 kcal per bottle. If consistently consumed, this supplement provided 550 kcal per day over a period of one week. A second supplement, identical to the first in appearance and flavour, contained 15 kcal per bottle and provided 24 kcal per day. Both supplements contained vitamin A (3.7 mg per bottle) and vitamin C (16 mg per bottle) and were well accepted by the workers. The median supplement intake as a percentage of total time offered never fell below 90 per cent among the high-energy-supplement workers.

The workers from the two communities could not be assigned at random to the treatment (high-energy-supplement) and comparison (low-energy-supplement) groups because of within-community interaction. There was little between-community interaction, and workers from each community were never assigned to the same canefield. Therefore, 95 workers from one community were designated the high-energy-supplement (HES) group, and 63 workers from the other community were in the low-energy-supplement (LES) group.

The mean daily energy of these workers amounted to 2,951 (SE: 68) kcal before supplementation. Sixty-seven per cent of the workers did not meet their estimated daily energy requirements (based on a daily energy requirement of 62 kcal per kilogram of body weight; mean body weight was 53.3 [SE: 0.9] kg). Based on haematocrit measurements, these workers ran a 0 to 20 per cent risk of having iron deficiency anaemia. No significant differences were found between the two groups in mean age, anthropometric indicators, daily productivity, and daily energy intake prior to supplementation.

The supplementation programme was effective in raising the total energy intake of the HES group during most of the supplementation period (9). Some substitution of supplement energy intake for home energy intake took place, but the mean net increase approximated 300 kcal per day. Workers in both groups generally maintained energy balance during the course of supplementation. Inter-temporal variation in mean body weight changes relative to pre-supplementation was small and was more pronounced in the LES group, but did not significantly differ between the two groups (paper in preparation). Triceps skinfold measurements inherently contain greater measurement errors and showed relatively more inter-temporal variation in both groups. Significant decreases relative to pre-supplementation values were observed towards the end of the cane harvesting, when work activity levels intensify. Nevertheless, these changes in mean triceps skinfolds are too small to be reflected by changes in body weight.

It is generally concluded that the HES group workers are likely to have increased their total level of energy expenditure during most of the supplementation period, with partial substitution of supplement energy intake for home energy intake. Interestingly, the degree of substitution tended to be less among HES workers with relatively low pre-supplementation body weight (9). The pre-supplementation energy adequacy status of the workers' households was not related to the degree of substitution among HES group workers. The households did not demonstrate an improved energy intake during worker supplementation; or, alternatively, the one-day recall method is not sufficiently sensitive to measure small changes.

RESULTS

Test of the Efficiency-Wage Hypothesis

The first approach used was to test cross-sectionally the productivity-consumption relation using pre-supplementation data. In order to estimate areas of increasing and decreasing productivity to higher levels of energy intake, the relation was modelled as a log inverse function. Weight of sugar-cane delivered per man per day (CANE-DAY) was used as the productivity indicator. Estimates of total basal metabolic requirements (BMR) were obtained using a coefficient of 26.8 kcal/kg body weight (10). The estimate of BMR was subtracted from the estimated total energy intake. Thus, the model was specified with available activity energy as the independent variable (ENERGY).

The estimated efficiency curve shows a significant but weak relationship between productivity and energy intake. The regression equation was

log of sugar-cane delivered per man per day = LN (CANE-DAY)

$$\text{LN(CANE-DAY)} = .22^{a} - 28.29^{b}\,(\text{ENERGY})^{-1}$$

$a_t = 16.5 \quad p < .01 \qquad r^2 = 0.12$

$b_t = 3.6 \quad p < .01 \qquad p < .001$

The fit of the curve is poor. The estimated function exhibits an initial region of increasing productivity returns that is, however, too small to be empirically relevant. It appears that sharply diminishing productivity returns start to set in, starting at relatively low levels of energy intake. This is inconsistent with the assumptions of the efficiency-wage hypothesis.

