Micronutrient Deprivation and Poverty Nutrition Trap in Rural India[1]

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ABSTRACT

We test for the existence of a Poverty Nutrition Trap (PNT) in the case of five important micronutrients- calcium, carotene, iron, riboflavin, and thiamine, for three categories of wages: sowing, harvesting, and other for male and female workers separately. We use household level national data for rural India for the period January to June 1994 and robust sample selection procedures due to Heckman to arrive at consistent and efficient estimates. It is discovered that the PNT exists for calcium for female workers engaged in harvesting. In the case of carotene male workers engaged in harvesting are subject to the PNT, whereas both males and females engaged in harvesting are subject to PNT in the case of iron. In the case of riboflavin female workers engaged in harvesting and sowing and male workers engaged in harvesting are subject to PNT and in the case of thiamine female workers engaged in harvesting and sowing are subject to PNT. Thus micronutrient deficiency is having a significant impact on labour productivity in rural India.

KEYWORDS: Micronutrient deprivation, Poverty Nutrition Trap, Heckman Models

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I. Introduction

The effect of nutritional intake on labour productivity and wage rates has been an important area for research for economists and nutritionists for some time. This found initial expression in the form of the efficiency wage hypothesis developed by Leibenstein (1957) and Mazumdar (1959) and formalized and extended by Mirrlees (1975), Dasgupta and Ray (1986, 1987), and Dasgupta (1993), among others. Early surveys include Bliss and Stern (1978a, 1978b) and Binswanger and Rosenzweig (1984). The efficiency wage hypothesis postulated that in developing countries, particularly at low levels of nutrition, workers are physically incapable of doing hard manual labour. Hence their productivity is low which then implies that they get low wages, have low purchasing power and, therefore, low levels of nutrition, completing a vicious cycle of deprivation. These workers are unable to save very much so their assets –both physical and human – are minimal. This reduces their chances of escaping the poverty-nutrition trap (henceforth PNT).[2]

There is a substantial literature on empirically testing for the existence of PNT.[3] Strauss (1986) models the effect of nutrition on farm productivity. He tests and quantifies the effects of nutritional status as measured by annual calorie intake on annual farm production and, hence, labour productivity using farm household level data from Sierra Leone. He finds significant and sizable effect of calorie intake on farm output, even after accounting for endogeneity. These effects are stronger at lower levels of calorie intake with this being determined through the presence of non-linear terms. Thomas and Strauss (1997) investigate the impact of four indicators of health (height, body mass index, per capita calorie intake and per capita protein intake) on wages of urban workers in urban Brazil. They discover that even after accounting for endogeneity issues and controlling for education and other dimensions of health, these four indicators have significant positive effects on wages. The effect of the nutritional variables - per capita calorie intake and per capita protein intake – was higher at low levels of nutrition, again determined through non-linear terms. In contrast Deolalikar (1988) finds in a (panel fixed effects) joint regression of the wage equation and farm production in rural South India that calorie intake does not affect either but a measure of weight-for-height does. He concludes that calorie intake does not affect wages or productivity indicating that the human body can adapt to short-run shortfalls in calorie intake. However, the fact that weight-for-height affects wages and productivity indicates that chronic undernutrition is an important determinant of productivity and wages. Barrett (2002) indicates that micronutrient deficiency directly reduces cognitive and physical activity and, hence, labours productivity. Such deficiency indirectly reduces labour productivity by increasing susceptibility to diseases and infections.

A significant gap in the extant literature is the neglect of the impact of micronutrient deprivation on labour productivity including the possibility of the existence of a PNT. Weinberger (2003), for instance, does not model the impact of micronutrient deficiency on PNT while discussing the impact of iron deficiency on labour productivity in rural India. To the best of our knowledge there does not exist any paper quantifying the important of micronutrient deficiency in the formation of PNT. This papers attempts to fill this gap. We test for the existence of a PNT in the case of five key micronutrients[4] - calcium, carotene, iron, riboflavin and thiamine - for each category of wages (sowing, harvesting, and other) and for male and female workers separately. We use robust sample selection procedures due to Heckman (1976, 1979) to arrive at consistent estimates. It is discovered that the PNT exists in nine cases. In the case of carotene male workers engaged in harvesting are subject to the PNT, whereas both males and females engaged in harvesting are subject to PNT in the case of iron. In the case of riboflavin female workers engaged in harvesting and sowing and male workers engaged in harvesting are subject to PNT and in the case of thiamine female workers engaged in harvesting and sowing are subject to PNT. Thus micronutrient deficiency is having a significant impact on labour productivity in rural India.

The plan of this paper is as follows. In section II we motivate the analysis of PNT and then discuss the data and present the estimation methodology in section III. Section IV discusses the results of the estimation and section V concludes.

II. Nutrition Poverty Traps

In Figure 1, a stylised version of the relationship between work capacity and nutrition is given.[5] The vertical axis represents a measure of work capacity and the horizontal axis income. Note first that work capacity is a measure of the tasks that an individual can perform during a period, say, the number of bushels of wheat that s/he can harvest during a day. Income is used synonymously with nutrition in the sense that all income is converted into nutrition. Nothing of importance changes if 70 or 80 per cent of income share is spent on nutrition. The shape of the capacity curve refelcts the assumption that much of the nutrition goes into maintaining the body's resting metabolism.

