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NUTRITION, HEALTH AND LABOR PRODUCTIVITY ANALYSIS OF MALE AND FEMALE WORKERS: A TEST OF THE EFFICIENCY WAGE HYPOTHESIS

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ABSTRACT

The objective of this study was to examine the effect of nutrition and health on labor productivity for women and men workers on subsistence farm households. The study emerged from the well founded Efficiency Wage Hypothesis which asserts that nutrition affects labor productivity in subsistence economies. This study develops the Efficiency Wage Hypothesis further by including an anthropometric measure of health along with caloric intake and other production inputs in the productivity analysis

The conceptual model was based on an economic model of household behavior developed by Gary Becker. Through optimization it was shown that consumption and production decisions were not separable. The relevant step was to estimate an inherently non-linear production function for the household. The empirical model specified dual causality between consumption and production , and thereby used a simultaneous equation system. A two-stage least squares estimation with instruments was used in the production function estimation to control the endogeneity in the model.

The data set consisted of a sample of forty households from six villages in India, covering three broad agroclimatic zones. Output value of production, inputs into the production including caloric consumption of the individuals in the households and anthropometric measures of health, were available in the data set, enabling the study to use all this information in the estimation of labor productivity.

The empirical results showed that an increase in caloric consumption increased the female labor productivity but health, as measured by weight-for-height, of the female workers was not significant. Caloric consumption of the male workers did not contribute to their productivity but their health, as measured by weight -for-height, significantly added to the value of output. Hired workers, cultivated area, input of fertilizer, bullock labor positively affected the value of farm output.

Increased daily caloric availability and consumption of female workers can be recommended to increase the productivity of the households. Health, as measured herein, can be viewed as a function of past calories and in that context increasing the present caloric consumption of the households would improve health and productivity of the workers in the future.

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1. INTRODUCTION

The theoretical basis for any kind of research may originate through a chain of demands. The demand for a certain type of commodity may give rise to demand for new knowledge leading to research and new technology. There is a demand for labor productivity because it affects growth in output. Therefore, there is a need to understand the determinants of labor productivity. Some of the traditional determinants of labor productivity are education, quantity and quality of complementary inputs of labor, and technology. This research studied how nutrition and health affects the productivity of labor, in a low income country.

Fogel (1994) stated that current biomedical techniques, combined with economic techniques, has made it possible to look at the impact of better nutrition on health, life expectancy, labor productivity, and economic growth. The synergy between the biomedical techniques and economic techniques provides analytical insights to the neglected issue of malnutrition.

When looking at the consequences of malnutrition, the important role of nutrition in human health and productivity becomes obvious. Malnutrition can be the outcome of an inadequate diet or the demand on the diet so huge to produce malnutrition which may have been adequate under a different circumstances (Fogel, 1994). Many research programs have dealt with the state of severe undernutrition, and it has been acknowledged that gaps exists in knowledge about cases of moderate to mild malnutrition. Malnutrition is responsible for a high percentage of high death rates and morbidity in less developed countries (Workshop on Nutrient Intake and Reproductive Competence, 1978). Extensive studies have also shown weight-for-height (a body mass index), height at given ages, or weight at given ages are constructive predictors of morbidity and mortality. (Fogel, 1994). Decreased energy intakes contribute to impairments of a number of human functions such as disease response, reproductive competence, work output and activity, cognitive and sensory capacities, and social and behavioral functions (Workshop on Nutrient Intake and Disease response, 1978). In its less severe form, malnutrition causes problems to the general well being of individuals. Much literature indicates that the relationship between nutrition and physical functioning of human beings is complex and varied. [Workshop on Energy Intake, Performance and Work, 1974.]

Better nutrition is believed to improve psychological and physiological well being which, in turn, leads to increased economic productivity and growth in the economy. There still exists a lack of knowledge about the connection between good nutrition for all people in a society and economic productivity and growth, and it has been quite difficult to quantify the relationship between nutrition, energy intake, activity, work output and productivity.

The potential relationship between labor productivity and nutrition has been of considerable interest to economists for several years. The Efficiency Wage Hypothesis literature (Liebenstien 1957) stresses the relationship between caloric intake and improved labor productivity at low levels of income. This hypothesis has important labor market implications, but has had little empirical testing.

This study empirically tested the Efficiency Wage Hypothesis using data from rural farm households in India. It presents a new household behavior model to test and quantify the relationship between caloric intake (nutrition) of men and women and productive output on their farms. In addition to calories, a measure of health was used as an exogenous variable to determine the long run affect of nutrition on productivity along with other explanatory variables.

The dissertation is organized as follows: Chapter 2 reviews the literature regarding the Efficiency Wage Hypothesis and other studies that have attempted to test the relationship of nutrition and productivity. Chapter 3 presents the conceptual household model of the study.

Chapter 4 deals with the empirical model. Chapter 5 describes the data set and all the variables used in the econometrics analysis. Chapter 6 describes the method of estimation and the justification of the estimating procedure. Chapter 7 examines the empirical results and the statistical significance of the variables used in the analytical model. Chapter 8 concludes the study.

2. LITERATURE REVIEW

Numerous studies have provided a rationale for research on nutrition by exploring the relationship between nutritional intake and health, reproduction, physical activity, productivity, work performance, cognitive development and social competence. [Workshop on Energy Intake, Performance and Work, 1974]. Each of them acknowledged a gap in the existing knowledge about how nutrition actually affects each of these factors. A need for further extensive research was emphasized in most of the studies. In this chapter, a critical examination of some of the previous literature that has attempted to identify the relationship between nutrition (caloric consumption), health, and productivity (output) is presented.

It is appropriate to begin with a study of the determinants of malnutrition. Sukhatme (1977) critically examined the methods used in estimating how poverty level income is linked with malnutrition. He defined malnutrition as inadequate energy intake and uses three separate terms, listed here in order of its impairment to the body, namely malnutrition, undernutrition, and protein malnutrition. The later poses the smallest problem to the human body and including it as a cause of devastation to the body tends to overstate the problem. The author found the estimates of the incidence of poverty highly exaggerated in studies by Dandekar and Rath (1971). Dandekar and Rath's approach consisted of three steps: (1) calculating energy intake by total expenditure, (2) calculating the level of total expenditure at which the energy needs are just met, (3) calculating the number of people under the poverty line. Dandekar and Rath's study found that for the energy requirement of 2,500 calories to be met the average per capita income would have to meet 334 Rupees(Rs.) in India, implying that the 40 percent of the rural population who were below this line, were undernourished [Secklar, 1980]. Sukhatme was extremely skeptical of this classification line, regardless of the relationship that existed between energy intake and the level of expenditure. He argued that this minimum requirement implied that anyone above this line was over nourished and anyone below it as undernourished. The method was not taking into consideration the inter-individual variation. Sukhatme pointed out the inaccurate assumptions were, namely, (a) the caloric requirement of an individual is known, (b) the requirement is constant for a person over the time span by age and sex group. The study stressed that energy usage of an individual varies day to day. A person's dietary habits are complicated and may be influenced by factors which are non-physiological.

Based on later studies, such as Third World Food Plan (1976) taken by FAO, Sukhatme contended that the energy requirement is at a much lower level of 2,200 calories with a threshold of undernourishment being around 1,900 calories. These statistics reduced the estimated number of undernourished people in India as found in Dandekar and Rath's study to 30 percent.

The importance in Sukhatme's study is that it presented statistical evidence of the decreased recommended level of needed energy. It was one of the very first studies to define malnutrition in terms of "energy need". However, the study did not relate employment and nutrition and what the effects of malnutrition may have upon workers' wages.

Studies done by Liebenstein [1957], Mazumder [1959], Stiglitz [1976], Bliss and Stern [1977] and Griffith [1978], postulated the existence of a relationship between food consumption and productivity. Myrdal [1968] stated that low productivity of labor was the main cause of undernourishment and malnutrition in South Asia. Myrdal further elaborated that dietary deficiencies reduced workers' ability to work lowering labor input and efficiency in production. He pointed out the cyclical pattern whereby undernourishment lead to low productivity and low productivity generated low wages which in turn lead to undernourishment. Thus, nutritional deficiencies posed an obstacle to development and growth in agriculture. Leibenstein [1957] was the first author to show the connection between increased wages, units of work and productivity. This postulation gave rise to the Efficiency Wage Hypothesis Theory. According to Bliss and Stern [1978] the productivity-consumption link and its influence on labor wages has been subjected to thorough examination by many authors. Mirlees [1976] and Stiglitz [1976], have discussed the relationship of productivity-consumption influence on the optimum allocation of labor and shadow wage. The study of Bliss and Stern [1978] which incorporates much of Liebenstein, Mirlees and Stiglitz's work, investigates the productivity-consumption influence on the positive theory of wages. The productivity-consumption relationship and its implication for the wage theory was beyond the scope of this study. This paper's concern was the effect of food consumption on labor productivity and that aspect of the Efficiency Wage Hypothesis.

2.1 Efficiency Wage Hypothesis

The Efficiency Wage Hypothesis model is based on the fundamental assumption that at low levels of income there is a positive relationship between levels of food consumption and labor productivity (Leibenstien, 1957). Following is the explanation of productivity-consumption relationship of the model [Bliss and Stern,1978].

