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THE IMPACT OF NUTRITIONAL STATUS ON AGRICULTURAL PRODUCTIVITY: WAGE EVIDENCE FROM THE PHILIPPINES*

Lawrence J. Haddad and Howarth E. Bouis

I. INTRODUCTION

This paper examines the impact of individual nutritional status on agricultural wage rates in a southern Philippine province. Recent empirical investigations have shown a positive relationship between nutritional status and labour productivity as measured by wages for agricultural labourers and/or own-farm output (Strauss, 1986, Sahn and Alderman, 1988, Deolalikar, 1988). Such results have an extremely important policy implication in that they demonstrate that expenditures for improved health and nutrition are not merely ends in themselves (important as that may be), but also investments in improved productivity and higher household incomes, particularly for the landless poor who are so dependent on wage income as a source of livelihood.

The discussion of a link between an individual's work productivity and nutritional status has a long history in both the nutrition and economics literatures. The relationship was first described within an economic framework by Leibenstein (1957) in his explanation of the coexistence of surplus labour and downward wage rigidities in labour markets. His treatment was used as the point of departure for subsequent theoretical work which was developed and extended by Rogers (1975), Mirrlees (1976), Stiglitz (1976), and Bliss and Stern (1978a, 1978b).[1]

Undernutrition has been defined recently by some nutritionists in terms of failures of bodily functions: 'unacceptable penalties in terms of hunger,

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[1] This body of work revolves around the efficiency wage hypothesis (EWH) which proposes an explanation for the coexistence of labour surpluses and downward wage rigidities for populations with low adult calorie intakes. According to the EWH, pushing wages below a certain level would be counterproductive for employers because workers would be unable to purchase sufficient dietary energy to be effective. We shall not be testing the EWH in this paper but rather attempting to test the hypothesis of a positive relationship between agricultural productivity (as measured by wage returns) and the avoidance of undernutrition, a necessary but not sufficient condition for the EWH.

illness, dysfunction, and risk of dysfunction' (Pacey and Payne, 1985). At just what level of nutritional deprivation this impairment occurs is the subject of some debate. On one side of the debate, the 'small but healthy' paradigm claims that individuals who have experienced mild to moderate malnutrition in childhood suffer no functional impairment (Seckler, 1982). Many nutritionists (e.g., Martorell, 1989; Martorell *et al.*, 1989) and economists (e.g., Dasgupta and Ray, 1987) dispute this view by pointing to nutritional evidence suggesting small body size does have functional implications in adults in terms of work productivity, work capacity, and female reproductive performance.

Empirical results to be presented in this paper support the latter view and the previously cited economic studies on the positive effects of adult nutritional status on wage achievement, in the sense that better nutritional status is associated with higher wages, after controlling for simultaneity and a number of other effects. However our results differ from these previous empirical studies in that higher wages appear to result from better height, a cumulative measure of the absence of poor diets and infection (controlling for genetic endowment) in early childhood, rather than from short-run (calorie intake) or medium-run (weight-for-height) proxies of nutritional status. This implies that short- to medium-run policies designed to improve calorie intakes and weights of adults will have little impact on agricultural productivity, at least in our survey area. Rather, productivity increases through better health and nutrition will be more fully realized with a substantial lag as better nourished, healthier children attain better height adults.[2]

II PREVIOUS EMPIRICAL STUDIES OF THE NUTRITION-AGRICULTURAL PRODUCTIVITY RELATIONSHIP

Empirical investigation of the impact of health and nutritional status on agricultural productivity has been undertaken most rigorously by Strauss (1986), Sahn and Alderman (1988), and Deolalikar (1988). Analyses prior to these failed to take account of the simultaneity of wage and nutritional status effects (e.g. Ryan, 1982). Strauss, and Sahn and Alderman demonstrate a positive calorie availability-agricultural productivity link while controlling for the right-hand side endogeneity of calorie availability, the former in an agricultural production function and the latter in a wage equation.[3]

Deolalikar (1988) improves on this work in several ways due, in part, to a more complete data set. Deolalikar's innovations are threefold: first, the use of individual calorie intake (versus household calorie availability expressed

[2] This conclusion needs to be qualified somewhat. Short- and medium-run improvements in health and nutrition are almost bound to increase the number of days worked. However, we find no evidence that short- and medium-run improvements increase productivity, given that labourers have entered the labour force for a particular time period.

[3] For a discussion of the distinction between calorie availability and calorie intake, see Bouis and Haddad (1990a).

on a per capita basis); second, the use of weight-for-length, a medium-run indicator of health and nutritional status to complement short-run calorie intake; and third, the panel nature of his data set allowed for the elimination of potential bias in regression coefficient estimates due to time-invariant, individual-specific effects.

His procedure is to include both individual calorie intake and weight-for-height as explanatory variables in the same wage equation estimation. He finds weight-for-height, but not calorie intake, to be an important determinant of wage achievement, and concludes that the medium-run effects of better nutrition are quite large and positive, even though the short-run effects are insignificant.

In the remaining sections of the paper, we argue that these procedures can be improved upon in three ways: (1) although previous studies make little mention of the age distribution of the wage-earners used, for our sample it is prudent to segregate the analysis between (a) adults who have attained maximum height and (b) the large number of children who also earn agricultural wages, but are still growing; (2) we undertake a more complete decomposition of nutritional status into short- and long-run effects, specifically the addition of height as an explanatory variable; and (3) we estimate the wage relationships within a framework that permits a more disaggregated investigation of the sources of nutritional status endogeneity; in particular, we control for bias due to correlation between time-varying unobserved effects and included explanatory variables. For our data set, the last two technical adjustments fundamentally alter the policy conclusion that is to be inferred from the regression estimations.

III THE DATA

The data used in this paper are taken from surveys of 448 rural households residing in Bukidnon province on the island of Mindanao in the Philippines. Households were surveyed four times at four-month intervals and data were collected on a wide range of topics including landholdings, income sources, expenditure patterns, calorie intakes, and nutritional status (see Bouis and Haddad, 1990b for a more detailed description of how the data were collected).

The analysis uses individual daily calorie intake data, derived from a 24-h recall by the mother, of foods consumed by individual household members. Weights, heights, and age are available for all individuals and an average agricultural wage is recorded over each four-month period, by crop and by task, for all individuals ever participating in the paid agricultural labour force.

