Energy Intake over the Life Cycle and Human Capital Formation in Guatemalan Sugarcane Cutters*

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1. Introduction

Improved nutritional intake is clearly a form of investment in human capital whenever a stream of economic benefits results beyond the immediate food-consumption period. The question that is being addressed in the present study is whether increased energy intake in the rural work force of developing countries may be expected to result in human capital formation. Of equal importance is the question related to the optimal life-cycle pattern of investments in human capital. Little evidence is available to evaluate the relative economic returns of improvements in nutritional status during the early stages of the life cycle, versus improvements in the nutritional status during the different stages of the productive phase. Yet, these are basic issues which need to be resolved before rational decisions can be made regarding the

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allocation of the scarce resources available to improve the nutritional status of both present and future rural work forces in developing countries.

Evidence suggests that improved nutrition during the preproductive phase of the life cycle, and especially during the first years of life, may be expected to improve mental development.[1] Selowsky and Taylor have attempted to show that improved mental development may be expected to have positive productivity effects among construction workers in Chile.[2] However, in physically strenuous occupations, the physical capacity of the workers may be a more important determinant of their productivity than the level of their mental development.

The available energy in rural workers in developing countries may well be the single most important determinant of their capacity to perform physical work over sustained periods of time. In the economics literature, the proponents of the so-called "efficiency wage theory" have based their arguments on the productivity effects of increased energy intake of workers during the productive phase of their life cycle. However, they did not consider that increased energy intake prior to reaching adulthood may also have important productivity effects upon entering the work force.

The efficiency wage hypothesis was first formulated by Leibenstein as part of his theory of underemployment in rural areas of developing countries.[3] The efficiency wage hypothesis was later used to explain why there may exist a long-run, constant real wage, which exceeds a minimum subsistence wage, in rural labor markets with pools of unemployed workers.[4] A thorough discussion of the theory, as well as some of the empirical evidence that exists, has been presented by Bliss and Stern.[5]

The central argument of the efficiency wage theory is the productivity-consumption relationship. Productivity is expressed in

[1] Michael C. Latham, "Protein-Calorie Malnutrition in Children and Its Relation to Psychological Development and Behavior," *Physiological Reviews* 54 (July 1974): 541–65.

[2] Marcelo Selowsky and Lance Taylor, "The Economics of Malnourished Children: An Example of Disinvestment in Human Capital," *Economic Development and Cultural Change* 22 (October 1973): 17–30.

[3] Harvey Leibenstein, *Economic Backwardness and Economic Growth: Studies in the Theory of Economic Development* (New York: John Wiley & Sons, 1957).

[4] See G. B. Rodgers, "Nutritionally Based Wage Determination in the Low Income Labour Market," *Oxford Economic Papers*, n.s. 27 (March 1975): 61–81; J. A. Mirrlees, "A Pure Theory of Underdeveloped Economies" in *Agriculture in Development Theory*, ed. L. G. Reynolds (New Haven, Conn.: Yale University Press, 1976); J. E. Stiglitz, "The Efficiency Wage Hypothesis, Surplus Labour, and the Distribution of Income in L.D.C.s," *Oxford Economic Papers*, n.s. 28 (July 1976): 185–207.

[5] C. Bliss and N. Stern, "Productivity, Wages and Nutrition. Part I. The Theory," *Journal of Development Economics* 5 (December 1978): 331–62; idem, "Productivity, Wages and Nutrition. Part II. Some Observations," ibid., pp. 363–98.

standardized work units, and the daily supply of work units is a function of the food intake of the workers. Starting at a level of daily energy intake which covers basal metabolic requirements, it is postulated that, at first, there are increasing productivity returns to higher levels of daily energy intake.[6] At some point, diminishing returns start to set in.

Private employers have an incentive to invest by means of productive wage increases in higher energy intake levels of their work force if they can internalize the productivity benefits. Thus, of crucial importance is how time-specific the productivity effect is. If increased energy intake has an immediate ("same day") effect on worker productivity, we may expect competitive employers to offer increased wages in kind (food rations, free meals, etc.) to their workers. If the productivity effect is a more long-run phenomenon only employers in monopsonistic labor markets, or employers who can enforce long-term employment contracts, would have an incentive to provide productive wage increases. Since it is assumed in the model that all wage increases are consumed by the worker, external benefits in the form of intergenerational productivity effects are not considered. However, as Bliss and Stern pointed out, workers may share wage increases in kind with members of their household.[7] In addition, there may be a secondary income effect. When workers are paid a piece rate, higher productivity will mean higher earnings for the worker, which in turn may lead to a more adequate nutritional intake by the worker's offspring. Any future productivity effects that may result cannot be internalized by the private employer. Thus, this possible divergence between private and social benefits would call for social investment in the nutritional status of the worker's children.

As a first step toward finding answers to some of these issues, the present paper attempts to assess the relative strength of the productivity effects of increased energy intake during different phases of the life cycle. A group of Guatemalan sugarcane cutters constituted the subjects of the study. Sugarcane cutting and loading is a physically demanding occupation, and one may expect, on a priori grounds, that these workers' physical capacity to perform work over long periods of time is an important determinant of their productivity.

2. Indicators of Energy Intake over the Life Cycle

Four indicators of lifetime energy intake are considered in this study. Two of these parameters, stature and upper-arm muscle area, are assumed to be indicative of past and chronic energy deficiency. Body

[6] Basal metabolic requirement refers to the daily energy intake necessary to maintain the basic life functions. It is usually expressed as the energy expenditure during 24 hours while the person is in a resting state. Any energy intake over and above the basal metabolic energy requirement is potentially available for activity.

[7] Bliss and Stern, "Productivity, Wages and Nutrition. Part II."

weight (standardized for height) and daily energy intake are taken to reflect more acute conditions of energy deficiency.