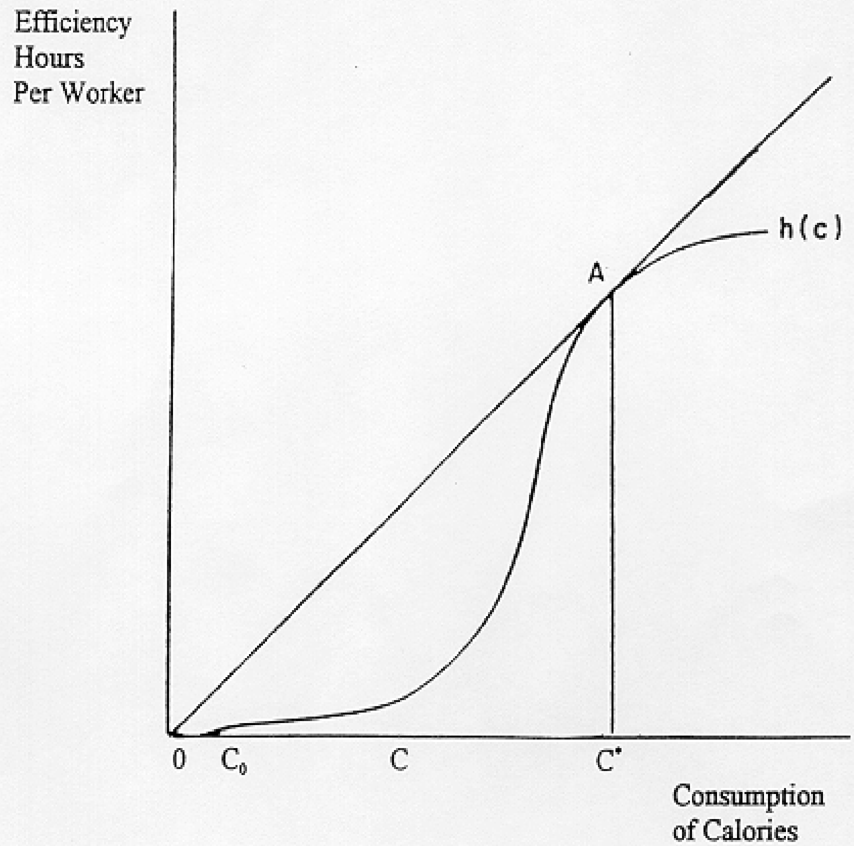
The length of a working day is given in terms of ordinary clock hours. A distinction is made between "clock hours" and "efficiency hours". Efficiency hours measures the productivity of the workers' effort. This is to say, a more productive worker will generate a higher number of efficient hours of labor in a given number of clock hours. These efficiency labor hours depend on the workers' consumption level *c* of calories and this relationship between efficient labor hours and consumption will be denoted by *h(c)*. Given the assumption that the length of the working day is fixed, the number of workers and clock hours are used interchangeably. All workers are given the same wage *w*, and they are hired to work the same number of clock hours. The workers spend all their wages for food consumption, and they have no other source of consumption. Therefore, the relation between efficient labor hours and consumption is expressed as *h(w)*. If the number of clock hours worked is *l*, which is proportional to the number of workers hired, then the number of efficient hours produced is *lh(w)*. The output, which is generated by these efficient hours, can be denoted by

$$y = f[lh(w)].$$

Figure 1 depicts the postulated productivity-consumption relation where the efficient hours a worker supplies is a function of the level of caloric intake. Wages are all spent on food for workers; Liebenstein (1957) translated the food consumption into energy intake. Thus, the productivity is expressed as a function of caloric intake or *h(c)*, where *c* stands for consumption in calories. A certain level of daily consumption (C_o) is required to cover

FIGURE 2.1

EFFICIENCY WAGE HYPOTHESIS



the basic metabolic requirements for basic life functions. The function *h(c)* is assumed to start in the origin with a horizontal segment equal to $(0\text{-}C_o)$. Consumption intake which exceeds $(0\text{-} C_o)$ provides energy to be spent in activity. Productivity is assumed to increase over a range of calories up to C*; beyond C* diminishing returns set in with further increases in caloric intake (Figure 1).

The Efficiency Wage Hypothesis does not assert any relationship between wage and nutritional level of workers. It simply hypothesizes that the wage per efficiency hour paid by cost minimizing employers will depend on the productivity-caloric relationship. At low levels of income, the technical relation between nutrition and productivity, as hypothesized by the Efficiency Wage Hypothesis, is an important one. It has strong implications for policy makers interested in increasing productivity in an economy by improving nutrition by way of caloric availability. It is a tangible investment in the human capital of the population.

A study by Pitt and Rosenzweig (1984) explored the effect of illness or morbidity on farm profits for a sample of Indonesian households. They used a profit function approach with agricultural households of Indonesia. They did not find significant effects of family illness on profits, but the effects of illness on family labor supply was significant. The authors pointed out that this does not necessarily imply the absence of an effect on labor productivity. If family and hired labor were perfect substitutes and wages were fixed, sick family labor could be substituted for healthy hired labor, and thus, the farm production function might be effected but the profit function would not, because the profit function holds hired labor constant.

Overall, Strauss's (1986) work is the most thorough study which tests and quantifies the current nutritional intake on farm productivity using the household level data from Sierra Leone, thereby testing the Efficiency Wage Hypothesis.

Strauss (1986) attempted to test the nutrition-productivity relationship directly using "effective" labor as input in the production function analysis where"effective" labor was a function of on-farm family labor and the caloric consumption of the household. Strauss found "effective" family labor to be a statistically significant input in measuring productivity. Strauss' output elasticity of per consumer calorie availability increases with increasing amount of calories available for household consumption. Energy availability for the household decreases beyond a certain amount of calories (4500) and has a negative impact on "effective" labor beyond this level of calories. Strauss concluded that in rural Sierra Leone more food increased labor productivity.

The major weakness in Strauss's analysis was that he did not have individual level data on caloric intake of the household. Data from Sierra Leone had caloric availability in the market so he used average caloric intake per consumer equivalent. The household level caloric variable had to be converted to an average per family worker by assuming that food consumption was proportional to approximate caloric "requirements" for a moderately active person given age and sex. FAO 1957 weights for caloric requirements were used. The author recognized the weak data on the nutrient intake and concluded that the nature of the nutrition-productivity relationship remained unanswered due to the unavailability of the individual level nutrient intake data.

Deolalikar (1988) estimated structural relationship for wage rates and a farm production function with nutritional intake and nutritional status (weight-for-height) of workers as explanatory variables. That study found neither market wage nor the farm output to be responsive to daily caloric intake. The farm output and the market wage were found to be very responsive to the weight-for-height measure.

Deolalikar used both daily nutrients and weight-for-height as independent variables in a production function estimation. The author contended that there may be a strong correlation between the two variables since weight-for-height may itself be a function of past caloric intake especially if dietary composition had not changed and caloric intake remained fairly stable over the past years. Thus, collinearity between the two variables could explain the positive and significant effect of weight-for-height on productivity and non-significant effect of caloric intake on productivity and negative effect of calories on the wage rate.

Nutritionists have used anthropometric data, namely, weight-for-height as an indicator of health status or strength. Conventionally, health status has been used by nutritionists and researchers in health studies to reflect morbidity experience. Several studies have found a strong association between weight-for-height and risk of various health outcomes. Weight-for-height is a more complex variable than the simple daily nutrient intake which measures the short run caloric intake of individuals. Spurr (1983) contends that weight-for-height can be used as a proxy for current nutritional status and hypothesized that it plays a role in raising work capacity. Deolalikar (1988) used anthropometric data of health as an indicator of past nutritional status. The joint effect of past and present nutritional intake has lead to attributing the effect on productivity to the weight-for-height variable alone.

In low income economies, workers are hired based on their health status such as weight-for-height, without any knowledge of their caloric intake, to perform strenuous forms of activities and may be paid a higher wage if they appear larger. This supports Deolalikar's (1988) findings of a positive relation between health and wages and an insignificant effect of daily caloric intake on wages.

One might conclude from Deolalalikar (1988) that the relationship between health and productivity is an end in itself with no further incentive to consider daily nutrition as a major means to increase the immediate or short run productivity.

Other empirical tests have been done on the relationship between nutrition and productivity. Key et al (1950) experiments in Minnesota showed that when the caloric intakes of male workers were decreased from 3,500 calories to 1,500 calories over a period of 24 weeks, the activity level of workers dropped immediately.

A more recent study by Wolgemuth et al (1982) showed a positive relationship between current caloric consumption and output of male workers in Kenya. The daily caloric intake of workers was about 2,000 calories a day. One group was supplemented by 1,000 calories a day and another group by 200 calories a day. The dirt dug per day increased 22.5 percent for high-caloric supplemented workers. Fogel (1994) asserted that chronic malnutrition caused by chronic diseases is not the only factor that reduces the productivity of labor, especially in poor countries where the intake of calories is extremely low, this depressed both labor productivity and labor force participation.

The study reported in this paper tested the Efficiency Wage Hypothesis using data from farm households in India. The model examined the effect of health along with the caloric intake via efficient labor hours on the productivity of the farm households. This estimation overcame the weakness in Strauss's study by using individual level data on caloric intake and anthropometric measures of health.

3. MODEL

This study assumed a simple producer cum consumer agricultural household model. The household model was slightly modified from the original Becker (1965) household model and Strauss (1986) where the allocation of time and household production were incorporated into the theory of consumer and household behavior. The general structure was the same as the conventional household model, where a farm household maximizes a utility function subject to constraints. In particular, this modified model analyzed the relationship between consumption, health and production.

The household utility function is of the following nature:

$$U = u\,(C_f, C_{nf}, L) \qquad 3.1$$

where,

C_f = household consumption of food

C_{nf} = household consumption of nonfood

L = household consumption of leisure

The farm household production function is expressed as:

$$Y = f\,(L^e, L_h, B, F, CA) \qquad 3.2$$

where,

Y = household production of agricultural output

L^e = efficient family labor

L_h = hired labor

B = bullock labor

F = fertilizer

CA = cultivated acreage

Following the Efficiency Wage Hypothesis efficient labor is a function of caloric intake and hours worked. This model assumes health will affect efficient labor hours along with caloric intake. Grossman (1972) asserted that heath is a capital stock that affects "healthy" or efficient time. Therefore, efficient labor hours (L^e) is a product of labor hours and a function of calories and health.

