Micronutrient intake and labour productivity

Evidence from a consumption and income survey among Indian agricultural labourers

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Abstract: *Economic losses due to iron-deficiency anaemia are believed to be substantial. This paper examines the impact of iron intake on the productivity of households engaged in agricultural labour in India by applying a two-stage least-squares (2SLS) estimation technique. The results indicate that productivity, measured in wages, is indeed affected by insufficient iron intake, and that wages would on average be 5 to 17.3% higher if households achieved recommended intake levels. The results demonstrate that enhancing micronutrient intake will contribute significantly to overall economic growth and development.*

Keywords: *micronutrient malnutrition; iron; productivity; India*

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Awareness of the role of micronutrient deficiencies in the health and well-being of the poor has only recently entered the policy debate. For many years, the focus was on protein–energy malnutrition. However, more recently attention has been shifting towards the role of micronutrient deficiencies for overall economic development and income increases, since it is debatable whether incomes will increase at all and whether economic development can happen without significant policy attention to micronutrient deficiencies.

Micronutrient malnutrition affects large population groups worldwide. It is estimated that up to 3.5 billion people are afflicted with iron deficiency, about two people out of three (ACC/SCN, 2000). On the South Asian subcontinent, anaemia prevalence in pregnant women is thought to be as high as 75%; for children from 5–14 years old it is thought to be 63%. Table 1 shows the daily nutrient availability per adult equivalent, and the recommended intake level for Indian farm workers. Both the vitamin A and iron intake per adult equivalent are highly deficient. On average, only 54% and 59% respectively of the recommended intake levels are achieved.[1]

Although it is recognized that, given the widespread prevalence of micronutrient malnutrition, the impact on losses in overall productivity and economic development may be considerable (Horton, 1999; Behrman, 1993), studies that quantify the impact of micronutrient deficiencies on productivity remain scarce. Even if it is widely believed that better nutrition increases labour productivity and hence contributes to economic growth, the focus of this discussion has been on protein–energy malnutrition rather than on inadequate micronutrient intake, largely due to insufficient data.

This paper examines the impact of micronutrient intake on the productivity of households engaged in agricultural labour in India. The micronutrient under investigation is iron. The results indicate that wages are indeed affected by insufficient intake. The elasticity of iron intake on wages is estimated to be between 0.102 and 0.343. This implies that if iron intake were to rise by 50%, wages would on average increase by 5.1 to 17.15%. In the following section, the theoretical background and the current status of the discussion concerning productivity–micronutrient linkages are summarized. In section three, the data sources and the methodology of the empirical

Table 1. Average nutrient intake in rural Indian labourer households.

Nutrient	Mean intake	SD	Recommended	% of recommended
Calories per adult equivalent (kcal)	2,254	557.5	2,400	94
Iron per adult equivalent (mg)	17	8.7	29	59
Vitamin A per adult equivalent (µg)	326	281.3	600	54
Vitamin C per adult equivalent (mg)	50	34.9	60	83

Source: NSSO, 50th round. N = 5,800 agricultural labourer households.

analysis are described. Section four illuminates current micronutrient intakes in India, and in section 5 the results of the productivity estimation are described. The last section presents a summary and policy implications.

Evidence of the effect of nutrients on productivity

It is a relatively old idea that at low income levels there is a relationship between nutrition and labour productivity. This hypothesis is known as the Efficiency Wage Hypothesis. Leibenstein (1957) and later Mirlees (1975) and Stiglitz (1976) argued that an increase in calorific intake enabled workers to perform more demanding tasks, expressed in a greater marginal productivity as measured by wages.

Households produce both marketable and non-marketable goods. The nutritional (such as improved weight-for-age of children) or health outcome (such as individual morbidity) of a household is 'produced' by inputs, some of which are subject to 'choice' by the household. Hence, individual nutrient intake, activity levels and infections may be regarded as resulting from current household decisions. In turn, the current nutrient intake may affect worker productivity. If this is recognized by the market, ie local labour markets operate relatively freely and higher productivity is rewarded with higher wages, then better nutrition should result in higher market earnings, since workers will either be paid more for a given time unit of work, or they will be able to work in particularly taxing and rewarding activities, or both (Strauss, 1993).