Figure 1 here

Assume that working in a labour market generates income, and that piece rates are paid. A piece rate, then, appears as a relationship between the number of tasks performed and the total income of a person. Using these assumptions, a supply curve of labour could be constructed that shows different quantities of labour supplied at different piece rates. Aggregation across individuals yields an aggregate supply curve, as shown in Figure 2.

Figure 2 here

At a piece rate of v_3 there is a gap in labour supply and a discontinuous jump. Introducing a downward sloping demand curve, an interesting case is that in which the demand curve passes through the dotted supply curve. If the piece rate is larger than v^*, there is excess supply, which lowers this rate. On the other hand, if the piece rate is lower than v^*, there is excess demand, so that wages rise. Note, however, that a piece rate of v^* is an equilibrium wage, provided we allow for unemployment.

Figure 3 here

Having some people work and restricting labour market access to others could fill the gap in labour supply. Those rationed out will be relatively undernourished. This completes the vicious cycle of poverty. Lack of labour market opportunities results in low wages and consequently low work capacity which feeds back by lowering access to labour markets. It is easy to show that higher non-labour assets (e.g. land) lead to higher wage incomes. Thus the poor without assets are doubly disadvantaged: not only do they not enjoy non-labour income but also have restricted access to labour market opportunities.

Note that nutritional status depends on both current consumption of nutrients (e.g. protein) and the history of that consumption. In the analysis that follows, we focus on the effects of differences in micronutrient intake.[6]

The essence of an empirical test for the PNT Hypothesis is the specification of a wage equation conditional on micronutrient intake and control variables as:

$$w_h = f(micronutrient_h, p_1, p_2, p_3, p_4, X)$$

where w_h and ‘micronutrient’ represents the wage and micronutrient intake of the h^{th} individual respectively. p_i is the probability of being occupied in the ith occupation with i =1 indicating employment in agriculture, i=2 employment in non-agriculture, i=3 self employment and i = 4 other employment. This set of variables controls for labour market participation. ‘X’ represents control variables such as prices of various food products, income of the household from the non-agricultural sector, some household characteristics as well as some regional dummies. The probabilities are taken as the control variables to incorporate the impact of labour market participation on wage rate. It is thus argued that the wage rate of the worker depends on his/her nutrition proxied by micronutrient intake, which in turn depends on his/her wages. Hence the wage rate and micronutrient intake are both endogenous in this model.

III. Data and Methodology

The data used in this paper comes from the National Council for Applied Economic Research (NCAER). This data were collected through a multi-purpose household survey spread over six months, from January to June 1994. The data were collected using varied reference periods based on some conventional rules. The wage data used are that for harvesting, sowing and other occupations for male and female workers separately.

Any empirical strategy to estimate the PNT must deal with the mutual endogeneity of wage and nutrition. In the literature two standard approaches to doing this have been followed. The first predicts the probabilities of labour market participation from a Maximum Likelihood Multinomial Logistic Regression (multi-logit) model and then uses these in as determinants of the wage in an appropriately specified Tobit model of the PNT (Tobin 1958). The second method uses the well-known Heckman self selection procedure.

The Tobit model has some notable limitations (Greene 2003, Smith and Brame 2003). The first limitation is that in the Tobit model the same set of variables and coefficients determine both the probability that an observation will be censored and the value of the dependent variable. Second, the Tobit analysis is not based on a full theoretical explanation of why the observations that are censored are censored. These limitations can be remedied by replacing the Tobit model with a sample selection model.

Sample selection models have the advantage that a different set of variables and coefficients determine the probability of censoring and the value of the dependent variable given that it is observed, unlike in the Tobit model. These variables may overlap, to a point, or may be completely different. Second, sample selection models allow for greater theoretical development because the observations are said to be censored by some other variable, which we call *Z*. This allows us to take account of the censoring process, as we will see, because selection and outcome are not independent. A popular empirical strategy to pursue this is the Heckman procedure which we now discuss.

The Heckman Procedure

The problem of sample selection arises when the data in the survey is incidentally truncated or non-randomly selected. Our model determining wage nutrition relationship contains following main regression equation:

$$Y_i = \beta' X_i + \varepsilon_i \qquad (1)$$

where Y_i is the wage rate and X_i is a vector comprising the nutrition and other household characteristics. The model may imply a wage rate for all the individuals but we observe it only for those who are actually employed. Hence the model is truncated as the sample is selected on the basis of wages (in the agricultural sector).

Formally, the wages are observed only if:

$$Z_i{*} = \gamma' W_i + u_i \qquad (2)$$

where W_i are independent variables that contribute to the employment probability of an individual. W_i may or may not overlap with the X_i. In our case it does.

Equation (4) is called the selection equation. The sample rule thus becomes that Y_i* (the wage rate) is observed only when Z_i*> 0 (or the person under consideration is employed in the agricultural sector). We now discuss the estimation issues related to the observations in our sample (based on the above rule).

A simple OLS regression of the observed data produces inconsistent estimates of β essentially because of omitted variables. Moreover, the disturbance term is heteroscedastic so that the estimates will be inefficient.

Marginal Effects

The marginal effect of the regressors on Y_i has two components: direct effect on mean of Y_i, which is β, and the indirect effect through the regressor which is present in X_i. The problem of sample selection can lead the marginal effects to be overstated for the observed category (for which Z_i* > 0) and understated for the other category. For example, suppose that micronutrient intake affects both the probability of working in agricultural sector and wage rate in either sectors (agricultural sector or non-agricultural sector). If we assume that the wages of the agricultural labourers (AL) is higher than that of otherwise identical non agricultural labourers (NAL), the marginal effects of nutrition has two parts: one due to its influence in increasing the probability of the individuals entering agricultural sector and the other due to its influence on wage rate within the group. Hence the coefficient on micronutrient in the regression overstates the marginal effect of the nutrition of AL and understates it for the NAL. In the opposite case it would understate the marginal effect.