Table 1 shows average daily wages earned and average days worked in the agricultural labour force over the 16 months covered by our surveys, by various demographic and socio-economic groupings of our respondents. Average wages for each individual for each survey round are weighted by days spent in the various crop-specific tasks reported (non-participants in the

TABLE 1

Average Wage Rates and Days Worked in the Off-Farm Paid Agricultural Labour Force by Age Group, by Farm Size, by Expenditure Quintile, Type of Household Member, 1984/85

	Average wage		*Days worked*		
Category	*Wage*	*Number of observations*	*Days*	*Number of observations*	*Participation rate*
Age group (in years)					
6–10	12.6	41	1.6	574	7.1
11–17	16.2	192	15.2	583	32.9
18–23	20.9	90	14.8	265	31.6
24–36	21.1	295	51.7	528	55.9
37–49	20.8	132	29.3	316	41.8
≥ 50	23.6	11	8.8	74	14.9
All	19.4	761	21.7	2,360	32.2
Farm size (in hectares)					
< 1	17.5	308	53.7	636	48.4
1–2	20.1	163	17.5	446	36.5
2–3	20.1	146	12.8	387	37.7
3–4	21.1	69	10.6	250	27.6
4–6	21.3	51	4.1	252	20.2
6–12	24.7	24	1.7	310	7.7
> 12	—	0	0.0	79	0.0
All	19.4	761	21.7	2,360	32.2
Expenditure quintile					
1	18.4	219	30.8	526	41.6
2	18.1	193	26.4	461	41.9
3	19.5	179	28.0	457	39.2
4	21.2	115	17.6	425	27.1
5	23.2	55	5.2	491	11.2
All	19.4	761	21.7	2,360	32.2
Type of household member					
Husband	21.6	313	75.1	448	69.9
Wife	20.9	156	11.8	448	34.8
Son	16.7	171	13.6	631	27.1
Daughter	15.1	105	5.5	576	18.2
Other	16.3	16	2.3	257	6.2
All	19.4	761	21.7	2,360	32.2
Crop-tenancy group					
Corn owner	19.5	65	5.0	295	22.0
Corn owner/tenant	21.5	62	10.9	252	24.6
Corn tenant	20.4	173	16.4	430	40.2
Corn labourer	16.8	130	70.3	195	66.7
Sugar owner	22.2	55	6.1	327	16.8

TABLE 1 — *contd*

Category	Average wage: Wage	Average wage: Number of observations	Days worked: Days	Days worked: Number of observations	Participation rate
Sugar owner/renter	24.2	16	3.0	178	9.0
Sugar renter	18.8	55	11.1	167	32.9
Sugar labourer	17.3	125	70.3	248	50.4
Corn other rent	21.1	27	18.6	75	36.0
Other occupation	19.7	53	15.7	193	27.5
All	19.4	761	21.7	2,360	32.2

Source: International Food Policy Research Institute–Research Institute for Mindanao Culture surveys, 1984/85.

Notes.

(1) Wages reported for specific crop-tasks are weighted by number of days spent in those crop-tasks.

(2) A maximum of 487 days were covered by the survey rounds; those who did not work in the agricultural labour force are included in average calculations.

(3) The participation rate is computed by dividing the number of observations for average wage by the number of observations for days worked, then multiplying by 100.

(4) Quintile 1 is lowest rank and quintile 5 the highest.

paid labour force are, of course, excluded from these calculations).[4] Average days spent in the paid labour force were calculated by including non-participants as zero observations, so that Table 1 also gives an indication of the distribution of paid agricultural labour force participation across the various demographic and socio-economic groupings.

As might be expected, persons in higher-income groups work fewer days in the paid agricultural labour force and have higher reservation wages for entering that labour force. Children below the age of 18 constitute a significant proportion of the paid agricultural labour force participants. Not surprisingly, older children earn substantially higher wages than younger children.

[4] Aggregation of the crop and task specific wage rates to provide a single wage 'achievement' for each individual per round could take the form of a simple average wage across crop-tasks (SIMPWAGE), an average wage across crop-tasks with days worked per crop-task as weights (WEIGWAGE), or the minimum wage reported over all crop-tasks in the survey round (MINWAGE). Real daily wages were calculated in these three ways. Patterns across the various demographic and socio-economic groupings shown in Table 1 are maintained when comparing SIMPWAGE and WEIGWAGE, but are more volatile for MINWAGE. We choose not to use MINWAGE, despite the fact that it may be the purest representation of an individual's marginal product value, because this representation of the wage variable is extremely vulnerable to reporting errors. Our selected wage variable, WEIGWAGE, represents a compromise in that this wage rate formulation is tainted with labour supply decisions about days worked, but is likely to be least sensitive to measurement error.

IV. LABOUR MARKET, NUTRITIONAL, AND ECONOMETRIC CONSIDERATIONS FOR MODEL FORMULATION AND ESTIMATION

4.1. The Agricultural Labour Market in Bukidnon

Several (not necessarily mutually exclusive) mechanisms could explain how better worker nutritional status might result in, or be associated with, higher agricultural wages: (i) an enhanced ability to undertake piece-rate work,[5] (ii) payment based on a worker's past performance, (iii) payment based on a worker's perceived work potential, and (iv) positive correlation between nutritional status and unobserved characteristics such as individual initiative (mediated through, say, a preference for education). The last effect can be controlled using panel data estimation methods, but the analysis that follows cannot distinguish between the remaining three mechanisms, primarily due to a lack of information about the employer decision-making process.

As implied above, one crucial assumption underlying our analysis is that local labour markets operate relatively freely, i.e. that higher worker productivity is rewarded with higher wages through a market mechanism. Our evidence, though indirect, suggests that labour markets work reasonably well in the survey area. First, there are no labour unions or restrictive practices by employers. Second, evidence for the existence of efficient staple food markets in the survey area (Bouis and Haddad, 1990b) attests to the existence of a necessary condition for a well-functioning labour market, namely, adequate infrastructure.

4.2. Decomposition of Nutritional Status Effects: Long versus Short Run

4.2.1. Restrictions on Parameters

In previous analyses, weight-for-height is interpreted as a medium-run 'stock' measure of nutritional status. But in the absence of height as an additional regressor, this specification is misleading. To see this, consider

$$\ln(w) = \alpha_0 + \alpha_1 W/H + \alpha_2 H + \alpha_3 X \quad (1)$$

$$W = f(H, Z) \quad (2)$$

where:

$\ln(w)$ = the natural logarithm of the daily wage rate,
H = height,
W = weight,
X = a vector of other explanatory variables for wage determination and,
Z = a vector of explanatory variables for weight determination

[5] This effect should not be confused with work capacity, as we are measuring wage rate, e.g. piece-rate completion per day.