However, in estimating this relationship, a methodological pitfall occurs: the causality can run in both directions. Better-nourished workers should be more productive and hence earn higher wages, and higher income will probably be spent on more nutrients and make household members more healthy, so that they can earn higher wages. If this simultaneity is not accounted for, estimates will be biased and inconsistent, a failure that has been attributed to a number of early studies. Both experimental studies and socioeconomic surveys have attempted to quantify the effect of nutrient intake on productivity.

Experimental studies

Among experimental studies, Keys *et al* (1950) researched how activity levels fall when males are subject to dramatic decreases in calorie intake. They found that activity levels fell abruptly when diets were reduced from 3,500 calories per day to 1,500 calories per day. In this experiment the whole diet was controlled, so that the problem of simultaneity did not arise. Wolgemuth *et al* (1982) compared the gains in productivity of workers moving earth, where one group was supplemented with 200 calories by day, and the other group with 1,000 calories per day. They found a 12.5 percentage gain in productivity for the highly supplemented group, and a significant output elasticity of calories on productivity of 0.5. Immink and Viteri (1981a, 1981b) reported a study in which whole villages in Guatemala were provided with either a high- or a low-energy supplement. In contrast, they did not find a significant effect of daily energy intake on amounts of sugarcane cut per day, but they failed to account for the endogeneity problem of the total energy intake.

Studying the relationship between iron deficiency and productivity, Basta *et al* (1979) compared the productivity of rubber plantation workers in Indonesia. One group of workers received iron supplements while another group received a placebo. Before the intervention the difference in productivity between anaemic and non-anaemic workers ranged from 18.7% to 20%, depending on the task. After intervention, no statistically significant difference in productivity was found between the two intervention groups – however, all participants had received a monetary incentive, which may have confounded the experiment's results, since the expenditure on leafy vegetables high in iron and vitamin C content increased. Levin (1986) summarized eight experimental studies analysing the relationship between blood iron levels and productivity, and concluded that the output elasticity of haemoglobin levels was as high as between 1 and 2. Based on the same estimates, a recent study (Horton, 1999) suggested that in some South Asian countries losses in GDP due to micronutrient malnutrition may be as high as 2–3%.[2.]

Socioeconomic surveys

Several socioeconomic surveys have related productivity to calorie intake, or aggregated nutrient measures, such as weight-for-height, to productivity. In these studies, productivity is usually measured in agricultural wages (since wages represent the marginal productivity of a worker) or in farm profits. Their major innovation as compared with the experimental studies is that they take account of the endogeneity of explanatory variables subject to household choice, and of non-labour inputs that affect productivity.

Strauss (1986) analysed the effect of average household calorie intake per adult equivalent on the productivity of on-farm family labour in Sierra Leone. He found a significant and positive relationship between calorie intake and labour productivity, and an output elasticity of calories of 0.34. In a similar study, Deolalikar (1988) analysed the impact of average calorie intake on agricultural productivity and on wages for a rural south

Indian stratified panel. He estimated an ordinary least squares (OLS) value and controlled for weight-for-height of workers, and in both relationships (wages and productivity), he found a positive effect only for the latter, but not for calorie intake. Sahn and Alderman (1988) regressed household calorie intake on individual wages in Sri Lanka, and found a positive impact on productivity in males, but not in females. They estimated the output elasticity for calories as 0.21. Haddad and Bouis (1991), who included individual calorie intake as well as height and weight-for-height of workers in the Philippines, found that the latter had an impact, but did not produce robust results for the other factors (calorie intake and height), when controlling for endogeneity. When they included only calories, the result was significantly positive (but the elasticity was not reported in their paper). They also estimated an OLS value and reported an output elasticity of 0.089 for calories, the lowest of all estimates reported here. Pitt and Rosenzweig (1985) took a slightly different approach. They present the only study (to the best knowledge of this author) that analyses the impact of nutrients other than calories and iron. In their study, they analyse the impact of a total of nine nutrients on health outcomes, using a 2SLS Tobit model. The results are difficult to interpret, since some of the nutrients seem to have a positive effect on the incidence of disease (ie protein, fat, carbohydrates and vitamin A), while calories, calcium, phosphorus, iron and vitamin C are negatively associated with illness.[3] Since the authors include all nutrients jointly into the regression, their results may well be confounded by multicollinearity. However, they do not report whether they tested for the presence of multicollinearity.

