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Nutrition and productivity among poor peasants in the Peruvian Andes

by

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This is to certify that the Master's thesis of

José Agustín Iturrios

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

DEDICATION

To my mother, María Elena Padilla Vda. de Iturrios who taught me the meaning of persistence, courage, caring and love for the life.

To the memory of my father, José Vicente Iturrios

To the memory of Martha Lucia Zuluaga

TABLE OF CONTENTS

CHAPTER I. INTRODUCTION

Around 800 million people are considered chronically undernourished in developing countries. This equals 20 % of the total population in these countries, with most of the undernourished living in rural areas. Poorer countries are expected to face severe food shortages in the next decade unless population growth is accompanied by increased agricultural production and/or increased purchasing power (Missiaen and Shapouri, 1995). Most of the suggestions to improve food production in developing countries are related to technological change in agricultural production, especially for small farmers. Little attention has been given to the study of health and nutrition as inputs into the agricultural production process. Nutritional level and health status have been considered as results but not as inputs in the productive process, even though, as Berhman (1993) points out, the returns from nutrition and health improvement are greater than the returns from education.

This study relates to the poorest region of Perú: the rural Andes. According to the Cuánto Institute (Cuánto, 1995d) income in this region is 40 % lower than the national average and 67 % lower than that of Metropolitan Lima, the country's capital city. Average per capita food consumption in this area is the lowest for Perú. The objective of this study is to test whether improved potential calorie intake has positive effect on labor productivity and agricultural output.

Chapter II reviews the relevant literature. The chapter is divided into two parts. The first part reviews the major theoretical contributions about the wage-efficiency hypothesis. This hypothesis states that for low levels of income there exits a positive relationship between nutritional level and productivity. A better nourished worker will earn higher wages because of the positive impact of nutrition on labor productivity. The second part reviews the findings of the empirical studies in this field.

Chapter III contains two parts. The first part focuses on the principal aspects of the process of energy intake and energy expenditure, primarily to determine the limits of the human body's adaptability to a chronically low level of food intake, as is characteristic of the rural Andes. The second part is a review of the main findings of the nutritional reality in the rural Andes using the primary data collected by the "Encuesta Nacional de Hogares Sobre Medicion de Niveles de Vida 1994 (ENNIV 1994)" (National Household Living Standard Survey 1994).

The model, the data base and the econometric estimation procedures and results are presented in the chapter IV. Final comments and suggestions for further research are founded in chapter V.

CHAPTER II. LITERATURE REVIEW

This literature review is divided in two sections. The first section introduces the nutritional-based wage efficiency hypothesis with a short review of the most important contributors: Leibenstein, Mirrlees, Stiglitz, and Bliss and Stern. Currently the wage-efficiency hypothesis covers a wide spectrum of theories but its original development by Leibenstein was confined to nutritional-based wage efficiency. Riveros (1994) wrote an interesting summary of the different forms of the wage-efficiency hypothesis and its relevance for analyzing the labor market in developing countries.

The second section summarizes important results between nutrition and productivity. Theoretical and empirical problems typical for this type of research will be explored.

The Wage-Efficiency Hypothesis.

Several authors (Mirrlees, 1976; Bliss and Stern , 1978a; Haddad and Bouis, 1991) recognized that it was Harvey Leibenstein who initiated an innovative treatment of the relationship between consumption and production in his book Economic Backwardness and Economic Growth (Leibenstein, 1957). He tried to find an explanation for the existence of a surplus of labor and the observation that those who work in agriculture receive non-zero real wages, whereas with perfect competition wages should be equal to zero. An answer to this paradox is the distinction between the supply of labor time (that is man-hours or man-years) and the supply of work (or effort). Units of work depend on the nutritional status of the worker, which in turn depends on the wage or income received by the worker. Different wages can therefore generate different quantities of work or effort forthcoming. In Figure

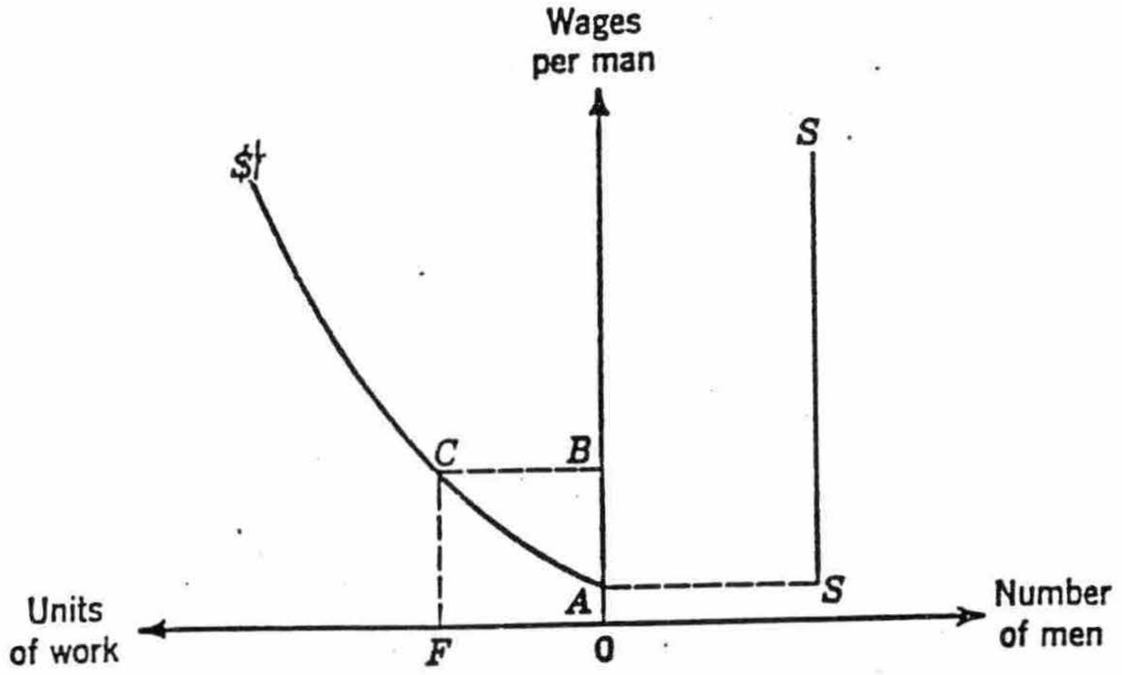

Figure 2-1. Supply of workers and supply of units of work under Leibeinstein wage-efficiency hypothesis.