The second test of the efficiency-wage hypothesis was to analyse longitudinally the effect of energy supplementation on the productivity of the sugar-cane cutters. Several productivity indicators were examined. In pairwise comparisons (supplementation versus pre-supplementation periods) it was found that during supplementation the two groups delivered more cane per day, worked longer hours, expended more energy at work, and cut longer furrows per hour but only in the first 15 months (11). However, either there was no significant difference between the groups in the mean increase in productivity, or the mean increase for the HES group was less than for the LES group. It was also demonstrated that certain physical characteristics of the canefields and their average yields explained a significant part of the inter-worker variation in the change in productivity during supplementation.

The productivity data were also submitted to time series analysis. New techniques of analysing time series by way of stochastic process models have recently been developed. These models are referred to as auto-regressive integrated moving average (ARIMA) models (12). They allow estimation of an abrupt or a gradual and sustained effect on the productivity series starting at the time supplementation was initiated. A time series that represents the difference between the mean values (weekly point estimates) of the

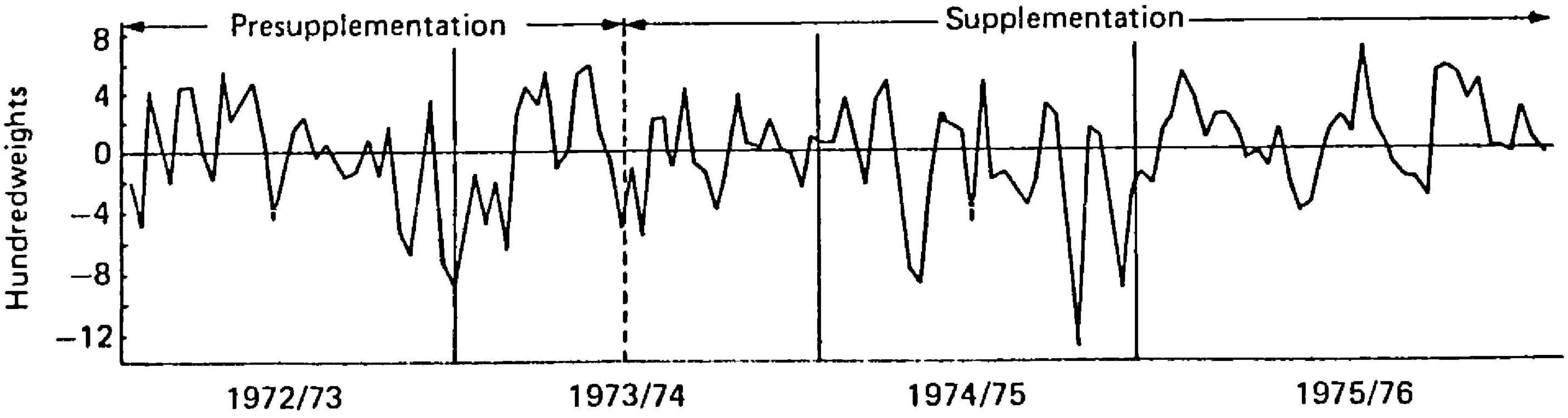

FIG. 1. Difference in the Mean Daily Supply (Weekly Point Estimates) of Work Units (Hundredweights of Sugar Cane) between the High-Energy-Supplement Group and the Low-Energy-Supplement Group

two supplementation groups is presented in figure 1. The series covers 1½ harvests prior to supplementation and 2½ harvests during supplementation. We recently submitted this series to the ARIMA analysis (paper in preparation). The 20 weekly observations of the 1976/77 harvest (post-supplementation) were excluded because more observation points would be needed for inclusion in the time series analysis. The HES group mean daily productivity tended to consistently exceed that of the LES group during this post-supplementation period. Most likely this was due to extraneous factors.

The first step was to estimate the underlying structure of the series using the pre-supplementation observation points. No auto-regressive schemes were detected, and the best model was found to be a moving average one. Zero- and first-order transfer functions were specified next for the whole series. None of the estimated parameters were statistically significant. Thus, it is concluded that energy supplementation did not have an abrupt or a gradual and sustained impact on the daily productivity of the HES group. However, an earlier analysis suggested that extraneous factors, including work organization/management practices, may have affected the productivity of the two groups differently over time, thus providing a powerful rival hypothesis (13).