These studies control for endogeneity by using prices, farm assets and household size and age distribution as instrumental variables. As has been pointed out before, all of these studies include calorie intake only, or aggregated nutrient intake, as measured by weight-for-height, but do not attempt to explain productivity by micronutrient intake. In sum, the evidence so far is by no means unambiguous. Aggregated nutrient measures such as weight-for-height have a significant impact on productivity. When this measure is not included, calorie intake also seems to have a significantly positive impact. For micronutrients, experimental studies that link iron intake and productivity show a significantly lower productivity for anaemic individuals.

Data and methodology

The data

The data for this study are from the rural sample of the Socio-Economic Survey (50th Round) of the National Sample Survey Organisation (NSSO), undertaken from July 1993 to June 1994. The NSSO collects food-consumption data based on consumer expenditure. The reference period for data collection on all items of consumer expenditure is the previous 30 days. A stratified two-stage sampling design is employed, with census villages as the first-stage units and households as the second-stage units. Sample villages are selected with probability proportionate to population, with households being selected by a circular systematic sampling method. The entire one-year survey period is divided into four quarters, each of three months' duration. For this sample, 5,800 households engaged in rural labour, and representing one of the poorest segments of society, were selected. Some characteristics of the households are summarized in the Appendix (Table A1).

A drawback to this data set is that, as 30-day consumption recalls usually do, it probably overestimates expenditures. Also, neither individual intakes nor individual incomes and wages are recorded. If nutrients at not equally shared at the margin,[4] the use of household nutrient intakes may result in biased estimates of the impact of such nutrient intakes on productivity (Behrman, 1993). For instance, individuals for whom the marginal impact of more nutrient intake on their labour productivity is greater may receive larger shares of nutrients at the margin. On the other hand, this data set offers a wide variation over space as well as over time, hence it ensures sufficiently high price variation, an important prerequisite to be able to use prices in the market as instruments for wages (Strauss, 1993).

For the 183 food codes identified by the NSSO, individual items were converted into micronutrient intake using a data set on the nutritive value of Indian foods published by Gopalan *et al* (1999). In case these values seemed highly discrepant from other food-composition tables, a composition table compiled at the University of Hohenheim[5] was used.

The estimation procedure

In order to account for simultaneity involved in household decisions regarding food purchases and wages received, the endogeneity of both variables is controlled for. Ignoring simultaneity results in inconsistent overestimates of the coefficients and biased standard errors. To eliminate the potential problem of reverse causality, wages and nutrients are simultaneously predicted, employing a two-stage least-squares (2SLS) estimation procedure. The 2SLS procedure is defined as first regressing each of the endogenous variables on all of the exogenous variables in the system, in order to calculate the estimated values of the endogenous variables. In the second stage, the estimated values are used as regressors in an OLS regression. The semi-log wage takes the following forms:

$$\ln W_{hh} = \alpha + \beta \hat{N}_i + \chi Z_{hh} + \delta X_{hh} + \varepsilon$$

where i indexes the individual, hh indexes the household, N is (estimated) nutrient intake in the respective unit, Z is a vector of time-invariant control variables at the household level, including schooling and gender of the household head, and household composition, X is a vector of time-variant control variables (season and age of household head) and ε is the error term.

The nutrients included in the model are energy, iron, vitamin C and vitamin A. A second model incorporates an interaction term for iron and vitamin C, because of the possible importance of vitamin C in the bioavailability of iron. Variables that are assumed to be exogenous to the household and that are used as instrumental variables for the nutrient intake estimate are food prices, as well as quasi-fixed household characteristics (such as size, as well

Table 2. Impact of nutrient intake on productivity – 2SLS results.

	Model 1		Model 2	
	Coefficient	*SE*	*Coefficient*	*SE*
Intercept	10.528***	0.061	10.761***	0.070
Estimated nutrient intake per adult equivalent (*1,000)				
Energy	–1.891***	0.028	–1.891***	0.028
Iron	20.219***	0.690	6.036**	2.199
Vitamin C	20.374***	0.495	15.629***	0.855
Iron x Vitamin C			0.299***	0.044
Vitamin A	–0.655***	0.057	–0.667***	0.057
Gender of household head	0.237***	0.012	0.233***	0.012
Age of household head	0.000	0.000	0.000	0.000
Dependency ratio	0.543***	0.017	0.534***	0.017
Education of household head (contrasted against illiterate)				
Primary and below	0.081***	0.009	0.081***	0.009
Secondary and below	0.082***	0.015	0.081***	0.015
Graduate and above	0.086	0.083	0.090	0.082
Season (contrasted against April–June 1994)				
July–September 1993	–0.143***	0.010	–0.140***	0.010
October–December 1993	–0.270***	0.011	–0.272***	0.011
January–March 1994	–0.288***	0.012	–0.293***	0.012
R-square	0.584		0.578	
Objective value	0.025		0.024	
Regression SE	0.272		0.272	
Minimum chi-square statistic	0.167 [12]		0.171[11]	