2-1 quantity supplied of labor time (measured as the number of men) is inelastic in the short run, but the units of work or effort are increasing as wage rates and consumption increase. The average productivity and the marginal productivity of workers as a group will therefore also depend on their wages. As Leibenstein points out " ..the higher the wage the higher the per capita productivity for the group, because the higher the wage the greater the units of work per man"(Leibenstein, 1957, p.67). Because level of effort depends on the level of consumption, it also depends on wage rate, assuming there is no other source of income. Consequently there will be a family of average and marginal productivity curves for any group of laborers. In Figure 2-2 we observe a set of average productivity curves. AP_1 is the average productivity for a lower wage (w_1), AP_2 is the average productivity for a higher wage (w_2) and AP_3 for an still higher wage (w_3). The average productivity curves have the same shape as in neoclassical theory, expressing increasing and then diminishing returns, with the only difference that for any given number of workers, the higher the wage, up to some point, the higher the output. The relationship between marginal productivity of work-units or effort and marginal productivity per-man and wage is an important answer to observed underemployment in densely populated rural areas. In Figure 2-3 we show the relationship between two marginal productivity curves. MP_2 is the marginal productivity curve for a higher wage w_2, and MP_1 is the correspondent one a lower for wage w_1. When the wage equals w_1 we observe an excess demand for labor: the quantity demanded of labor (wage = marginal product) is equal to OA and the quantity supplied of labor is equal to OS. How does this happen? At this low level of wage rate w_1 the marginal product per final unit of work and per worker is larger than the wage rate. Additional workers will be hired before the marginal product declines sufficiently to equal the wage rate. With the wage w_1 sufficiently low the marginal product of labor at full employment, SC, is positive. What occurs when the wage is relatively high? Each newly-hired worker now contributes a lot of units of work. The

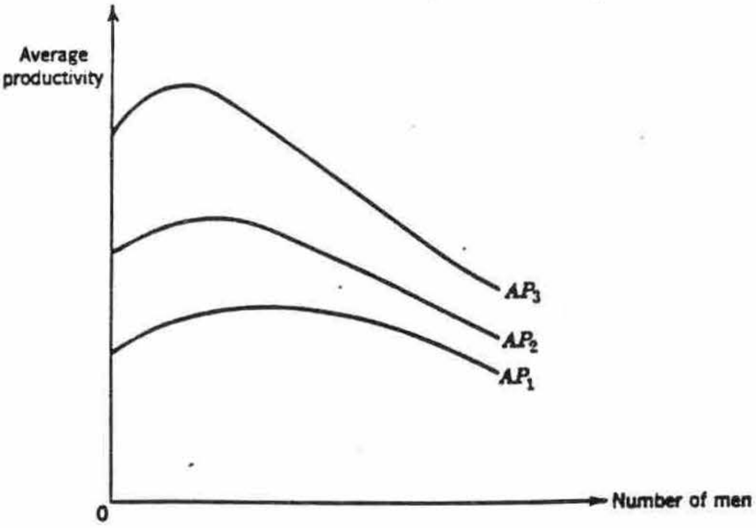

Figure 2 -2. Average Product of different wages.

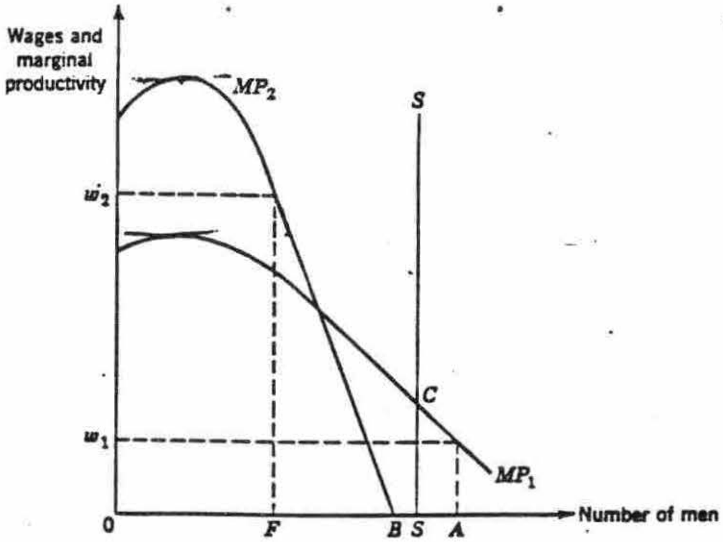

Figure 2-3. Marginal products of different wages and supply of workers

marginal product per final unit of work and per workers declines rapidly until it reaches equality with the wage rate. In this case we observe a surplus of labor, because the quantity demanded of labor would equal OF, versus a quantity supplied equal to OS. The marginal product at full employment will equal zero or less (point B). Leibenstein concluded:

> at very low wages there may be a labor deficit because the units of work produced per man are so few. But at higher wages the units of work per man increase so rapidly that a labor surplus is created. For the underdeveloped areas this may mean that the allegedly observed manpower surpluses in agriculture do not really exist when wages are very low, but they do indeed become a fact when wages increase sufficiently (Leibenstein, 1957, p.69).