The stature of the workers is used as an indicator of their nutritional history during childhood and adolescence. Adult stature in healthy males is normally reached by the age of 16–17. Genetic, as well as environmental factors, including nutrition during the pre- and postnatal growth period, determine adult height. However, in populations living under poor socioeconomic conditions, nutrition appears to play a relatively greater role than genetic factors. Habicht and his co-workers concluded, after reviewing several studies of pre-school-aged children (i.e., from birth to 6 years) from widely different ethnic and socioeconomic backgrounds, that the variation in their heights due to socioeconomic differences was about four times as great as the variation due to ethnic differences.[8] Among school-aged children suffering from protein-energy malnutrition, the parent-child height correlations have been found to be significantly lower than among well-nourished school-aged children.[9]

Evidence shows that chronic undernutrition during the postnatal period results in both slow height-growth velocity during childhood and adolescence and in a prolonged period of growth, and that in spite of the extended period of growth (up to 22–24 years of age in males), the adult height of poorly nourished populations is reduced by 10%.[10] Thus, short adult stature in populations of low socioeconomic status can safely be assumed to be due in large part to chronic undernutrition (particularly, protein-energy malnutrition) during childhood and adolescence.

Upper-arm muscle area (standardized for height) is included as another indicator of chronic conditions of energy deficiency. The upper-arm muscle area was computed from mid-upper-arm circumference and triceps skin-fold measurement.[11] Wasting of body muscles takes place when protein reserves in the body are depleted. The absence of protein reserves reflects chronically low levels of protein and/or energy intake. When protein-intake levels are adequate, but

[8] Jean-Pierre Habicht et al., "Height and Weight Standards for Pre-School Children. How Relevant are Ethnic Differences in Growth Potential," *Lancet* 1 (April 6, 1974), pp. 611–15. Poor nutritional intake is clearly associated with low socioeconomic status. The impact on physical growth of inadequate nutrient intake, per se, is admittedly difficult to separate from the effect of other factors which are associated with poor living conditions. E.g., there exist synergistic relationships between disease state and nutritional status, and both affect physical growth.

[9] William H. Mueller, "Parent-Child Correlations for Stature and Weight among School Aged Children: A Review of 24 Studies," *Human Biology* 48 (May 1976): 379–97.

[10] Roberto A. Frisancho, "Nutritional Influences on Human Growth and Maturation," *Yearbook of Physical Anthropology* 21 (1978): 174–91.

[11] The formula is: (arm circumference [mm] π − Skin-fold [mm])^2 × π 4 (π − 3.1416). Upper-arm muscle area is standardized for height, since these parameters are usually correlated. The correlation coefficient in this group of workers was .34 ($p < .01$).

energy intake is low, part of the protein intake is diverted for energy purposes. Low muscularity has been found to be associated with chronically low levels of energy intake in Guatemalan agricultural workers.[12] Increased levels of energy (and protein) intake seem to improve muscularity in these workers.

Body weight is an indicator of energy stores and is more sensitive to acute and marginal conditions of energy deficiency. Reduced energy stores may be indicative of low levels of energy intake, or of high levels of energy expenditure, during a recent period prior to the measurement. For example, seasonal variation in energy availability and in energy needs may produce periods of negative and of positive energy balance in rural populations, as suggested by Oshima.[13] The absence of energy reserves means that the level of energy expenditure is wholly dependent on the current level of energy intake and that sudden increases in energy demand cannot be sustained for any length of time without an increased level of energy intake.

For body weight to be a useful indicator, it must be standardized for height, since these two parameters are strongly correlated. To determine the degree of weight deficiency, measured body weight was expressed as a percentage of the reference weight, using weight for height standards for adult males.[14]

Lastly, the level of daily energy intake is included as an indicator of the degree of energy deficiency at the time of the study. The daily energy intake of the workers in the study was obtained using the 1-day recall method. The survey was conducted twice during a 4-month period, and a point estimate was calculated by averaging the two estimates. The intraworker variation in daily energy intake raises questions regarding the validity of a point estimate of energy intake. The test-retest correlation coefficient, when using the 1-day recall method, has been shown to decline with the length of the interval between surveys.[15] On the other hand, the degree of monotony in the daily diet typically found in rural, low-income populations, should reduce the intraworker variation in daily energy intake. Since daily energy intake may be dependent on body size and composition, energy intake was also expressed per kilogram of body weight.

[12] Fernando E. Viteri, "Considerations on the Effect of Nutrition on the Body Composition and Physical Working Capacity of Young Guatemalan Adults," in *Amino Acid Fortification of Protein Foods*, ed. N. S. Scrimshaw and A. M. Altschul (Cambridge, Mass.: MIT Press, 1971).

[13] Harry T. Oshima, "Food Consumption, Nutrition and Economic Development in Asian Countries," *Economic Development and Cultural Change* 15 (July 1967): 385 97.

[14] See, e.g., D. B. Jelliffe, *The Assessment of the Nutritional Status of the Community*, World Health Organization Monograph Series no. 53 (Geneva: World Health Organization, 1966).

[15] Aaron Lechtig et al., "The One-Day Recall Dietary Survey: A Review of Its

The four lifetime-energy-intake parameters were correlated for the workers in the study. The correlations are presented and discussed in the next section.

3. Description of the Workers

A group of 158 sugarcane cutters who permanently resided on a large sugarcane plantation located in the Pacific lowlands of Guatemala constituted the subjects of the study. The data presented here were obtained during a 4-month period in 1974, prior to the introduction of an energy supplementation program. These sugarcane cutters normally cut and loaded sugarcane during approximately 30 weeks each year. During the remainder of the year they were employed in sugarcane-field maintenance tasks (planting, weeding, fumigation). They were paid a piece rate, in addition to certain payments in kind, and they determined their own working hours. The workers voluntarily participated in the study, and were not given any remuneration for their participation.