It then follows that

$$\frac{\partial \ln(w)}{\partial H} = \frac{\alpha_1}{H}\left[f_1 - \frac{W}{H}\right] + \alpha_2 \tag{3}$$

and

$$\frac{\partial \ln(w)}{\partial Z} = \frac{\alpha_1}{H} f_2 \tag{4}$$

where $f_1 = \partial W/\partial H$ and $f_2 = \partial W/\partial Z$.

Equation (4) represents the impact of weight on wages, keeping height constant. Finally,

$$\frac{\partial \ln(w)/\partial H}{\partial \ln(w)/\partial Z} = \frac{f_1 - W/H}{f_2} + \frac{\alpha_2}{\alpha_1}\left[\frac{H}{f_2}\right] \tag{5}$$

From the last equation, if $\alpha_2 = 0$, the relative effect of height and weight upon $\ln(w)$ is entirely independent of the coefficient estimated on W/H. The inclusion of the height variable term (in equation 1) allows for a test of the *direct* effect of height on $\ln(w)$. Moreover, the total effect of height on $\ln(w)$ now depends on α_1 *and* α_2, and the relative effect of W and H on $\ln(w)$ depends on estimated parameters (equation 5). This distinction is important, as height may not be a productivity-limiting factor for light to moderate activities, but may be a limiting factor for strenuous activities (Martorell and Arroyave, 1988; Payne and Lipton, 1990).

In addition to the inclusion of height as a separate variable for some of the wage equation specifications, we replace weight-for-height with body mass index (BMI = weight/height^2). Body mass index is judged to be superior to weight-for-height as a measure of chronic adult energy deficiency (James *et al.*, 1988; Womersley and Durnin, 1977). This substitution also has a fortuitous statistical implication in that body mass index is less collinear with height as compared to weight-for-height.[6]

4.2.2. *Weight and Height Gains in Adolescents*

Previous theoretical and empirical studies which have looked at the link between nutrition and labour productivity have implicitly focused on adults who have attained maximum height. The case of adolescents has not been specifically mentioned in any of the previous studies cited in this paper; yet persons 17 years of age and below account for nearly one-third of the 761 respondents who ever participated in the agricultural labour force during the

[6] An alternative specification would be to include W and H directly as regressors. This would lose the precise short versus long run interpretation of nutritional status effects on wage, and in practice would prove difficult to estimate reliably due to high collinearity between the two variables.

16 months covered by our surveys. In the estimation procedures, what are the implications of mixing observations for these younger individuals, who are gaining weight and height over time, with observations for adults whose heights are fixed?

Table 2 shows average height, weight, weight-for-height, and body mass index by age and by sex for all of the respondents in our sample above the age of five (both those who participated in the agricultural labour force, and those who did not). In Table 2, average weight-for-height increases monotonically and doubles in value from the age of 6 to the age of 19 for both males and females, at which point weight-for-height levels off until the age of 50 or so, when it declines. Data presented in Table 1 suggest that wages earned by persons who are teenagers and younger increase rapidly with age, so that wage and calorie intake, weight-for-height, and height are positively correlated, as are presumably wage and experience, maturity, and physical strength, three factors which could be expected to contribute to higher wages for older children as they approach adulthood.

By contrast, for adults experience and maturity can be treated as (individual-specific) characteristics that are likely not significantly correlated with nutritional status. The implication is that OLS estimation of the wage equation for adolescents would amost certainly result in biased coefficients for any right-hand side nutritional status variable. The within fixed-effects estimator could also result in biased estimates for adolescents since experience, maturity, and physical strength (which are not included as explanatory variables) are not differenced out (they exhibit a positive trend over time), and can be expected to be positively correlated with included variables that also trend positively over time such as weight-for-height and height.[7] This is not a problem for the Hausman-Taylor (1981) random-effects technique, since it avoids bias due to time-varying unobserved effects.[8]

4.3. Sources of Nutritional Status Endogeneity

Previous studies make the (untested) assumption that the endogeneity of nutritional status variables in the wage and farm production equations is due entirely to their covariance with unobserved time-invariant factors (e.g. Deolaliker, 1988). The implicit assumption is that the elimination of unobservable time-invariant individual effects using panel techniques will completely eliminate calorie intake's endogeneity. A Hausman test across fixed versus random effects estimators for whether or not calorie intake has a

[7] The extent of the bias would depend, however, on the length of time between panel observations, the extent of the bias increasing with time.

[8] Using the Hausman-Taylor technique for adults, height is treated as an exogenous, time-invariant variable. For adolescents, height is treated as time-varying endogenous variable. For both adults and adolescents, weight-for-height and body mass index are treated as time-varying endogenous variables, as are calorie intakes.

TABLE 2
Height, Weight, Weight-for-Height, and Body Mass Index by Age and by Gender

	Female				*Male*			
Age	*Height*	*Weight*	*Weight-for-height*	*BMI*	*Height*	*Weight*	*Weight-for-height*	*BMI*
6	106.2	16.4	15.4	14.5	106.2	16.4	15.4	14.5
7	110.9	17.7	15.9	14.3	112.0	18.2	16.2	14.5
8	116.1	19.9	17.1	14.7	116.3	20.0	17.2	14.8
9	121.2	22.1	18.1	15.0	120.2	21.4	17.8	14.8
10	125.2	23.6	18.9	15.1	123.6	23.0	18.6	15.1
11	130.2	26.8	20.6	15.8	129.0	25.7	19.8	15.3
12	135.9	30.3	22.1	16.2	133.0	28.0	20.7	15.6
13	142.2	34.7	24.2	17.0	137.6	30.2	22.0	16.0
14	145.9	38.2	26.2	17.9	143.9	34.2	23.6	16.4
15	147.4	41.0	27.7	18.8	150.1	39.2	26.1	17.3
16	148.9	42.9	28.9	19.3	154.7	42.8	27.7	17.9
17	149.4	45.6	30.3	20.2	157.9	46.6	29.4	18.6
18	150.0	47.1	31.6	21.0	157.8	47.8	30.3	19.2
19	150.0	47.6	31.8	21.2	159.3	49.8	31.3	19.7
20	149.5	46.5	31.1	20.9	160.7	50.5	31.2	19.4
21	151.2	46.5	31.0	20.5	159.3	51.8	32.3	20.2
22	149.0	44.4	30.1	20.2	161.1	52.3	32.1	19.9
23	151.0	47.3	31.3	20.7	164.1	52.3	32.2	19.7
24	150.2	45.4	30.3	20.2	161.2	51.9	31.8	19.7
25	149.5	45.7	30.7	20.5	161.4	52.7	32.7	20.3
26–30	151.3	47.2	31.3	20.7	162.9	53.6	32.9	20.2
31–35	151.1	48.0	31.8	21.0	161.0	52.4	32.6	20.2
36–40	149.8	48.2	32.1	21.4	162.0	53.6	33.1	20.4
41–45	150.3	47.3	31.4	20.9	160.4	53.2	33.2	20.7
46–50	149.2	45.5	30.6	20.5	159.5	51.7	32.4	20.3
>50	146.0	38.3	26.2	17.9	157.8	49.7	31.4	19.9