An important consequence of the wage-productivity relationship is that under certain circumstances it is better for the employer to pay a real wage above the competitive level, i.e. above the marginal product. To demonstrate this it is necessary to derive the appropriate demand and supply curves for our wage-efficiency labor market. As neoclassical theory postulates the optimum demand level of labor is reached when the nominal wage is equal to marginal value product of labor. We will therefore have one optimal point of labor demand for each marginal product curve. The locus of such points will be our demand curve for labor. It connects all optimal employment points according to the above rule of maximization and corresponds to the OE curve in Figure 2-4. In the short run the supply curve is represented by the vertical line SS. There will be a surplus of labor at higher wages, and a deficit at lower wages. For every wage rate and related point on the OE curve, there exits a corresponding net revenue , called optimum employment revenue, as represented by the OR curve on the left side of Figure 2-5. But assuming that the whole labor force is employed we obtain the full employment revenue curve, FR (Figure 2-5). Both OR and FR have a segment which increases with the wage rate, because "as wages increasing, as effort per man grows, and as the optimum number of men decline, overhead costs per unit of work decline accordingly, and, as a consequence, we would expect net revenue to rise" (Leibenstein, 1957, p.73). Beyond a specific point higher wages cause net revenue to decrease, because the units of work done per man will increase less than proportionately with wages. At wage w_4 the employers maximize their net revenue, resulting in a surplus in the labor market measured as a number of men (right side of Figure 2-5). At this point the pressure of the competition would bring the wages down to w_2, where demand and supply coincide. Wage w_2 creates a net revenue equal to OL, but with a wage equal to w_3 employers' net revenues will increase to OM (the maximum point on the full employment revenue curve). Given the existence of a wage (or consumption)-productivity relationship, then from the employers' point of view it will be advantageous to employ the entire labor force, even if a part of it is surplus, because it will increase their net revenue. This then could explain the occurrence of a positive wage rate in densely populated areas with a of surplus of labor.

The key of Leibenstein's theoretical development is that for sufficiently low income areas there exists a positive relationship between nutritional level and productivity of the workers. Above a minimum wage necessary to sustain life in the labor force, the number of units of work supplied will increase gradually as wage rates and consumption rise, however beyond a specific point, increases in consumption are unlikely to add appreciably to health,

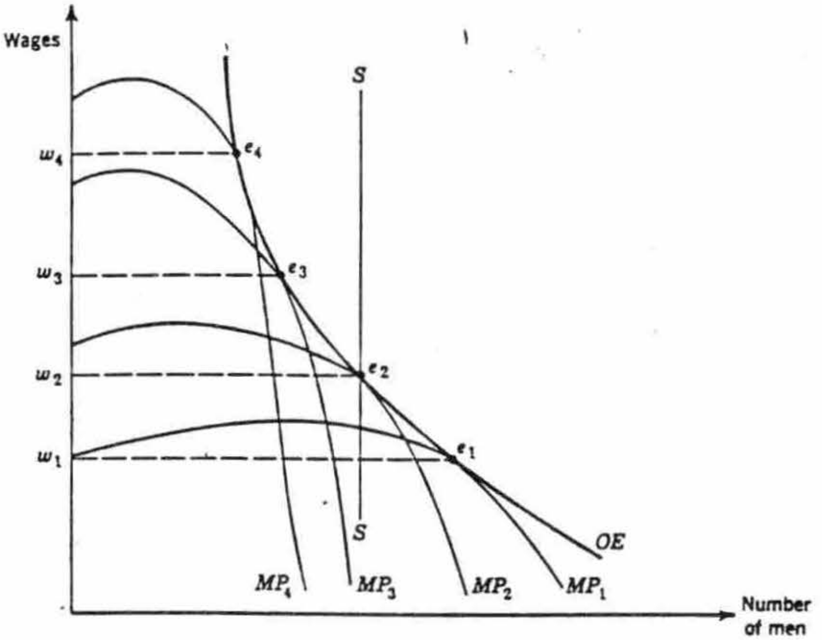

Figure 2-4. Derived demand of units of work

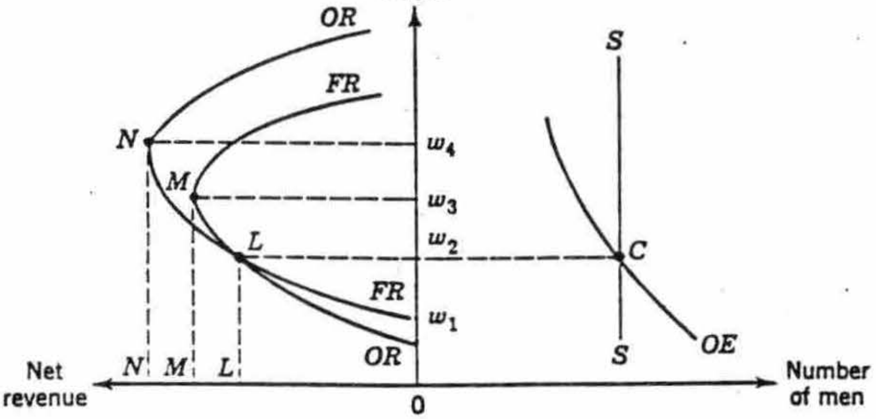

Figure 2-5. Equilibrium in the rural labor market under the wage-efficiency hypothesis developed by Leibenstein

vigor, and vitality of the average worker so that the work performed per unit of time is no greater than at the lower wage (Leibenstein, 1957).

In "A pure theory of underdevelopment economies" Mirrlees (1975) extends the nutrition-based wage efficiency hypothesis. He assumes profit-maximizing employers and a production function which depends on the effective units of labor. To define this effective unit of labor Mirrlees assumes that the quantity and quality of the labor a worker provides can be measured by a single number, *h,* which is a function of the wage, *w*, he receives. This results in the following equation:

$$y = f[\, n \;\; h\,(w)\,]$$

where *n* is the number of men working and *h (w)* is the effective labor function. The production function is subject to constant returns and diminishing marginal product. Mirrlees hypothesizes the shape of an effective labor function as drawn in Figure 2-6, with a first segment showing an increasing marginal product and a second one with a decreasing marginal product. He argues "the shape is plausible - as the production function for a typical piece of capital equipment designed for relatively specific purposes - consistent with such scant evidence as I have seen, and broadly necessary if the theory is to have any interest" (Mirrlees, 1975, p.85). Given this the profit function will be:

$$\Pi = f[\, n \;\; h(w)\,] \; - \; n\,w\,.$$

The employers not only can choose the number of workers that they want to hire in order to obtain some amount of production, but they also set *w* , the wage time rate. They could pay more than the supply price of laborers, but in absence of a productivity-wage relationship they would have no reason to do that. We can rewrite the profit function as:

$$\Pi = f[\,n\ h(w)\,] - n\,h(w)\,.\,w\,/\,h(w).$$

The last part of the second term is very important in Mirrlees's argument. To maximize their profits employers can choose wage w which makes $w\,/\,h(w)$ (the cost per unit of effective labor) as small as possible and then choose nh to maximize his profits. In Figure 2-7 one can see that $w\,/\,h(w)$ is the smallest possible when the tangent to the h-curve passes through the origin, at this point $w = c^*$. If the supply price of laborers is above c^*, the employer cannot do better than pay the supply price, but if it is less than c^*, he will not pay less than c^*. Thus , the profit maximizing rate will be:

$$w = \text{Max}\,(\,c^*,\ w_S\,),$$

where c^* maximize h/w (the yield per cost of unit of labor) and w_S is the supply price of labor. Hence we may conclude that "where there is a fixed supply of laborers available, and a number of factories, the supply price of labor will be greater than c^* only if there would be an excess demand for labor by producer were the wage is equal to c^*. If on the contrary there is an excess supply of labor when $w = c^*$, the supply price of labor is lower, but it ceases to operate: we have an equilibrium with unemployed laborers who do not choose to be unemployed…the 'efficiency wage' notion introduces a new concept of equilibrium…we can think of the supply and demand for labor, rather than the supply and demand for laborers" (Mirrlees, 1975).

Like Leibenstein and Mirrlees, Stiglitz (1976) wondered about the coexistence

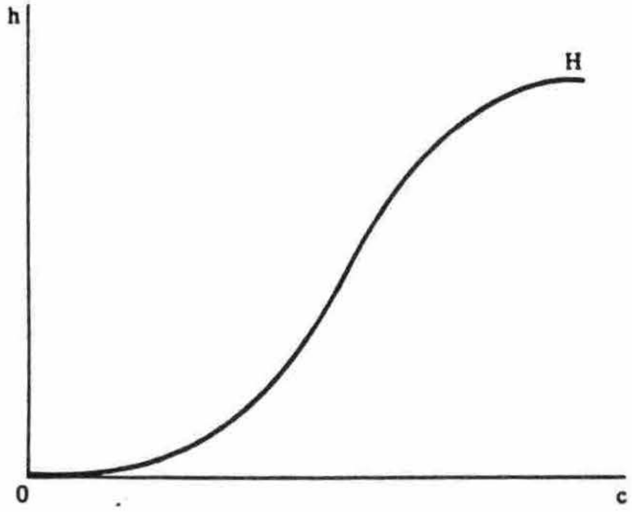

Figure 2-6. Wage-efficiency curve by Mirrlees

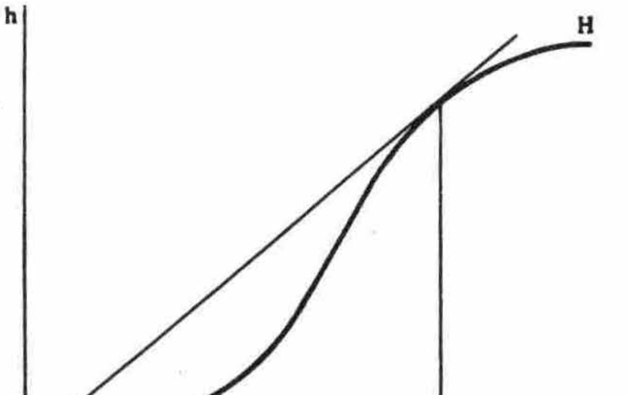

Figure 2-7. Efficiency wage determination

of unemployment with a positive (although low) wage for hired laborers in developing countries. He too offers the efficiency wage hypothesis as an explanation (Stiglitz, 1976). If w is wage received for a worker, then $\lambda(w)$ will be the index of efficiency which will correspond to this wage. The shape of $\lambda(w)$, or efficiency curve, is shown in Figure 2-8. Stiglitz, like Mirrlees, hypothesizes "a region of increasing returns to scale where, as the individual is brought the 'starvation' level, additional increments in wages result in increasing increments in efficiency, although eventually diminishing returns set in" (Stiglitz, 1976, p.187). The wage cost per efficiency unit equals: $\theta = w / \lambda$. To minimize this we set the derivative of θ with respect to w equal to zero:

$$\delta\theta / \delta w = 1/\lambda - \lambda' w / \lambda^2 = 0$$

$$\lambda' = \lambda / w$$

This expression represents the *efficiency wage*, as a ratio between the efficiency labor function and the market wage, or, the slope of the efficiency curve. In Figure 2-8 it is indicated as w^*. If we reverse the axes we obtain a different interpretation of the efficiency wage curve i.e. the wage required to obtain a given number of efficiency units from an individual. Stiglitz refers to this as the wage-requirements curve and it is show in Figure 2-9. Assuming the same framework as Mirrlees (1976), it implies that agricultural output depends on the number of efficiency units of labor provided and not directly on labor time. Examining various institutional scenarios, - output maximizing farm, rent maximizing plantation farm, egalitarian and utilitarian family farms -, Stiglitz developed conclusions about income distribution and unemployment in the agricultural sector of developing countries. They are

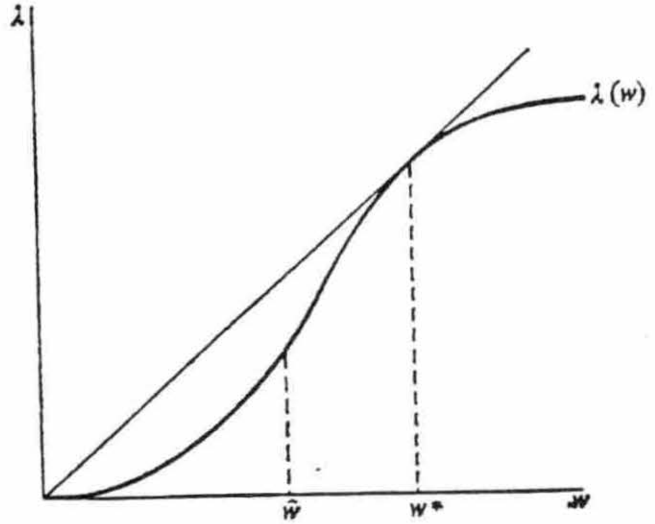

Figure 2-8. Wage-efficiency curve by Stiglitz and efficient wage determination.