In table 1 the group of workers is described in terms of certain attributes. The workers ranged in age from 17 to 73 years. Over half of the workers were under 35 years of age (median age, 31). The workers' mean height was 160 cm, and they weighed on the average 53 kg.[16] They generally had a lean appearance and reduced energy stores as evidenced by their weight deficiency. Of the workers, 41% weighed less than 86% of their reference weight. The mean upper-arm muscle area in the group was 28.3 mm^2 per centimeter of height. It appears that the upper-arm muscle mass in this group was generally not severely diminished.[17] The estimates of daily energy intake show considerable interworker variation. The workers' daily energy requirement was estimated using an energy requirement coefficient of 62 kcal per kilogram of body weight. This is the estimated energy requirement for extremely active men.[18] Of the workers, 67% did not meet their estimated daily energy requirement.[19]

Usefulness to Estimate Protein and Calorie Intake," *Archivos Latinoamericanos de Nutrición* 26 (September 1976): 243–71.

[16] Twelve workers (7.6% of the sample) were 22 years of age or younger at the time of the study (age computed as of January 1, 1974). Height measurements taken in these workers a year later showed no significant increase for any of the workers. Thus, it was assumed that all workers in the sample had reached adult stature at the time of the study.

[17] Using a different indicator of upper-arm muscle mass, muscle circumference, we found that 15% met more than 100% of the standards. Of the workers, 55% fell between 90% and 100% of the standard, and only 2% fell below 80% of the standard.

[18] Institute of Nutrition of Central America and Panama (INCAP), *Daily Dietary Recommendations for Central America and Panama* (Guatemala: INCAP, 1973).

[19] Protein intake in this group of workers was generally adequate: mean intake was 83.1(±23.2) grams per day; on the average, 19% of total protein intake was from animal sources. Of the workers, 90% or more of the estimated daily protein requirement established for male adults (60 grams per day).

Age and the four parameters of lifetime energy intake were correlated, and the correlation coefficients are presented in table 2. The results may be summarized as follows. No secular improvement in environmental factors and nutrition appears to have taken place during the first half of the century, since age and adult stature were not significantly correlated. Older workers tended to be on lower daily energy intakes, but did not tend to be more energy deficient than their younger colleagues.[20] The latter do tend to have larger upper-arm muscle area than older workers. Body weight and upper-arm muscle area, both standardized for height, were significantly correlated. Workers on higher current energy intakes also tended to be less weight deficient and to have more upper-arm muscle mass. The significant correlations among these three parameters of lifetime energy intake suggest a relatively low intertemporal variation in energy intake within individual workers. However, most of the significant correlations are not strong.

Data on the daily output (tonnage of sugarcane cut and loaded) of the workers were obtained from company payrolls. A point estimate was calculated making use of the data for the whole 4-month period. Mean tonnage of cane delivered per man-day was 1.22 tons (table 1). In

TABLE 1

AGE, BODY COMPOSITION, DAILY ENERGY INTAKE, AND PRODUCTIVITY OF GUATEMALAN SUGARCANE CUTTERS, JANUARY–APRIL 1974 (N = 158)

A. AGE AND BODY COMPOSITION OF GUATEMALAN SUGARCANE CUTTERS

	Age (years)	Stature (cm)	Body Weight (kg)	Percentage of Weight/ Height (%)	Upper-Arm Muscle Area/Height (mm^2 cm)
Mean	35.1	159.5	53.3	88.4	28.3
+SD	11.0	5.6	5.9	7.6	3.5
Range	17 73	144.4–174.7	39.4–67.9	72 108	19.6–38.0

B. DAILY ENERGY INTAKE AND PRODUCTIVITY OF GUATEMALAN SUGARCANE WORKERS

	Daily Energy Intake* (kcal)	Daily Energy Requirement† (kcal)	Cane Deliveries per Man-day (tons)	Weekly Gross Earnings (quetzales)‡
Mean	2,951	3,303	1.22	10.27
+SD	689	366	.14	2.21
Range	1,480–5,276	2,440–4,210	.90–1.55	.00–14.90

* Subsample only (N 103).
† 62 kcal per kilogram of body weight.
‡ 1 quetzal US$1.

[20] This is consistent with expectation, since daily energy requirements tend to decline with age, after age 40.

TABLE 2

AGE AND PARAMETERS OF LIFETIME ENERGY INTAKE OF GUATEMALAN SUGARCANE CUTTERS: PRODUCT-MOMENT CORRELATION COEFFICIENTS

	Age (years)	Age Squared	Stature (cm)	Percentage of Weight/ Height (%)	Upper-Arm Muscle Area/Height (mm² cm)	Daily Energy Intake (kcal)[a]	Daily Energy Intake/Body Weight (kcal/kg)[a]
Age (years)							
Age squared	.96*						
Stature (cm)	−.11	−.08					
Percentage of weight/ height (%)	−.15	−.16	.16				
Upper-arm muscle area/height (mm²/cm) ..	−.19**	−.21*	.13	.79*			
Daily energy intake (kcal)[a]	−.28*	−.30*	−.03	.23**	.27*		
Daily energy intake/ body weight (kcal/kg)[a] .	.18	−.21**	−.28*	−.13	.02	.90*	

[a] Subsample only (N 103).
* $p < .01$.
** $p < .05$.

comparison with daily productivity levels reported for sugarcane cutters in Colombia, Jamaica, Tanzania, and Rhodesia, the Guatemalan cutters exhibited a low level of daily output.[21] Intercountry differences in work organization, environmental conditions, economic incentives, worker motivation, and other factors no doubt help to explain these differences in productivity levels.