Weight-for-height is a proxy for health, and is a more complex variable than simple caloric intake. Health can be viewed as a "stock" of past caloric intake. The anthropometric variable, weight-for-height, is viewed by scientists, as a long- term indicator of past nutritional status (Deolalikar, 1986). Fogel (1994) however distinguished between height and weight-for-height as measures of malnutrition and health. He considered height to be a net measure of nutrition and final height a reflection past nutritional intakes during their growing years. He considers weight-for-height as a net measure of nutrition because it reflects the balance between current nutrient intakes and the claims on the caloric intakes.

According to Grossman (1972), health is a durable capital stock that can produce an output of healthy time or "efficient" time. The flow of services that go into the production of health includes nutrition, exercises, medical services, etc. In this context , health can be viewed as a "stock" measure of calories or nutrition.

$$L^e = h(.)\, L_f \qquad 3.2.1$$

where,

L^e = efficient family labor

L_f = hours of family labor

$h(.) = f(C_f, H)$

C_f = food consumption of household farm workers in calories

H = anthropometric measure of health (weight -for-height)

The Time Constraint consists of labor hours working on farm, household leisure time which could be sold out, and household consumption of leisure.

$$T = L_f + L_o + Lc \quad 3.3$$

where,

T = total time available to the household

L_f = hours of family labor on own farm

L_o = leisure time available (or labor sold out)

L_c = household consumption of leisure

Grossman (1972) asserted that total time available is a function of health. Assuming that present daily caloric intake represents current health status and past caloric consumption affects accumulated health, measured by weight-for-height, the time constraint can then be written as follows:

$$T(C_f, H) = L_f + L_o + L_c$$

The budget constraint simply states that the total income equals the expenditures of the household. The expenditures of the household consists of the value of inputs for production, such as fertilizer, hired labor, hired bullocks, and other non-food expenditures. The income source consists of the value of household output sold, family labor sold to an outside employer and some exogenous income.

$$P_f(Y - C_f) + W(L_o) + E = P_{nf}(C_{nf}) + W(L_h) + P_v(V) \quad 3.4$$

where,

P_f = price of food

$Y - C_f$ = household output sold after home consumption

L_o = household leisure time sold out as labor hours

W = market wage of workers

E = exogenous income

P_{nf} = price of nonfood

C_{nf} = household consumption of nonfood

L_h = hired labor hours

P_v = price of variable inputs

V = variable inputs purchased by the household

The budget constraint combined with the time constraint can be expressed as:

$$P_f Y - W L_h - P_v V + W [T(.) - L_f] + E = P_f C_f + P_{nf} C_{nf} \qquad 3.5$$

or, $$P_f Y - W L_h - P_v V + W [T(.)] + E = P_f C_f + P_{nf} C_{nf} + W L_f \qquad 3.6$$

Solving the optimization problem in the section (3.1) to follow, it is shown that wage per efficiency hour is equal to the marginal product of labor (eq. 3.1.8). Importantly, the first order conditions show that production depends on consumption through labor efficiency hours, and likewise consumption depends on production (3.1.4). Therefore , production and consumption are not separable in the model; Caloric consumption is an endogenous variable.

In this study, the production function equation 3.2 was estimated , since the objective of the study was to examine the role of food consumption and health on labor efficiency, and the subsequent value of household production. Female and male labor efficiency in the productivity estimation were examined separately.

3.1 Optimization Problem

$$\text{Max } U = u\,(C_f, C_{nf}, L)$$

$$\text{s.t} : P_f Y - P_v V - W L_h + W [T(.)] + E = P_f C_f + P_{nf} C_{nf} + W L_f$$

Assuming the utility function to be usual convex to the origin and continuously differentiable function;

Forming the Lagrangian:

$\mathscr{L}$: $u (C_f , C_{nf} , L) + \lambda[P_f Y - P_v V - WL_h + W[T(.)] + E - P_f C_f - P_{nf} C_{nf} -WL_f$ First Order Necessary Conditions for an Interior Maximum:

$$\delta\mathscr{L}/\delta C_f = \delta u/\delta C_f - \lambda[P_f + P_f (\delta Y/\delta C_f) - W (\delta T/\delta C_f)] = 0 \qquad 3.1.1$$

or $\delta u/\delta C_f - \lambda P_f [1 - \delta Y/\delta C_f -W/P_f (\delta T/\delta C_f)] = 0$

or $\delta u/\delta C_f - \lambda P_f [1 - (\delta Y/\delta L^e_f)(\delta L^e_f / \delta C_f) - W/P_f (\delta T/\delta C_f)] = 0$

or $\delta u/\delta C_f - \lambda P_f [1 - (\delta Y/\delta L^e_f) (\delta h(.)/\delta C_f).L_f - W/P_f (\delta T/\delta C_f)] = 0$

$$\delta\mathscr{L}/ \delta C_{nf} = \delta u/\delta C_{nf} - \lambda P_{nf} = 0 \qquad 3.1.2$$

$$\delta\mathscr{L}/\delta L_f = -\lambda[W - P_f (\delta Y/\delta L^e_f) (\delta L^e_f /\delta L_f)] = 0 \qquad 3.1.3$$

or $-\lambda[W - P_f (\delta Y/ \delta L^e_f)(\delta L_f. h(.))/\delta L_f] = 0 \qquad \{ L^e_f = h(.)L_f \}$

or $-\lambda[W - P_f (\delta Y/\delta L^e_f)h(.)] = 0$ 3.1.4

$$\delta\mathscr{L}/\delta L_h = -\lambda[W - P_f (\delta Y/\delta L^e_h)h(.)] = 0 \qquad 3.1.5$$

$$\delta\mathscr{L}/\delta V = -\lambda[P_v - P_f (\delta Y/\delta V)] = 0 \qquad 3.1.6$$

By dividing the equation 3.1.3 by the efficiency units per efficient worker namely h(.) :

$$-\lambda[W/h(.) - P_f (\delta Y/\delta L^e_f)] = 0 \qquad 3.1.7$$

$$W/h(.) = P_f (\delta Y/\delta L^e_f) \qquad 3.1.8$$

In equation 3.1.8, the wage per efficiency labor hour , W/h(.),

is equal to the marginal value product of the efficiency of labor which is

$P_f (\delta Y/\delta L^e_f)$. Equation 3.1.4 asserts that production depends on consumption and through efficient labor hours are not separable. Separability would indicate that household input and output decisions are independent of consumption. Similarly, equation 3.1.1 says that consumption choices are dependent on production.

Establishing the endogeneity of consumption (calories) in the production of subsistence farm households, demands that the method of estimating this model should account for this endogeneity. Furthermore, the estimating model should account for the non-linear nature of the effect of human capital variables - calories and health on the efficiency of labor. These challenges are met and described in the following chapters.

4. EMPIRICAL MODEL

4.1 Production Function

The initial agricultural household production function was estimated with the commonly used Cobb-Douglas functional form . Using it here allowed comparisons of this study with results of other studies, particularly Strauss (1986) and Deolalikar (1988). The production function estimated was specified as follows:

$$\ln Y_i = \alpha_0 + \alpha_1 \ln L^e_{ij} + \alpha_2 \ln L^f_{ij} + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i + \alpha_5 \ln CA_i + \alpha_6 \ln F \qquad 4.1$$

where,

$\alpha_1 , \alpha_2, \alpha_3 , \alpha_4 , \alpha_5 , \alpha_6 \succ 0$.

i indexes the farm household

j indexes female or male

Y = value of output in Rupees of the farm household averaged over the two years, 1976-77 and 1977-78

L^e = efficient farm labor hours of a household averaged over all adult family labor hours together (male and female) for a combined model; over female and male labor hour separately for the separate models, and over the two years, 1976-77 and 1977-78

L^f = labor hours of male or female household member averaged over the two years, 1976-77 and 1977-78. This variable will not appear in the combined model but it appears for males when testing the L^e for females and it appears for females when testing the L^e for males.

L_{ih} = hired labor averaged over the two years, 1976-77 and 1977-78

B_i = pair of farm and hired bullock hours averaged over the two years 1976-77 and 1977-78

CA_i =cultivated area in acres of the household averaged over the two years 1976-77 and 1977-78

F_i = fertilizer quantity in kilograms averaged over the two years 1976-77 and 1977-78

4.1.2 Labor Efficiency Function

The efficiency labor function ($L^e = h(.)L_f$) was specified as it was in the original Efficiency Wage Hypothesis where the function h(.) or the efficiency curve was postulated to have a "S" shape (Figure 1). The h(.) function that transforms farm labor clock hours into efficiency hours starts in the origin with a horizontal segment because it takes some minimum amount of nourishment and health to do the basic activity of life . As calories increase, productivity returns increase more rapidly initially and then diminish after a particular range of caloric intake (Stiglitz, 1976).

An exponential function is well designed to describe the efficiency process and can be used to fit an "S" curve. An analogy with the law of biological growth functions can be drawn here. The potential biological relationship that relates nutrition to work effort and output has been of wide interest to economists and health scientists. The characteristic of the exponential function is attractive because the efficient labor process is viewed as an intermediate transition between lower initial levels of efficiency and an upper stable rate. Initially the increase in efficiency may be slow, then increasing at an increasing rate, and then increasing at an decreasing rate. Thus, there is a point of inflection where the rate of change in efficiency begins to decline. The line of maturity or the existence of an upper asymptote is a special feature of the exponential function.

