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The Nutrition- Productivity Link and the Persistence of Poverty[1]

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Abstract

In poor societies where nutrition and health status is very low, consumption of basic needs amounts to investment. It enhances labour productivity and reduces morbidity. In this paper it is shown that inequality can persist in rural Ethiopia due to the existence the low nutrition- low productivity trap. It is done mainly by establishing the link between nutrition and health on the one hand and labour productivity on the other. Using a panel data from rural Ethiopian households, farm production functions as well as earnings functions are estimated. In both cases, calorie intakes do affect the labour productivity of farm households. However, the effect of the stock of nutrition on productivity is observed only in the earnings function. For workers employed in social safety nets such as food for work programs, the productivity effect of nutrition is minimal. Moreover our estimates indicate that the returns to calorie intakes are much larger than that of chemical fertilizers.

Key words: Poverty, Nutrition, Productivity
JEL Classification: C33, D13, I1, I3, J24, J41.

Résumé

Le lien entre nutrition et productivité et la persistance de la pauvreté
Tekabe Ayalew

Dans les sociétés pauvres où la nutrition et la santé sont à un bas niveau, la consommation des produits de premiëre nécessité est un véritable investissement. Cela augmente la productivité et diminue la morbidité. Cet article démontre que l'inégalité peut persister en Ethiopie rurale, du fait de l'existence de la malnutrition et d'une productivité limitée. Cela se fait surtout en établissant un lien entre la nutrition et la santé d'une part, et la productivité de la main d'oeuvre d'autre part. En utilisant un tableau de données sur les ménages ruraux en Ethiopie, la production agricole et les revenus, on peut présenter des estimations. Dans les deux cas, la consommation de calories influence la productivité du travail des familles agricoles. L'effet des provisions de nutrition sur la productivité est observé uniquement dans la fonction des revenus. Pour les travailleurs, employés dans le secteur de la sécurité sociale comme les programmes de "alimentation pour travail"(food for work), l'effet de la productivité de la nutrition est minimale. De plus, nos estimations indiquent que les rétributions de la consommation de calories sont bien plus importantes que celles des engrais chimiques.

Mots clef: pauvreté, nutrition, productivité
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Introduction.

The discussion concerning the relationship between nutritional intakes and labour effort per unit of time is not new. Since the issue was brought to the attention of economists by Leibenstein (1 957) subsequent authors have used this relationship to develop the theory of efficiency wage, which could then explain the coexistence of positive wages and involuntary unemployment, wage rigidities and issues related to intrahousehold distribution of food and activity (Mazumdar, 1959; Mirrlees, 1975; Stiglitz, 1976; Bliss and Stern, 1978a; 1978b; Pitt, Rosenzweig and Hassan 1990). Originally the efficiency wage theory focused on the biological relationship that might exist between nutrient intakes and labour effort per unit of time in the context of poor societies. But gradually the theory has been developed into a theory of wage determination in general and has been called up on to explain involuntary unemployment in the industrialized world as well, though not necessarily via the nutrition-productivity link (Shapiro and Stiglitz, 1984; Weiss, 1991).

Dasgupta (1988, 1993, 1997) shows the mechanism by which inequality determines malnutrition through the nutrition-productivity link. When individuals differ in their possession of physical assets, the probability of securing employment follows the distribution of asset ownership. It is argued that consumption affects productivity via its effect on physical strength, endurance and stamina. In other words, the quality of labour supplied depends up on the level of consumption. However this relationship is far from linear mainly because of the minimum level of consumption needed to maintain oneself. One requires a minimum level of consumption to maintain the basic metabolism of the human body, referred in the nutrition literature as the Basal Metabolic Rate (BMR). The BMR is the energy expenditure when the individual is in a 'complete state of rest' with a constant body temperature and has been fasting for at least 13 hours (Dasgupta, 1993).

Nutritionists compute energy requirements as having a fixed and variable component that depends on the type and the duration of the activity being done. The fixed component, which includes the basal metabolic requirement plus the minimum level of physical activity that allows for dressing, standing and keeping personal hygiene, accounts for 127 percent of the BMR requirement (Payne, 1992). This is a fixed requirement that is spent without being engaged in any kind of productive activity. Depending on the type of the activity to be done, the requirement rises. For example for 'light' activities it rises to 154 percent of the BMR while for moderate and heavy it goes up to 178 and 214 percent of the BMR, respectively. The importance of these requirements for our purpose is that it demonstrates that the fixed requirement is a very large proportion of what is needed to undertake a productive activity. It is this and the resulting increasing returns from additional intakes that underlie the low nutrition-low productivity trap.

This non-convex relationship between labour supply and consumption underlies the argument about the link between nutrition and productivity on the one hand and the persistence of poverty on the other. Due to this non-convexity multiple equilibria are possible[1] At the lower end of this spectrum of equilibria lies a low nutrition-low productivity point where people stay unemployed involuntarily. At the other extreme lies the high nutrition-high productivity equilibrium where people enjoy high levels of productivity and better nutrition. Because of the fixed requirement, individuals could be trapped in the low equilibrium point where they stay poor with little chance of getting out of the poverty. Not surprisingly, it is the assetless that are trapped in the low equilibrium point. Those who have access to non-labour income can secure some level of consumption while the poor requires employment to finance the same level of consumption. Ironically the quality of labour that is supplied depends upon the level of consumption. From the employers perspective hiring the poor is therefore expensive, because the poor require a wage high enough to be able to consume what is required for BMR plus additional amounts needed to undertake external work. Those who own assets, however, can partly finance their consumption even without having to work. Hence, a wage level below what is required by the poor would enable those with assets to supply the quality of labour that the poor can not offer.

[1] Since we assume other things being constant (e.g. technology), the equilibrium concept used here is a partial one.

A poor person is thus unable to get employment because she is poor and she remains poor because she can not get employment. This is at the core of the relationship between persistent poverty on the one hand and the nutrition-productivity link on the other. In fact, for poor households where labour is their major, if not the only, source of income poverty is the consequence of failure to maintain and invest in their human capital. Whereas a well fed and healthy labourer is attractive for employers, an overtly weak person is less likely to get any market for her labour in a competitive environment. The same applies to subsistence farmers who can not produce enough to provide themselves adequate nutrition; and poor nutrition in turn keeps their productivity low.

A number of empirical studies have been trying to substantiate this theoretical relationship in various work conditions and environmental settings. In Minnesota, for instance, an experiment conducted to establish the relationship reported that when daily caloric intake was reduced from 3500 calories to 1500 over a 24 week period and increased again to 1800, activity levels decreased enormously (Keys et al. 1950). Though the finding that activity level drops with consumption is important by itself, it does not say much about the effect on labour productivity per unit of time. Since what was observed in the study was reduced activity, the implication for labour productivity per unit of time is not clear.

Kraut and Muller (1946) observed an increase in the productivity of German workers engaged in labour intensive activities (which include coal miners, steelworkers and workers engaged in dumping debris out of railcars) when daily food availability was increased. Two major drawbacks of the study are the absence of a control group and that it does not control for other productivity-enhancing effects of changes in pay that works through other mechanisms than via the nutrition-productivity link. In the absence of control groups, all changes in labour productivity are incorrectly attributed to changes in food availability. However changes in productivity might be due to other factors that occur simultaneously with the changes in the food ration. Not controlling for such confounding factors is a clear shortcoming. On the other hand even when a rise in pay results in increase in output, it is no proof for the presence of the nutrition-productivity link. A mere increase in food ration may entail increase in labour productivity not because of the link between nutrition and productivity but because workers are motivated due to a rise in the ration. A number of studies documented that a rise in pay results in increase in labour productivity due to other reasons than the nutrition-productivity link. Models of shirking (Shapiro and Stiglitz, 1984), for example, stipulate that factors that raise the cost of job loss increase productivity. When pay is high employees do not shirk because if caught the cost of losing job is high. The gift exchange models also explain a rise in labour productivity following an increase in pay through a gift exchange relationship (Akerlof, 1982; 1983; Akerlof et al, 1986; Akerlof et al, 1989). A raise in pay increases labour productivity by making grateful workers feel they should reciprocate.

The study by Wolgmuth et al (1982) is superior in that they were able to observe the behavior of both experiment and control groups. The calorie consumption of the experiment groups was increased by 1000 calories per day while that of the control group was increased only by 200 calories per day. Though the actual increase could be less than what was provided (because it may 'crowd out' food consumed at home), the study was able to identify a significant relationship between energy supplementation and output of Kenyan road construction workers. It is important to note that both groups had similar initial daily calorie intake of about 2000 calories per day. When initial level of calorie intake differ, the effect of exogenous increases in calorie are dependent on the initial level.