It was concluded that the results from the energy supplementation study with the sugar-cane cutters are not supportive of the efficiency-wage hypothesis.

Body Composition, Physical Capacity, and Productivity

In order to extend the analysis of marginal malnutrition, two body composition factor scores were related to indicators of worker productivity. The procedures employed to generate these factors and their interpretation in terms of body composition are described in part I. Indicators of physical working capacity were related to the same productivity indicators in subsamples of workers. Data from both studies were included in the analysis. The results from this analysis are described in detail in a paper in preparation and are summarized here.

In linear regression models, fat-free mass (FFM) factor scores were significantly ($p < .05$) related to (a) tons of cane delivered per day (CANE DAY), (b) time required to perform a standardized weeding task (TASKTIME), and (c) kilograms of coffee beans picked per day. Thus, workers with more FFM tended to deliver more cane per day, pick more coffee beans per day, and finish a weeding task in less time than their colleagues with less FFM. The fact that the FFM factor was significantly associated with productivity in several agricultural tasks suggests that this finding may be applicable to a wide variety of physically demanding tasks.

Daily cane deliveries (CANE-DAY) were negatively associatied with the factor that appears to be related to adipose tissue deposits. Thus, workers with relatively more fat-free mass and less body fat may be physically better adapted to higher productivity than their colleagues with relatively less FFM and more body fat. A negative association between percentage of body fat and daily productivity of Colombian sugar-cane cutters has been reported by Spurr et al. (14).

It was previously shown that the FFM factor was significantly related to indicators of physical working capacity (PWC). From the results just presented, it follows that PWC should be related to worker productivity, as most of the effect of FFM on productivity probably runs via the effect on PWC. Our data only allow us to investigate this question for a subsample of the sugar-cane cutters, since the submaximal exercise tests were performed in only 17 of the 58 coffee pickers with productivity data. Full results will be reported in a paper in preparation.

Regression models were formulated with CANE-DAY and TASKTIME as dependent variables. The first was significantly and positively correlated with $\dot{V}O_2$ 150/kg of body weight ($r = .27$; $p < .05$). The correlation with $\dot{V}O_2$ MAX was not statistically significant, which is contrary to results reported by Spurr et al. (14). However, in that study, $\dot{V}O_2$ MAX was directly determined, which was not the case in the present study. The regression models were linearly and non-linearly estimated. The results suggest that, in spite of the positive relationship, there are diminishing productivity returns to increased physiological efficiency. The $\dot{V}O_2$/kg elasticity coefficient with respect to CANE-DAY, as estimated by a double-log function, was .18 ($p < .05$).

Time required to complete a weeding task (TASKTIME) was only marginally correlated with $\dot{V}O_2$ MAX ($r = .22$, $p < .10$) and not at all with $\dot{V}O_2$ 150. These results suggest that body composition as affected by nutritional intake explains a small part of the inter-worker variation in productivity. The same pattern emerged for the relationship between physiological indicators and worker productivity.

Human Capital Formation

The analysis of the previous section was extended in order to estimate what different levels of fat-free mass (FFM) among these agricultural workers might mean in terms of life-time earnings or their stock of human capital. The results are in press (15). On the basis of cross-sectional data, age-productivity profiles were estimated for sub-samples of workers with "high" FFM scores (greater than the median score) and with "low" scores. Regression models were formulated to test whether workers with relatively more FFM can be expected to be more productive over their life cycles than their colleagues with low FFM values. Although we recognize that inter-temporal extrapolation from cross-sectional data has limited validity, the results indicated that this is likely to be the case and that the productivity differential is likely to remain constant with age.

The estimated age-productivity profiles were converted into earnings profiles, using appropriate wages for both the sugar-cane cutters and the coffee pickers, and the present value of the earnings differential was calculated at different ages. The present value may be said to represent the increase in the stock of human capital associated with different levels of FFM in these workers (holding all other factors associated with productivity constant).