Efficient labor hours were estimated for adult household labor and for males and females in households separately. Therefore, L^e was specified as

$$L^e_{ij} = h(C,H)L^f_{ij} \tag{4.2}$$

where,

L^f = average farm labor hours of the adult members in the household measured in clock hours

j = 1 indexes the female hours on the farm

j = 2 indexes the male hours on the farm

i = indexes the farm household

C = C_{ij} average daily caloric intake of female and male member separately who worked on the farm during the years 1976-77 and 1977-78

H= H_{ij} weight-for-height averaged over the male or female members who worked on the farm during the period of 1976-77 and 1977-78

Consistent with the exponential function, the h(.) function is specified with parameters α, β', φ'.

$$h(C, H) = e^{\alpha-\beta'/C-\varphi'/H} \tag{4.3}$$

Therefore the L^e can be written as

$$L^e_{ij} = (e^{\alpha-B'/C-\varphi'/H}) L^f_{ij} \tag{4.4}$$

Substituting equation 4.4 into 4.1 and renumbering the parameters yields:

$$\ln Y_i = \alpha_0^{'} + \alpha_1 \ln [(e^{\alpha - \beta'/C - \varphi'/H})] + \alpha_1 \ln L^f_{ij} + \alpha_2 \ln L^f_{ij} + \alpha_3 \ln L_{ih}$$
$$+ \alpha_4 \ln B_i + \alpha_5 \ln CA_i + \alpha_6 \ln F_i \qquad 4.5$$

Rearranging,

$$\ln Y_i = \alpha_0^{'} + \alpha_1 [\alpha - \beta^{'}/C - \varphi^{'}/H] + \alpha_1 \ln L^f_{ij} + \alpha_2 \ln L^f_{ij} + \alpha_3 \ln L_{ih}$$
$$+ \alpha_4 \ln B_i + \alpha_5 \ln CA_i + \alpha_6 \ln F_i \qquad 4.6$$

Simplifying equation 4.6,

$$\ln Y_i = \alpha_0 - \beta/C - \varphi/H + \alpha_1 \ln L^f_{ij} + \alpha_2 \ln L^f_{ij} + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i$$
$$+ \alpha_5 \ln Cai + \alpha_6 \ln F_i \qquad 4.7$$

where,

$$\alpha_0 = \alpha_0^{'} + \alpha_1 \alpha$$
$$\beta = \alpha_1 \beta^{'}$$
$$\varphi = \alpha_1 \varphi^{'}$$

The production function in 4.7 was estimated to test the Efficiency Wage Hypothesis for a combined total household model where j was dropped from C_{ij}, H_{ij}, and L^e_{ij} in equation 4.4 and ($\alpha_2 \ln L^f_{ij}$) was omitted as it appears in equation 4.7. That is, the efficiency of all adult workers, regardless of gender was estimated. The estimating equation was as follows:

$$\ln Y_i = \alpha_0 - \beta/C_i - \varphi/H_i + \alpha_1 \ln L^f_i + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i + \alpha_5 \ln CA_i$$
$$+ \alpha_6 \ln F_i \qquad 4.8$$

In order to test whether calorie intake and health had a different impact on the efficiency of labor of males and females equation 4.7 was also estimated in two separate equations. That is

$$\ln Y_i = \alpha_0 - \beta/C_{i2} - \varphi/H_{i2} + \alpha_1 \ln L^f_{i2} + \alpha_2 \ln L^f_{i1} + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i$$
$$+ \alpha_5 \ln CA_i + \alpha_6 \ln F_i \qquad 4.9$$

In equation 4.9 the effect of calories and health on the efficiency of male labor was examined. When L^e_{ij} was for males, the clock hours of labor time for females was entered as a separate variable ($\alpha_2 L^f_{i1}$) to avoid bias due to missing variables.

When the L^e_{ij} was for females was examined, the ($\alpha_2 L^f_{i2}$) for males was entered as a separate variable. Following was the estimating equation:

$$\ln Y_i = \alpha_0 - \beta/C_{i1} - \varphi/H_{i1} + \alpha_1 \ln L^f_{i1} + \alpha_2 \ln L_{12} + \alpha_3 \ln_{ih} + \alpha_4 \ln B_i$$

$$+ \alpha_5 \ln CA_i + \alpha_6 \ln F_i \qquad 4.10$$

All adults household labor was accounted for and the efficiency of labor was tested for males and then females in sequential models. It was not possible to estimate L^e_{ij} for both males and females (separately) in the same equation where L^e_{ij} contained the endogenous variable calories.

5. DATA DESCRIPTION

The International Crops Research Institute (ICRISAT) for the Semi-Arid Tropic Village Level Studies (VLS) data on India was used in the study. The VLS started in May 1975 in six villages covering three broad agroclimatic zones of Andhra Pradesh (two villages) and Maharastra (four villages). The data were collected annually from a sample of forty households in each village for a period of five cropping years. In the second stage (1980-81),VLS were extended to new areas in Gujrat and Madhya Pradesh . The ninth year of regular data collection of the original forty households chosen was 1983-84. Ten households were randomly sampled as agricultural labor households which operated less than 0.2 (hectares) of land, and hired out their labor as their primary occupation. Agricultural wages were their main source of income. Thirty cultivating/farm households were chosen representing small, medium, and large farmers. In each of the six villages, these thirty households from the cultivator group and ten households from the labor (non-cultivating) group were randomly selected. The information provided socioeconomic and agronomic details such as age, education, consumption, wealth, income, resources. Production information included plotwise details of inputs, labor use , output quantity, output value, harvest prices, and cropping patterns for each household. Expenditure, wholesale and retail prices of major commodities, irrigation and fertilization expenditure of households were also collected. The data set was extremely large in the number of observations and several data manipulations were carried out to generate a workable format. For example, the input-output data file for the years 1976-77 and 1977-78 alone contained 4916 observations and 20 variables.

This research will use information from the years of 1976-77 and 1977-78 because four rounds of a special nutrition survey were done only for these two years in the same six villages and the same forty households. The nutrition files contain detailed information about individual family members intake of calories (kcal), protein (grams), fat (grams), calcium (mg), iron (mg), vitamins and other nutrients collected by a twenty four hour recall method. All caloric intakes were stated in the commonly used unit of kilo calorie (1 kcal=1000 calories). Along with the nutrition file, anthropometric data of individuals in the same forty households were collected . Anthropometric data consists of weight (kgs) and height (cm) , arm circumference (cm) and fat fold measures.

Table 5.1 shows the six villages and their districts and states where the data were from in the VLS study. A map follows to show the geographic location.

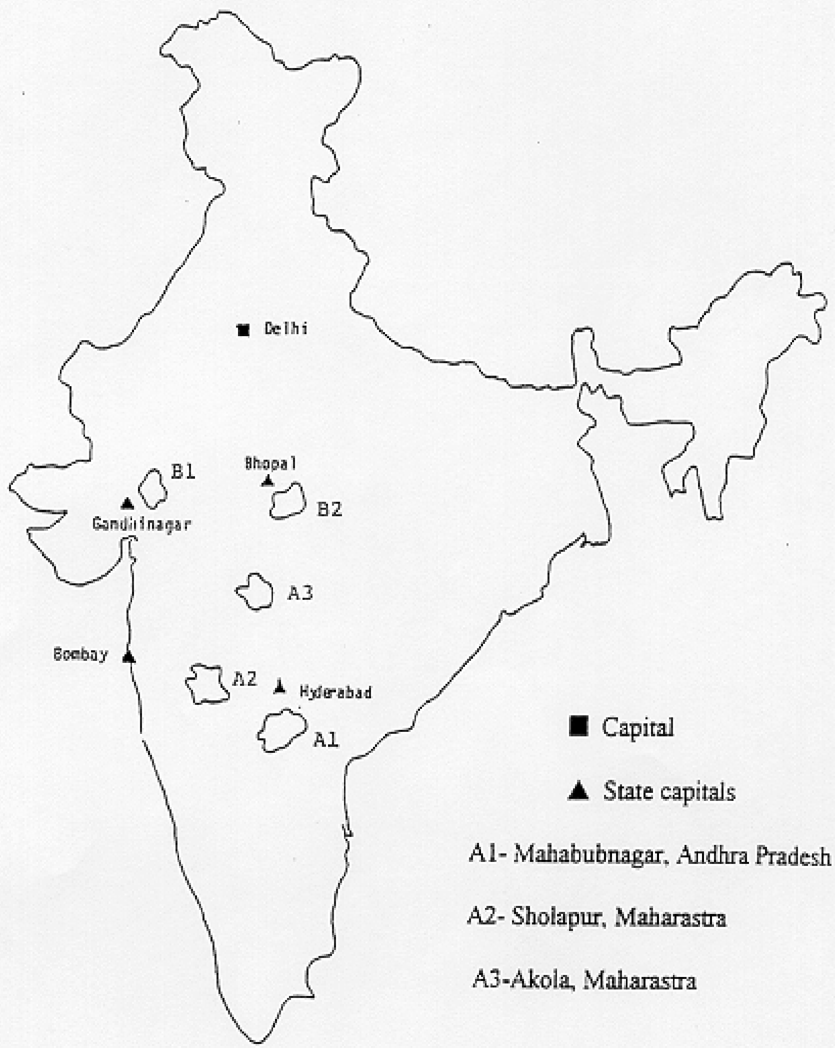
Table 5.0

Six Villages and their District and States

VILLAGE	DISTRICT	STATE
Aurepalle	Mahbubnagar	Andhra Pradesh
Dokur	Mahbubnagar	Andhra Pradesh
Shirapur	Sholapur	Maharastra
Kalman	Sholapur	Maharastra
Kanzara	Akola	Maharastra
Kinkheda	Akola	Maharastra

Source: Manual of Instructions for Economic Investigators in ICRISAT's Village Level Studies by Singh, Binswanger, and Jodha. ICRISAT, Andhra Pradesh, India., 1985.