The workers' mean gross earnings were approximately $10 per week. This did not include wage payments in kind.[22] Wage earnings from employment at the plantation typically constituted 90% of the total household income. We estimated the median household income in 1974 at US$550 per year (range, $297–$2,336) and the median per capita income at US$126 per year (range, $50–$549). None of the households owned or leased land to cultivate food for home consumption or for sale.

Of the workers, 81% were heads of households. The level of educational attainment was low: Only 23% of the workers had completed some formal education, though 45% reported to be able to read and write. Of the workers, 59% were born in the same plantation community as where they were living in 1974, pointing to a relatively low degree of population movement and labor turnover.

4. Parameters of Lifetime Energy Intake and Worker Productivity

Adult height has been found to be positively related to the daily productivity levels of Colombian sugarcane cutters, but height does not appear to be related to the daily productivity of sugarcane loaders.[23] Taller workers have been observed to have a greater mechanical efficiency in cutting cane.[24] The taller cutters are also likely to have a distinct advantage over the shorter workers when the cane stalks stand very tall, since cutters are normally required to remove the tops of the stalks ("topping").

[21] See G. B. Spurr, M. Barac-Nieto, and M. G. Maksud, "Productivity and Maximal Oxygen Consumption in Sugar Cane Cutters," *American Journal of Clinical Nutrition* 30 (March 1977): 316–21; Peter F. Heywood, "Malnutrition and Productivity in Jamaican Sugar Cane Cutters" (Ph.D. diss., Cornell University, 1974); C. T. M. Davies, "Relationship of Maximum Aerobic Power Output to Productivity and Absenteeism of East African Sugar Cane Workers," *British Journal of Industrial Medicine* 30 (1973): 146–54; J. F. Morrison and G. T. W. Blake, "Physiological Observations on Cane Cutters," *European Journal of Applied Physiology* 33 (1974): 247–54.

[22] The workers received for each day worked one food ration (distributed once a week) consisting of 2 pounds of maize and half a pound of black beans (a total market value of 26 cents at average 1974 prices for maize and black beans). Other non-monetary wage components included rent-free housing, free medical care, free primary education for school-aged children, and interest free loans.

[23] G. B. Spurr, M. Barac-Nieto, and M. G. Maksud, "Productivity and Maximal Oxygen Consumption"; idem, "Energy Expenditure, Productivity, and Physical Work Capacity of Sugarcane Loaders," *American Journal of Clinical Nutrition* 30 (October 1977): 1740–46.

[24] Morrison and Blake.

Muscle strength is clearly related to muscle mass, although the number of muscle fibers only in part determines muscle strength.[25] In cutting and loading of sugarcane, muscle strength, especially in the arms, should be important for productivity. Greater muscular strength allows a greater force to be exerted in cutting the cane stalks, perhaps allowing the simultaneous cutting of several stalks as observed in Australian cutters.[26] The time required to remove the leaves from a stalk may be reduced when a greater force is exerted with the cutting knife. Loading time of a given weight of cane stalks may also be reduced with greater muscle strength, as a greater weight can be handled with each loading movement.

Studies with sugarcane cutters in Jamaica led to the conclusion that workers who are seriously weight deficient are probably less able to maintain a constant level of daily productivity over time when faced with significant daily variations in energy intake.[27] To the extent that reduced energy stores reflect high levels of energy expenditure, an inverse relationship between weight deficiency and daily productivity may also be possible for limited periods of time.

High levels of daily energy intake were found to be positively associated with increased levels of energy expenditure and improved productivity of agricultural workers in Guatemala.[28] Two groups which significantly differed in mean daily energy intake showed a markedly different pattern of daily activity under similar conditions. Time-motion studies revealed that the high-energy-intake group spent a significantly larger portion of the day in activity and was able to perform standardized work tasks in significantly less time. However, this group also weighed more, was generally taller, and had more muscle mass and adipose tissue (when standardized for weight or height). Thus, it is difficult to separate the associations among the different indicators of energy intake and daily productivity in this study. It was concluded that long-run increases in the protein-energy intake of sub-optimally nourished agricultural workers can be expected to have beneficial effects in terms of body composition and work output.

The daily output of the workers tended to fall with their age ($r = -.24$ [$p < .01$] with age, and $r = -.27$ with age squared). Daily energy intake and upper-arm muscle area/height were also negatively correlated with age (table 2). Other factors may be responsible, as well, for the negative effect of older age on daily productivity.[29]

25 P. O. Åstrand and K. Rodahl, *Textbook of Work Physiology* (New York: McGraw Hill Book Co., 1970).

26 Morrison and Blake.

27 Heywood.

28 See Fernando E. Viteri (n. 12 above).

29 Physical capacity and psychomotor skills decline with age (Åstrand and Rodahl). Poor health is associated with older age. In addition, we may have a cohort effect: The

In order to examine the relationships between indicators of lifetime energy intake and daily productivity, several regression models were formulated and tested. The last equation in table 3 involves a subsample of the workers ($N = 103$), because dietary data are not available for the full sample. The results are as follows.

The indicators of chronic energy-intake deficiency are significantly related to the daily productivity of the workers (eq. 1). Taller workers, and workers with larger upper-arm muscle mass, tended to be more productive. However, these two indicators explain little of the interworker variation in daily productivity, and the regression coefficients are of small magnitude. For example, a difference in adult stature of 15 cm (6 inches) is associated with a difference in daily productivity of .06 tons. The percentage of weight/height is not significantly related to daily productivity.[30] This is contrary to the findings of the Jamaican study. Daily productivity and energy intake/kilogram of body weight are significantly related, but the regression coefficient is small: A difference in daily energy intake of 20 kcal per kilogram of weight (or about 1,000 kcal per day for the average worker) is associated with a difference in daily productivity of .06 tons. In the next sections we look at the implications of these findings for human capital formation through increased energy intake over the life cycle.