Heckman suggested a two step procedure for estimating the above model. The model is first reformulated to a probit form. It should be noted that although the variable Z_i* is not observed, one can infer its sign (for example whether an individual works in agricultural sector or not) but not the magnitude. Thus the model can be reformulated as follows:

Selection Mechanism and Regression Model:

$Z_i^* = \gamma' W_i + u_i \; if \; Z_i^* > 0 \; and \, 0 \, otherwise.$ Whence we can write the regression model as:

$$Y_i = \beta' X_i + \varepsilon_i \; observed \, only \, if \; Z_i = 1, (u_i, \varepsilon_i) \sim bi\,\mathrm{var}iate\,normal[0,0,1,\sigma_\varepsilon, \rho]$$

The parameters of the sample selection model can be estimated using Heckman's two step estimation procedure discussed next.

Heckman's two step procedure

Heckman's two step estimation procedure (Heckman 1976, 1979) involves the following steps:

• Step 1: Estimate the probit equation by maximum likelihood to obtain estimates of γ. For each model in selected sample compute the inverse Mills ratio:

$$\hat{\lambda}_i = \frac{\phi(\hat{\gamma} w_i)}{\Phi(\hat{\gamma} w_i)} \text{ and } \hat{\delta}_i = \hat{\lambda}_i (\hat{\lambda}_i + \hat{\gamma} w_i)$$

where $\phi \; and \; \Phi$ are, respectively, the probability density function and the cumulative density function of a standard normal distribution.

• Step 2: Estimate β and $\beta_\lambda = \rho\sigma_\varepsilon$

by least squares regression of Y_i on X_i and $\hat{\lambda}$.

This methodology allows consistent estimates of the individual parameters. In this paper we present Heckman estimates for the wages for which we have a PNT in case of five major micronutrient categories- calcium, carotene, iron, riboflavin, and thiamine. A table in the Appendix lists the variables used in this paper.

IV. Results

The estimation indicates that the PNT exists in nine cases. In the case of carotene male workers engaged in harvesting are subject to the PNT, whereas both males and females engaged in harvesting are subject to PNT in the case of iron. In the case of riboflavin female workers engaged in harvesting and sowing and male workers engaged in harvesting are subject to PNT and in the case of thiamine female workers engaged in harvesting and sowing are subject to PNT. These results are shown in Table 1.

Table 1 here.

In Table 2 we report on the nutritional requirement to break out of the PNT. From the regression equation we compute the nutritional requirement to break the PNT. Thus if we use the Heckman method for female harvest wage we discover that the minimum daily calorie requirement to break the PNT in this case is 524.45 gm. From the data the minimum annual per capita expenditure that can attain this is Rs. 555, which is much lower than the per capita poverty line for that year which was Rs 2484 per year. Figures for other wage and micronutrient categories are noted in Table 2. In only two of the nine cases for which PNT holds does the required minimum annual expenditure rise above the poverty line for that year.[7] Hence, the extreme poor appear to be subject to the PNT.

Table 2 here.

V. Conclusions

The possibility that when workers have inadequate intakes of micronutrient they may not be able to exert sufficient effort so that their wages remain low which then leads to further poor nutritional outcomes has been known in the literature for almost fifty years now. A number of authors have tried to empirically test for this existence of this trap but none has been able to establish unambiguously that this holds for a subset of the working population and not the whole, but there has been no attempt to do so for micronutrients. Further, the extant literature also has not been able to establish the existence of PNT by occupation.

This paper has attempted to quantify and formally test for the presence of PNT in rural India. It outlines a methodology that can identify the impact of micronutrient consumption on wage rates, even in the presence of mutual endogeneity.

This paper has an important policy implication in that it argues that worker earnings in agriculture must be adequate to ensure that workers are not caught in the poverty-nutrition trap. Workers living in severe poverty in rural India would not be able to use labour market earnings to escape the PNT. Breaking these traps should be a matter of urgent policy concern.

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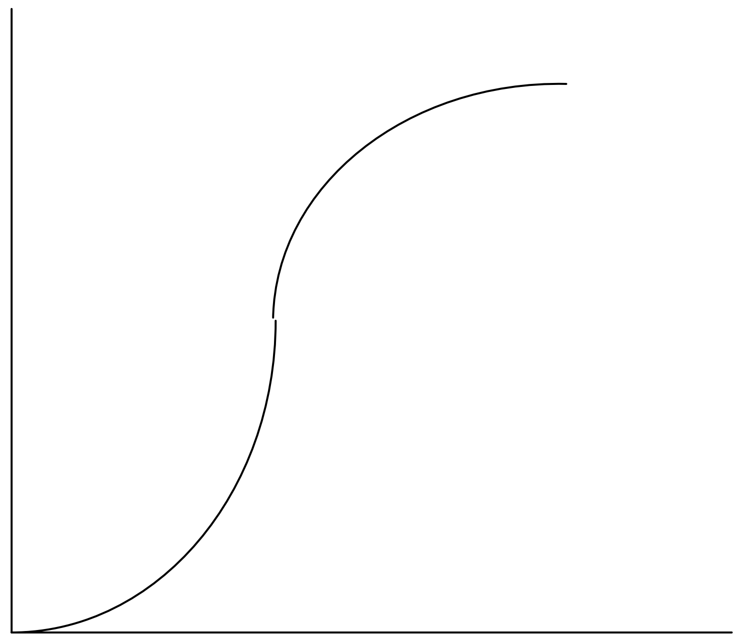
Figure 1: The Capacity Curve