FIGURE 5.1
INDIA
LOCATION OF THE FIVE STUDY REGIONS



Source: Manual of Instructions for Economic Investigators in Icrisat VLS, India.

5.1 Variable Description

The nutrition file had to be merged with the anthropometric data for the two years 1976-77 and 1977-78. The nutrient-anthropometric file was then merged with the input-output file which consisted of information about plotwise crop output and its value and all their production inputs, for the same households and for the years 1976-77 and 1977-78. Each sampled household in each village had a code number and each member had an identification number, thus merging and stacking of the files was possible to create a data file following SAS data format.

ENDOGENOUS VARIABLES

OUTPUT : The value of agricultural output was used as a measure of productivity. The main products were grains, vegetables and fruits. The quantities for grains and vegetables were recorded in kg, and fruit was recorded in number of 100 units. Households had different plots of different crops of output. All the crops were coded by a class code such as cereals (code C), pulse(code P), oilseeds (code B), vegetables (V), fruits (F). Following is a list of variety of the crops grown.

Cereals

Bajra/Pearl millet (local and HYV), Jowar/Sogram (local and HYV), Maize (local and HYV), Ragi/Finger millet, Paddy (local and HYV), Wheat (local and HYV), Rice (local and HYV), other cereals.

Pulses

Redgram (Tur)/Pigeonpea, Greengram (Mung), Blackgram (Urad), Bengalgram (Chenna)/Chickpea, Redgram Dhal, Greengram Dhal, Blackgram Dhal, Bengalgram Dhal, Guar, Cowpea, Soybean, other pulses, other dhal.

Oilseeds

Groundnuts, Sesamum, Castor, Mustard, Linseed, Linseed oil, Castor (HYV), Sunflower, Safflower,Safflower oil, Groundnut oil, other oilseeds.

Sugarcane

Sugarcane, sugar, Gur (Jaggery)

Vegetables and Spices

Onion, Chillies, Brinjal, Cabbage, Tomato, Cauliflower, Leafy Vegetables, Potato, Carrot and radish, Fennel, Tubers, Tamarind.

Fruits

Grapes, Lemon, Orange, Mango, Coconut, Toddy trees, Banana, Papaya.

The value of the plotwise crops was recorded at the time of harvest, using the prevailing prices in Rupees (Rs.) at the time of harvest. The value for different crops were summed for each household. The value of output in Rs. of each household was then averaged over the two years (1975-76, 1977-78) to obtain a single observation per household. An example of this output value for a household in a village is given in Table 5.1 in the following page.

Table 5.1

Calculation of Household Data

Village Aurepalle (A) Household Number 30 (30A)

Output Value (Rupees)

1976-77	1977-78	
38.4	61.6	44.0
57.6	92.4	70.4
23.1	79.2	143.0
115.36	242.0	110.0
12.00	334.4	77.0
183.40	191.4	121.0
16.50	109.20	66.0
38.4	80.00	40.0
76.8	43.12	52.8
268.8	123.76	231.0
144.0	110.0	167.2
72.0	45.0	
172.8	31.36	
72.0	171.6 (continued)	
Total 1291.60	Total 2837.44	

Average over the two years: 2064.52

CALORIES :

Individual caloric intakes were recorded in kilocalories for each household member. The caloric intakes recorded were from twenty-four hour dietary recall of individual caloric consumption in the sample households. The caloric intake was averaged over the members aged 16 and above who worked on the farm. This study did not include children in the analysis. Labor force is defined as household labor age 16 and over; this study was interested in the labor productivity of workers as defined by the labor force. For each household this was also averaged over the four rounds in years 1976-77 and 1977-78. In addition, the individual daily caloric intake was averaged for all household laborers and separately over female workers and male workers of the household for the two years. The following table shows how caloric variable was calculated.

Table 5.2

Calculation of the Calorie Variable

Village Kinkheda (F) Household number 1

Member	Resource	Round*	Calories	Member	Resource	Round	Calories
01	Male	1	2077.1	02	Female	1	1772.2
		2	2695.4			2	2398.9
		3	2940.1			3	2490.2
		4	2704.5			4	2425.4
	Average of rounds		2604.22				2271.68
03	Male	1	2496.5	04	Female	1	1683.2
		2	2759.8			2	2725.9
		3	3384.1			3	2490.2
		4	2438.0			4	1947.2
	Average of rounds		2769.6				2211.63
	Average of male intake		2686.91 kcal				
	Average of female intake		2241.66 kcal				
	Average of the household		2464.28 kcal				
	Household size		4 (Two males and two females)				

* Round refers to the interview period; each household was interviewed four times

EXOGENOUS VARIABLE

ANTHROPOMETRIC DATA:

Weight (Kg) and height (cm) were recorded for individual members of the farm households. The weight-for-height variable was constructed for each member aged 16 and above who worked on the farm for the same two years; the weight-for-height was then averaged over the members in the households and over the two years. Again, the weight-for-height was averaged separately for female and male workers. The same averaging procedure used for caloric intake was carried out for the health variable. This variable was treated as an exogenous variable. Since the output produced in the current time period was not affected by the weight-for-height in the same time period.

LABOR HOURS:

Data on male, female and child labor hours on the farm were recorded for each household. Labor hours for females and males aged 16 and above were separately averaged over the two year period for every household in the sample. Following is an example of data calculations for male labor.

Table 5.3

Calculation of Labor Hours

Village Aurepalle (A) Household Number 30 (30A)

Farm Labor hours (Male)

1976-77		1977-78	
16	8	6	4
8	8	8	3
4	6	6	3
4	8	4	3
8	54	6	2
4	24	6	3
2	48	4	2
8	16	6	3
8	16	6	3
4	16	8	2
24	16	9	2
8	4	9	2
2 (continued)	4	3 (continued)	
Total	632		112

Average over the two years: 372 hours/year

Data on hired male and female labor hours were also recorded for the households. The hired labor hours for male and female were averaged together over the 1976-77 and 1977-78 for all households in the sample. Similar averaging procedures were used for farm labor hours were carried out for hired labors. The data set had no information on the health status and dietary intakes of the hired labor. The model assumed hired labor was exogenous and homogenous, that is male and female were assumed to be equally productive.

BULLOCK LABOR

A pair of farm bullock hours on the farm was available from the VLS data set. The farm bullock hours were averaged over the two years of 1976-77 and 1977-78.

A pair of hired bullock hours were available and was averaged similarly over the two years for each household in the sample. Similar calculations for averaging the bullock labor were performed.

CULTIVATED ACRES

The total area of the main plot/subplot/ sub-subplots in acres was recorded for each household. The actual cultivated acres were in some cases, less than the total plot since some portion may not have been cultivated due to grasses, stones and trees. Cultivated acres were used in the production function estimation. The cultivated acres of land for each household was averaged over the two year period of estimation. This is as follows:

Table 5.4

Calculation of Cultivated Area

Village Aurepalle (A) Household Number 30 (30A)

Cultivated Acres

	1976-77	1977-78
	.33	.33
	1.00	2.50
	2.50	1.20
	1.20	1.30
	1.20	1.30
	1.30	
Total	7.53	6.63
Average	7.08 acres	

FERTILIZER

The quantity of fertilizer, in kilograms used on the household plots was available in the data set of the VLS study. Types of fertilizers were coded according to whether they were nitrogenous, phosphatic, potassic, compound and/or complex fertilizers. These quantities of fertilizers were aggregated and averaged over the two years for the households.

Tables 5.5-5.7 show the mean and standard deviation of the variables for the combined household model and for the models where the efficiency of male and female labor are estimated separately.

Table 5.5

Table of the Mean and Standard Deviation of the Variables in the Combined Household Labor Model

Variable	N	Mean	Std. Dev	Min	Max
Output value	178	6527.39	13422.61	78.51	148716.29
Farm labor	165	934.59	1052.12	19.50	.3683
Hired labor	178	1891	2766.46	24	16475
Bullock	178	514.05	585.67	0	4469.0
Fertilizer	178	95.39	87.44	0	1062.50
Cultivated Area	178	16.30	15.84	.40	85.70
Calories	175	2490.31	592.56	1183	4419.15
Health(wfh)	164	.28	.03	.19	.3683

Table 5.6

Table of the Mean and Standard Deviation of the Variables of the Female Model

Variable	N	Mean	Std. Dev	Min	Max
Output value	167	6232.58	13625.57	78.51	148716.29
Farm labor	167	294.25	459.41	2.00	5164.00
Hired labor	167	832.26	1309.28	0	9329.50
bullock	167	368.13	480.59	0	2470.50
Hired bullock	167	96.01	88.22	0	612.00
Fertilizer	167	90.26	188.33	0	1062.50
Cultivated Area	167	15.45	14.71	40	80.80
Calories	164	2478.41	583.74	1183	4395.62
Health(wfh)	153	.28	.03	.19	.3683

5.7 Table of the Mean and Standard Deviation of the Variables of the Male Model

Variable	N	Mean	Std. Dev	Min	Max
Output value	176	6579.78	13489.54	78.51	148716.29
Farm labor	176	619.73	709.01	3.5	4371
Hired labor	176	952.71	1477.53	0	10856
Farm bullock	176	423.18	601.16	0	4447.50
Hired bullock	176	94.70	87.40	0	612.00
Fertilizer	176	103.40	204.07	0	1062.50
Cultivated Area	176	16.39	15.90	.4	85.70
Calories	176	2782.25	645.73	1027	4651.90
Village calories	176	2705.26	308.66	2297.05	3092.98
Health(wfh)	170	.30	.03	.21	.40

6. METHOD OF ESTIMATION

6.1 Justification For The Method of Estimation

The production function in equation (3.2 and 4.1) was specified under the assumption that one of the independent variables was determined in part by the dependent variable. To be specific, the Efficiency Wage Hypothesis assumes that household farm production is dependent on calories consumed by the household members, and that calories consumed is jointly determined by the amount of food produced on the farm. This is especially relevant for poor subsistence farm households who produce most or all of their own food. Health, at least as measured here, is not an endogenous variable since health is assumed to be a function of past caloric consumption which is a function of past farm production and not the current farm production. Other inputs are exogenous. The current year inputs that determine current output are labor hours of household workers and their efficiency, hired labor, cultivated area, and fertilizer.