Source: International Food Policy Research Institute–Research Institute for Mindanao Culture surveys, 1984/85.
Notes:
(1) Averages computed for all surveyed individuals, regardless of whether he/she participated in the agricultural labour force.
(2) Height expressed in centimetres; weight expressed in kilograms; weight-for-height expressed in kilograms per metre; body mass index expressed in kilograms per metre squared.

zero covariance with the unobserved time-invariant effects ignores potential sources of time-varying calorie intake endogeneity, for example, seasonality effects and measurement error.

The well-documented phenomenon of seasonality in wage level and in nutritional status in poor rural societies (Sahn, 1989) suggests the existence of time-varying factors which could contribute to their simultaneous determination. While measurement of these factors may prove difficult within the framework of a household survey, their possible presence should at least be controlled for. In this paper, we shall attempt to mitigate any possible covariances of calorie intake and weight-for-height with the unobserved time-varying factors by using instrumental variables (2SLS and Hausman-Taylor) estimation.

It is generally accepted that the incidence of random measurement error in rural household surveys is likely to be widespread and of a significant magnitude (Scott *et al.*, 1980). Random measurement error in right-hand side variables will lead to biases in OLS estimates, which GLS estimation, in the absence of prior information about the variance of the measurement error, cannot eliminate (Kmenta, 1986, p. 352), and which fixed effects estimation may even exacerbate (Bouis and Haddad, 1990a).[9]

In this paper, we estimate the wage relationship using ordinary least squares (OLS), two-stage least squares (2SLS), within fixed effects (WITHIN), and Hausman-Taylor (H-T) random-effects techniques. The matrix of estimates produced will permit us to say something about the relative importance of the various sources of nutritional status endogeneity. A comparison of the 2SLS and H-T estimates will permit us to assess whether individual specific effects are important in the joint determination of wage rate and nutritional status. Furthermore, a comparison of the WITHIN and H-T estimates will provide some indication as to the importance of time-varying endogeneity in the nutritional status variables (Bouis and Haddad, 1990a). OLS estimation will permit an examination of the magnitude of the unadjusted nutritional status effect on wage level. Finally, a comparison of OLS and 2SLS will provide another indication of the importance of time-varying nutritional status endogeneity.

4.4. *Wage Equation Specification*

Our general wage equation specification follows previous studies except for the specification of nutritional status and the method of estimation:

$$\ln w_{it} = a + bC_{it} + dY_{it} + eX_i + \alpha_i + \varepsilon_{it} + v_{it} \tag{6}$$

where:

i = indexes the individual,
t = indexes the survey round $t = 1, 2, 3, 4$,
w = the real daily wage in pesos,

[9] Deolalikar (1988) rules out the presence of significant random measurement error by appealing to the closeness of OLS, GLS, and fixed-effects estimates. This is neither a necessary nor a sufficient condition for the absence of measurement error.

C = a vector containing individual daily calorie intake per adult equivalent (in Kcal), weight-for-height (or body mass index; kg/cm or kg/m^2), and height (cm),
X = a vector of time-invariant variables including household demographics,
Y = a vector of time-varying control variables including an individual's age,
α = an unobserved time-invariant individual-specific effect,
ε = an unobserved time-varying effect, and
υ = an iid error term.

Table 3 provides the definitions of variables used and their means.

V. EMPIRICAL RESULTS

Because two of the estimators used require panel data, the empirical analysis includes only individuals with wage observations for at least two survey rounds. In total, 390 individuals are represented, contributing 1,168 observations (133 individuals supply four observations, 122 supply three observations, and 135 supply two observations). The adolescents (all individuals less than 20 years of age) provide 212 observations from 84 individuals, and the adults provide 956 observations from 306 individuals.

5.1. Descriptive Results

It is instructive to examine the distribution of various tasks among short and tall adult men and women (individuals at least 20 years in age), and those with low and high weight-for-height and body mass index values. For the regression subsample, Table 4 breaks down wages and days worked for men and women into five task-specific categories by body size quartiles running from lowest to highest in value. Not controlling for any intervening variables, we can see that, on average, taller men substitute days in weeding activities (low mean wage) with higher-paying cutting activities. A similar, but less marked pattern is displayed across weight-for-height quartiles. For body mass index, no such pattern is evident. Compared to men, women in the off-farm agricultural labour force spend more days in weeding and harvesting tasks, while spending virtually no time in the ploughing and cutting tasks.

As for the daily wage rate, Table 4 suggests that the individual wage earned varies more across task than within task by nutritional status, i.e. taller labourers tend to work disproportionately in tasks which pay higher wages. For men, wages rise from the lowest to the highest height quartile, but for women, the strongest effect is across weight-for-height quartiles.[10]

[10] We were unable to pursue gender differences in the context of a regression analysis due to the small number of adult women for whom we have at least two wage observations.