Work Capacity



Income

Figure 2: Individual and Aggregate Labour Supply

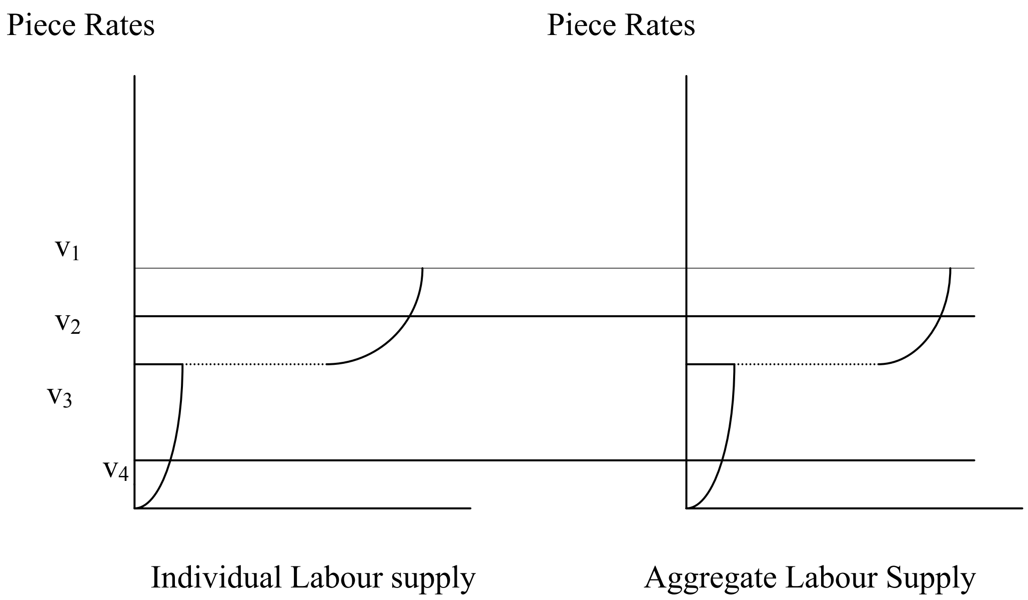
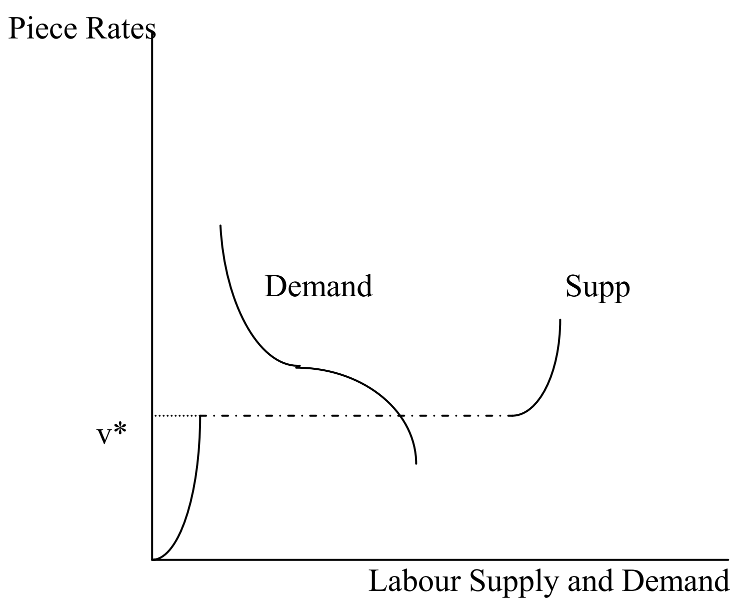


Figure 3: "Equilibrium" in the Labour Market



Source: Ray (1998).

Table 1a: Existence of PNT in the case of Calcium – Female Harvest Wages

Heckman selection	model -- two-step estimates	Number of obs	=		6594
(regression model	with sample selection)	Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		1308.29
		Prob > chi2	=		0
	Coef.	Std. Err.	Z	P>z	
fem_harvest					
Bimaru	-7.17685	0.724717	-9.9	0	
Coastal	5.055971	0.866453	5.84	0	
Calcpchat	0.057689	0.021438	2.69	0.007	
Calcpchat2	-5.5E-05	2.64E-05	-2.08	0.037	
pr_pulses	-0.22183	0.060289	-3.68	0	
pr_gur_sugar	-0.11574	0.206103	-0.56	0.574	
pr_oil	0.029713	0.019033	1.56	0.119	
pr_milk	-0.06793	0.041575	-1.63	0.102	
Headage	0.011615	0.077976	0.15	0.882	
headage2	0.000281	0.0009	0.31	0.755	
NO.ADULTMALE	-1.93965	0.425108	-4.56	0	
NO.ADULTFEMALE	1.585221	0.279846	5.66	0	
Hhsize	-0.17335	0.144216	-1.2	0.229	
SC/ST	2.20168	0.889581	2.47	0.013	
RAINFALLINDEX	0.001665	0.000519	3.21	0.001	
_cons	10.76975	2.880375	3.74	0	
Select					
Headage	-0.00384	0.007484	-0.51	0.608	
headage2	2.98E-05	7.67E-05	0.39	0.698	
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044	
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024	
SC/ST	0.496191	0.036991	13.41	0	
Land_own	-0.00463	0.000427	-10.84	0	
Land_own2	-6.04E-08	1.77E-07	-0.34	0.734	
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087	
Landrain	4.84E-06	6.13E-07	7.9	0	
Bimaru	0.306848	0.041688	7.36	0	
Coastal	1.004761	0.066374	15.14	0	
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004	
_cons	0.289162	0.166635	1.74	0.083	
Mills					
Lambda	-0.83782	1.84359	-0.45	0.65	
Rho	-0.07119				
Sigma	11.76923				
Lambda	-0.83782	1.84359			