Most studies that attempt to establish the relationship between labour productivity and nutrition are contaminated by simultaneity between caloric intake and labour productivity. The causation of the relationship could go in either direction. Variables that affect earnings or production affect consumption via the associated effect on income in which case consumption is rendered endogenous. Studies that regress earnings/production on consumption, thus suffer from simultaneity bias.

One systematic study is by Strauss (1986), where the response of farm labour productivity to caloric intake is measured. Using data from Sierra Leone where physically demanding hoe agriculture is practiced, he quantified the effect of current nutritional status on farm labour productivity. Aware of the reverse causality, he used prices, household characteristics and farm assets as instruments. He found a strongly significant effect of calorie intake on farm productivity. However, the effect is not linear and the marginal effect on productivity falls as calorie consumption rises, but remains positive. Yet, his emphasis is on the effect of the flow of nutritional status measured by caloric intake. Caloric intake however also affects the stock of nutritional status, namely the body mass which is directly related to productivity (Osmani, 1992). This relationship is very important especially when individuals can adapt to short term changes in caloric intake by drawing from the stock of nutrition without any significant reduction in their productivity. Moreover, as Strauss acknowledges, failure to control for time persistent household effects (e.g. managerial ability) may lead to biased estimates. The bias could go in either direction depending on the relationship between caloric intake and the omitted time persistent variables. Both of these shortcomings are addressed in Deolalikar (1988).

Aware of the short and long term effects of nutrition, Deolalikar (1988) made the distinction between the effects of current caloric intake and that of weight on labour productivity. Employing panel data from rural India, he found that while neither farm output nor market wages respond to caloric intake, weight given height significantly affects both farm output and the market wage. He interpreted the result as an indicator of the fact that while the human body can adapt to inadequate intake in the short term, it can not adapt as readily to persistent deficiencies in nutritional intakes.

Similar to the study by Keys et al, Bhargava (1997) examined the activity pattern of men and women in Rwanda. He found that decreases in intakes forces adults to reduce their work time and increase the time spent on resting and sleeping. Both of these studies, however, fail to confirm the relationship between labour productivity per unit of time and caloric intake. It is not clear whether individuals would not adapt to low level of calorie intake for a certain time without a drop in productivity (in section 2 we present the contending views on this issue).

Thomas and Strauss (1997) used survey data to show the effect of nutritional status on the wages of men and women in urban Brazil. They reported that height has a significantly positive effect on the wages of both groups. However, low per capita calorie consumption has a negative effect only on the wages of market workers not on the earnings of the self employed.

Because market workers are generally poorer than the self employed, their result could suggest to the fact that calories have stronger effect when consumption is low.

Croppenstedt and Muller (CM) (2000) also estimated the impact of health and nutritional status on the efficiency and productivity of cereal growing Ethiopian farmers. They specify a stochastic frontier production function that enables them to examine the effect on efficiency as well. They reported that both indicators of health (measured in travel time to the daily source of water) and nutrition (measured in terms of weight for height of the household head) have significant effects on farm production. Since they used cross sectional data all the limitations of the study by Strauss mentioned above apply to CM's as well.

The current study uses the same data set as that of CM and attempts to cover issues not addressed by them. The study by CM uses only the cross sectional part of the data set, consequently it fails to control for time persistent household fixed effects. Such effects could be very important if farmers differ in their unobserved time persistent characteristics. Moreover, the CM study does not address the effect of the flow of nutrition on productivity.

Our interest here is to examine whether malnutrition leads to inequality via its effect on productivity. When nutritional status affects productivity (earnings), there is a possibility that the poor are trapped in a low nutrition-low income state. And such trap could be dynastic because first, the poor may not be able to provide adequate nutrition for their off spring thereby leaving them with poor nutritional status as adults. Second, maternal nutritional status leaves a significant mark on future nutritional status by, for example, determining the infant's birth weight which in turn constrain the child's future nutritional status. In a way we set aside the issue related to the determinants of malnutrition; given the level of nutrition we are interested in its role in sustaining poverty and inequality via productivity.

The remaining parts of the paper are organized as follows. First a brief overview of the theories of malnutrition is presented in section 2, followed by the basic model in section 3. Section 4 describes the data and estimation strategies employed. The findings are reported in section 5 and the last section concludes the paper by presenting some policy implications of the study.

1. Theories of malnutrition.

In what follows two contending theories of malnutrition are presented. Emphasis is given to the implication of the theories for issues addressed in this paper.

1.1. The genetic potential theory

Also known as the establishment view, is the most commonly used in practice for measuring either individual or group nutritional status. The human body is viewed as a system that regulates and optimizes itself. It is assumed that for each individual there exists an optimum level of body size and composition. This optimal state is characterized by the fact that all the functions and capabilities of the person taken together maximize fitness. Owing to their genetic constitution, individuals differ in the level of the optimum state (e.g. height, food intake, weight, etc.) and in the level of activity they can undertake when at their optimum state. Malnourished individuals are those who are prevented from returning to their preferred optimum state due the environment (e.g. lack of adequate food intake, diseases or other constraints) (Gopalan, 1983a; 1983b; 1984). Malnutrition is thus the manifestation of the extent to which the environment causes the body to depart from the preferred state. Malnutrition can, therefore, be measured and ranked for severity by the extent of deviation on one or more of the state variables from those that characterize the optimum state. For instance, it is a common practice to regard people who are two standard deviations below some reference mean as undernourished. The presumption is that these people are likely to have had adjusted to stress from the environment than to have low preferred values.

One important implication is that malnourishment affects a person's current activities and her potential for dealing with future increased work load or future health. It also implies that for malnourished persons increased caloric consumption, for instance, would increase their productivity immediately as well as in the future through its effect on the stock of nutrition.

Opponents of the theory question why nutrition should be regarded as inadequate when someone's genetic potential is not achieved (Osmani, 1992). In other words why should undernutrition be associated with some normative targets, as defined by the genetic potential of the reference group, rather than failure to maintain the functional capabilities that depend on the level of nutrition.

Moreover, they argue that the model seems to associate low stature with being unhealthy. Yet, size and being healthy could also be positively correlated in a way hypothesized by the small but healthy hypothesis (Seckler,1980, 1982). This is because being small has an advantage in that in an environment of constraints it requires less energy to maintain itself as well as undertaking external activities[2]. Similarly, some argue that bigger should not be considered as if it is necessarily better (Tanner, 1978; Goldenstein and Tanner, 1980).

[2] Because energy requirement at the BMR level is proportional to the body size.

1.2. The adaptability theory

In this model the human body is still seen as a self regulating system, but unlike the genetic potential model this is based on the view that individual genes define the range and nature of adaptive adjustments that can be made in response to changes in food intake , work, etc. Yet such adjustments, to which there are limits, could be short lived and reversible or long lasting and irreversible. Malnutrition is the result of adaptive adjustments that exceed the limits (Seckler 1982; Sukhatme 1981; Payne 1985). Malnutrition is regarded as the end point of some kind of system failure rather than a condition of being in a range of sub optimal states. It is important to note that the non-convexity implied in this model is akin to the assumed relationship between food intake and productivity in the literature. The transition from normality to a state of malnourishment is rather discrete, not gradual as such.

In the adaptability model individuals are still regarded to differ in both their capacity to adapt and their capacity and efficiency in converting, say, food intake into energy. Different individuals thus may require different amount of food intake to undertake similar activities. Any difference in the state variables among individuals should be viewed as indicators of the overall effects of their respective environment, since it shows the extent of adaptive adjustments they have gone through.

One implication is that the difference in either food intake or weight among individuals at any point in time does not necessarily reflect differences in work ability/productivity, because people can adapt to their environment with little effect on their capacity to undertake a specific task. However when some adjustments are irreversible, an individual is unlikely to adapt to changes in food intake or weight through time with no associated loss on work capacity. In the nutshell, what it implies for the empirical relationship between nutrition and productivity is that studies employing cross sectional data would fail to take into account individual differences in adaptability. On the other hand methods that rely on intra-individual changes are much more relevant in explaining the relationship.

Gopalan (1992) sharply criticizes this theory on the grounds that it implies that a person is considered undernourished only when her condition deteriorates to the point where she is close to death. He interpreted the theory to imply that any undernutrition, even those that could entail functional impairment, should not be considered undernourished. For example, even when an individual is stunted (i.e. shows growth deficit) if she has a weight 'appropriate' for her height, she is regarded as a successful adaptor. Such treatment is unacceptable to many including Agarwal et al (1987). Challenging the adaptability theory, Agarwal et al (1987) have shown that children who are stunted but have normal weight to height ratio exhibit the same order of functional impairment as equally stunted with poor weight-height ratio.