6.1.1 Structural vs. Reduced Form Production Function

If the production function was a reduced form where the right hand side variables are completely exogenous equation 4.6 could be estimated with ordinary least squares. The model would have the following form:

$$Y = \beta X + \epsilon \qquad 6.1$$

where

Y is the vector of dependent variable

X is the matrix of exogenous, independent variables

β is the vector of unknown parameters to be estimated

ϵ is the vector of random errors

Imposing the classical assumptions on the error term,

I. $E(\epsilon) = 0$; zero expected value

II. $E(\epsilon^2_i) = \sigma^2$; constant variance for all i's (homoskedastic)

III. $E(\epsilon_{ij}) = 0$ for $i \neq j$; uncorrelated

The ordinary least squares estimator of β is

$$b = (X^{/}X)^{-1} (X^{/}Y) \quad 6.2$$

which has been proven to be an unbiased and efficient estimator of β. (Johnston 1972; Pindyck and Rubinfeld, 1982).

An econometrics model that has inherent feedback effects and dual causality requires the application of simultaneous equations. A simultaneous system is one where in addition to the effect Xs have on Y , Y clearly has an effect on at least one of the Xs. These features are modelled by distinguishing between the variables that are simultaneously determined (endogenous variables) and those that are not (exogenous variables).

The behavioral equations in this system are called "structural equations" (Studenmund and Cassidy, 1987). The structural equations characterize the model's underlying economic assumption or hypothesis behind each endogenous variable by expressing it in terms of both endogenous and exogenous variables. An appropriate treatment of such a model would be to view the entire system (set of equations) in order to see the dual causality of the model. Following are the structural equations of the combined model to be estimated:

$$\ln Y_i = \alpha_0 - \beta/C_i - \varphi/H_i + \alpha_1 \ln L^f_i + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i + \alpha_5 \ln CA + \alpha_6 \ln F_i \quad 6.1.1$$

$$\ln 1/C_i = \delta_0 + \delta_1 \ln Y_i + \delta_2/H_i + \delta_3 \ln L^f_i + \delta_4 \ln L_{ih} + \delta_5 B_i + \delta_6 \ln CA + \delta_7 \ln F_i \qquad 6.1.2$$

6.1.2 Simultaneous Equation and Violation of the Classical Assumption (III).

In section 6.1.1, it was stated that under the assumption that each of the independent variables in the regression model is uncorrelated with the true error term, the estimator of β is unbiased and consistent. In this section, the possible failure of that assumption in a simultaneous equation system will be discussed.

To understand how a simultaneous equation system can lead to correlation between an independent variable and the error term, a simple model of simultaneous equations is illustrated below.

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_3 X_2 + \epsilon_1 \qquad (a)$$

$$X_1 = \beta_0 + \beta_1 Y + \beta_3 X_3 + \epsilon_2 \qquad (b)$$

If for some reason, ϵ_1 increases then Y increases in equation (a), and when Y increases then X_1 will also increase in equation (b) and the increase in X_1 in equation (b) means X_1 also increases in equation (a), the assumption that X and ϵ are uncorrelated as in equation (6.1) is violated and the estimator of β is no longer unbiased and consistent. This is a common problem when there are endogenous variables in a system of simultaneous equations. (Studenmund and Cassidy, 1987; Pindyck and Rubinfeld 1982). In particular the β estimator of the regression model will be of the following nature and not the one specified as in equation 6.2:

$$b' = (X' X)^{-1} (X'Y) + (X' X)^{-1} (X' \epsilon) \qquad 6.1.3$$

Equation (6.1.3) tells us that the term on the right hand side is positive and b´ will overestimate the true value of β.

Imposing an expectation rule on the above:

$$E(b') = \beta + E\,(X'X)^{-1}\,(X'\epsilon) \qquad 6.1.4$$

[$E(b') = \beta$ given by the Classical OLS model]

When X and ϵ are not independent, but correlated, the E(.) on the right hand side will not disappear. Therefore, b' is a biased estimator of β.

Furthermore, applying the probability limit to equation 6.1.3, we get

$$\text{plim } b' = \beta + \text{plim}[\,(X'X/n)^{-1}\,(X'\epsilon/n)] \qquad 6.1.5$$

plim b' will be equal to β only if the right hand side term [.] equals 0. This can occur only if X and ϵ are uncorrelated.

Econometricians have offered the use of instrumental- variables in a Two Stage Least Square estimation to avoid the problem of inconsistent and biased parameter estimates (Pindyck and Rubinfeld 1980). Following is the explanation of the method used in the estimation of equations 6.1.1 and 6.1.2 where the endogenous variables are jointly determined.

6.2 Two Stage Least Squares and Instrumental Variables

The method of instrumental variables entails the search for a new variable which is highly correlated with the independent variable X but uncorrelated with the error term. Therefore we define a random variable Z to be the instrument under the assumption that

(1) The correlation between Z and ϵ is zero or approaches zero as the sample size gets large

(2) The correlation between Z and X is nonzero

According to Pindyck and Rubinfeld (1980) there may be situations where no instruments will exist or many will exist. The data set in this study contained several variables that were likely candidates for instruments.

Going back to the simple model (equation 6.l), and assuming that an instrument can be found, the parameter estimates were derived using 2SLS following Johnston (1960), Pindyck and Rubenfeld (1982), Studenmund and Cassidy (1980), Bowden and Turkington (1984).

The two-stage least squares, with instrumental variables, involves estimating the endogenous variable against all the exogenous variables in the reduced form using OLS. (Equation 6.1). Then, the predicted value of the endogenous variable is treated as "instrument", and substituted back into the original structural equation (6.1.1). The revised structural equation is then estimated with OLS. To see this, return to the simple model, where

$$b = (X^{/}X)^{-1}(X^{-1}Y)$$

Regress X against the instrumental variable Zs, to obtain x.

$$X = Z(Z^{/}Z)^{-1}Z^{/}X$$

Next Y will be regressed against $\hat{x}$ to get a consistent estimator of β which is

$$b = (Z X^{/})^{-1}(Z^{/} Y)$$

Thus, b is the instrumental variable estimator from the two stage least square estimation; it is a consistent estimator of β given dual causality in the simultaneous equation system of the model.

Given the justification for the method of estimation and the procedure to circumvent the problem of inconsistent estimates, this study estimated the following structural equations (6.1.1) and (6.1.2) with an instrumented two stage non linear least squares method of estimation using SAS.

$$\ln Y_i = \alpha_0 - \beta/C_i - \varphi/H_i + \alpha_1 \ln L^f_i + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i + \alpha_5 \ln CA$$

$$+ \alpha_6 \ln Fi \qquad 6.1.1$$

$$\ln 1/ C_i = \delta_0 + \delta_1 \ln Y_i + \delta_2/H_i + \delta_3 \ln L^f_i + \delta_4 \ln L_{ih} + \delta_5 B_i + \delta_6 \ln CA$$

$$+ \delta_7 \ln F_i \qquad 6.1.2$$

7. EMPIRICAL RESULTS

The empirical model of this study was essentially non-linear in its parameters and variables. The nonlinear Cobb-Douglas production function was transformed into a linear form for estimation purposes by taking logarithms of the variables. Inspection of equation 4.7 and 6.1.1 reveals that the parameters of calories and weight- for-height remained non-linear. An non-linear two stage least square (NL2SLS) method was used to empirically estimate these inherently non-linear models. The term NL2SLS means a set of instruments consisting of exogenous variables and polynomials of low order in these variables have been used (Bowden and Turkington, 1984). As previously discussed in Chapter 6, the endogenous variable was regressed on the exogenous variables and the instrument set . The fitted or predicted values of the endogenous variable (calories) was then substituted into equation 6.1.1 to obtain estimates of parameters. The instruments formed this way are referred to as "internal instruments" because of the substitution of the predicted value inside the non-linear function (Bowden and Turkington, 1984).

7.1 Choice of Instruments

The estimation of equation 6.1.2 started out with a an "elementary" or "primitive" set of predetermined instruments that were assumed to be highly correlated with calories. They were the fat consumption of the household members, the average weight of the household members, and the average height of the household members. These instruments were assumed to be uncorrelated with the error term. During the estimation second order terms of the exogenous variables were added to the instrument set. The final augmented sets of instruments consisted of predetermined variables correlated with calories together with the squared terms of the exogenous variables , chosen to proxy the non-linearity of the model. This procedure was suggested by Amemiya (1974) and Bowden and Turkington (1984). The NL2SLS technique worked well when higher order variables were included among the instruments. Bowden and Turkington (1981) found that unaugmented sets of instruments resulted in disastrous performance as a NL2SLS estimator. The reason being, that if the parameters of the equation are non-linear, then the linear instruments are unable to pick up any pattern of the non-linearity, so the predicted value may be constant or zero. The use of a simple quadratic-augmented instrument set resulted in improvement in the estimators. Therefore, the full set of instruments consisted of $(\text{weight-for-height})^2$, $(1/\ \text{weight-for-height})^2$, $(\text{age})^2$, fat, $(\text{fat})^2$,weight , height, $(\text{cultivated area})^2$, $(\text{male labor hours})^{2,}$ $(\text{female labor hours})^2$. Some econometricians assert that there is no standard method for choosing instruments for non-linear models. The main purpose of the instrumental projection is to purge the regressors of their correlation with the residuals. Following are some of the possible instruments provided by the Econometrics and Time Series Computer software(SAS,1993):

a) any variable that is independent of the error term

b) derivatives with respect to the parameters, if the derivatives are assumed independent of the error term

c) low degrees of polynomial as suggested by Bowden and Turkington(1981).

d) lags of a variable in the system.