Table 1b: Existence of PNT in the Case of Carotene – Male Harvest Wages

Heckman selection (regression model	model -- two-step estimates with sample selection)	Number of obs	=		6594
		Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		855.78
		Prob > chi2	=		0
	Coef.	Std. Err.	z	P>z	
male_harvest					
Bimaru	-4.56189	0.838686	-5.44	0	
Coastal	8.536757	1.247139	6.85	0	
Carothat	0.042226	0.025161	1.68	0.093	
carothat2	-3.6E-05	5.48E-05	-0.66	0.512	
pr_pulses	-0.09016	0.081245	-1.11	0.267	
pr_gur_sugar	-0.75888	0.167689	-4.53	0	
pr_oil	0.07944	0.032429	2.45	0.014	
pr_milk	-0.21556	0.045148	-4.77	0	
Headage	-0.19455	0.129314	-1.5	0.132	
headage2	0.001972	0.001283	1.54	0.124	
NO.ADULTMALE	-0.33049	0.330673	-1	0.318	
NO.ADULTFEMALE	-0.35287	0.415004	-0.85	0.395	
Hhsize	0.16192	0.178945	0.9	0.366	
SC/ST	3.456164	0.801135	4.31	0	
RAINFALLINDEX	-0.00418	0.000706	-5.92	0	
_cons	23.65583	4.10081	5.77	0	
Select					
Headage	-0.00384	0.007484	-0.51	0.608	
headage2	2.98E-05	7.67E-05	0.39	0.698	
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044	
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024	
SC/ST	0.496191	0.036991	13.41	0	
land_own	-0.00463	0.000427	-10.84	0	
land_own2	-6.04E-08	1.77E-07	-0.34	0.734	
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087	
Landrain	4.84E-06	6.13E-07	7.9	0	
Bimaru	0.306848	0.041688	7.36	0	
Coastal	1.004761	0.066374	15.14	0	
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004	
_cons	0.289162	0.166635	1.74	0.083	
Mills					
Lambda	5.950737	2.459262	2.42	0.016	
Rho	0.3613				
Sigma	16.47056				
Lambda	5.950737	2.459262			

Table 1c: Existence of PNT in the Case of Iron – Female Harvest Wages

Heckman selection	model -- two-step estimates	Number of obs	=		6594
(regression model	with sample selection)	Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		1307.95
		Prob > chi2	=		0
	Coef.	Std. Err.	z	P>z	
fem_harvest					
Bimaru	-9.75545	0.768342	-12.7	0	
Coastal	4.095827	0.949288	4.31	0	
Ironpchat	0.406556	0.156977	2.59	0.01	
ironpchat2	-0.00108	0.001051	-1.03	0.303	
Pr_pulses	-0.15073	0.060789	-2.48	0.013	
Pr_gur_sugar	0.066958	0.104089	0.64	0.52	
Pr_oil	0.053591	0.013637	3.93	0	
Pr_milk	-0.1079	0.034045	-3.17	0.002	
Headage	-0.00831	0.084869	-0.1	0.922	
headage2	-0.00029	0.000861	-0.34	0.737	
NO.ADULTMALE	-1.53716	0.288819	-5.32	0	
NO.ADULTFEMALE	1.324359	0.296754	4.46	0	
Hhsize	0.287801	0.190837	1.51	0.132	
SC/ST	1.509875	0.658751	2.29	0.022	
RAINFALLINDEX	0.002067	0.0005	4.13	0	
_cons	5.353557	3.751462	1.43	0.154	
Select					
Headage	-0.00384	0.007484	-0.51	0.608	
headage2	2.98E-05	7.67E-05	0.39	0.698	
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044	
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024	
SC/ST	0.496191	0.036991	13.41	0	
land_own	-0.00463	0.000427	-10.84	0	
land_own2	-6.04E-08	1.77E-07	-0.34	0.734	
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087	
Landrain	4.84E-06	6.13E-07	7.9	0	
Bimaru	0.306848	0.041688	7.36	0	
Coastal	1.004761	0.066374	15.14	0	
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004	
_cons	0.289162	0.166635	1.74	0.083	
Mills					
Lambda	-0.13373	1.77995	-0.08	0.94	
Rho	-0.01137				
Sigma	11.75714				
Lambda	-0.13373	1.77995			