Source: NSSO, 50th round. N = 5,800 agricultural labourer households.
** = significant at the 0.05 level or better.
*** = significant at the 0.01 level or better.

as religious affiliation and ecoregion). Since some of these variables may be affected through unobservable household characteristics, some of them may be inappropriate as instruments. The exogeneity of instruments is therefore tested with a generalized method of moments-specification test.

It is assumed that wages will be higher with higher predicted nutrient intake. This is in accordance with the nutrition–wage efficiency hypothesis, which requires the relationship between intake and wages to be positive. Yet it should be pointed out that there are several mechanisms that could explain how a better nutritional status may be associated with higher agricultural wages. These include: (1) enhanced ability of workers to undertake piece-rate work, (2) payment based on the past performance of workers, (3) payment based on the perceived work potential of workers. Because information about the employer's decision-making process is not available, one cannot distinguish between the three mechanisms (Haddad and Bouis, 1991).

Effect of micronutrient intake on household productivity

The results of the 2SLS wage estimation are summarized in Table 2. The nutrients included in the first model are energy, iron, vitamin C and vitamin A. The second model includes an interaction term for iron and vitamin C.

Of the *nutrient estimates*, iron and vitamin C have a positive and significant impact on productivity measured in wages. The effect of energy and vitamin A intake has a negative sign in both models. The iron elasticity on wages at the sample mean is 0.343 in the first model and 0.102 in the second. The iron and vitamin C interaction term in the second model has an elasticity of 0.253. This would imply that if average iron intake were to rise by 10%, the average productivity (of agricultural wage labourers) should rise by 1% to 3.4%. Levin (1986) reported an output elasticity for iron with respect to rises in haemoglobin levels of between 1 and 2 (ie a 10% rise in blood haemoglobin levels would be associated with a rise in work output of 10 to 20%). Considering that on average only 5% of the iron consumed is bioavailable and can contribute to increases in haemoglobin levels, these results are comparable.

Since the current intake level of iron is highly deficient, increases in the range of 50% would be needed to enable households to consume recommended levels. If iron intake rose by 50% (from the current 17 mg per day to 25.5 mg per day) productivity would on average rise by between 5.1% and 17.15%. Put differently, households on average experience between 5 and 17% losses in productivity that can be attributed to deficiencies in iron intake. While this effect is large, it is still lower than those estimates presented by Basta *et al*, and later used by Horton (1999), which suggested that between 17 and 20% lower productivity (of heavy labour workers) could be attributed to iron deficiencies. Two reasons may explain this. First, Basta *et al* (and other experimental studies) compare an anaemic group with a non-anaemic group, while here iron intake (and hence iron deficiencies) is considered on a continuous basis. Second, Basta *et al* consider male workers only, while the estimates presented here are an average for the whole household.

Of the variables accounting for characteristics of the household head, *age* is not significant. *Male-headed households* earn higher wages than female-headed households. The effect of the *education of the household head* is significant at primary and secondary level, as indicated by the positive and significant parameter estimates for the two dummy variables. The variable for graduate-level education is not significant. That gross returns on education increase with higher levels of schooling, as indicated by the size of the coefficients, is in keeping with the results of Behrman and Wolfe in Nicaragua (1984) and Sahn and Alderman in Sri Lanka (1988). However, the returns are relatively low when compared, for instance, with the effect of iron and vitamin C intake.

The *household composition,* indicated by the dependency ratio,[6] is significant in both models. Not surprisingly, the fewer children in a household, the higher the average wage earned by household members. *Season* has a significant impact on wages in both models: they are highest during the summer.