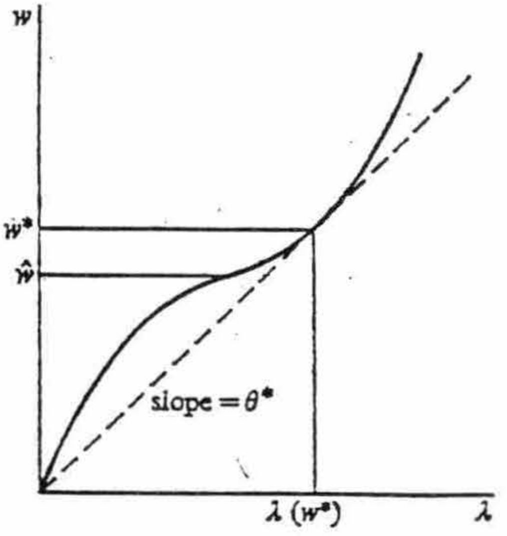

Figure 2-9. Wage-requirements curve

beyond the scope of this research. We nevertheless want to comment on the shape of the wage-efficiency curve assumed by Mirrlees-Stiglitz models. Rosenzweig noted that "the non-convexity in the Mirrlees-Stiglitz function gives rise to a number of theoretical oddities, including the implication that an unequal distribution of consumption among family members may be optimal even when the family welfare function is additive in family members' utilities" (Rosenzweig, 1988, p. 722). Other authors (Bliss and Stern, 1978a, 1978b) specified a strictly convex shape starting on the positive range of the x-axis (Figure 2-10). The selected positive level of food consumption can be considered as the minimum biological subsistence level. Rosenzweig (1988) mentions that either shape provides an explanation for the coexistence of unemployment and a downwardly rigid real wage rate.

Bliss and Stern (1978a, 1978b,1978c) made additional contributions to the nutrition based wage efficiency hypothesis. They explore a case where an agricultural employer has the opportunity to employ two different types of workers, landowners and landless workers. They conclude that landowners will receive lower wages as hired workers than landless workers, because the former have an additional source of consumption and they are therefore more efficient than landless laborers. The differences in wages equalize the degree of efficiency of these two types of workers. Workers owning land will be hired before landless workers, because they are less expensive for the employer. If there is some degree of unemployment it will be among landless workers. Above conclusions assume a monopsonistic labor market (Bliss and Stern 1978b). Nevertheless in a competitive market there will remain differences in wages rates between workers with different levels of nutrition. Given the competition among employers competition the paid per-unit of effort or

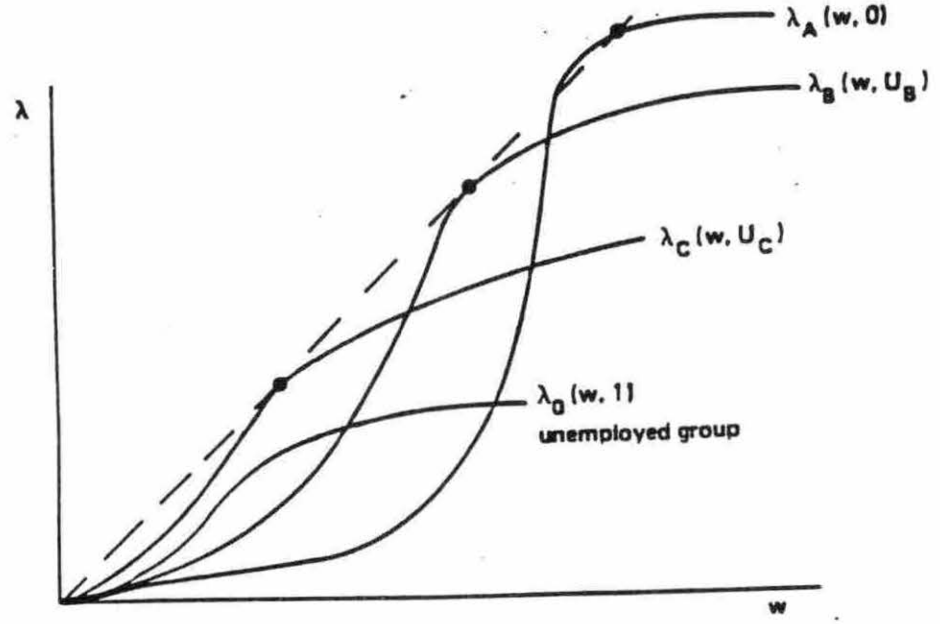

Figure 2-10. Different wage-efficiency curves for workers with different levels of productivity (consumption) under perfect competition.

work is uniform. Therefore workers with access to a supplemental source of consumption, i.e. workers who have own land will receive a higher time wage rate. Figure 2-11 shows four different efficiency labor functions for different kinds of workers given a competitive market for effective labor. Stiglitz observes that in a competitive market with groups with distinct wage-productivity curves, group specific unemployment rates will adjust to ensure that in