Moreover, if stunting implies adaptation, it means that adaptation is a characteristic of persistent poverty. Because when height determines productivity, stunting ensures that currently stunted individuals as well as their offsprings will languish in poverty (see also Schultz, 2002). Stunted children with impaired ability will end up with low schooling and as stunted adults having low productivity and earning ability. As a result they would be unable to provide adequate nutrition for their offsprings who will end up facing the same situation as their parents[3].

The existence of such poverty trap is shown in various studies that attempt to examine the relationship between height and earning ability (Satyanurayana, Rao and Chatterjee, 1977; Hanumantha and Sastry, 1977; National Nutrition Monitoring Bureau, 1980; Deolalikar, 1988). What is consistent in most of these studies is the strong relationship between occupational status, indicating income, and height. Those with a low earning occupation are the

[3] That is in addition to what the children inherit genetically from stunted parents. One example of what offsprings may genetically inherit from parents is that stunted mothers are likely to give birth to a child with low birth weight which increases the susceptibility to diseases and the likelihood of infant mortality (Barker, 1998; Schultz, 2002).

most stunted and ironically those are the ones for whom physical strength has a greater say in their earnings.

In general, the basic critique is that as long as adaptation entails impairment of functioning, it is unacceptable to regard any substandard outcome for the poor as satisfactory on the basis that they adapt to the existing situation. Rather adaptation should be viewed as a strategic retreat from normality than an acceptable state of normality.

2. The model

We employ the standard agricultural household model where a typical farm household is assumed to maximize its utility given the production function and effective labour constraint.

$$\underset{C_a, C_n, C_l, K, L_h, L_f}{Max} \quad u(C_a, C_n, C_l)$$

$$Q = q(L_f^e, L_h^e, N, K)$$

$$L_f^e = \lambda(C_a, C_n, B(C_a, C_n), \theta) L_f$$

As usual the *Cs* are consumptions and subscripts a,n, and *l* stand for the consumption of agricultural, non-agricultural goods and leisure, respectively. *Q* is the farm production function where *N* stands for a fixed amount of land and *K* for other non labour inputs and $L^e s$ are effective labour (or labour power) as opposed to labour hours *(L)*. Effective labour is a multiple of labour hours, where the multiplier λ (.) is a function of the flow of consumption, other factors affecting labour efficiency, θ (e.g. health shock) and the stock of nutritional status *(B)*. The stock of nutrition is a function of consumption. Subscript *f* and *h* stand for family and hired labour respectively.

In the standard case, wage is assumed to be exogenous to the household's decision where it maximizes its utility given the full income and other constraints. However, when nutrition affects efficiency of labour and hence productivity, the assumption regarding the exogeneity of wage can no longer be sustained. As a way out, wage can be specified in units of per efficiency hours instead of clock hours so that the latter can be assumed to be exogenous.

Using w^e as a measure of wage per efficiency units (i.e. $w^e = \frac{w}{\lambda(.)}$), P_a, P_n for prices of C_a and C_n respectively; $T_N(.)$ as total non-sick time[4] available and E exogenous income, the full income constraint is given as:

$$p_a C_a + p_n C_n + w^e L_h^e + p_k K = w^e \lambda(.) T_N(C_a, C_n, B(C_a, C_n), \theta)$$
$$- w^e \lambda(.) C_l + p_Q Q + E - w^e L_f^e.$$

[4] Following Grossman (1972), this is defined as total time minus time lost due to sickness. It can also be regarded as a healthy time that can be devoted to leisure, market work and home production.

Before continuing with the household's maximization problem, few words about the functions λ(.) and T_N(.) seems in order. Though both have the same sets of arguments and the partial derivatives with respect to each of the arguments have the same sign in both functions, they represent separate effects of consumption. The λ(.) function represents the productivity enhancing effect of consumption. However, the T_N(.) function stands for the effect of consumption in enabling the individual encounter less sick time, hence increasing the total time available for leisure and work by reducing the sick time. Put it differently, illness may prevent the person to attend to its farm, which is a reduction in her working time. One of the contributions of consumption is reducing the likelihood of illness. This aspect is captured by the T_N(.) function. The fact that a sick person attends to her farm but with reduced productivity is captured by the λ(.) function. Whereas the λ(.) function reflects the productivity enhancing role of consumption with no consideration for the effect on healthy time available, the T_N(.) function stands to represent the effect of consumption in increasing the healthy time available to the individual.

Now turning to the household's maximization, we get the following equations from the first order conditions.

$$\frac{\partial u(.)}{\partial C_a} = \mu p_a \begin{bmatrix} 1 - L_f\left(\frac{\lambda(.)}{\partial C_a} + \frac{\partial B(.)}{\partial C_a}\frac{\partial \lambda(.)}{\partial B}\right)\frac{p_q}{p_a}\frac{\partial Q}{\partial L_f^e} \\ -\frac{w^e}{p_a}\left(T_N - C_l - L_f\left(\frac{\partial \lambda(.)}{\partial C_a} + \frac{\partial B(.)}{\partial C_a}\frac{\partial \lambda(.)}{\partial B(.)}\right)\right) \\ -\frac{w^e}{p_a}\lambda(.)\left(\frac{\partial T_N(.).}{\partial C_a} + \frac{\partial B(.).}{\partial C_a}\frac{\partial T_N(.)}{\partial B(.)}\right) \end{bmatrix}. \quad \text{Equation [1]}$$

$$\frac{\partial u}{\partial C_l} = \mu w^e \lambda(.). \quad \text{Equation [2]}$$

where μ is the Lagrangean multiplier for the full income constraint.

Similarly a third equation can also be obtained by maximizing with respect to C_n. It is exactly the same as equation [1] except C_a is replaced by C_n and p_a by p_n. Additional equations can also be obtained by maximizing with respect to K, L_h and L_f. For our purpose eq [1] suffices and we concentrate on it to demonstrate the link between nutrition and productivity.

Equation[1] presents an elaborated expression of the nutrition-productivity relationship. It shows that the shadow price of consumption is reduced to the extent consumption enhances productivity. It does so in two ways. First, an immediate (short term) effect through increased energy availability that can be converted into effective labour. And second, a long term effect via increased stock of nutrition. In fact these two returns to consumption in terms of both the flow and the stock of nutrition are best captured in a dynamic model which is not convenient to show in a timeless model like ours. However for the sake of exposition we present the sketch of the idea in the appendix.

Another way of interpreting Eq [1] is that it clearly illustrates the mechanism by which consumption affects earnings. Looking at the expressions between the brackets, the second term gives the effect of consumption on the productivity of labour per unit of time. Such effect is both an immediate effect of consumption on productivity and also a long term effect via the stock of nutrition. On the other hand, the last term shows the effect of consumption in increasing ones ability to work for a longer duration. Given labour productivity per unit of time, consumption enables one to endure more working hours.

The link

Customarily nutritional requirements are measured in terms of food energy that collapses all kinds of macro (carbohydrates, proteins, fats etc.) and micro (vitamins, minerals etc.) nutrients into a single index. The emphasis on calorie consumption in the relationship between productivity and consumption by and large has its roots in the very fact that the human body mainly needs energy to maintain itself (i.e. internal functions such as tissue repair, digestion, growth, etc.) and do external work.

Maintenance requirement has two components. The human body requires energy even at a state of complete rest; it expends energy to undertake digestion. This is what is called the energy requirement at a resting metabolic rate. The other component is energy required to do basic things like keeping ones hygiene, walking, standing, sitting, etc., where no 'productive' work is involved[5]. What it means for the consumption-productivity relationship is that any meaningful effect of consumption on productivity is observed only after a certain minimum level of intake. This minimum requirement, called maintenance requirement in the literature, depends on the type of activity the person is involved in and his body mass. It ranges from 75 % to 65 % of the total energy requirement (WHO, 1982; Dasgupta, 1993). No doubt this fixed requirement represents a large proportion of the total energy requirement. It is important to note that the fixed requirement falls in its proportion as the total energy requirement rises (say, following a need to undertake physically demanding tasks), hence increasing returns to intakes.

[5] When energy intake is less than the sum of the two components of maintenance requirements some thing needs to give in: either the person loses weight or would be in state of system break down.