5. Estimates of the Stock of Human Capital

The Human Capital Stock of a "Typical" Guatemalan Sugarcane Cutter

As a first step toward obtaining estimates of the stock of human capital of a typical worker, we established the age-earnings profile for the sample of workers. Gross earnings represent in this case two aspects of worker productivity: (*a*) tons of cane supplied per man-day, and (*b*) number of man-days supplied. Gross earnings for the harvest season, as well as for the whole year, were used.[31] Polynomial regressions of the second degree were estimated and are presented in table 4A. The explanatory power of the models is low; thus, the regression lines have wide confidence limits. Clearly only rough estimates of the stock of human capital of a typical worker can be obtained by estimating the area under these age-earnings profiles.

The estimated age-earnings profile suggests that, over the life

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more capable workers are likely to be promoted (to positions with higher social status and or more pay) before they reach older age.

[30] Multicollinearity between independent variables is a problem in eqq. 2 and 3 (see table 2), but does not provide an explanation for the statistically insignificant regression coefficient of the percentage of weight/height. The partial correlation coefficient of the percentage of weight/height with respect to daily cane deliveries is .13 ($p > .10$).

[31] Interworker variation in earnings during the off harvest season only reflect differences in the number of man-days supplied, since all workers performed one standard task a day.

TABLE 3

REGRESSION MODELS OF LIFETIME ENERGY-INTAKE PARAMETERS ON DAILY PRODUCTIVITY OF GUATEMALAN SUGARCANE WORKERS
(Dependent Variable: Cane Deliveries per Man-day)

		INDEPENDENT VARIABLES[a]						
Equation	Constant	Height	Upper-Arm Muscle Area/ Height	Percentage of Weight/ Height	Daily Energy Intake Body Weight	R^2	F	$P > F$
1	.342	.004**	.007**	...	...	.071	5.28	.01
	(1.07)	(2.12)	(2.26)					
2.	.386	.004**	.010***	−.002	...	.074	3.67	.02
	(1.18)	(2.17)	(1.97)	(.70)				
3	.040	.005**	.016**	−.002	.003*	.177	4.89	.01
	(.09)	(1.99)	(2.50)	(.89)	(2.79)			

[a] The t-statistic is in parentheses.
* $p < .01$.
** $p < .05$.
*** $< .05 < p < .10$.

TABLE 4

ESTIMATES OF THE AGE-EARNINGS PROFILE AND HUMAN CAPITAL STOCK OF A TYPICAL GUATEMALAN SUGARCANE CUTTER

A. POLYNOMIAL REGRESSION MODELS TO ESTIMATE THE AGE-EARNINGS PROFILE OF A TYPICAL GUATEMALAN SUGARCANE CUTTER

	INDEPENDENT VARIABLES[a]					
DEPENDENT VARIABLES	Age	Age Squared	Constant[a]	R^2	F	$P > F$
Gross earnings—harvest season .	3.30** (2.02)	−.08** (2.20)	282.90* (17.51)	.031	2.45	.09
Gross annual earnings	3.52** (1.98)	−.08** (2.18)	428.33* (24.90)	.031	2.44	.10

B. ESTIMATES OF THE STOCK OF HUMAN CAPITAL OF A TYPICAL GUATEMALAN SUGARCANE CUTTER: PRESENT VALUES OF LIFETIME EARNINGS UP TO AGE 62 (quetzales)

	ANNUAL GROWTH RATE			
	0%		6%	
DISCOUNT RATE	Estimate 1	Estimate 2	Estimate 1	Estimate 2
6%	4,972	7,398	13,886	20,709
8%	3,948	5,877	9,426	14,037
10%	3,254	4,856	6,810	10,134

NOTE.—Estimate 1 is based on gross earnings during sugarcane harvesting. Estimate 2 is based on gross annual earnings. One quetzal = US$1.

[a] The t-statistic is in parentheses.

* $p < .01$.

** $p < .05$.

cycle, the gross earnings of these workers tend first to increase with age, tend to peak around age 37, after which they steadily fall with age. The relatively early peak in earnings is consistent with the predictions of the Becker model of the allocation of time and goods over the life cycle: The lower the level of investment in human capital, the earlier in the life-cycle peak efficiency is reached.[32]

The present value of lifetime earnings was calculated as of the seventeenth birthday,[33] and an average productive life of 45 years was assumed. A sensitivity analysis was performed with different rates of discount. What the "correct" rate of discount should be is an issue that we shall not attempt to tackle here. During the period 1972–78, the piece rate per ton of sugarcane cut and loaded increased on the study plantation by 6% a year, on the average. Thus, we estimated the present value of lifetime earnings, assuming a 0% and a 6% increase in annual earnings over the whole life cycle. These estimates are presented in table 4B and demonstrate the low level of investment in the human capital stock of these workers. Comparative data are difficult to obtain and, in any case, valid comparisons are difficult to make, since that would assume that the marginal rental value of the same stock of human capital is equal in different markets.[34] By way of contrast only, we include some estimates reported elsewhere. The reported median weekly earnings of farm workers in the United States in 1974 was $107.[35] Ignoring the effect of age on earnings, and assuming a discount rate of 8%, the present value of lifetime earnings over a 45-year period comes to $67,370 (vs. $5,877 in table 4B). Using 1963 age-earnings data for urban males in Mexico with 1 year of formal schooling, the estimated present value of their lifetime earnings approximates $9,455 (at a discount rate of 8%).[36] An estimate of $23,240 is obtained when using 1959 age-earnings data for U.S. males with from 0 to 4 years of formal schooling completed.[37]

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The results presented in the previous section indicate that the workers'

[32] Gary S. Becker, *Human Capital. A Theoretical and Empirical Analysis, with Special Reference to Education*, 2d ed. (New York: National Bureau of Economic Research, 1975).