TABLE 3

Descriptive Statistics for of Variables used in the Regression Analysis

Variable label	*Variable description*	*Mean of variables*		
		Adult	*Adolescent*	*Pooled*
AGEYNGCH	Age of youngest child in household, months	29.63	39.44	31.41
AGEYR	Age in years	34.21	14.86	30.69
AVHT	Height in centimetres	159.65	144.76	156.95
AVNETWTH	Net worth of household (pesos)	5,519.02	7,141.06	5,813.43
BMI	Body mass index = weight (kgs)/ height squared (metres)	19.97	17.40	19.51
ED	Years of formal education	5.00	4.17	4.85
HHSIZE	Household size	6.79	9.07	7.20
IDCAL	Calorie intake per day, 24-h recall	2,605.06	1,937.30	2,483.86
LNWAGE	Natural log of real daily wage (pesos), average weighted by crop-task days	2.94	2.64	2.89
MARKDIST	Distance to nearest food market (metres)	4,393.64	4,682.52	4,446.07
MEANAGE	Mean age of household members (months)	188.75	212.05	192.98
NLABYPC	Weekly per capita non-labour income (pesos)	23.20	20.76	22.76
NUTRSCI	Measure of mother's nutritional knowledge	7.27	8.23	7.44
OWTLAR	Total land area owned by household (hectares)	0.58	1.21	0.70
POPDEN	Population density/square kilometer. village	155.40	163.24	156.83
RD1	Round 1 dummy	0.25	0.25	0.25
RD2	Round 2 dummy	0.25	0.24	0.25
RD3	Round 3 dummy	0.24	0.28	0.24
SEX	Gender, 1-male 0-female	0.88	0.78	0.86
WTBYHT	Weight (kg)/height (cm)	0.32	0.25	0.31
Number of observations		956	212	1,168

TABLE 4

Average Days Worked Per Survey Round and Average Wages Received by Quartile for Weight-for-Height, Body Mass Index, and Height, by Agricultural Task, and by Gender

Quartile of	Level of	Days of work per round by task: Harvest	Ploughing	Cutting	Weeding	Other	All	No. of observations
Weight-for-height: men								
1.00	28.6	2.97	8.16	11.38	12.50	3.22	38.23	212
2.00	31.0	2.83	7.60	7.74	13.19	4.03	35.40	207
3.00	32.8	3.31	5.26	14.88	11.36	3.38	38.20	215
4.00	35.9	4.69	5.84	13.56	9.31	5.32	38.71	206
Weight-for-height: women								
1.00	26.5	6.72	0.00	0.00	20.10	2.72	29.55	29
2.00	28.9	7.20	0.00	0.20	10.97	6.00	24.37	30
3.00	30.9	6.39	0.00	0.00	10.50	0.71	17.61	28
4.00	36.3	5.55	0.00	0.14	12.83	0.55	19.07	29
BMI: men								
1.00	17.9	2.65	8.60	10.91	11.23	3.40	36.78	209
2.00	19.3	3.57	6.48	11.72	11.13	2.95	35.85	209
3.00	20.3	4.15	5.75	12.48	11.91	5.05	39.35	211
4.00	22.2	3.40	6.02	12.54	12.11	4.48	38.55	211
BMI: women								
1.00	17.5	7.83	0.00	0.00	19.14	3.76	30.72	29
2.00	19.1	6.17	0.00	0.21	13.31	4.59	24.28	29
3.00	20.6	6.59	0.00	0.00	8.07	1.10	15.76	29
4.00	24.1	5.31	0.00	0.14	13.90	0.72	20.07	29
Height: men								
1.00	153.1	2.33	7.06	9.98	17.00	3.76	40.13	206
2.00	159.1	4.45	7.39	11.78	11.69	2.68	37.97	210
3.00	162.8	2.72	6.57	13.03	8.94	3.87	35.14	212
4.00	168.2	4.25	5.84	12.82	8.91	5.57	37.40	212
Height: women								
1.00	143.7	5.03	0.00	0.00	11.90	3.30	20.23	30
2.00	148.7	7.57	0.00	0.36	19.86	2.82	30.61	28
3.00	152.9	5.62	0.00	0.00	4.76	1.03	11.41	29
4.00	158.3	7.76	0.00	0.00	18.17	3.00	28.93	29
All men		3.44	6.71	11.92	11.60	3.97	37.64	840
All women		6.47	0.00	0.09	13.60	2.54	22.71	116

TABLE 4 – *contd*

Quartile of	*Level of*	*Daily wages by task* *Harvest*	*Ploughing*	*Cutting*	*Weeding*	*Other*	*All*	*No. of observations*
Weight-for-height: men								
1.00	28.6	24.89	23.12	19.03	15.03	16.30	18.70	212
2.00	31.0	24.64	24.12	18.66	14.89	18.28	18.69	207
3.00	32.8	24.79	22.33	18.81	14.13	16.53	18.51	215
4.00	35.9	26.43	19.56	18.43	15.74	18.69	18.86	206
Weight-for-height: women								
1.00	26.5	23.86	–	–	13.63	15.00	15.97	29
2.00	28.9	17.59	–	5.97	13.72	12.25	14.20	30
3.00	30.9	24.81	–	–	12.79	11.44	17.39	28
4.00	36.3	27.71	–	10.00	12.84	12.91	17.47	29
BMI: men								
1.00	17.9	23.91	23.86	19.45	14.81	16.79	19.15	209
2.00	19.3	27.49	22.74	17.74	15.36	18.57	18.75	209
3.00	20.3	22.24	21.58	19.08	14.51	17.92	18.49	211
4.00	22.2	27.95	21.11	18.68	14.96	17.32	18.40	211
BMI: women								
1.00	17.5	21.25	–	–	13.94	14.61	15.16	29
2.00	19.1	23.24	–	5.97	13.11	11.93	15.77	29
3.00	20.6	21.29	–	–	12.71	12.14	17.23	29
4.00	24.1	27.95	–	10.00	12.97	12.22	16.87	29
Height: men								
1.00	153.1	23.84	22.63	16.29	15.00	16.57	17.30	206
2.00	159.1	26.56	22.77	20.53	14.27	16.74	19.45	210
3.00	162.8	24.14	21.54	19.64	15.02	17.13	18.87	212
4.00	168.2	25.60	22.99	18.03	15.45	19.09	19.20	212
Height: women								
1.00	143.7	16.91	–	–	12.99	13.32	14.25	30
2.00	148.7	23.40	–	7.58	13.41	12.81	15.46	28
3.00	152.9	27.52	–	–	14.18	12.20	20.57	29
4.00	158.3	23.80	–	–	13.18	12.98	16.20	29
All men		25.33	22.48	18.73	14.91	17.63	18.69	840
All women		23.11	–	7.58	13.31	12.97	16.06	116

Source: International Food Policy Research Institute–Research Institute for Mindanao Culture surveys, 1984/85.

Notes:

(1) Mean wages are weighted by days worked by each individual in each quartile.

(2) Sample restricted to individuals 20 years of age and older who are included in the reported adult regression estimations.