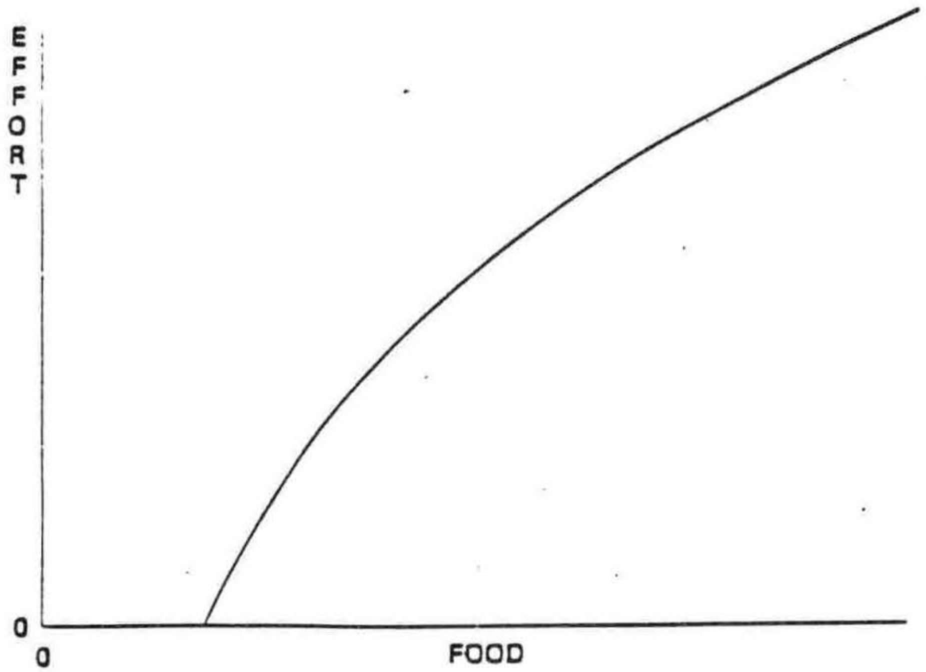

Figure 2-11. Wage-efficiency curve by Bliss and Stern approach.

equilibrium all groups which are partially employed receive the same per efficiency unit. Fully employed groups will have higher wages reflecting higher productivity. Low productivity groups may be totally unemployed (Stiglitz, 1988).

Bliss and Stern (1978a, 1978b, 1978c) also expanded the analysis of the wage-efficiency hypothesis to the supply side. They therefore address the work-consumption decisions of the workers in the context of the wage-productivity hypothesis. Above the subsistence wage level a worker has the option of choosing between work and leisure. The wage-efficiency curve developed by Mirrlees and Stiglitz is transformed into a concave curve having the same shape as that postulated by Leibenstein (see Figure 2-1). This curve represents the consumption frontier of the worker, but unlike the Mirrlees and Stiglitz approach, inside the frontier we find a set of indifference curves indicating that the typical worker, given a base level of consumption must make a choice between more or less consumption or more or less work effort. As these authors mention " (the Mirrless-Stiglitz model) portraits the worker as a passive respondent in the determination of wages and effort. There are in the model no preferences between working harder and eating more on the other hand, and working less hard and eating less on the other" (Bliss and Stern 1978a, p. 6). This is shown in Figure 2-12. The solid concave curve will be the function which relates consumption and efficiency units of work. In the Bliss-Stern approach, the solid concave curve will relate consumption (vertical axis) and number of tasks (horizontal axis), i.e. work effort. The broken lines are indifference curves inside the consumption set which are derived from an utility function with consumption and number of tasks as components. Each task has some announced price 'p', so the worker-consumer tries to maximize his utility function subject to the price line or budget constraint. Thus at the optimum, the indifference curve is tangential to the budget constraint. The line showing how the optimum levels of consumption and number of tasks vary with price 'p' is called the offer curve. With the introduction of a worker-consumer decisions framework we now have in Figure 2-13 a curve of the supply of work units

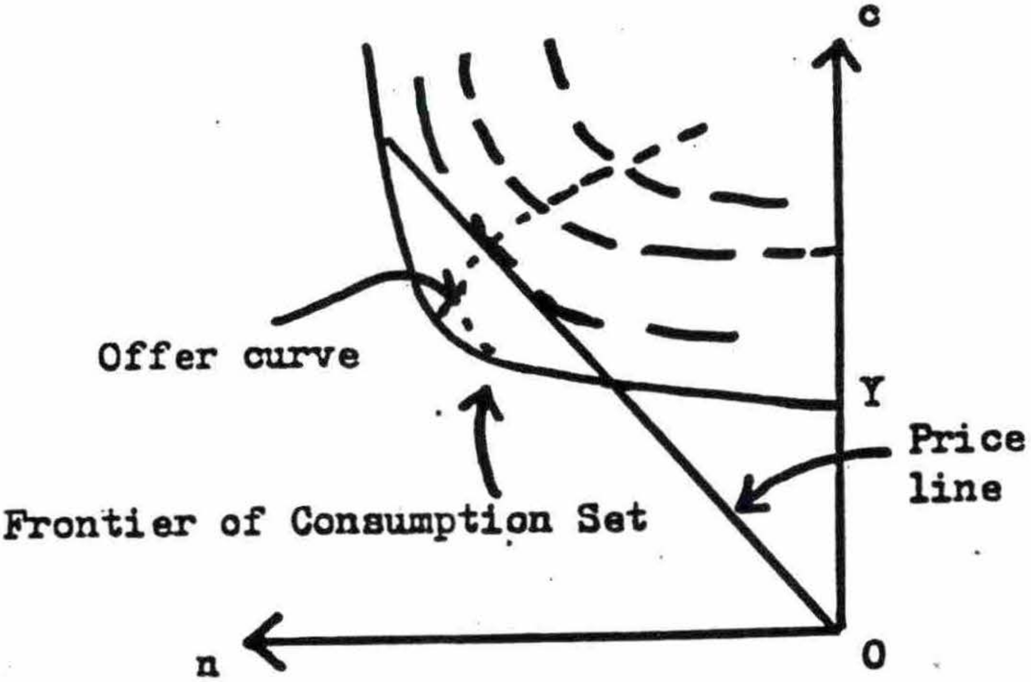

Figure 2-12. The standard model of choice developed by Bliss and Stern for the consumption-effort relationship.

(number of tasks). At price p_y the employer will obtain less units of work than at the price p_t. From the employers point of view the best option is to bring the workers to the frontier of consumption x_h. This yields is the same result as the nutritional-based wage efficiency hypothesis by Mirrlees and Stiglitz.