Furthermore, the NL2SLS estimation requires that there are as many instruments as the maximum number of parameters in any equation. One can, however, use many instruments, provided that the number of observations is greater than the number of instruments. The full benefit of instrumental variables is achieved in large finite samples where there is an excess of observations over the number of instruments. Thus the bias is reduced and the results are consistent and efficient estimators. This combined model's data set consisted of 147 observations, 170 observations in the male model and 167 observations in the female model. Therefore adding more instruments resulted in superior efficiency properties of estimates.

Following the above argument, the model included the parameter associated with the weight-for-height variable. The partial derivatives of the equation with respect to the parameter (the column of the Jacobian matrix associated with the parameter) was used as instrument . The parameter itself is not used as an instrument in the estimation process.

7.2 Results of The Non-Linear Two Stage Least Squares Estimation

Non-linear ordinary least square estimation was performed iteratively using a linearization of the model with respect to parameters as predicted by the instrumental regression. NL2SLS is one of several models using instrumental variables in the PROC model of the SAS estimating method that was used in the study. The NL2SLS model accommodates the simultaneous equation and the non-linearity in the efficiency labor function (L^e_f).[1] Table 7.2.1 presents the results of the estimation of the labor productivity of household labor on the value of agricultural production in their farm/household in the combined model. Table 7.2.3 and 7.2.4 present results of female and male labor productivity on the value of farm production separately.

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[1]See Appendix for the results of the more traditional production function model.

Table 7.2.1

Production Function Estimation Results of the Combined Model:

VARIABLE	COEFF	STD.ERR	T-RATIO	SIGNIFICANCE
Constant	4.5915	.9706	4.73	.0001
Calories	503.418***	503.91	1.00	.3195
Health (wfh)	.1354**	.0892	1.52	.1315
Labor Hours(hh)	.1574*	.0305	5.16	.0001
Labor Hours(hired)	.1486*	.0328	4.55	.0001
Bullock Hours(hh+hired)	.0121	.0295	.41	.6810
Cultivated Area	.4362*	.0749	5.82	.0001
Fertilizer	.0888*	.0300	2.95	.0995

The coefficient determination (R^2) was .81 and the adjusted (R^2) was .80

* indicates significance at 5 percent probability

** indicates significance at 10 percent probability

*** indicates significance at 20 percent probability

The coefficient of calories for male and female adult workers was of the positive sign but significant only at the 20 percent level of significance using one-sided t-distribution. Weight-for-height was found to be of the correct sign and was significant at 10 percent level of significance. The health of the household workers affected the value of the productivity of the farm household. The more the weight-for-height measure of the household members the higher the value of output. The household labor hours was of the expected positive sign and was significant at .005 percent significance level. The more hours the family labored on the farm, the higher was the value of output of the farm. Hired labor hours were also found to be significant at .005 percent indicating that hiring more labor hours for farm work increased the value of output.

Family owned and hired bullock hours was positive but not significant. Examination of the data set reveals that the average use of hired bullock hours was only 374 hours compared to family bullock hours which averaged to 1244 hours. Most households that consistently used family bullock hours did not hire bullock for farming purposes. Both cultivated areas and fertilizers were positive and significant at .005 percent level, supporting the higher usage of fertilizer and cultivated land led to higher value of output.

Any estimated regression equation should be capable of explaining the sample observations of the dependent variable (Y) with some degree of accuracy; the better the fit of the equation, the closer the estimated Y will be to the actual Y. The coefficient of determination is the R^2. The higher the R^2, the closer the estimated regression equation fits the sample data and is a measure of "goodness of fit". A value of R^2 close to one shows a "good" overall fit , and value near zero reflects a failure of the estimated equation to fit the sample data. (Pindyck and Rubenfeld,1980; Johnston ,1970). The R^2 was .81 and the adjusted R^2 was .80 which is considered very high for a household sample like the one used in the study. An R^2 of .50 is generally considered very good for cross-sectional sample. Therefore, it can be concluded that the exogenous variables explain 80 percent of the variations in the dependent variable.

Table 7.2.2

Production Function Estimation Results of the Female Model:

VARIABLE	COEFFICIENT	STD.ERROR	T-RATIO	SIGNIFICANCE
Constant	4.1263	.8007	5.15	.0001
Calories	1123.69**	861.37	1.30	.1941
Health (wfh)	.0962	.1263	.76	.4478
Labor Hours(female)	.1404*	.0539	2.60	.0102
Labor Hours(male)	.1616*	.0640	2.52	.0127
Labor Hours(hired)	.1517*	.0321	4.73	.0001
Bullock (hh+hired)	.0062	.0306	.20	.8388
Cultivated Area	.4545*	.0681	6.67	.0001
Fertilizer	.0846*	.0311	2.72	.0074

The coefficient of determination (R^2) was .80 and the adjusted (R^2) was .79.

* indicates significance at 5 percent probability

** indicate significance at 10 percent probability

The coefficient of the caloric variable for adult female workers was of the expected positive sign and was significant at the 10 percent level of significance for one-sided t-distribution. Caloric intake of the females was statistically significant for increasing the value of agricultural productivity in their households. The more calories the female members of the household consumed the more value of output was generated on the farm. Furthermore, this supports the Efficiency Wage Hypothesis that calories, via the efficiency function h(c), affects the productivity of labor hours and thus the value of the output of the farm. Health, weight-for -height, was found to be of the correct sign (positive), but was not statistically significant for female workers. Being physically bigger did not affect their labor efficiency. The number of female labor hours was of the expected sign , that is positively related to the farm output and was significant at the 0.005 percent significance level. The more hours females worked on the farm, the higher was the value of output. Male labor hours was also significant at the 0.01 percent indicating that male labor increased the value of output of the farm. Hired labor hours was significant at .005 percent.

Family owned and hired bullock hours were positive but not significant. Both cultivated area and fertilizers were of the expected positive sign and highly significant. Fertilizer use was significant at the .005 percent level, indicating that a higher usage of fertilizer lead to more output. The coefficient of cultivated area was significant at the .005 percent level.

The R^2 was .80 and the adjusted R^2 was .79 which is considered very high for a household sample like the one used in the study. Therefore, it can be concluded that the independent variables explained 79 percent of the variations in the dependent variable when the efficiency of the females labor hours was tested separately.

Table 7.2.3

Production Function Estimation Results of the Male Model

VARIABLE	COEFFICIENT	STD.ERROR	T-RATIO	SIGNIFICANCE
Constant	4.28	1.04	4.11	.0001
Calories	-891.59	1736.5	-.51	.6084
Health(wfh)	.3521*	.1509	2.33	.0210
Labor hours(male)	.0668**	.0518	1.29	.0001
Labor hours(female)	.1326*	.0403	3.29	.0001
Labor hours(hired)	.1668*	.0343	4.85	.0001
Bullock (hh+hired)	.0411**	.0303	1.36	.1768
Cultivated Area	.4522*	.0781	5.79	.0027
Fertilizer	.0965*	.0316	3.05	.0001

The coefficient of determination (R^2) was .82 and the adjusted (R^2) was .81.

*   significant at 5 percent probability

** significant at 10 percent probability

The coefficient of all the variables estimated, except calories, had the expected positive sign, in the model in Table 7.2.3 where the efficiency of male labor was tested separately. Unlike the model for female workers, the coefficient on caloric intake was not significant. On the other hand, the health variable (weight-for-height) was significant at the .01 percent level. Thus, the hypothesis that the health of the adult male workers affects their productivity on the farm is not rejected. Some rigorous farming tasks require strength and more body weight for efficient performance. A higher weight-for-height adds to the male efficiency of their labor hours. The number of male labor hours was significant at the 10 percent and female labor hours was significant at the .005 percent level. Increasing male and female labor hours would increase the value of the farm output. Hired labor hours were found to be significant at the .005 percent level of significance. This indicated that if more hired and own farm labor hours were available more output would be generated.

The farm and hired bullock hours' coefficients was significant at the 10 percent level. Similar to the female and the combined model the coefficients of both fertilizer and cultivated area were significant at .005 percent level of the t-statistics.

The coefficient of determination, R^2 was .82 which is very high similar to the female and the combined model.

7.2.3 Interpretation of the Estimated Coefficients

To determine how the changes in the explanatory variables would affect the value of productive output the following mathematical analyses were carried out to derive the marginal product and elasticity coefficients.