Sugar-cane cutters and coffee pickers who enter the work force (at age 17) with relatively more FFM may enjoy higher lifetime earnings — estimated to be 4.3 and 21.7 per cent higher respectively — than their colleagues with less FFM. The later during the productive life cycle that the increase in FFM takes place, the lower the increase in present value of lifetime earnings (at age 17). At age 35, for example, the above percentages are reduced to 1.0 and 7.1 respectively.

Thus, more fat-free mass at an early productive age and maintained throughout the productive life cycle represented a significant increase in the stock of human capital of these workers. More FFM is likely to result in private economic benefits in the form of increased lifetime earnings. In addition, there may be external benefits that accrue to rural employers and to society as a whole.

An additional analysis was performed to investigate inter-generational forms of human capital formation by relating an indicator of childhood nutrition to worker productivity. Adult stature has been shown to be positively correlated with the productivity of sugar-cane cutters (14, 16). Among the workers in our study, height was significantly correlated with daily productivity ($r = .18$, $p < .05$) and with days worked per week ($r = .20$, $p < .02$).

Workers were classified as tall ($\bar{X}$: 165.7 cm), medium height ($\bar{X}$: 159.5 cm), and short ($\bar{X}$: 153.3 cm), using the 33rd and 67th percentiles of the frequency distribution as cut-off points (17). Age-productivity profiles were estimated for each height class. Two productivity indicators were employed: tonnage of sugar-cane harvested, and gross earnings. Regression analysis results suggested that there is a significant productivity differential between "tall" and "short" workers; this differential remains constant over the productive life cycle. We previously reported that the increase in the stock of human capital associated with a significant increase in adult stature may range from 5.5 per cent (based on tons of cane harvested) to 16 per cent (based on gross earnings). Some of this difference is probably due to less worker absenteeism among taller workers.

It appears that improved energy (and protein) intake during the pre-productive life cycle phase may be an important form of investment in human capital, at least among sugar-cane cutters.

SUMMARY OF FINDINGS

Two groups of agricultural workers with different agricultural occupations were included in the study. One group, sugar-cane cutters, participated in an energy supplementation programme for 28 months in order to simulate a productive wage increase (in the form of food) and to measure the effect on worker productivity. Both groups of agricultural workers were included in cross-sectional studies in which their nutritional status (body composition indicators) was related to indicators of worker productivity. Their physical working capacity was also related to productivity. The implications for human capital formation were examined.

The energy supplementation programme was effective in raising the total energy intake of the high-energy-supplement group for most of the supplementation period. Workers remained in energy balance, and it is inferred that the HES group workers, on average, increased their total energy expenditure.

No positive and consistent effect on the productivity in market production activities of the supplemented workers can be demonstrated. Sharply diminishing productivity returns to increased energy intake were suggested by a cross-sectional estimation of the productivity-energy intake relation as postulated by the efficiency-wage hypothesis.

A small part of the inter-worker variation in the productivity of sugar-cane cutters, weeders, and coffee pickers is explained by certain indicators of body composition, particularly fat-free mass. Among the sugar-cane cutters and weeders, indicators of physical working are also positively related to their productivity, reflecting the positive effect of fat-free body mass.

Extending the analysis into a human capital framework, it was found that workers who entered the work force with relatively more fat-free mass and who maintain high levels of fat-free mass throughout their productive life cycle are likely to receive significantly higher lifetime earnings. Thus, in certain physically demanding agricultural occupations, better nutrition that leads to a body composition with a high proportion of FFM represents an investment in human capital.

Similarly, improved levels of energy and protein during the pre-productive phase of the life cycle, when these lead to taller adults among the rural poor, represent an investment in human capital and may result in significantly increased lifetime earnings in certain agricultural occupations.

CONCLUDING REMARKS

The results to date show that marginal malnutrition in economically active rural populations may have economic consequences. Increased energy intake may not necessarily result in improved productivity in rural wage employment. The nutritional status of the workers interacts with economic incentives to produce specific productivity outcomes, and nutritional improvements may instead result in increased productivity in home and leisure production. The fact that the nutritional status factor explained a small part of total inter-worker variation in productivity underscores this point. It also means that an improvement in physical working capacity cannot necessarily be equated with increased productivity of workers engaged in market production.