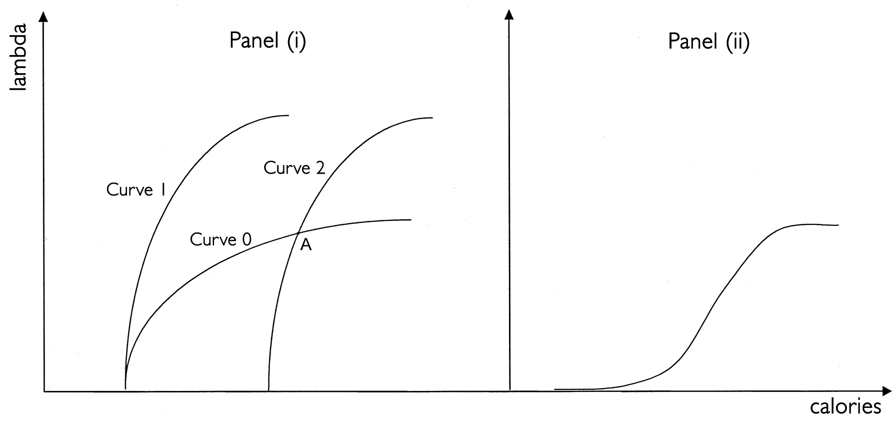

Figure 1:
The Nutrition - Productivity Link

Curve 0 = $\lambda(c, \theta_0, B_0)$,
Curve 1 = $\lambda(c, \theta_1, B_0)$,
Curve 2 = $\lambda(c, \theta_0, B_1)$,

Because of this fixed minimum energy requirement, the curve that shows the relationship between productivity and intake starts not from the origin but at a certain positive level of intake (fig. 1).

In Panel (i) of fig. 1, the stock of nutrition *(B)* and illness (θ) are treated as shift factors; for a given intake and *B*, a decrease in θ is represented by an inward shift of the $\lambda(c, \theta_0, B_0)$ curve upwards to the left. Since *B* is constant which essentially keeps the minimum requirement fixed, both the new ($\lambda(c, \theta_1, B_0)$) and the old $\lambda(c, \theta_0, B_0)$ curves start from the same point on the calorie axis. Hence, given all other things, a reduction in the burden of illness increases productivity. A rise in *B* while keeping θ constant shifts the curve to the right ($\lambda(c, \theta_0, B_1)$). Since larger *B* implies higher maintenance requirement, the curve with large *B*, $\lambda(c, \theta_0, B_1)$, starts from the right of the one with lower *B*, $\lambda(c, \theta_0, B_0)$, so that the two curves intersect each other at point A. Because of the effect of *B* on the maintenance requirement, smaller individuals are more productive up to a certain level (point A) of energy intake. From there on however, for a given level of intake, productivity rises with *B*.[6]

[6] What we have plotted is just one case where curve0 and curve2 intersect. In other words, the two curves do not necessarily cross each other. What is important is that curve 2 should start from the right of where curve0 starts.

A slightly differently shaped $\lambda(.)$ curve also appears in the literature. Panel (ii) shows the most common shape where the curve has first a convex then a concave shape. The rationale for such shape is that at lower level of consumption, intake exhibits increasing returns till a point is reached where decreasing returns sets in (compare curve 0 and curve 1 in panel i). Theoretically, it is feasible to have negative returns to increased intake at the margin: after a point, intake may lead to a loss in productivity by reducing the activity level of a person who might be, say, overweight. However in our setting it is less likely that the curve reaches such a point.

3. Data and Empirical Specification

The setting

The problem of low productivity in the Ethiopian agricultural sector is very well recognized. As part of the overall effort to address the problem, emphasis has been given to the adaptation of modern agricultural inputs like chemical fertilizer. During the last fifteen years use of chemical fertilizer has increased by 294 % (Mulat, 1995). Yet very little, if any, attention, has been given to the health and nutrition aspect of the causes of low productivity in the agricultural sector. It is partly because it is not easy to sell it to policy makers that improving the health and nutritional status of farmers does increase productivity. Worse, not much studies have been conducted that may provide the argument a solid ground. It is known that undernutrition is one of the major problems of public health importance in Ethiopia (Zewdie, 1992). What is missing is the link that connects this problem with low labour productivity, especially in the agricultural sector.

A look at the annual figures published by the Ministry of Health reveals the severity of undernutrition in Ethiopia. The fact that undernutrition is one of the major causes of under five mortality informs the severity of the problem in Ethiopia (MOH, 1996). Undernutrition, as measured by anthropometric indicators are among the highest in the world (Zewdie, 1992). A survey by the Central Statistical Authority indicated that 64 percent of children aged between 6 and 59 months have low height for age (i.e. stunted), 8 percent have low weight for height and about 48 percent are underweight for their age (CSA, 1993). Concerning adult nutrition, about a quarter of the adults residing in the villages covered by our study are undernourished in the sense that they exhibit a weight-to-height squared ratio of less than 18.5 (Dercon and Krishnan, 2000). Though this should be interpreted cautiously in view of the underlying assumptions made in measuring undernutrition (as discussed in section 1.1), there seems to be a potential gains to be made in terms of both improving labour productivity and welfare in general by addressing the issue.

3.1. Data:

For estimating the effects of nutrition, we made use of the data set that has been collected by the department of Economics of the Addis Ababa University and the Center of Studies of African Economies (CSAE) of Oxford University since 1994. It contains a panel of more than 1400 households from fifteen villages in rural Ethiopia that were visited three times in 18 months period of time. This data set has been described on several occasions; the interested reader is referred to Dercon and Krishnan (1997; 1998) for details. Because no data on output is available on two villages, they are exempted from the regressions.

As a first step to examining the relationship between nutrition and productivity, it is illuminating to look at the proportion of the minimum daily calorie requirements of 2200 kcal that can be met by daily wage earnings.

Table 1, Wages and the cost of food

Village (PA)	Mean wage/day[1]	Food Poverty[2]	HH size[3]	HH members working[4]	% covered by wage[5]
Hersaw	3.75	1.23	3.23	1.41	133
Geblen	2.56	1.47	3.99	1.34	59
Dinki	6.99	1.17	3.4	1	176
Yetmen	3.58	1.23	3.35	1.14	99
Shumsha	3.62	1.3	3.37	1.08	89
Sirbana Godenti	4.27	1.13	4.71	1.43	115
Adelekeke	4.85	1.53	4.78	1.43	95
Korodegaga	2.59	1.37	4.65	1.38	56
Tirufe ketchema	4.72	1.13	5.49	1.18	89
Imdibir	3.01	0.87	4.47	1.42	110
Aze Deboa	5.14	0.9	6.24	1	91
Adado	2.82	0.93	4.45	1	68
Gara Godo	3.99	1.47	5.65	1.29	62
Doma	3.74	1.5	4.36	1.17	67
Milki	8.5	1.2	4.15	1	171
Kormargefia	10	1.2	4.59	1	182
Karafino	10.87	1.2	4.48	1.2	246
Bokafia	4.86	1.2	4.45	1	91

[1] The average wage paid for a day work. It is expressed in birr (1birr= \ 8.5 USD).
[2] Monetary equivalent of food poverty line per adult. Obtained from Dercon and Krishnan (1996).
[3] Adult equivalent household size is the weighted sum of household numbers (by age/sex).
[4] Average number of household members working for pay. It is averaged over households with at least one working member.
[5] The percentage of the daily food requirements satisfied by wage income alone. It is computed by dividing the product of wage per day and number of household members working for pay by the product of food poverty line and adult equivalent household size.

In Table 1 mean daily wages, mean adult equivalent household size and the cost of minimum daily calorie requirements for each village (Peasant Association) are presented. The mean wage per day is computed from the data on individuals who had worked for cash and/or for payments in kind. Adult equivalent household size is a weighted sum of household members with the FAO (FAO, 1957) adult equivalence scale serving as a weight. In the fifth column the average number of working individuals per household is indicated. This average is over households with at least one working member, not the average of all households in the village.

Wage income is a major source of income for households involved in selling their labour. It ranges from an equivalent of 56 to 246 percent of the daily food requirements. Its importance however varies immensely among villages. In some villages for instance, little more than half of the daily requirement can be provided by wage income (e.g. Korodegaga, Geblen). On the other hand, in villages like Karafino a one day household wage income can pay for two and half days of the household's food requirement.

Most of the households in these villages have consumption levels just above the minimum requirement which is equivalent to the fixed cost / maintenance cost of labour[7]. If the relationship between nutrition and productivity is strong, then a great deal of potential to increase labour productivity seems to exist in these villages.

[7] Depending on the type of poverty line used, from 27 to 85 percent of these households' consumption falls below the minimum consumption level (Dercon and Krishnan, 1996).