A generalized method of moments-specification test is used to test whether the instruments are truly uncorrelated with the error term. This test examines the existence of correlation between the instruments and the estimation residuals, by assessing how close the cross-products of instrumental variables and residuals are to zero when evaluated at the estimated parameter values.[7] The specification test is general in that rejection can occur not only because of endogeneity of variables, but also because of omitted variables. The statistics for both models have probability values of around 0.17. Statistical evidence for endogeneity of household demographic variables is therefore very weak.

Summary and policy implications

Large numbers of people within the South Asian population, and particularly Indians, suffer from iron and vitamin A deficiencies. Intake levels in the sample of agricultural labourers are grossly insufficient and reach only approximately 50 to 60% of recommended levels. This study quantifies the losses that the average household faces due to insufficient micronutrient intake. The largest effects on productivity were found for the interaction terms of iron and vitamin C intake and for vitamin A intake.

The micronutrient elasticities on wages at the sample mean appear lower than in other studies, ranging from 0.102 to 0.343. Lifting current intake levels by 50% should mean that average total household productivity increases would be in the range of 5% to 17%. The results demonstrate that policy interventions that aim at enhancing micronutrient intake are not merely ends in themselves. They can be regarded as investments in improved productivity and higher household incomes. Enhancing micronutrient intake will contribute significantly to overall economic growth and development. This will particularly benefit the landless poor, who are dependent on wage income as a source of livelihood. Since the current study takes only direct effects of micronutrient malnutrition on productivity into account, it can be assumed that losses due to micronutrient deficiencies are even higher. There are considerable costs in terms of diversion of household and other community members from other activities to care for those who suffer from micronutrient deficiencies, such as vitamin A-related blindness, which are not considered here.

The question remains as to how enhanced micronutrient intake can best be achieved, and how micronutrient intake will respond to economic growth and development. Related studies that consider the effect of economic development on protein–energy malnutrition state that increases in income alone will not be sufficient to eliminate malnutrition (see for instance Haddad *et al*, 2003). Although income elasticities for micronutrients may be higher than for calories, it seems reasonable to suppose that income growth alone will not suffice. Additional measures, such as increasing the availability of micronutrients, reducing their price (ie through new technologies) and the promotion of healthy and diversified diets through community-based behaviour-changing activities will be needed.

Notes

1 Note that iron intake levels should be higher (29 mg) for South Asians to compensate for low bioavailability and the lack of enhancers in the diet. Because meat is relatively less prominent in the diet, and because iron from plant sources has low bioavailability, plant-based diets need to ensure a higher iron intake.

2 Horton assumes a 17% loss in heavy labour and a 5% loss in blue-collar work productivity due to iron deficiency. In her scenario, this translates into a 1.25% loss in GDP in India due to iron deficiencies. Eduardo Doryan, Vice President of the World Bank, in a keynote address at the ACC/SCN 27th Session (Washington DC, April 2000), suggested that overall losses due to micronutrient malnutrition might be as high as 5% of GDP.

3 As well as, surprisingly, the use of tobacco and betel.

4 After controlling for different requirements.

5 This database may be found at www.nutrisurvey.de.

6 The dependency ratio is measured as 1 (children/all people living in the household). Hence it takes the value 1 if no children live in the household, and approaches 0 as the ratio of children to all household members increases.

7 The statistic is $e'Z(Z'Z)^{-1}Z'e/\sigma^2$, where e is the estimated residual, Z is the matrix of instrumental variables, and σ^2 is the estimated regression variance. The numerator is the minimized value of the objective function that is used by the 2SLS, so this statistic can easily be computed. The result of this test is reported in the last row, labelled 'Minimum chi-square statistic'. The degrees of freedom are equal to the number of overidentifying instruments.

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Appendix

Table A1. Household characteristics.

Variable	Description	Mean value	SD
Wages	Monthly income (Rs)	2,292.3	1,129.4
		2,253.9	557.5
		17.0	8.7
		49.8	34.9
		325.6	281.3
Household head is female	(%)	10.8	31.1
Age of household head		39.9	12.5
Dependency ratio		0.7	0.2
Education of head	Illiterate (%)	73.3	44.2
	Primary and below (%)	20.3	40.2
	Secondary and below (%)	6.1	24.0
	Graduate and above (%)	0.2	4.4
Season	July–September 1993	22.7	41.9
	October–December 1993	26.3	44.0
	January–March 1994	24.4	43.0
	April–June 1994	26.6	44.2

Source: 5,800 agricultural labourer households, 50th Round NSSO.