Table 1d: Existence of PNT in the Case of Iron – Male Harvest Wages

Heckman selection	model -- two-step estimates	Number of obs	=		6594
(regression model	with sample selection)	Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		857.62
		Prob > chi2	=		0
	Coef.	Std. Err.	z	P>z	
male_harvest					
Bimaru	-5.85683	1.05078	-5.57	0	
Coastal	6.155161	1.304095	4.72	0	
Ironpchat	0.598753	0.213019	2.81	0.005	
ironpchat2	-0.00192	0.001424	-1.35	0.176	
pr_pulses	-0.08201	0.08254	-0.99	0.32	
pr_gur_sugar	-1.01802	0.141314	-7.2	0	
pr_oil	0.140011	0.018439	7.59	0	
pr_milk	-0.22575	0.046168	-4.89	0	
Headage	-0.28626	0.117056	-2.45	0.014	
Headage2	0.002674	0.001188	2.25	0.024	
NO.ADULTMALE	-0.75653	0.395835	-1.91	0.056	
NO.ADULTFEMALE	-0.60186	0.40731	-1.48	0.14	
Hhsize	0.713695	0.259034	2.76	0.006	
SC/ST	4.249521	0.904818	4.7	0	
RAINFALLINDEX	-0.00382	0.000692	-5.53	0	
_cons	17.93737	5.123513	3.5	0	
Select					
Headage	-0.00384	0.007484	-0.51	0.608	
Headage2	2.98E-05	7.67E-05	0.39	0.698	
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044	
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024	
SC/ST	0.496191	0.036991	13.41	0	
land_own	-0.00463	0.000427	-10.84	0	
land_own2	-6.04E-08	1.77E-07	-0.34	0.734	
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087	
Landrain	4.84E-06	6.13E-07	7.9	0	
Bimaru	0.306848	0.041688	7.36	0	
Coastal	1.004761	0.066374	15.14	0	
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004	
_cons	0.289162	0.166635	1.74	0.083	
Mills					
Lambda	5.965028	2.438496	2.45	0.014	
Rho	0.36217				
Sigma	16.47008				
Lambda	5.965028	2.438496			

Table 1e:Existence of PNT in the Case of Riboflavin – Female Harvest Wages

Heckman selection	model -- two-step estimates	Number of obs	=	6594
(regression model	with sample selection)	Censored obs	=	2134
		Uncensored obs	=	4460
		Wald chi2(23)	=	1315.04
		Prob > chi2	=	0
	Coef.	Std. Err.	Z	P>z
fem_harvest				
Bimaru	-8.69979	0.682973	-12.74	0
Coastal	4.856649	0.874654	5.55	0
Ribopchat	19.68506	5.33042	3.69	0
ribopchat2	-3.10063	0.884144	-3.51	0
pr_pulses	-0.32036	0.0766	-4.18	0
pr_gur_sugar	-0.46444	0.212682	-2.18	0.029
pr_oil	0.014812	0.019389	0.76	0.445
pr_milk	-0.07253	0.035181	-2.06	0.039
Headage	0.029473	0.078239	0.38	0.706
headage2	-0.00083	0.000812	-1.02	0.31
NO.ADULTMALE	-1.32507	0.254593	-5.2	0
NO.ADULTFEMALE	2.14764	0.326558	6.58	0
Hhsize	-0.45924	0.186634	-2.46	0.014
SC/ST	3.532966	0.917421	3.85	0
RAINFALLINDEX	0.001959	0.000498	3.93	0
_cons	17.70938	3.919207	4.52	0
Select				
Headage	-0.00384	0.007484	-0.51	0.608
headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
land_own	-0.00463	0.000427	-10.84	0
land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	-0.93	1.805126	-0.52	0.606
Rho	-0.07905			
Sigma	11.76476			
Lambda	-0.93	1.805126		

Table 1f:Existence of PNT in the Case of Riboflavin – Female Sowing Wages

Heckman selection	model -- two-step estimates	Number of obs	=	6594
(regression model	with sample selection)	Censored obs	=	2134
		Uncensored obs	=	4460
		Wald chi2(23)	=	1163.96
		Prob > chi2	=	0

	Coef.	Std. Err.	z	P>z
fem_sowing				
Bimaru	-6.25982	0.582979	-10.74	0
Coastal	4.59119	0.746842	6.15	0
Ribopchat	7.953568	4.54607	1.75	0.08
ribopchat2	-2.65996	0.754095	-3.53	0
pr_pulses	-0.21417	0.065345	-3.28	0.001
pr_gur_sugar	0.025202	0.181411	0.14	0.89
pr_oil	-0.09891	0.016536	-5.98	0
pr_milk	-0.05186	0.030008	-1.73	0.084
Headage	0.111524	0.066825	1.67	0.095
headage2	-0.00146	0.000693	-2.1	0.035
NO.ADULTMALE	-0.57902	0.217344	-2.66	0.008
NO.ADULTFEMALE	1.540435	0.278725	5.53	0
Hhsize	-0.82952	0.159207	-5.21	0
SC/ST	5.095268	0.782903	6.51	0
RAINFALLINDEX	-0.00231	0.000426	-5.43	0
_cons	13.21408	3.344257	3.95	0
Select				
Headage	-0.00384	0.007484	-0.51	0.608
headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
land_own	-0.00463	0.000427	-10.84	0
land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	1.255952	1.540643	0.82	0.415
Rho	0.12488			
Sigma	10.05737			
Lambda	1.255953	1.540643		

Table 1g: Existence of PNT in the Case of Riboflavin – Male Harvest Wages

Heckman selection (regression model	model -- two-step estimates with sample selection)	Number of obs	=	6594
		Censored obs	=	2134
		Uncensored obs	=	4460
		Wald chi2(23)	=	855.85
		Prob > chi2	=	0