(3) Weight-for-height expressed in kilograms per metre; height expressed in centimetres; body mass index expressed in kilograms per metre squared.

(4) Agricultural employment information was collected for the previous four months during each survey round.

5.2. *Regression Results*

Sixty equations were estimated altogether: six nutritional status health specifications by four estimation techniques by three groups of observations (adolescents, adults, and pooled), with 12 blank cells.

One set of estimations excludes weight-for-height and height to provide results comparable to the estimations of Sahn and Alderman (1988). A second set excludes height and so permits a direct comparison with Deolalikar's (1988) results, while a third set includes height but excludes weight-for-height. A fourth set includes all nutritional status and health proxies. The fifth and sixth sets of regressions substitute body mass index for weight-for-height in the previous equations.[11] A matrix of nutritional status results is presented in Table 5, while full regression results for the adult group are presented in Appendix 1. We draw five main conclusions from the regression results.

(1) For adults, over the range of estimation techniques and specifications tried, the estimated coefficient on height is significantly different from zero, positive in sign, and sturdy in inference. The elasticity of height on wage at the mean of the data centres on 1.0 across the range of estimates. For our preferred estimate, the H–T estimate, the elasticity is 1.38 (row 8, column 13). An individual 15 centimetres taller than an individual of mean height may expect to achieve a 13 percent increase in wage rate. We conclude that this result adds to the body of evidence contradicting the 'small but healthy' hypothesis, at least given the nature of the task structure observed for our data set.

(2) The two-stage least squares estimates are not reported because of their highly unstable nature, especially when calories and weight-for-height are included in the same specification. Appendix 2 shows that because these two variables share a similar set of determinants, rank identification of their equations (endogenous variables are IDCAL, WTBYHT or BMI) becomes *ad hoc*, and high collinearity between the values of fitted IDCAL, fitted WTBYHT, and HT becomes an intractable problem. If reliable 2SLS estimates could have been obtained, it would have been possible to decompose differences between OLS estimates and H–T estimates into two effects: those due to simultaneity between wages and nutritional status, and those due to unobservable effects.

(3) By following econometric procedures similar to those used by Sahn and Alderman, and Deolalikar, we find that we can 'reproduce' the results of the former but not of the latter. In particular, when individual calorie

[11] Since wage observations are available only for those participating in the agricultural labour force, our single-equation estimates are vulnerable to selectivity bias. To test whether the expected value of v is zero, we ran a two-stage reservation wage correction (Maddala, 1983, p. 230) with the 2SLS estimates, for all three samples (adolescents, non-adolescents, pooled). In each case, we could not reject the null hypothesis that $E(v)=0$ This result is in accordance with that of Deolalikar.

TABLE 5

Wage-Nutritional Status Elasticity Estimates

Estimation technique and sample	Nutritional status specification												
	IDCAL (1)	*IDCAL (2a)*	*WTBYHT (2b)*	*IDCAL (3a)*	*HT (3b)*	*IDCAL (4a)*	*WTBYHT (4b)*	*HT (4c)*	*IDCAL (5a)*	*BMI (5b)*	*IDCAL (6a)*	*BMI (6b)*	*HT (6c)*
OLS													
(1) POOLED	0.101	0.079	0.31	0.068	1.467	0.071	−0.067	1.547	0.098	0.059	0.071	−0.058	1.484
	(3.35)	(2.57)	(2.83)	(2.28)	(6.09)	(2.36)	(0.50)	(5.27)	(3.20)	(0.45)	(2.34)	(0.45)	(6.07)
(2) ADOLSC	−0.026	−0.034	0.19	−0.032	1.02	−0.026	−0.16	1.22	−0.022	−0.119	−0.025	−0.20	1.068
	(0.41)	(0.53)	(0.79)	(0.50)	(2.28)	(0.41)	(0.55)	(2.16)	(0.33)	(0.38)	(0.38)	(0.60)	(2.37)
(3) ADULTS	0.089	0.088	0.012	0.079	1.19	0.083	−0.12	1.28	0.095	−0.17	0.084	−0.11	1.16
	(2.61)	(2.56)	(0.09)	(2.33)	(3.65)	(2.45)	(0.78)	(3.68)	(2.78)	(1.04)	(2.44)	(0.70)	(3.52)
WITHIN													
(4) POOLED	0.015	0.012	−0.293						0.012	−0.277			
	(0.40)	(0.30)	(0.91)						(0.36)	(0.91)			
(5) ADOLSC	−0.079	−0.079	−0.15	−0.079	0.604	−0.079	−0.15	0.620	−0.081	−0.19	−0.081	−0.19	0.620
	(1.02)	(1.03)	(0.26)	(1.02)	(0.004)	(1.03)	(0.26)	(0.00)	(1.04)	(0.36)	(1.04)	(0.36)	(0.00)
(6) ADULTS	0.034	0.034	−0.34						0.034	−0.32			
	(0.85)	(0.83)	(0.92)						(0.83)	(0.88)			
Hausman–Taylor													
(7) ADOLSC	−0.084	−0.083	−0.19	−0.084	0.233	−0.083	−0.19	dropped	−0.082	−0.25	−0.083	−0.26	0.397
	(0.95)	(0.93)	(0.24)	(0.93)	(0.06)	(0.93)	(0.24)		(0.92)	(0.37)	(0.91)	(0.33)	(0.02)
(8) ADULTS	0.039	0.038	0.025	0.039	1.38	0.039	0.022	1.359	0.039	0.04	0.039	0.035	1.38
	(0.77)	(0.77)	(0.05)	(0.78)	(3.68)	(0.78)	(0.05)	(2.58)	(0.77)	(0.09)	(0.78)	(0.08)	(3.60)

Notes:

(1) The estimated elasticities are reported at the mean of the data and are calculated by multiplying the regression coefficients by the relevant explanatory variable.

(2) See appendices 1 and 2 for estimation details.

(3) Absolute value of *t*-statistics reported in parentheses.

(4) White's (1978) heteroscedasticity-adjusted standard errors are reported for OLS.

intakes are included as an explanatory variable (and weight-for-height excluded) in a two-stage least squares wage estimation, calorie intakes are a positive and significant determinant of wage achievement (not shown in Table 5). However, if both calorie intakes and weight-for-height are included in a within, fixed-effects estimation, both calories and weight-for-height have insignificant coefficients (columns 2a, b, rows 4, 5, and 6). We can reproduce Deolalikar's finding that weight-for-height is significant in the OLS regressions which include calorie intakes, but only when the data are pooled, a procedure we have argued against (row 1, columns 2a, b). Interestingly, this result for the pooled sample is not reproduced when we replace weight-for-height with body mass index (row 1, columns 5a, b); this could be because body mass index is not as strongly associated with age as is weight-for-height.