[33] The legal minimum age for entry in the work force is 16 years in Guatemala.

[34] This would be a difficult assumption to maintain, since factor proportions in the production processes differ among geographically separate markets. And these labor markets may not be in long-run equilibrium, so that we cannot assume that wages equal the marginal rental value of the stock of human capital in each market.

[35] U.S. Bureau of the Census, *Statistical Abstract of the United States* (Washington, D.C.: U.S. Department of Commerce, 1978), p. 423, table 685.

[36] Martin Carnoy, "Rates of Return to Schooling in Latin America," *Journal of Human Resources* 2 (Summer 1967): 359–74.

[37] Giora Hanoch, "An Economic Analysis of Earnings and Schooling," *Journal of Human Resources* 2 (Summer 1967): 310–29.

heights were generally related to their daily productivity. Our objective here is to estimate the age-earnings profiles associated with different height levels. This will allow us to determine the increments in the stock of human capital that may be expected from signficant increments in the adult stature of these workers. A simple model will demonstrate how we shall proceed with the analysis. The increment in the human capital stock (I) associated with an increase in adult height is given by

$$\frac{d(t)(1 + g)^t}{(1 + i)^t}, \tag{1}$$

where $d(t)$ is the lifetime earnings differential of two levels of adult height, g is the annual rate of growth in the earnings differential ($g \gtrless 0$), and i is the rate of discount. Our task is to determine $d(t)$ and g. As before, we shall perform a sensitivity analysis with various rates of discount. We again assume that t 1, . . . , 45, as before.

The workers were classified according to three height categories: (*a*) "short" (mean, 153.3 [±2.9] cm); (*b*) "medium" height (mean, 159.5 [±1.7] cm); and (*c*) "tall" (mean, 165.7 [±2.7] cm). We used as cutoff points the thirty-third and sixty-seventh percentiles of the frequency distribution of stature. Regression models were formulated in order to test whether medium and tall workers were more productive than short workers, and whether tall workers were more productive than workers of medium height. Thus, in the regression models (table 5), the dummy variables HTGRP1 and HTGRP2 test for intercept differences, $d(t)$, among the three height levels. Also, we tested whether significant productivity differentials can be expected to remain constant over the whole life cycle. In the regression models the crossed effects, HTGRP1(age squared) and HTGRP2(age squared), test whether the annual rate of growth in the productivity differentials is significantly different from zero ($g \gtrless 0$). Two dependent variables, tons of cane delivered per 30 weeks, and gross earnings per 30 weeks are included in the regression analysis. To complete the models, upper-arm muscle area/height and percentage of weight-height were included as independent variables, along with age squared.

The results of the regression analysis presented in table 5 may be summarized as follows. The explanatory power of all four models was low. Upper-arm muscle area/height and percentage of weight/height were not significantly related to the productivity indicators. Tall workers were significantly more productive than short workers, $d(t) > 0$, and the productivity differential may be expected to remain constant over the productive life cycle ($g = 0$). Early on in the productive phase, tall workers appear not to be more productive than their colleagues of medium height. However, later on, a significant productivity differential between tall- and medium-height workers becomes apparent.[38]

It appears that there may be a critical minimum adult height below which the productivity of the sugarcane cutters of all ages is significantly reduced. Clearly then, those workers who suffered most severely from deficient energy (and protein) intake during childhood and adolescence can expect their productivity in sugarcane cutting to be most seriously affected. There appears to be no significant marginal return, in terms of increased productivity, to increased height above average height among young workers. However, increased stature be-

TABLE 5

REGRESSION MODELS TO ESTIMATE AGE-EARNINGS PROFILES FOR WORKERS WITH DIFFERENT HEIGHT LEVELS

	DEPENDENT VARIABLES			
	Cane Deliveries per 30 weeks (tons)		Gross Earnings per 30 weeks (US$)	
INDEPENDENT VARIABLES	Equation 1[a]	Equation 2[a]	Equation 3[a]	Equation 4[a]
Age squared	−.01*	.01	−.01	.02
	(2.60)	(.77)	(.63)	(.92)
Upper-arm muscle Area/height	1.37	.94	3.98	2.94
	(1.47)	(1.02)	(1.68)	1.23)
Percentage of weight/height	−.28	−.29	−1.06	−1.05
	(.66)	(.73)	(.99)	(.99)
HTGRP1[b]	−12.08**	−6.14	−41.97*	−36.18**
	(2.50)	(.97)	(3.43)	(2.22)
HTGRP2[c]	−4.31	9.07	−14.08	9.65
	(.89)	(1.46)	(1.14)	(.60)
HTGRP1(age squared)	...	.02	...	−.02
		(1.63)		(.71)
HTGRP2(age squared)	...	.03*	...	−.06**
		(3.29)		(2.29)
Constant	215.13*	222.35*	313.17*	332.25*
	(8.56)	(9.07)	(4.95)	(5.28)
R^2	.134	.201	.111	.146
F	4.16	4.74	3.46	3.30
$P > F$	.01	.01	.01	.01

[a] The t-statistic is in parentheses.
[b] Short = 1; all others = 0.
[c] Medium − 1; all others − 0.
* $p < .01$.
** $p < .05$.

[38] In other words, comparing short- and medium height workers, $d(t) > 0$ and $g < 0$, since the crossed effect HTGRP2(age squared) has a negative coefficient (see eqq. 2 and 4 in table 5).

yond the average height seems to provide additional productivity returns among older workers.[39]

Estimates of the stock of human capital of a typical short and tall worker are presented in table 6. These estimates were based on gross earnings, and on the tonnage of cane delivered valued at the going piece rate per ton. We assumed that $d(t)$ was provided by the regression coefficients of HTGRP1 in equations 1 and 3 (table 5), and that the productivity differential remains constant over the whole productive life cycle ($g = 0$).