A broad definition of "productivity" to include productivity in all economic activities, within the context of the home production model, is called for. A better understanding of the many interactions between the nutritional status of economically active populations and economic incentives is required within different socio-cultural settings. This will equip us to estimate fully the total economic consequences of marginal malnutrition in different populations.

REFERENCES

1. C. Bliss and N. Stern, "Productivity, Wages, and Nutrition: Part 1. The Theory," *J. Develop. Econ.*, 5: 331 (1978).
2. R. E. Evenson, "Food Policy and the New Home Economics," *Food Policy*, 6: 180 (1981).
3. G. S. Becker, "A Theory of the Allocation of Time," *Econ. J.*, 75: 493 (1965).
4. F. E. Viteri, "Considerations on the Effect of Nutrition on Body Composition and Physical Working Capacity of Young Guatemalan Adults," in N. S. Scrimshaw and A. M. Altshul, eds., *Amino Acid Fortification of Protein Foods* (MIT Press, Cambridge, Mass., USA, 1971), p. 350.
5. B. Belavady, "Nutrition and Efficiency in Agricultural Labourers," *Indian J. Med. Res.*, 54: 971 (1966).
6. J. D. Wolgemuth, M. C. Latham, A. Hall, A. Chester, and D. W. T. Crompton, 'Worker Productivity and the Nutritional Status of Kenyan Road Construction Laborers," *Am. J. Clin. Nutr.*, 36: 68 (1982).
7. Wu Leung and Woot-Tsuen, with the collaboration of Marina Flores, *Table de Composición de Alimentos para Uso en América Latina* (Interdepartmental Committee of Nutrition for National Defense and Institute of Nutrition of Central America and Panama, Guatemala; US Government Printing Office, Washington, D.C., 1961; English edition, 1962).
8. P. O. Åstrand and K. Rodahl, *Textbook of Work Physiology* (McGraw-Hill, New York, 1977).
9. M. D. C. Immink, F. E. Viteri, and R. W. Helms, "Food Substitution with Worker Feeding Programs: Energy Supplementation in Guatemalan Sugarcane Workers," *Amer. J. Clin. Nutr.*, 34: 2145 (1981).
10. F. E. Viteri, B. Torún, J. C. Galicia, and E. Herrera, "Determining Energy Costs of Agricultural Activities by Respirometer and Energy Balance Techniques," *Amer. J. Clin. Nutr.*, 24: 1418 (1971).
11. M. D. C. Immink and F. E. Viteri, "Energy Intake and Productivity of Guatemalan Sugarcane Cutters: An Empirical Test of the Efficiency Wage Hypothesis, Part 1," *J. Develop. Econ.*, 9: 251 (1981).
12. R. McCleary and R. A. Hay, Jr., *Applied Time Series Analysis for the Social Sciences* (Sage Publications, Beverly Hills, Calif., USA, 1980).
13. M. D. C. Immink and F. E. Viteri, "Energy Intake and Productivity of Guatemalan Sugarcane Cutters: An Empirical Test of the Efficiency Wage Hypothesis, Part II," *J. Develop. Econ.*, 9: 273 (1981).
14. G. B. Spurr, M. Barac-Nieto, and M. G. Maksud, "Productivity and Maximal Oxygen Consumption in Sugarcane Cutters," *Amer. J. Clin. Nutr.*, 30: 316 (1977).
15. M. D. C. Immink, F. E. Viteri, R. Flores, and B. Torún, "Microeconomic Consequences of Energy Deficiency in Rural Populations in Developing Countries," in E. Pollitt and P. Amante, eds., *Energy Intake and Activity* (Alan R. Liss, Inc., New York, in press).
16. J. F. Morrison and G. T. W. Blake, "Physiological Observations on Cane Cutters," *Europ. J. Appl. Physiol.*, 33: 247 (1974).
17. M. D. C. Immink, F. E. Viteri, and R. W. Helms, "Energy Intake over the Life Cycle and Human Capital Formation in Guatemalan Sugarcane Cutters," *Econ. Develop. Cultural Change*, 30: 351 (1982).