(4) Elasticity estimates generated using the two panel techniques, although imprecise on the time-varying variables, are quite stable across specifications (in contrast with the 2SLS results), but are quite different across techniques.[12] This suggests that the possible existence of time-varying unobservable effects (which the within estimator cannot account for) may be an important phenomenon in the estimations.[13]

(5) The estimated elasticity for height is not statistically significant for adolescents using either panel technique. Height may not affect wages for adolescents because, for the most part, they are not called upon to undertake tasks which require strength. That height is significant in the OLS regressions, but not with the panel techniques, is consistent with the argument made in Section 4.2.2 that unobserved factors such as experience and maturity are important determinants of wages and are correlated with height (or calories or weight-for-height). However, there is no evidence that the hypothesized positive correlation between height (or calories or weight-for-height) and these unobserved effects for adolescents leads to biased estimates using the within technique for the relatively short time period covered by the surveys (comparing columns 2b and 3a across rows 3b and 4b).

[12] For the adult sample and the specification represented by columns (9) and (10), a Hausman test rejected the null hypothesis of the equality of the two sets of panel estimates at the 5 percent level, but not at the 1 percent level ($F = 3.57$).

[13] The Hausman–Taylor estimates are efficient only if the *a priori* designation of time-varying and time-invariant variables as either endogenous or exogenous is correct. The null hypothesis that the designations chosen are correct can be tested only if the within estimates are consistent benchmarks. If we believed the within estimates to be consistent, then the above Hausman test would lead us to conclude that a variable classified in our X_1 vector should belong in the X_2 vector (see Appendix 2 for a discussion of the Hausman–Taylor estimation procedure, and for definitions of the X_1 and X_2 vectors). Since our only X_1 variable is age, we do not think this is an appropriate conclusion to draw. We suggest that although the null hypothesis of the joint insignificance of the individual dummies is rejected for all specifications (within is always superior to OLS), the within estimates are reflecting their sensitivity to errors-in-variables and other sources of time-varying endogeneity, and are therefore an inconsistent benchmark.

Finally, we discuss other regression results, presented in Appendix 1, not directly related to nutrition. In general, the low adjusted r-squares which are typical of wage equations estimated for rural, predominantly male samples, reflect the proxy nature of wage as a measure of productivity. Nevertheless, far from invalidating the points made above with respect to height, the large estimated standard errors reported on more conventional earnings variables reinforce the result for height.

Area owned by the household has a positive significant estimated coefficient in all the specifications, reflecting the data in Table 1 which suggested a reservation wage effect. Interestingly, the H–T estimate of this coefficient is higher than that for OLS. This could be due to a negative correlation between area owned and land quality, land quality being the unobserved effect. Households with lower land quality, ceteris paribus, would have lower farm productivity and conseuently would be more likely to enter the agricultural labour force at a lower wage.[14]

Although not reported in Appendix 1, years of formal education was tried in several specifications, but had no effect on the agricultural wage rate. This result is in common with Deolalikar but not with Sahn and Alderman. Given the nature of the tasks described in Table 4, we do not find this too surprising.

VI. CONCLUSIONS AND DISCUSSION

Our results indicate that substantial lifetime income losses may be expected to be incurred by adults who depend heavily on agricultural wage income and who are stunted as a result of poor health and nutrition during childhood. Such stunting is permanent for present-day adults, with the implication that little can be done to improve their productivity through better nutrition. A more encouraging aspect of our results over the long run, however, is that once investments in better health and nutrition are made during childhood which result in improved adult heights, these effects are permanent and result in incremental income flows over a number of years.

The policy implication of previous findings was that incremental income flows could only be maintained through continuous investments in better adult weights. Identification of height as an important productivity-enhancing factor serves to divert concern away from energy intake as the primary productivity constraint, and focuses policy attention instead on other health-improvement inputs designed to reduce morbidity.

A further implication of our results is that improved heights for the present generation may result in incremental income flows for following generations.

[14] Area owned by the household, household demographic variables and distance to the nearest food market are included as structural variables in order to capture local labour market effects on observed wages, although it is recognized that these variables may also determine the labour force participation decision, hence the failure to reject the null hypothesis that $E(v) = 0$ in footnote 11.

Regressions of parental heights on standardized height for-age for preschoolers in our sample population show a strong positive effect for both parents (Bouis and Haddad, 1990b). Such a 'ripple' effect of parental heights across generations has been substantiated in other studies (e.g. Calloway *et al.*, 1988; Thomas *et al.*, forthcoming).

Our evidence on the lack of impact of short-run nutritional status upon agricultural wage determination needs to be treated with some caution. Positive and significant calorie-wage effects, present with a zero restriction on height for OLS, are rendered insignificant by (i) the addition of the height variable, and/or (ii) the use of panel techniques, indicating that increased calorie intakes have little impact on productivity. However, a vast nutrition literature would argue that relatively strenuous agricultural labour can only be sustained (without weight loss) through relatively high calorie intakes.

It needs to be kept in mind that variation in wages across individuals are, after all, crude measures of differences in productivity. Calorie intakes are measured for only one 24 h period for each individual at the end of each four-month wage recall period, and which are therefore only rough indicators of calorie intakes over the longer-run.[15] Although this calorie intake information is available for a relatively large sample and has given results in accordance with *a priori* expectations in other analyses, the failure to control for day-to-day variation in calorie intakes and/or for energy expenditures over the short or medium run may conceal an underlying, positive relationship between energy intake and productivity.