3.2. Empirical specification

The farm production function

A Cobb-Douglas functional form is employed to enable comparison with previous studies (see Strauss, 1986; Deolalikar, 1988 and Croppenstedt and Muller, 2000). The farm production function is specified as:

$$LogQ = \beta_0 + \beta_1 LogL_f^e + \beta_2 LogL_n^e + \beta_3 LogL_s^e + \gamma LogN + \delta LogK + \varepsilon$$ Equation [3]

where L_s^e is shared labour, $\beta_0, \beta_1, \beta_2, \beta_3, \gamma, \delta$, are parameters to be estimated and ε stands for the stochastic error term. The rest as defined earlier.

Shared labour is treated separately from family and hired labour because it is distinctly different from both types of labour and it is one of the major sources of farm labour in rural Ethiopia. Individuals pool together their labour during peak seasons to undertake tasks like harvesting, weeding and ploughing. There are several kinds of labour sharing arrangements. For example Wonfel involves arrangements where farmers get together and attend to each individual's farm in turn. It is implicitly understood that the turn depends on how urgently one's plot needs to be attended. Mostly labour sharing arrangements are made among farmers of the same village. Village level average calorie consumption, therefore, should proxy the effective shared labour.

Collapsing all consumptions into energy intake, let λ(.) be specified as: $\lambda(C_a,C_n,B(C_a,C_n)\theta) = \theta C^{\sigma} B^{\rho}$. Using this expression and the definition of effective labour into [3], the estimated farm production function is obtained as

$$LogQ = \beta_0 + \beta_1 LogL_f\theta + \beta_1\sigma LogC + \beta_1\rho LogB + \beta_3 LogL_s + \beta_2 LogL_h + \gamma LogN + \delta LogK + \varepsilon$$ Equation [4]

Note that both the energy intake and *B* of the hired labourer as well as the village level *Bs* are not included. Including village level *B* entails aggregation of individual level *Bs* to a village level. It is not clear how to interpret the resulting coefficient as it may carry all kinds of village level effects. Rather we capture this effect by including a village level dummy in our estimation. As to hired labour, both the consumption level and their *Bs* are not recorded during the survey thus not included in the regression.

Calorie consumption and health status indicators are clearly endogenous[8]. Farm production directly affects the consumption level of the household and other health related outcomes and behaviors including the demand for health related goods. The same applies to purchased farm inputs. In order to address this problem of endogeneity two estimation procedures are pursued. Both procedures are chosen so as comparison with previous studies is possible.

[8] Arguably, purchased farm inputs should also be treated as endogenous. However, instrumenting these inputs in our case produces no significant difference in the reported results.

First the instrumental variable approach is employed. Instruments include prices of goods consumed and produced, assets and other wealth indicators, and the composition and size of household demographics (Lau, 1978; Strauss, 1986). The exogeneity of these instruments is tested using the Davidson-MacKinnon test (1993). The sensitivity of the estimates to the choice of instruments is also tested by dropping some instruments from the set.

The second method adopted is to use changes rather than levels in the regression. Under the assumption that changes in energy intake and body mass on the one hand and changes in output are not correlated contemporaneously, we can afford to side step the issue related to the endogeneity of the explanatory variables as in Deolalikar (1988).

The earnings function

The specification of the wage equation is motivated by the life cycle and human capital theories of earnings. Village dummies are included to control for village level effects in wage and employment opportunity differentials. To allow for the concavity of earnings in age, both age and its square are included. We used four measures of nutrition and health: Calorie intake per capita per day and its square, height of the person, an indicator of whether the individual is ill in the last four weeks and indicators of physical strength as defined later. To control for the effect of job characteristics on wage, indicators for type of work are also included.

As the commonly used functional form in the earnings literature, the following semi-log wage equation is estimated.

$$LogW_i = \alpha_0 + \beta_1\theta_i + \beta_2 C_i + \beta_3 B_i + \beta_4 g_i + v_i$$

where g_i stands for individual characteristics such as age, education, and sex. The rest as defined earlier.

To address the endogeneity of the health and nutritional variables predicted values are used. Household demographics, mother's and household head's education and prices are instruments used for the endogenous variables height, physical strength and calorie intake. When not all individuals report participation in the labour market, there is a need to account for the possible non-randomness of the sample[9]. Heckman's two step estimation is used to control for the selectivity of the sample. Since the likelihood of working is affected by expected wages, variables that affect wage are included in the participation equation. Variables included in the participation but not in the wage equation include assets, area of land owned, fertility of the land and its steepness.

[9] The presence of non random selectivity in the panel data is checked following Verbeek and Nijman (1992) and Wooldridge (1995). The test procedures are discussed in section 5.

4. Results and discussion

4.1. The farm production function

In a competitive market where labour is paid its marginal product, the nutrition-productivity hypotheses predicts nutrition to be one of the determinants of wage. However, when markets are imperfect, the presence of such relationship is far from being a proof of the validity of the hypothesis. Neither its absence render the hypothesis invalid. A more reliable conclusion would be reached by examining the effect of nutrition on output directly. This is exactly what is done below.

In an effort to make our results comparable with previous studies, we have estimated farm production functions using both an instrumental variable (IV) estimator (Table 2) as well as using a panel estimator (Table 3). First the cross sectional estimates are discussed followed by the panel estimates. The validity of the instruments is tested using the Davidson-MacKinnon test (1993) (DM). The variables are defined in the appendix.

Table 2 The Productivity effect of nutrition: Cross-sectional IV estimates

Variiables	Regression				
	[1]	[2]	[3]	[4]	[5]
Calorie	1,4175 (5,43)(2)	1,2916 (3,29)(2)	1,796 (2,62)(1)	1,4708 (3,18)(1)	,3181 (,60)
Cal_sqr	-,1963 (-3,15)(1)	-0,1608 (2,4)(1)	-,2563 (-195)(5)	-,2279 (-3,07)(1)	-,0771 (-,77)
Fam_lab	,1994 (,25)	,2833 (,40)	,4550 (,54)	,4506 (,95)	,5471 (1,80)(6)
Hired_lab	,1019 (,46)	,2074 (3,45)(2)	,1380 (,51)	,2024 (2,46)(1)	,1900 (4,43)(2)
Shared_lab	-	,0332 (,56)	,0257 (,29)	,0291 (,55)	,0319 (,57)
Height	-	-	6,1333 (1,04)	-	-
V_calorie			-	-	,8429 (2,7)(1)
Physical	-	-	-	,4289 (,52)	-
hhh_age	-	-	-	-	-
hh_fem	-	,0148 (1,98)_	-	-	-
hhh_edu	-	,0139 (,27)	-	-	-
Land_typ	-,9238 (-0,57)	-,6489 (-,54)	-,6789 (-,47)	-,2864 (-,29)	-,1606 (-,26)
Land_slp	,0841 (,16)	,2258 (,62)	,1093 (,25)	-,0400 (-,08)	-,1589 (-,33)
Cult_land	,2999 (2,31)(5)	,3513 (1,28)(1)	,3300 (1,24)	,1952 (1,95)(5)	,4626 (2,49)(1)
Capital	,2089 (1,14)	,1652 (1,07)	,2687 (,89)	,3762 (1,93)(5)	,1445 (1,41)
Fam_lab*landtyp	,0062 (,36)	,0027 (,21)	,0055 (,28)	-,0033 (-,54)	-,0049 (-1,17)
Hired_lab*landtyp	,0027 (,36)	-,0054 (-1,23)	,1380 (,51)	,0000 (,02)	-,0005 (,23)
Capital*landtyp	-,0019 (-0,57)	-,0008 (-,3)	-,0020 (-,45)	-,0008 (-,36)	,0007 (,75)
Mem_ill	-1,236 (-0,29)	-,9788 (-,23)	-1,4603 (,24)	-,4111 (-,10)	-
Constant	1,5071 (,48)	,7306 (,26)	-30,9095 (-1,03)	-,1174 (-,06)	-,0193 (,02)
Dependet variable	Agricultural output in the main agricultural season				
N	960	960	960	960	960
DM test (F)	8,23(3)	49,56(3)	7,62(3)	9,43(3)	8,95(3)

(1) = at 10%; (2) = at 5%; (3) = significant at 1%; (4) = at 15%; (5) = at 20%

In line with previous studies calorie intake has a strong positive effect on farm production. Farm output rises with calorie intake up to a point under almost all specifications. One exception is when village level calorie is included, col [5]. When household consumption and village consumption covary as in the village insurance literature (see Townsend, 1994), the inclusion of village level intakes and household level intakes may introduce multicollinearity and may explain why household level intakes became non significant. Column [1] reports what is commonly estimated in the literature. Illness reduces labour time as well as efficiency per unit of time. Land is significant at 11 % while capital is not. Output increases with calorie intake; however, its effect reaches a maximum at an intake nlevel of 4078.9 calories. The inclusion of shared labour and characteristics of the household head, in col [2] does not change much the significance of the coefficients in col [1], except that of hired labour. Shared labour itself has no significant effect.