The key to the nutritional-based efficiency-wage hypothesis is the technical association between a worker's consumption and his work effort per-unit of time. The

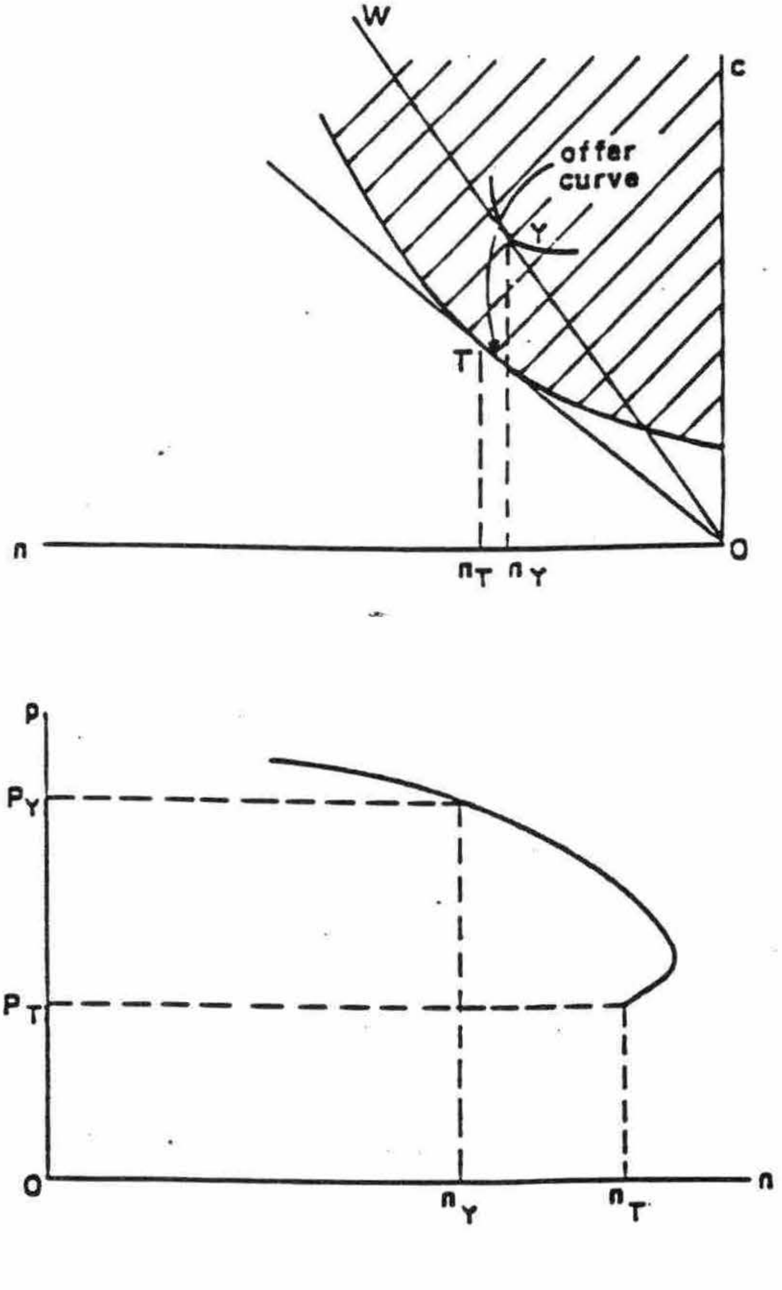

Figure 2-13. Offer curve of task and supply of effort (work) under Bliss and Stern approach

production function is modified in such a way that output depend on labor effort rather than labor time. According to Rosenzweig "in its simplest form, the efficiency wage theory assumes that the consumption of all workers is provided solely out of wage income, there is no lag between productivity and consumption, and employers can appropriate all of the additional effort induced by the wage increase" (Rosenzweig, 1988, p.722). This theory predicts long-term contracts between workers and employers and the provision of meals directly to the worker as part of these long-term contracts. In this context a profit maximizing firm selects the optimal level of efficient units of labor which maximizes its profits, i.e. both the optimal number of workers and the wage paid. Operationally the wage which minimizes the cost per efficiency unit of labor will correspond to the tangent between a straight line through the origin and the efficiency labor function. At the efficiency-wage the cost per-unit of efficiency labor is at a minimum or, what is the same, it maximizes the yield per unit of cost of labor. Firms that pay time wages below the efficiency wage will experience decreased profits. If the efficient-wage model is modified to include workers with different sources of consumption, then the model predicts diversity in wages among workers in order to achieve the uniform efficiency per-worker. Bliss and Stern (1978c) mention that the model predicts sticky real wages in the context of long term contracts in order that the employers may appropriate the benefits of a better nourished labor force. Finally as Rosenzweig concludes, "it is clear that a nice feature of the nutrition-based efficiency wage model is its large number of testable implications. Despite this, there have been few direct tests of the predictions of the theory ...There are number of different tests possible. The most basic would be to test if productivity is positively related to food consumption" (Rosenzweig, 1988, p.725). This is precisely the topic of the second part of this literature review and also the principal goal of the research presented in chapters 4 and 5.

Nutrition and productivity studies

Several studies (Bliss and Stern ,1978b; Popkin, 1978; Berhman and Deolalikar, 1988; Korjenek, 1990, 1992; Berhman, 1993; Sorkin, 1994) summarize the principal findings of research into the linkage between nutrition and productivity. Sorkin (1994) and Berhman (1993) divide these studies in two groups: experimental and non-experimental studies based on socio-economic surveys. We will use that classification.

Experimental Studies

Leibenstein's work (Leibenstein, 1957) was based on experimental studies conducted in Germany between 1942 and 1945 by Kraunt and Mueller (Kraunt and Mueller,1946). Nutritional supplements increased output per-worker significantly. Most recent experimental studies are also based on food supplements: Basta et al. (1979), Popkin (1978), Imminik and Vitteri (1981a,1981b), Wolgemuth et al. (1982), Martorell (1993).