Based on the value of the tonnage of sugarcane harvested, there appears to be a 5.5% increase in the human capital stock associated with a significant increase in adult stature. However, based on gross earnings, the increase in the stock of human capital appears to be close to 16%. This sharp difference in the two estimates of the marginal increase in the stock of human capital deserves comment. One interpretation may be that low energy intake during childhood and adoles-

TABLE 6

ESTIMATES OF THE STOCK OF HUMAN CAPITAL AT AGE 17: PRESENT VALUES OF LIFETIME EARNINGS UP TO AGE 62 OF A TYPICAL SHORT AND TALL WORKER

A. BASED ON TONNAGE OF SUGARCANE HARVESTED

	ANNUAL GROWTH RATE					
	0%			6%		
DISCOUNT RATE	Tall Worker	Short Worker	Difference	Tall Worker	Short Worker	Difference
6%	4,837	4,584	253	13,235	12,531	704
8%	3,869	3,668	201	9,034	8,556	478
10%	3,217	3,049	168	6,570	6,225	345

B. BASED ON GROSS EARNINGS DURING SUGARCANE HARVESTING (quetzales)*

	ANNUAL GROWTH RATE					
	0%			6%		
DISCOUNT RATE	Tall Worker	Short Worker	Difference	Tall Worker	Short Worker	Difference
6%	5,465	4,710	755	15,277	13,165	2,112
8%	4,353	3,752	601	10,343	8,914	1,429
10%	3,608	3,109	499	7,471	6,438	1,033

* 1 quetzal = US$1.

[39] Further evidence of diminishing marginal returns to increased adult stature was provided by the height-elasticity coefficient of daily cane deliveries, which was .58 ($p < .05$) as estimated by a double log function.

cence also negatively affects dimensions of worker productivity other than daily physical output. In fact, we found that the stature of the workers was positively correlated with the number of days worked per week ($r = .20$; $p < .02$). Thus, workers who were on higher energy intake during childhood and adolescence generally tend to be less absent from work.

Though these results clearly represent rough estimates, they do provide evidence which suggests that a significant improvement in energy intake during the preproductive phase of the life cycle may be expected to lead to human capital formation, at least among sugarcane cutters. Whether the increase in the stock of human capital associated with different height levels would provide a sufficient incentive, even under perfect market conditions, for parents to invest in significantly increased energy intake levels for their offspring during childhood and adolescence cannot be assessed here. That is, without estimates of the investment outlay in increased energy intake required to produce tall adults in chronically malnourished populations, it is not possible to estimate the private rate of return.

6. Investment in Increased Energy Intake of Sugarcane Cutters

In this last section we shall consider increased energy intake of the workers as an investment in improving daily productivity. We assume that increased energy intake does not lead to increased energy stores, or if it does, that this does not result in future returns in terms of increased productivity. The evidence which was presented supports this latter assumption: We found no significant relationship between the level of weight deficiency and daily productivity. Thus, increases in the daily energy intake of the workers are assumed to render immediate returns. This, in fact, is the basic assumption that underlies the productivity-consumption relation of the efficiency wage hypothesis. In this case, the returns which we measure are those which would accrue to the employer who is also assumed to undertake the investment in increased energy intake of the workers.

We deal with the investment cost first. We calculated that 1,000 kcal could be purchased at average market prices in 1974 for about 5.8 cents, if we assume that all of the calories were obtained from the consumption of maize and black beans, in the proportion of 4:1.[40] This constitutes a minimum-cost diet. However, the total cost per 1,000 kcal is likely to be considerably higher for the employer. The workers may not accept just more of the same food items they normally consume, but require different, higher priced foods. Though the employer may

[40] This was, in fact, what the food rations which the workers received consisted of. We found that among the households of the workers, on the average, 56% of total energy intake came from the consumption of maize, and 16% from black beans.

obtain the food items at below market prices through bulk purchases, costs will be incurred for storage, record keeping, and other administrative costs. In order to ensure that only the workers consume the food supplements, they may have to be provided on the job in the form of prepared meals, which further raises the costs per 1,000 kcal "delivered" to the workers. These delivery costs could easily double the total investment cost. Since we do not have data for these delivery costs, we shall use just the minimum-cost diet in our computations.

We do not have data on the marginal net revenue of sugarcane producers in Guatemala. Net revenue data are not easily obtained. We do know that the market price of a ton of sugarcane was established at $11.34 during the 1973–74 harvest season.[41] This price was slightly below the average market price of sugarcane in Guatemala during the 1970s.[42]

In order to estimate how a marginal increase in daily energy intake was related to daily productivity, a regression model was formulated and tested. The results are presented in table 7A. The main coefficient of interest is what we may call the energy-intake elasticity of worker productivity. An estimate of the basal energy requirement was subtracted from total energy intake, and the difference is daily energy intake available for activity.[43] In a double log function we estimated the sensitivity of daily productivity to changes in activity energy per kilogram of body weight, holding height constant. Daily productivity is strongly subject to diminishing returns to increased energy intake. This appears to be true for the whole subsample as well as for workers over 39 years of age. In younger workers we may expect zero returns.

The benefits from investment in increased energy intake were estimated at the median values of the variables, using the regression coefficients in table 7A, and assuming arbitrarily that the marginal net revenue equals 10% of the 1973–74 market price for sugarcane. The benefit-cost ratios in table 7B include the estimate of the minimum-cost diet (5.8 cents per 1,000 kcal). The benefit-cost ratio for the average worker in the whole subsample comes close to 1, and close to 2 for the average worker over 39 years of age. On the assumption that em-

[41] Foreign Agricultural Service, "Guatemala: Sugar," Agricultural Attache Report no. GT-5016 (Washington, D.C.: U.S. Department of Agriculture, 1976).