By conforming to *a priori* expectations, three behavioural relationships estimated with the survey data tend to confirm that the sample was sufficiently large and individual calorie intake measurements sufficiently accurate. First, the percentage increases in calorie intakes for adults in higher expenditure quintiles was quite consistent with percentage increases in adult weights in higher expenditure quintiles, controlling for activity patterns across expenditure quintiles and weight changes over time within expenditure quintiles (see Bouis and Haddad, 1990a). Second, regression estimates indicate greater competition for scarce household calories in low income households (Bouis and Haddad, 1990b, chapter 8). Third, regression estimates show preschooler calorie intakes to be negatively associated with sickness and positively associated with nutritional status, more so with short-

[15] Because of wide day-to-day variation in individual calorie intakes, at the outset of data collection there was a great deal of uncertainty, first whether four 24-h recall surveys for a sample of approximately 500 households would constitute a sufficiently large sample that the presumed correlation between daily calorie intakes and average intakes over some longer period of time would generate reasonable estimates of the relationship between individual calorie intakes and nutritional status. Second, the obvious inability of mothers to know or to remember with total accuracy what each individual in the household had eaten in the previous 24 h only added to the uncertainty. Because of the prohibitive cost of weighing actual intakes and the fear that this would alter food intake behaviour, this alternative technique was not used.

run nutritional status than long-run nutritional status (Bouis and Haddad, 1990b, chapters 8 and 9).

Ideally, if panel data were available for energy expenditures and for calorie intakes for individuals over an extended period of time, modelling could then distinguish between labour supply and labour intensity, which at present are combined via a composite wage rate, necessitated by an insufficient number of observations to undertake the regression analysis for specific tasks individually.

Our results do not provide direct information on the mechanism(s) by which height raises observed agricultural wages. The most likely productivity-increasing effect of height is increased strength which allows taller individuals to perform more work per unit of time for tasks which require strength (e.g. ploughing with a carabao or cutting and loading sugarcane which are often paid on a piece-rate basis). Is it possible that height is intrinsically valued (e.g. fruit picking), or is a screening mechanism for employers? The first possibility is discounted because there are no agricultural tasks in our sample for which height *per se* is desirable, while the second point is only convincing if employers are not well informed about the available labour pool; however, we do not have the requisite 'starting' wages to examine this possibility. One further possiblity, that height is a proxy for human capital, is discounted by the small change in the estimated coefficient on height between the panel and non-panel estimates.

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APPENDIX 1

Detailed Regression Results

APPENDIX 2

Details of Instrumental Variable Estimation

Identification of a three equation system (endogenous variables are IDCAL, WTBYHT or BMI, LNWAGE; and AVHT for adolescents), where the first two variables are co-determined by similar factors is, by definition, problematic.

TABLE 6
Estimated Wage Equation by Estimation Technique, Adult Sample

Variable	*Estimation technique*		
	OLS	*WITHIN*	*Hausman–Taylor*
Constant	1.589		1.99
	(4.22)		(2.63)
IDCAL*	0.0032	0.0013	0.0019
	(2.44)	(0.83)	(0.96)
BMI*	−0.556	−1.6	0.186
	(0.70)	(0.88)	(0.08)
AVHT	0.725		0.804
	(3.52)		(3.52)
OWTLAR*	3.90		62.06
	(5.74)		(1.68)
AGEYR	0.427		−0.032
	(2.22)		(0.10)
SEX	10.42		−7.68
	(2.12)		(0.57)
HHSIZE	−0.269		−7.56
	(0.44)		(1.60)
MEANAGE	0.0075		0.0031
	(0.29)		(0.12)
MARKDIST	0.00065		−0.00103
	(1.39)		(0.88)
POPDEN	0.0077		−0.057
	(0.27)		(1.20)
NLABYPC	0.0038		−0.0038
	(0.52)		(0.36)
RD1	−10.15		−10.90
	(2.81)		(2.99)
RD2	−10.45		−11.57
	(2.92)		(3.22)
RD3	−11.36		−12.02
	(3.32)		(3.26)
Adjusted R^2	0.075	0.340	0.051
$F_{\text{all coeff}=0}$	6.56	16.30	4.73
n	956	956	956

Notes:
(1) Dependent variable is the natural logarithm of the real wage rate.
(2) Absolute value of t-statistics reported in parentheses.
(3) * Designates an endogenous variable.
(4) See Table 3 for variable definitions and descriptive statistics.
(5) Report coefficient estimates are multiplied by 100.

Two-Stage Least Squares

For adults, the system can be written as:

Endogenous			Exogenous												
LW	IC	WH (BMI)	HT	SX	AGE	ED	OL	HS	MA	NS	AN	NLY	PD	MKD	AGY
1	a_{12}	a_{13}				0				0	0				0
a_{21}	1	a_{23}									0			0	
a_{31}	a_{32}	1						0				0			

where:

LW = LNWAGE, IC = IDCAL, WH = WTBYHT, HT=HT, AGE = AGEYR, ED = ED, OL = OWTLAR, HS = HHSIZE, NS = NUTRSCI, AN = AVNETWTH, NLY = NLABYPC, PD = POPDEN, AGY = AGEYNG SX = SEX, MA = MEANAGE, MKD = MARKDIST (see Table 3 for variable definitions).

All the right-hand side coefficients are non-zero unless indicated otherwise above. The above system satisfies the sufficient (rank) condition for identification through the imposition of zero restrictions. *A priori*, it is arbitrary to hypothesize that, for example, average net worth will affect weight-for-height but not calorie intake. Therefore, the zero restrictions were imposed based on prior analysis of the data, with no real theoretical justification. It is important to note, however, that the estimates on IDCAL and BMI were reasonably robust to variation in the instrument set. For the wage equation, the identifying instruments are household size, non-labour income, and distance to nearest market.

Hausman–Taylor

Identification for this estimation depends on the *a priori* designation of the explanatory variables into four groups:

X_1 = a $k_1 \times 1$ vector of time-varying variables which are not correlated with household-specific effects,

X_2 = a $k_2 \times 1$ vector of time-varying variables which are correlated with household-specific effects,

Z_1 = a $g_1 \times 1$ vector of time-invariant variables which are not correlated with household-specific effects,

Z_2 = a $g_2 \times 1$ vector of time-invariant variables which are correlated with household-specific effects.

Identification requires the number of X_1 variables to be at least as great as the number of Z_2 variables. For our data set, X_1 = age of individual, X_2 = calorie intake, weight-by-height (or body mass index), and height (for adolescents only), Z_1 = household demographics (which exhibit virtually no variation over time), distance to nearest market, net worth, nutritional knowledge score, population density, and non-labour income, and Z_2 = total land area owned. The model is just-identified ($k_1 = g_2 = 1$), implying that in the absence of time-varying endogeneity, the Hausman–Taylor and within estimates should be very close. The mean values (across t observations for the ith individual) of the X_1 and Z_1 variables and the deviations from the mean of the X_2 variables proved to be less than ideal instruments for X_2 and Z_2, in terms of strength of correlation.

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