Col [3], [4] and [5] are estimated with a reduced sets of instruments in that all the characteristics of the household head and household demographics are not included in the instrument set. Yet the rest of the instruments are valid and the coefficient of calorie intake remains significant. The inclusion of shared labour alone without including household head's characteristics make no significant difference from that of col [1] (not reported here). Whereas the effect of height is not significantly different from zero, its inclusion in column [3] brings about changes in the coefficients of the rest of the variables. Notably , the coefficient of calorie intake as well as that of its square has risen; the net effect of which is to bring down the output maximizing level of calorie intake by 21.8 % (to 3189.4 calories which is still higher than the caloric intake of the top 25 %). Given that height can summarize past nutritional status including calorie intake and is also one of the major determinants of productivity (Osmani, 1992), it is not surprising to see the level of calorie reduced compared to the case where height is not included (col [1]). When col [3] is re-estimated with the full set of instruments, the coefficient of height has dropped to 3.7798 still not significant (not reported here)). Those of calorie intake and its square remain surprisingly the same. The last two columns include physical strength[10] and village level calorie intake. Physical strength somehow summarizes past as well as current nutritional status. Nevertheless unlike height, its inclusion does not make calorie intake any less important.

[10] As defined in Appendix B.

Farm level capital, area of land cultivated and the age of the household head, all have positive and mostly significant effect. The only case where the coefficient of land is not statistically significantly different from zero is when height is included (col [3]). The DM test demonstrates that in all of the specifications the instruments used are valid.

By and large the IV estimates show that nutrition does determine farm output. In the panel estimates, however, current calorie intake has no significant effect (Table 3). In contrast to the cross sectional estimates, here both physical strength and height are significant (col [1] and col [2]). This might be explained if there are correlations between changes in calorie on the one hand and changes in height and changes in physical strength, on the other. Indeed, when height is excluded from the regression calorie becomes slightly significant, col [3]. But when both height and physical strength are excluded, calorie intake becomes strongly significant (not reported). It is likely, thus that calorie intake is picking up the effect of the medium and long term indicators of nutritional status.

The variable physical strength measures activity levels one is capable of doing currently. Within the context of the discussion in section 2 even when one is considered adapted by having 'appropriate' weight to a given height, physical strength measures her ability to work vis a vis the person with the 'standard' weight to height ratio. Even if one accepts the view of the adaptability theory, the fact that physical strength informs about the nutritional status of a person can not be denied. The use of physical strength as a measure of nutritional status thus should be less controversial and is unlikely to be accused of favoring either of one the theories.

Once the point is made about the appropriateness of using physical strength as a measure of nutritional status for our purpose, what remains is to examine whether it measures current or long term nutritional status. As it is affected by episodes of illness and injury, compared to height it is more likely to vary over time. Height on the other hand, takes quite some time to change, if it changes at all for adults. Relative to height, therefore, we claim that our measure of physical strength can be regarded as a medium term indicator of nutritional status.

Area of land cultivated, its type and slope, are all significant determinants of farm output. Farm output rises with increased fertilizer use, increase in ownership of hoe and ploughs. Households headed by a female are disadvantaged; it could be because mostly households are headed by female when the male partner leaves the household (due to death, divorce, etc.) and in rural Ethiopia women usually have only supporting roles on the farm, consequently are less experienced as independent farmers than male partners.

Table 3: Estimates of the farm production function: Panel estimates

Variiables	[1]		[2]		[3]	
	Fe	Re	Fe	Re	Fe	Re
Calorie	,4099 (,99)	,1096 (,39)	,4099 (,99)	,1110 (,40)	,5521 (1,36)(?)	,2140 (77)
Cal_sqr	-,0276 (-101)	-,0033 (-,18)	-,0276 (-1,01)	-,0033 (-,18)	-,0368 (-1,38)(?)	-,0115(3)(-0,63)
Physical	,8598 (1,96)(3)	,3545 (1,72)(3)	,8598 (1,96)(3)	,3596 (1,74)	,7931 (1,88)(3)	,3657 (1,78)(3)
Height	,0475 (,34)	,3895 (3,56)(1)	,0498 (1,18)	,3934 (2,13)(3)	-	-
Fam_lab	,1336 (2,81)(1)	,1886 (5,80)(1)	,1336 (2,81)(3)	,1880 (5,78)(3)	,1388 (3,07)(1)	,1921 (5,95)(1)
Shared_lab	,0498 (1,18)	,0525 (1,79)(3)	,0498 (1,18)	,0530 (1,81)(3)	,0428 (1,05)	,0428 (1,47)(?)
Hired_lab	,0183 (,37)	,0800 (2,35)(2)	,0183 (,37)	,0862 (2,53)(2)	,0252 (,53)	,0777 (2,31)(2)
V_calorie	-	-	-	4,7269 (2,13)(2)	-	-
V_cal_sqr	-	-	-	-,5047 (-2,01)(2)	-	-
Land_typ	-	-,3789 (-2,60)(1)	-	-,3082 (-2,62)(3)	-	-,3920 (-2,69)(1)
Land_slp		-,4381 (-2,31)(2)	-	-,4336 (-2,29)(2)	-	-,4416 (-2,34)(2)
hhh_age	-	-,0509 (-,96)	-	-,0484 (-,91)	-0,1195 (-1,67)(3)	-,0423 (-,85)
hh_fem	-	,4478 (-4,13)(1)	-	-,4436 (-4,10)(1)	-	,4609 (4,24)(1)
hhh_edu	-	,0593 (,92)	-	,0646 (1,00)	-	,0547 (,84)
Cult_land	-	,2804 (6,51)(1)	-	,2759 (6,41)(1)	-	,3007 (6,99)(1)
Fert	,1529 (3,79)(1)	,1906 (6,79)(1)	,1529 (3,79)(1)	,1961 (6,95)(1)	,1359 (3,49)(1)	,1909 (6,82)(1)
Hoe	,2082 (1,84)(3)	,0535 (1,62)(?)	,2082 (1,84)(3)	,0518 (1,57)(?)	,2080 (1,87)(3)	,0628 (1,91)(3)
Plough	,2503 (2,84)(1)	,1527 (4,58)(1)	,2503 (2,84)(1)	,1505 (4,51)(1)	,2566 (2,96)(1)	,1650 (4,98)(1)
Constant	2,1455 (1,19)	3,9955 (3,15)(1)	2,1455 (1,19)	0	1,7821 (1,10)	0
N	2387	2387	2387	2387	2433	2433
Overall Sign,	F=3,04(1)	Chi-2=3882,56(1)	F= 33,04(1)	chi-2= 26722,14(1)	F=35,3(1)	Chi-2=26454,33(1)
Hausman test	chi-2 (24)= 206,87(1)		chi-2 (24)= 73,38***		chi-2 (24)= 51,25(1)	

[1] = significant at 1%; [2] = at 5%; [3] = at 10%; [4] = at 15%; [5] = at 20%

Comparing the panel estimates with that of the cross section, in the former long and medium term indicators of nutrition are significant whereas in the latter current energy intake is significant which is in line with previous studies (Strauss, 1986; Deolalikar, 1988; Croppenstedt and Muller, 2000). This could be the reflection of the asymmetric effect of nutrition in the short, medium and the long term. If the human body is able to adapt to a low level of energy intake with minimal functional impairment , as the adaptability theory suggests, this can not go on indefinitely. Inadequate energy intake will eventually take its toll and reflects itself through the depletion of the stock of nutrition which results in impairment and loss of productivity in the long term. In this respect the two estimates rather complement each other. A full picture would only be obtained if one observes both the cross sectional and panel estimates.

4.2. The earnings equation

Following Verbeek and Nijman (1992), the presence of non random selectivity is checked using the variable inclusion method as well as the method that compares the random effect estimates from the balanced and unbalanced panel. The former[11] involves running a random effect regression by including dummies that indicate i) - the number of rounds the individual participates ii)

[11] Selection bias is said to be absent if the distribution of wage given its observable determinants is same as the distribution conditional upon selection. Let α_i+v_{it} be the error term of the random effect specification and $E(\alpha_i+v_{it}/r_{it})$ its conditional expectation, where rit is the response indicator variable defined as =1, if both wage and the determinants of wage are observed and 0 otherwise, then if $E(\alpha_i+v_{it}/r_{it})$were known one can enter it in the wage equation and a test for the significance of its coefficient would be a test for selectivity. But it is not possible to obtain $E(\alpha_i+v_{it}/r_{it})$ unless one knows the selection process. However, since the conditional expectation above is a function of rit, one can use rit as discussed in the text.