Marginal Product

Marginal product shows the change in output with one unit change in input. To calculate the marginal product with respect to calories (∂Y/∂C), equation 4.7 was rewritten, taking the anti-log, as follows:

$$Y_i = \exp\{\alpha_0 - \beta/C - \varphi/H + \alpha_1 \ln L^f_{ij} + \alpha_2 \ln L^f_{ij} + \alpha_3 \ln L_{ih} + \alpha_4 \ln B_i + \alpha_5 \ln B_{ih} + \alpha_6 \ln CA + \alpha_7 \ln F_i\} \quad 7.2.1$$

Since all variables except calories, C are held constant , the above equation can be written as:

$$Y = \alpha' \exp(-\beta/C) \quad 7.2.2$$

$$\partial Y/\partial C = \alpha'[\exp(-\beta/C)](\beta/C^2)$$

$$= Y\beta/C^2 \quad 7.2.3$$

Similar mathematical steps were followed to determine the marginal product of health, that is, a unit change in the health variable (H) and its effect on output (Y). The following was derived.

$$\partial Y/\partial H = Y\varphi/H$$

For the rest of the explanatory variables which are expressed in the logarithmic form, such as farm labor hours, equation 7.2.1 is written as:

$$Y = \exp(A_1 + \alpha_2 \ln L_{ij})$$

where A_1 equals all other variables held constant

or $$Y = \alpha' \exp(\alpha_2 \ln L_{ij}) \quad 7.2.4$$

Marginal product of output with respect to labor hours is given by $\partial Y/\partial L_{ij} = Y/L_{ij}\alpha_2$

7.2.5

Table 7.2.4 illustrates the marginal productivity estimation for all inputs in the production of output from the male and the female models. For example, an extra calorie consumed by female workers increased the value of output by 1.14 Rupees.

An extra hour of efficient female labor increased the value of output by 3.08 Rupees while an extra unit of efficient male labor hours increased the value of output by 0.71 Rupees.

Elasticity

Elasticity measures the percentage increase in output for one percent increase in input. The calorie elasticity coefficient is given by $(\partial Y/\partial C)(C/Y)$. Substituting the value of $\partial Y/\partial C$ from equation 7.2.3:

$$(\partial Y/\partial C)(C/Y)=Y(\beta/C^2)(C/Y)$$

$$= \beta/C \qquad 7.2.6$$

Similar steps were followed to derive the health elasticity coefficient as follows:

$$(\partial Y/\partial H)(H/Y) = \varphi/H \qquad 7.2.7$$

For other variables in the logarithmic form, such as labor hours, using equation 7.2.5, elasticity coefficient is given by

$$(\partial Y/\partial L_{ij})(L/Y) = (Y\alpha_2 /L)(L/Y)$$

$$= \alpha_2$$

Table 7.2.5 illustrates elasticity coefficients for all the inputs in the production of output from the male and female models. For example, a 10 percent increase in female worker caloric intake increased the value of output by 4.5 percent. A 10 percent increase in the weight-for-height for male workers increased the value of output by 11.6 percent.

Table 7.2.4

Interpretation of the Estimated Coefficients in terms of Marginal Product

Variables	Marginal Product*	Numerical Value	
		Female	Male
Calorie	$Y\beta/C^2$	1.14	----
Health	$Y\varphi/H^2$	----	25,588
Female Labor Hours	$Y\alpha_1/L_f$	3.08	2.96
Male labor Hours	$Y\alpha_2/L_f$	1.62	.71
Hired Labor Hours	$Y\alpha_3/L_h$	1.13	1.15
Bullock Hours	$Y\alpha_4/L_b$	----	1.04
Cultivated Area	$Y\alpha_5/CA$	183.34	181.53
Fertilizer	$Y\alpha_6/F$	5.84	6.14

* Marginal product was calculated at the mean values

--- coefficient not significant

Table 7.2.5

Interpretation of the Estimated Coefficients in terms of Elasticity Coefficients

Variables	Elasticity	Numerical value	
		Female	Male
Calorie	β/C^*	.45	----
Health	φ/H^*	----	1.16
Female Labor Hours	α_1	.14	.13
Male labor Hours	α_2	.16	.07
Hired Labor Hours	α_3	.15	.17
Bullock Hours	α_4	----	.07
Cultivated Area	α_5	.45	.45
Fertilizer	α_6	.08	.10

* elasticity was calculated at the mean values

---- coefficient not significant

8. SUMMARY AND CONCLUSION

This dissertation examined the relationship between nutrition (calorie consumption), health, and labor productivity of adult males and females and the value of output on farm households in India. In a subsistence economy there is a premise that a certain minimum food consumption is necessary to increase the productivity of workers which in turn affects the output level. Their food consumption depends on the output produced. The Efficiency Wage Hypothesis was used to postulate the relationship between calorie consumption and efficient labor hours. The literature reviewed identified prior research on productivity and caloric consumption (nutrition). The model in this study further developed the Efficiency Wage model by using an anthropometric measure of health to investigate if health and caloric consumption resulted in more productive labor hours, thereby affecting the value of the output of the farm household.

The conceptual model included a consumer-cum-producer household model based on the Becker model of household economics. Since this thesis was measuring the relationship between caloric consumption, health and value of output, the relevant equation for estimation was the production function. An exponential functional form was used to explain labor efficiency function which was hypothesized to have an 'S' shape by the Efficiency Wage Hypothesis. The labor efficiency function showed how caloric consumption and health variables produced efficient labor hours which in turn would generate more output through the production function estimation.

The chapter on the empirical specification showed the dual causality between consumption and production of output, that is, more consumption led to more output which in turn provided more food for consumption for the household. A simultaneous equation system was specified to depict this relationship between output and consumption. The simultaneous equation system results in biased and inconsistent estimates of the parameters. Therefore, an instrumented two-stage was adopted for estimating the production function in order to avoid the problems of inconsistency and bias.

The production function was inherently non-linear, thus, the instruments used were of second order terms of exogenous variables together with the "elementary" set of instruments that were assumed to be highly correlated with calories. The parameters of the equation were non-linear and so an unaugmented linear set of instruments were unable to pick up the pattern of non-linearity. The results obtained with the quadratic form of instruments showed improvement over the linear instruments.

From the results of the empirical estimation of the production function of the female model, caloric intake of the females was statistically significant for increasing the value of the output of the households. This result supports the Efficiency Wage Hypothesis that calories affect the labor efficiency of labor hours and thus the output of the farm. In the six villages under study, women's labor was concentrated on seven types of work, namely, nursery bed raising, transplanting, planting, weeding , harvesting and threshing. Women's labor was greater than men in operations such as transplanting paddy and hand weeding (Walker and Ryan, 1990). All these operations require high energy expenditure. These activities do not necessarily require large physical stature as represented by the weight-for-height measure. The empirical results also showed that value of the output was not affected by the health of the female workers as measured by weight-for-height.

The hypothesis that an increase in family and hired labor hours would increase the farm output was supported by the significance of the coefficients of these variables in the estimation of the combined household model, female model and male model. Family farm labor affected the output positively and was significant. Hired labor significantly added to the value of output. Average labor force participation in the VLS was measured by Walker and Ryan(1990) as the proportion of time spent on one's own farm, in labor market and seeking employment. The mean estimate across the six villages of female labor force participation rate was .40. The average labor market participation rate excluding own-farm work was .37 for female workers and .30 for men. The mean estimate of the average labor force participation of male workers was .42 and the labor market participation rate was .30 (Walker and Ryan,1990). Women engaged in the daily market considerably more than men in the villages of Mahabunagar and Kinkheda, while Dokur had the highest female market participation in 1976. Women workers from large farm households participated in the daily labor market in Dokur supporting that notion that paddy irrigation resulted high demand for women labor. Walker and Ryan's study also shows that women's labor force participation increased as the population density of the village increased.

Fertilizer and cultivated area added to the value of output as predicted by all three estimating models. These are more traditional inputs into the agricultural production and these inputs are generally used in agricultural production to augment output level.

The estimation of the production function of the male model showed that health (weight-for-height) positively affected the value of output. Current caloric consumption of the male workers did not, however, affect the labor efficiency or the value of output. Walker and Ryan (1990) state that male workers were engaged in nine major operations, four of them involving bullock power. The other tasks were plowing, dung transport, well digging, bund making, sugar cane tying, and pesticide application. Most of these tasks require large physical stature and strength as reflected by the weight-for-height measure. The results of this empirical study supported the hypothesis that health affects the productivity of male labor. These tasks performed by the men in these villages also required high energy expenditure but the study found that current caloric intake of male workers did not add to the value of output.

Strauss (1984) using a normalized calorie intake found calories to be significant in the productivity measure. The weakness in the study was that individual level caloric intake was not available, therefore the market availability was converted to an average per family worker. The absence of health measure in Strauss's study made it difficult to distinguish the effect of past nutritional deficiencies on productivity. Spurr (1983) asserted that the body size may have a separate effect from current daily caloric intake on labor productivity. Deolalikar (1986) found health to have a positive and significant effect on wages and productivity of labor.

Calorie intake was not found significant in the measure of labor productivity and wages. Deolalikar did not use a normalized version of the calorie variable. The study did not separate the male and the female data in estimating the production function. From this study it can be concluded that an increase in caloric availability and consumption by female workers increases the productivity of the farm households of this subsistence economy. If health (weight-for-height) is viewed as function of past caloric intake, then increasing the present caloric consumption of the households members would affect the productivity of male workers in the future. If weight-for- height index reflects primarily current nutritional status (Fogel,1994), then improving this current nutritional status would increase the productivity of all workers in low income economies. The Efficiency Wage Hypothesis was supported by the findings of this study.

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Appendix

Table A

Production Function Estimation Results of the Combined Model using Ordinary Least Squares Method [1]

VARIABLE	COEFF	STD.ERR	T-RATIO	SIGNIFICANCE
Constant	6.00	1.90	3.14	.0020
Calories	-0.28**	.23	-1.24	.2151
Health (wfh)	.74**	.59	1.25	.2133
Labor Hours(hh)	.15*	.027	5.42	.0001
Labor Hours(hired)	.16*	.029	5.36	.0001
Bullock Hours (hh+hired)	.021	.027	.78	.4321
Cultivated Area	.429*	.064	5.82	.0001
Fertilizer	.081*	.027	2.91	.0041

The coefficient determination (R^2) was .81 and the adjusted (R^2) was .80

* indicates significance at 5 percent probability

** indicates significance at 20 percent probability

[1] OLS clearly does not consider the endogeneity of calories.