	Coef.	Std. Err.	z	P>z
male_harvest				
Bimaru	-5.02615	0.93709	-5.36	0
Coastal	7.754375	1.205664	6.43	0
Ribopchat	16.57579	7.224245	2.29	0.022
ribopchat2	-1.01885	1.1994	-0.85	0.396
pr_pulses	-0.11481	0.104198	-1.1	0.271
pr_gur_sugar	-0.99214	0.28879	-3.44	0.001
pr_oil	0.096188	0.026285	3.66	0
pr_milk	-0.21793	0.047769	-4.56	0
Headage	-0.26531	0.108266	-2.45	0.014
headage2	0.002524	0.001123	2.25	0.025
NO.ADULTMALE	-0.47042	0.349914	-1.34	0.179
NO.ADULTFEMALE	-0.06158	0.447569	-0.14	0.891
Hhsize	0.233556	0.253754	0.92	0.357
SC/ST	4.184962	1.254253	3.34	0.001
RAINFALLINDEX	-0.00401	0.00069	-5.81	0
_cons	24.6572	5.351575	4.61	0
Select				
Headage	-0.00384	0.007484	-0.51	0.608
headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
land_own	-0.00463	0.000427	-10.84	0
land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	6.014543	2.472365	2.43	0.015
Rho	0.36493			
Sigma	16.4812			
Lambda	6.014543	2.472365		

Table 1h: Existence of PNT in the Case of Thiamine – Female Harvest Wages

Heckman selection model -- two-step estimates		Number of obs	=	6594
(regression model with sample selection)		Censored obs	=	2134
		Uncensored obs	=	4460
		Wald chi2(23)	=	1313
		Prob > chi2	=	0

	Coef.	Std. Err.	z	P>z
fem_harvest				
Bimaru	-9.05127	0.717627	-12.61	0
Coastal	4.730654	0.880668	5.37	0
Thiapchat	6.997471	2.034776	3.44	0.001
Thiapchat2	-0.37406	0.129869	-2.88	0.004
pr_pulses	-0.27722	0.077499	-3.58	0
pr_gur_sugar	-0.34702	0.212143	-1.64	0.102
pr_oil	0.026536	0.017349	1.53	0.126
pr_milk	-0.07771	0.036087	-2.15	0.031
Headage	0.013247	0.078387	0.17	0.866
headage2	-0.00062	0.000808	-0.76	0.445
NO.ADULTMALE	-1.28784	0.262139	-4.91	0
NO.ADULTFEMALE	2.030463	0.334037	6.08	0
Hhsize	-0.3516	0.208711	-1.68	0.092
SC/ST	3.131536	0.934811	3.35	0.001
RAINFALLINDEX	0.00204	0.000495	4.12	0
_cons	14.79265	4.084994	3.62	0
Select				
Headage	-0.00384	0.007484	-0.51	0.608
headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
land_own	-0.00463	0.000427	-10.84	0
land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	-0.57224	1.789614	-0.32	0.749
Rho	-0.04867			

Table 1i: Existence of PNT in the Case of Thiamine – Male Harvest Wages

Heckman selection	model -- two-step estimates	Number of obs	=		6594
(regression model	with sample selection)	Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		857.87
		Prob > chi2	=		0

	Coef.	Std. Err.	z	P>z
male_harvest				
Bimaru	-5.69569	0.984831	-5.78	0
Coastal	7.805282	1.215557	6.42	0
Thiapchat	6.437212	2.758467	2.33	0.02
thiapchat2	-0.0082	0.176281	-0.05	0.963
pr_pulses	-0.02868	0.105445	-0.27	0.786
pr_gur_sugar	-0.77659	0.288127	-2.7	0.007
pr_oil	0.100326	0.023506	4.27	0
pr_milk	-0.24395	0.048985	-4.98	0
Headage	-0.28335	0.108714	-2.61	0.009
headage2	0.002729	0.001121	2.43	0.015
NO.ADULTMALE	-0.61864	0.36063	-1.72	0.086
NO.ADULTFEMALE	-0.34556	0.458259	-0.75	0.451
Hhsize	0.538432	0.283913	1.9	0.058
SC/ST	3.371457	1.279248	2.64	0.008
RAINFALLINDEX	-0.00389	0.000687	-5.66	0
_cons	18.99829	5.58184	3.4	0.001
Select				
Headage	-0.00384	0.007484	-0.51	0.608
headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
land_own	-0.00463	0.000427	-10.84	0
land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	6.377306	2.454175	2.6	0.009
Rho	0.38555			
Sigma	16.54083			
Lambda	6.377306	2.454175		

Table 1j: Existence of PNT in the Case of Thiamine – Female Sowing Wages

Heckman selection	model -- two-step estimates	Number of obs	=		6594
(regression model	with sample selection)	Censored obs	=		2134
		Uncensored obs	=		4460
		Wald chi2(23)	=		1161.76
		Prob > chi2	=		0