- a dummy indicating whether the individual participates in all rounds. The test that compares the estimates of the balanced and unbalanced panel rests on the assumption that under the true data generating process, it is unlikely that the two estimates are identical unless both estimates are consistent (Verbeek and Nijman, 1992).

The test result obtained from the two tests is mixed. While the variable inclusion test rejects the presence of selectivity, the second test rejects the null hypothesis that the difference between the two estimates is not systematic. As a third alternative the method discussed in Wooldridge (1995)[12] is also employed. We are unable to reject the null that there is no selectivity. Consequently only the cross sectional estimates are reported.

In the sampled villages as many as 259 individuals have participated in public sponsored Food For Work (FFW) programs. Earnings from this activity barely indicate marginal productivity; after all the aim of the program is to protect the consumption of vulnerable households. Rather than providing the support freely, what FFW programs do is involve the participants in tree planting, construction of terrace, roads, etc[13]. Since our objective is to measure the productivity effect of nutrition and health, earnings from FFW is unlikely to measure the productivity we want to measure. If at all , one would expect a negative relationship between nutrition and earnings from FFW activities. Nevertheless, a number of individuals have reported participating both in FFW programs and in other rural employment activities including helping on the farm, as unskilled worker, in a paid traditional labour arrangements, etc. Wage equations for all individuals and only for those who do not participate in FFW programs are estimated. To examine the difference in the productivity effect of nutrition on male and other workers, a wage equation for the male-only sample is estimated separately. Table 4 presents the result.

[12] Similar to Heckman's two step procedure, this method also suggests estimating a participation equation on the pooled sample from which the inverse Mills ratio is obtained. The test for the significance of the Mills ratio in the wage equation is a test for the absence of non random selectivity.

[13] In some areas FFW programs are major sources of off farm employment. Due to excess demand for participation, at least theoretically, priority is given to the poorest of the poor. All payments to the participants are made in the form of unprepared food, mostly in terms of wheat and cooking oil.

Table 4: Estimates of the wage equation,

Variiables	Without FFW		With FFW	
	ALL	Male	All	Male
Calorie	,0014 (3,39)[1]	,0015 (3,30)[1]	,0014 (4,75)[1]	,0013 (4,02)[1]
Cal_sqr	5,39e-8 (2,60)[1]	5,84e-08 (2,25)[2]	3,18e-09 (,24)	7,81e-09 (,48)
Height	,0743 (1,82)[3]	,0790 (1,87)[3]	,0325 (1,20)	,0167 (,54)
Ill_4wks	-1,8549 (-2,86)[1]	-2,1123 (-2,75)[1]	-,6458 (-1,71)[3]	-,7074 (-1,65)[3]
Farm worker	-,0296 (-,09)	-,0030 (-,01)	,1022 (-,45)	,0537 (,21)
Unskilled	,9696 (2,31)[2]	1,3901 (2,88)[1]	,8227 (2,34)[2]	1,2134 (2,96)[1]
Trad, work	4,1226 (-7,12)[1]	-4,2016 (-6,85)[1]	-3,5884 (-8,73)[1]	-3,5361 (-8,36)[1]
Age	,0593 (1,03)	,0773 (1,22)	,0567 (1,71)[3]	,0945 (2,35)[2]
Age_sqr	-,0002 (-,33)	-,0004 (-,54)	-,0003 (-,86)	-,0007 (-1,62)[4]
ALP	1,4915 (2,16)[2]	1,8148 (2,50)[2]	,8947(1,56)[4]	1,0630 (1,69)[3]
Primary	,8178 (1,17)	,7088 (,98)	,5152 (,88)	,3923 (,61)
Junior	3,9169 (-4,53)[1]	-4,3474 (-4,44)[1]	-235428 (-4,70)[1]	-2,6144 (-4,33)[1]
Lambda	-,5664 (-1,87)[3]	-,1257 (-,47)	-,8028 (-1,71)[3]	-,6408 (-1,56)[4]
Constant	11,0935 (-1,20)	10,0597 (-,94)	-6,7788 (-1,40)[5]	-3,3031 (-,56)
Dependent variable		Cash plus in kind payments per day:		
N° of observers	142	123	259	200
Dependent variable= Log daily wage				
Overall Sign,	wald ch-2 = 238,11[2]	282,9[2]	247,34[2]	249,51[2]*

[1] = significant at 1%; [2] = at 5%; [3] = at 10%; [4] = at 15%; [5] = at 20%

Calorie intake has a strongly positive effect on the earnings of all workers irrespective of whether they participate in the FFW program or not. In fact the effect does not change much when those participating in the FFW program are excluded, except that the effect is higher for workers without FFW. In contrast to the result obtained in the farm production estimates, here the effect of consuming more calories is always positive at the margin. Given that most of the individuals who are involved in hiring out labour are the poorest of the poor, it is not surprising to see rather a convex effect of calorie on productivity. In terms of Fig _1 these individuals may lie on the convex part of the $\lambda(.)$ curve in panel (ii).

It appears that the magnitude of the effect of calorie on wages received is not that large. An increase in calorie intake by 1500 kcal on average brings about at most 2.25 percentage increase in wage. In the absence of a smoothly functioning labour market, where wage hardly measures productivity, such low level of response of wage to calorie should not be surprising.

Height also has a large and strong positive effect on wages. Relatively wage responds more to height than to calorie intake. It could be because height summarizes long term health and nutritional conditions including past calorie intake. Moreover one can argue that such difference in magnitude is due to the fact that while the employer can easily observe height but not calorie intake, one may expect the former to have more weight in determining wage than the unobservable calorie intake. What is interesting is that the coefficient of height becomes smaller and ceases to affect wage when workers who have participated in FFW program are included. For the same reason mentioned above about the selection of individuals into the FFW program, such effect is not unexpected. In all cases the magnitude of height is higher for male workers.

Illness in the past four weeks is used to proxy health status. Compared to the two measures of nutrition, illness has a large effect on wage. Its effect is higher on male workers not participating in the FFW program. As expected the lowest magnitude is for workers participating in the FFW program.

Whereas working on the farm in the form of paid labour sharing arrangements is the least paid work, workers employed as unskilled rural labourers get a higher wage. Male workers working as unskilled labourers but not employed in FFW program are the highest paid of all. At the same time it is the same group of people who get the lowest pay when employed in jobs involving paid traditional labour arrangements.

The effect of age is significant only when individuals who have participated in the FFW program are included. Wage reaches its highest level at the age of 67.5 years. Given that life expectancy at national level is not more than 50 years, the fact that people seem to enjoy a rising wage throughout their life sounds an overstatement.

While the effect of participating in the adult literary program is large and positive, completing junior level of schooling reduces wage. It could be because at higher level of education individuals have other options than participating in the small village labour market. They might also shy away from participating in the village labour market because they view jobs in the rural village as inferior to jobs in the towns. The positive effect of education is the highest for male workers not participating in FFW program and lowest for all sampled individuals participating in the FFW program. Similarly, the negative impact of schooling is also the highest on male workers not participating in the FFW program, and is the lowest for all sampled individuals participating in the FFW program. At a lower level education has a positive impact on wages. When male workers have better employment opportunities, the effect of education (both positive and negative) should be stronger on these groups.

5. Implications

In a country where the peasantry accounts for a good proportion of its population improving the nutritional status of farmers should be an end per se. Moreover our study shows that because it enhances labour productivity improved nutrition also has an added advantage. In fact its effect on farm production is much higher than the effect of other productivity-enhancing inputs such as chemical fertilizers. This can be seen from our estimates that the coefficients of the nutritional variables are higher than those for chemical fertilizer under almost all specifications.

The elasticity of agricultural output with respect to fertilizer is .14 whereas the calorie elasticity of agricultural output is .48. If one is to include all measures of nutritional status, the effect of nutrition rises sharply. Even the combined effect of all capital inputs (chemical fertilizers, hoe and plough) is much lower than that of nutrition (calorie intake, height and physical strength).

To substantiate this claim further, in what follows we employ national level data on the productivity of fertilizers and our estimate of the productivity of calorie and do rough computations to see the relative return of calorie intake vis a vis chemical fertilizers. The highest incremental yield from the use of the optimum level of fertilizers (i.e. 120 kg of Urea and 140 kg of DAP per hectare) at the most favorable soil is about 641 kg of teff (Mulat 1995). It means that employing a fertilizer worth of 369.08 birr gives an additional output worth of 961.5 birr; which roughly means 2.6 birr per each birr spent on fertilizer. Note that we have considered the most expensive cereal and the highest possible yield that can be produced. Similarly taking conservatively higher price for calorie from Table 1, each birr can buy 1438 kcal; which, using the lowest elasticity from Table 2, yields about 3.11 birr worth of output.