[42] The market price of sugarcane in Guatemala was set during various harvest seasons as follows: 1973–74, $11.34 per ton; 1974–75, $18.00 per ton; 1977–78, $8.50 per ton; and 1978–79, $11.30 per ton, with an average of $12.29 per ton for these four harvest seasons. We do not have price figures for the 1975–76 and 1976–77 harvests.

[43] The basal energy requirement is like a fixed energy cost, which does not change with the level of activity. Viteri and co workers estimated the daily basal energy requirement at 26.8 kcals per kilogram of body weight for a group of agricultural workers in Guatemala, and that is the estimate that was used here. See Fernando E. Viteri et al., "Determining Energy Cost of Agricultural Activities by Respirometer and Energy Balance Techniques," *American Journal of Clinical Nutrition* 24 (December 1971): 1418–30.

ployers cannot exclude workers from a supplemental feeding program based on age, the average benefit-cost ratio falls below 1 if we use the age-group specific ratios and weigh these by the relative frequency of the workers in the two age groups. For reasons which were previously mentioned, the total cost to the employer of delivering 1,000 kcal to the workers is likely to be much higher than just the cost of the basic staple foods. Possible substitution of supplemental calories for home energy intake may further increase the cost to the employer of achieving a given net increase in total daily energy intake of the workers. Given that the marked price of sugarcane is subject to sharp year-to-year fluctuations, the assumption that the marginal net revenue equals 10% of the average long-run market price may not be far off the mark.

TABLE 7

ESTIMATES OF ENERGY-INTAKE ELASTICITY OF WORKER PRODUCTIVITY AND BENEFIT-COST RATIO OF INVESTMENT IN INCREASED ENERGY INTAKE

A. REGRESSION MODELS TO ESTIMATE THE ENERGY-INTAKE ELASTICITY OF WORKER PRODUCTIVITY
(Dependent Variable: Log of Cane Deliveries per Man-day)

Independent Variables	All Workers (N = 96)[a]	Workers with Age < 39 Years (N = 60)[a]	Workers with Age ≥ 40 Years (N − 36)[a]
Height	.0038***	.0020	.0085*
	(1.80)	(.47)	(3.01)
Log (Activity energy/body weight	.0734*	.0013	.1024*
	(3.41)	(1.01)	(3.38)
Constant	−.6535***	1.490**	−1.511*
	(1.80)	(2.44)	(3.15)
R^2	.119	.030	.339
F	6.30	.88	8.46
$P > F$	.01	.43	.01

B. BENEFIT-COST RATIO OF INVESTMENT IN INCREASED ENERGY INTAKE OF AN AVERAGE WORKER, ASSUMING MARGINAL NET REVENUE EQUAL TO 10% OF 1973–74 MARKET PRICE OF SUGARCANE

All Workers	Workers with Age ≤ 39 Years	Workers with Age > 40 Years
1.2	...	1.8

[a] The t-statistic is in parentheses.
* $p < .01$.
** $p < .05$.
*** $< .05 < p < .10$.

The results indicate that increased energy intake of the sugarcane cutters may not have strong productivity returns. Whether such productivity returns provide a sufficient incentive for employers to augment the energy intake of their workers by means of productive wage increases and/or supplemental feeding remains to be seen.

7. Concluding Comments

Increased energy intake during childhood and adolescence appears to have a positive productivity effect in sugarcane cutting once adulthood is reached. Our calculations tended to show that increased energy intake during the preproductive phase of the life cycle may be an important form of investment in human capital under certain circumstances. The evidence does suggest that there are diminishing productivity returns to increased adult stature, especially among younger workers. But we may generalize by stating that the intergenerational productivity effects of increased energy intake of the present rural work force should not be left unconsidered. There may be a significant economic cost associated with childhood malnutrition, not only in occupations in which mental ability determines productivity, but also in those occupations in which physical capacity may be expected to be the main determinant of productivity.

The results show a weak productivity/energy-intake relationship among the sugarcane cutters. Increased energy intake of these workers may be expected to have an "immediate" effect on productivity rather than a delayed or long-run effect. Our calculations tended to show that for the employer there existed little economic incentive to invest in increased energy intake of his resident work force under existing conditions. This conclusion is subject to two caveats. An intertemporal extrapolation from the results of an intratemporal analysis has admittedly limited validity. And we focused on only one aspect of worker productivity: tonnage of sugarcane delivered per man-day. Increased energy intake may have a positive effect on the supply of labor time through a reduction in absenteeism; or the quality of work performance may improve. Such positive productivity effects would reduce average costs of production, thus creating an economic incentive for employers to invest in the energy intake and nutritional status of their work force.

Perhaps stronger arguments can be advanced for social investment in the energy intake and nutritional status of present and future rural work forces in developing countries. As stated before, the investment in the nutritional status during the growing years of the life cycle can be expected to have productivity returns once adulthood is reached. But increased energy intake and improved nutritional status of adult workers may also produce external benefits. Assuming that workers remain in energy balance (at least in the long run), then workers on high energy intakes, though perhaps not much more productive than their colleagues on lower intakes, are more active, and expand more energy, off the job. Important economic benefits may result when greater energy availability for off-the-job activities transforms into greater involvement in community affairs, improved social interaction, and so on. Clearly, private benefits also accrue to the worker because of a more intensive use of leisure time.

The weak productivity/energy-intake relationship brings into question the empirical relevance of some of the crucial arguments on which the efficiency wage theory is based. The sharply diminishing productivity returns from increased energy intake raises doubts whether the "wage elasticity of productivity" can realistically be expected to exceed unity, as proposed by Leibenstein. One case study is not sufficient to repudiate a theory. But the results reported here do point to the need for a better understanding of the productivity-consumption relationship among rural workers in developing countries.