	Coef.	Std. Err.	z	P>z
fem_sowing				
Bimaru	-6.71154	0.612547	-10.96	0
Coastal	4.516915	0.752	6.01	0
Thiapchat	4.062358	1.735448	2.34	0.019
thiapchat2	-0.3821	0.110773	-3.45	0.001
pr_pulses	-0.16762	0.066114	-2.54	0.011
pr_gur_sugar	0.094087	0.180957	0.52	0.603
pr_oil	-0.10361	0.014797	-7	0
pr_milk	-0.06626	0.030781	-2.15	0.031
Headage	0.089459	0.066956	1.34	0.182
Headage2	-0.00125	0.00069	-1.81	0.071
NO.ADULTMALE	-0.59356	0.223791	-2.65	0.008
NO.ADULTFEMALE	1.568734	0.285119	5.5	0
Hhsize	-0.77374	0.178048	-4.35	0
SC/ST	5.064527	0.797781	6.35	0
RAINFALLINDEX	-0.00236	0.000423	-5.59	0
_cons	10.62989	3.485853	3.05	0.002
Select				
Headage	-0.00384	0.007484	-0.51	0.608
Headage2	2.98E-05	7.67E-05	0.39	0.698
NO.ADULTMALE	-0.03827	0.019037	-2.01	0.044
NO.ADULTFEMALE	0.049924	0.022145	2.25	0.024
SC/ST	0.496191	0.036991	13.41	0
Land_own	-0.00463	0.000427	-10.84	0
Land_own2	-6.04E-08	1.77E-07	-0.34	0.734
RAINFALLINDEX	8.92E-05	0.000052	1.71	0.087
Landrain	4.84E-06	6.13E-07	7.9	0
Bimaru	0.306848	0.041688	7.36	0
Coastal	1.004761	0.066374	15.14	0
FEMALE_HHHEAD	0.246493	0.085797	2.87	0.004
_cons	0.289162	0.166635	1.74	0.083
Mills				
Lambda	1.121481	1.527492	0.73	0.463
Rho	0.11156			
Sigma	10.05244			
Lambda	1.121481	1.527492		

Table 2: Nutritional Requirement to break Poverty Nutrition Trap

Micronutrient Category	Requirement to Break PNT	Minimum Equivalent Per Capita Expenditure per year
Calcium (grams/day)		
HFH	524.45	555
Carotene (microgram/day)		
HMH	586.47	1197
Iron (milligram/day)		
HFH	188.22	2504
HMH	155.93	2038
Riboflavin (milligram/day)		
HFH	3.17	1790
HFS	1.50	110
HMH	8.13	2428
Thiamine (milligram/day)		
HFH	9.35	4524
HFS	5.32	1633

N.B. The first letter in the acronyms used in this table refers to technique of estimation, i.e. “H” for Heckman; the second refers to gender of workers “M” for male and “F” for female and the third refers to wage category: “H” for harvesting, “S” for sowing and “O” for other.

Appendix Table: Variables Used in the Analysis

Household Level Variables	
Variable Name	*Variable Description*
headage	Age of Household Head
headage2	Square of Age of Household Head
NO.ADULTMALE	no. of adult males in Household (HH)
NO.ADULTFEMALE	no. of adult females in HH
hhgrp	HH Group Dummy Variable 1 if SC/ST HH and 0 Otherwise
HINDU, MUSLIM, CHRISTIAN, SIKH, BUDDHIST, TRIBAL, JAIN, OTHERS	Religion dummies.
FEMALE_HHHEAD	Whether head of household is female.
HIGHESTFEMEDUPRIMARY	Highest level of education for any adult female in household is primary
HIGHESTFEMEDUMIDDLE	Highest level of education for any adult female in household is middle
HIGHESTFEMEDUMATRIC	Highest level of education for any adult female in household is matric
Land_own	Land Owned in Acres
Land_own2	Square of Land Owned
Other Variables	
RAINFALLINDEX	Rainfall Index (actual - normal rain fall) for 76 agroclimatic zones in India.
bimaru	Dummy for Bimaru states (Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh)
coastal	Dummy for Coastal districts
landrain	Landowned*rainfall
pr_pulses	Price of Pulses
pr_gur_sugar	Price of Gur Sugar
pr_oil	Price of Oil
pr_milk	Price of Milk
Generated Variables	
Calcpchat	Predicted value of calcium consumption per capita
Calcpchat2	Predicted value of square of calcium consumption per capita
Carothat	Predicted value of carotene consumption per capita
carothat2	Predicted value of square of carotene consumption per capita
ironpchat	Predicted value of iron consumption per capita
ironpchat2	Predicted value of square of iron consumption per capita
Ribopchat	Predicted value of riboflavin consumption per capita
ribopchat2	Predicted value of square of riboflavin consumption per capita
Thiapchat	Predicted value of thiamine consumption per capita
thiapchat2	Predicted value of square of thiamine consumption per capita

Endnotes

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[2] In this paper we use the terms efficiency wage hypothesis and PNT interchangeably.

[3] For a comprehensive review see Strauss and Thomas (1998). See also Lipton (2001).

[4] From a policy perspective it is likely to be more useful to test for PNT for different nutrients separately. An aggregate of deprivation across various nutrients is essentially arbitrary and does not indicate which the most pressing deprivation is.

[5] The following exposition is based on Ray (1998).

[6] For critiques of PNT hypothesis, see Srinivasan (1994), and Subramanian and Deaton (1996).

[7] It should be noted that the micronutrient requirements to break the PNT stated in Table 2 could overstate the requirements to break out of the PNT because these workers would not be performing the demanding tasks of harvesting or sowing throughout the year. However, since these workers are classified according to their primary function, the extent of such overestimation may be limited. In any case the expenditure needed to break the PNT is higher than the poverty line for that year in only two of the nine cases.