So even from the point of view of pure efficiency, money spent on improving the energy intake of farmers is much better spent than money spent on the most publicized agricultural input. Note that this all is without taking into account the risks involved in spending on chemical fertilizers. Spending on own nutrition on the other hand is by far a riskless venture one possibly can imagine.

The elasticity of output to calorie intake varies widely depending on the initial level of consumption. It is the highest for households with low calorie consumption. It drops from .15 at 1720 kcal which corresponds to the lowest 25 percentile to .05 at 3035 which is equal to the intake level of the highest 25 percentile. For policies aimed at reducing inequality, increasing the energy intake of the poor is therefore an ideal instrument. It induces efficiency while reducing inequality at the same time. Equipped with such instrument, therefore, the social planner does not necessarily face a trade-off between efficiency and productivity.

By measuring the effect of food consumption on labour productivity we have shown that inequality could be sustained due to the productivity effect of consumption. Because food consumption affects the productivity of own cultivators as well as that of daily labourers, the low consumption-low productivity trap is a real possibility in rural Ethiopia.

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Appendix A. Returns to consumption in a dynamic framework.

For the sake of exposition we assume a more simplified objective function where a one member household and a unit of effective labour $L^e(.)$ produces a unit of output. The farmer maximizes his net output given by

$$\int_0^{\infty} e^{-rt}\left[L^e(C(t),B(t))-pC(t)\right]dt \qquad \text{[A1]}$$

where C is consumption, B stands for the stock of nutrition as opposed to the flow and p is the price of C, hence $L^e(.) - pC$ is the net returns. $L^e(.)$ is assumed to satisfy L^e_c, $L^e_B > 0$; L^e_{cc}, $L^e_{BB} < 0$ and $L^e(.) < Z$ where Z is a certain positive constant (i.e. $L^e(.)$ is concave in both arguments and is bounded from above).

Consumption affects efficiency directly as it is one of the arguments of $L^e(.)$ and indirectly by augmenting the stock of nutrition. The stock of nutrition accumulates according to the following proces.

$$\dot{B} = b(C,\gamma) - \delta B \qquad \text{[A2]}$$

The function $b(.)$ is assumed to be concave in both of its arguments. γ stands for those variables affecting the accumulation of nutrition (e.g. illness) and δ is the rate at wich the stock of nutrition depreciates.

Setting the initial condition

$$B(0)=B_0 \qquad \text{[A3]}$$

the current value Hamiltonian[14] is written as

$$\pi = (C(t),B(t),\eta(t)) = L^e(C(t),B(t) - pC(t) + \eta(t)(b(C,\gamma) - \delta B)) \qquad \text{[A4]}$$

The concavity of π in both C(t) and B(t) insures that the necessary conditions for the maximazation (obtained by the Pontrygin's maximum principle) are also sufficient conditions. The first order conditions, with the transversality condition $\eta(t) >$ are[15]

$$\frac{\partial \pi}{\partial C} = L^e_C(.) + \eta b_C(.) - p = 0 \qquad \text{[A5]}$$

$$\dot{\eta} = -\frac{\partial \pi}{\partial B} = (\delta + r)\eta - L^e_B(.) = 0 \qquad \text{[A6]}$$

Differentiating [A5] with respect to time and using [A6] and [A5] and setting $\dot{C} = \dot{B} = 0$ at equilibrium, we get

$$p = L^e_c(.) + \frac{b_c(.)L^e_B(.)}{\delta + r} \qquad \text{[A7]}$$

Expression [A7] shows that at equilibrium the benefit and costs are equalized. A unit increase in consumption, which costs p, brings about both an immediate increase in labour productivity ($L^e_c(.)$) and a long term increase in productivity by augmenting the stock of nutrition $\frac{b_c(.)L^e_B(.)}{\delta + r}$ via the effect of consumption on the stock of nutrition $b_c(.)$ and the stock of nutrition on productivity $L^e_B(.)$; as these benefits are not immediate they are discounted.

[14] The current value Hamiltonian is obtained by multiplying the Hamiltonian equation e^{rt}. hence, given the Hamiltonian $H = e^{rt}\left[L^e(C(t),B(t)) - pC(t) + \lambda(t)(b(C,\gamma) - \delta B)\right]$, we get the current value Hamiltonian (π) as $\pi = e^{rt}H = \left[L^e(C(t),B(t)) - pC(t) + e^{rt}\lambda(t)(b(C,\gamma) - \delta B)\right]$ Equation [A4] is obtained after defining $e^{rt}\lambda(t)=\eta(t)$ as the costate variable of the current value Hamiltonian. The relationship between the two costate variables is that where as $\lambda(t)$ gives marginal value of the state variable at time t discounted back to time zero, $\eta(t)$ gives the marginal value of the state variable at time t in terms of the values as t (see Kamien and Schwarz, 1991).

[15] Condition [A6] is obtained by taking the derivative of $\eta(t)$ with respect to time: $\dot{\eta}=re^{rt}\lambda+e^{rt}\lambda$. Since from the first order condition of the maximization we have $\dot{\lambda} = -\frac{\partial H}{\partial B}$, substituting and rearranging gives $r\eta - \frac{\partial \pi}{\partial B}$.

Appendix B. Variable Definition

Variable	Description
Agricultural output	The value of farm output deflated by overall deflator obtained from a separate price survey in the same village.
Calorie	Weekly household consumption converted into calorie per adult equivalent per day.
Calorie-sqr	Calorie square.
Fam_lab	Person days of household members invoved in ploughing, weeding and harvesting.
Hired lab	Person days of hired labour for ploughing, weeding and harvesting.
Shared_lab	Person days labour obtained through traditional labour sharing arrangements..
Height	Average height of all household members working on the farm.
V_calorie	Village average calorie intake
hhh_age	Age in years of the household head.
hhh_fem	Dummy. = 1 if the head is female; 0 otherwise
hhh_edu	Level of education of the head.
Land_typ	Measure of the fertility of the land. A weighted sum of the variable that assigns a value = 1 for fertile, = 2 for moderate and = 3 for infertile plot. Where the weight is the contribution of each plot to the total land cultivated.
Land_slp	Measure of the steepness of the land. A weighted sum of the variable that assigns a value = 1 for flat, = 2 for moderate incline and = 3 for steep incline plot. Where the weight is the contribution of each plot to the total land cultivated.
Cult_land	Area of land cultivated (in hectares).
Capital	The sum of the values of Hoe and plough owned and fertilizer used.
Fam_lab*landtyp	Interaction terms of family labour and land type.
Hired_lab*landtyp	Interaction terms ofhired labour and land type.
Capital*landtyp	Interaction terms of capital and land type.
Mem_ill	Dummy. = 1 if a working member of the household is ill in the past 4 weeks; = 0 otherwise.
Ill_4wks	Dummy. = 1 if ill in the past 4 weeks; = 0 otherwise.
Farm worker	Dummy. = 1 if working on someone else's farm for pay; = 0 otherwise.
Unskilled	Dummy. = 1 if working as unskilled labourer, = 0 otherwise.
Trad. worker	Dummy. = 1 if working as part of traditional labour sharing with pay, = 0 otherwise.
ALP	Dummy. = 1 if \ completed adult literacy program, = 0 otherwise.
Primary	Dummy. = 1 if \ completed primary school, = 0 otherwise.
Junior	Dummy. = 1 if \ completed junior school, = 0 otherwise.
Fert.	Value of fertilizer employed.
Hoe	Value of hoe owned by the household.
Plough	Value of plough owned by the household.
Lambda	Inverse Mills ratio.
Physical	This is obtained by constructing an index from four variables: whether the person i) sweep the floor, ii) walk for 5 km, iii) carry 20 lts of water for 20 meters and iv) hoe a field for a morning. The responses to each of these questions are either of the following four options. a) easily, b) with a little difficulty, c) with a lot of difficulties and d) not at all. The index is the weighted sum of the response to these four questions. To each individual's response of performing a given task value ranging from 1 to 4 is assigned. (i.e. easily, with a little difficulty, with a lot of difficulties and not at all). The sum of these values for a particular observation is used to compute the index. Activities of Daily Living Index formula. The formula for the index is $\frac{\text{score - min}}{\text{max - min}}$; where score = score obtained by a particular individual (i.e. the sum of all the responses for the five questions). min = minimum score possible (which is 5 in our case). max = maximum score possible (wich is 20 in our case).

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