Basta et al. (1979) studied the impact of iron deficiency anemia on the productivity of adult male workers in a rubber plantation in Indonesia. Output of workers with anemia was significantly lower than that of healthy workers. As they were paid by piecework anemic workers earned less income, ate less and increased their exposure to diseases, increased absenteeism leading to yet a lower income and so on. This vicious circle of undernutrition, sickness and poverty trapped these workers. Basta (1979) selected randomly 302 workers from a list of 440 workers, 152 were considered anemic and 150 nonanemic according with an hematocrit test. The treatment group received a 100 mg. of ferrous sulfate for 60 days, while the control group received an identical placebo. After the period of the treatment workers that were initially diagnosed with anemia and then received the treatment, significantly improved their productivity(tappers/day for tappers, area of trenches dug/day for weeders). Before the treatment nonanemic tappers collected an average of 18.7 % more latex than anemic tappers. After the treatment all originally anemic tappers showed a higher productivity but only those that received the iron suplementation (and not the placebo recipients) reached the level of productivity of the nonanemic workers. Nonanemic workers did not register any significant increment in average productivity, no matter whether received the iron suplementation or the placebo.

Weeders showed a statistically significant difference of approximately 20 % in productivity between anemic and no-anemic workers. After treatment there was no significant differences in output between these two groups of workers. Untreated workers did not register any change from the original situation. Additionally, in order to promote the participation of the workers an amount of 15 rupiahs was given daily to all participant when the supplement was taken. Most of this incentive was used to buy food and resulted in added 3 to 5 mg. of iron and 50 mg. of vitamin C. After the treatment was stopped, hemoglobin levels reverted in the placebo group but were unchanged in the iron treated group.

Results of the Basta et al. are interesting from the perspective of the wage-efficiency hypothesis, but we must mention the following. The changes in productivity referred to are measures of average productivity of labor not marginal productivity of labor. The wage-efficiency hypothesis refers to marginal productivity of labor. It must measure how much an additional unit of food supplementation increases total 'output' of labor, effort or efficiency. It is not easy to derive a correct measure of the marginal productivity of labor from experimental studies. Basta et al. (1979), based on above results, calculated a benefit/cost ratio for this kind of intervention equals to 260:1. Berhrman mentions that "this ratio appears to be exaggerated as a guideline for decisions by not incorporating the cost of identifying who is anemic, by attributing the entire value of the extra latex to labor productivity, by not incorporating into the calculation the cost of attrition … and by not adjusting for the result that only piece-work laborers seemed to have differential gains from taking iron versus the placebo" (Berhrman 1993, p.1753).

Popkin (1978) directed a study of labor intensive road construction workers in the Bicol region of the Philippines. Hemoglobin, weight, height and socioeconomic data were collected from 157 workers. Fifty-eight percent of the workers were considered anemic according results of hemoglobin concentration. Output was measured in terms of cubic meters of soil loaded, unloaded and tamped by each group of workers. A massive drop in participation by workers caused by a change in the type of payment system led to a study that reported a complete information for only 38 workers. Among loaders the anemic group achieved 64 % of the total volume of soil loaded by the no anemic group. Among tampers the situation was similar: anemic workers produced at a level of 62 percent of the no anemic group. Ordinary least square were used to regress worker productivity (tamped soil output per day) against hemoglobin levels and other factors. The results shows significant positive association between hemoglobin and productivity for both functional forms, additive and multiplicative(log) forms. The study tries to find the ranges of hemoglobin with increasing and decreasing productivity. A parabolic relationship was tested:

$$\text{Productivity} = a_0 + a_1 \text{ Hemoglobin} + a_2 \text{ Hemoglobin}^2 + \text{other factors}$$

This yield no statistically significant results. In particular it did not identify a range of increasing returns as the wage-efficiency theory predicts. The study identified the impact of nutritional status on labor time. Hemoglobin level increases were associated with significant increases in the average time worked and a decrease in days missed, "workers with a hemoglobin level about 14g/100ml had 0.67 more days of work than those with lower hemoglobin levels" (Popkin 1978, p.123).

Popkin like Basta et al. (1979) uses average productivity to measure the impact of nutrition intake. Also the productivity and nutrition are both endogenous variables from the statistical point of view.

Nutrition, time worked and productivity are simultaneously determined as we see in Figure 2-14. Ordinary least square regressions are regressions among endogenous variables. Green (1993) mentions that the parameters obtained will be biased and inconsistent. Even for large samples the estimated parameters will not converge to the true values.

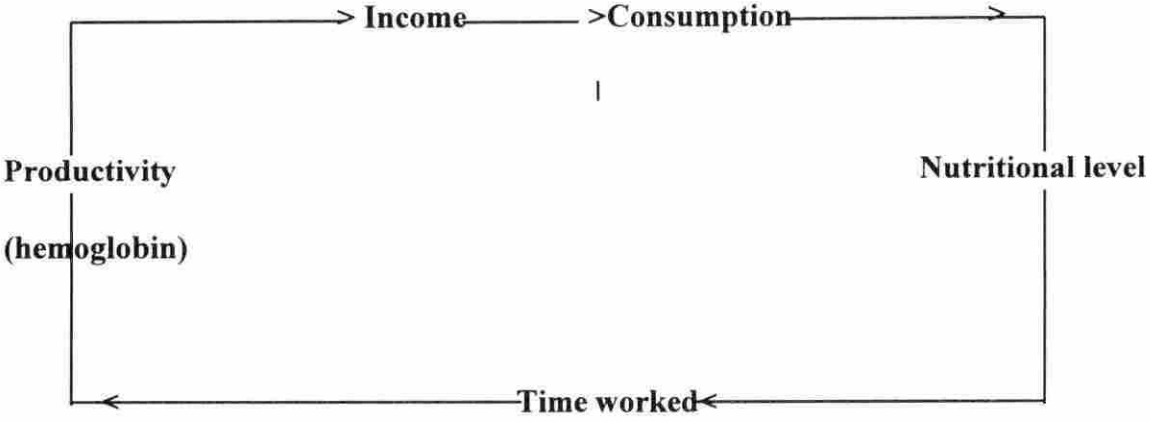

Figure 2-14. Simultaneously determination of variables in a farm household

Wolgemuth et al. (1982) made a study of Kenyan road construction laborers. The objectives of the study were "to determine the relationship between the nutritional status of road workers and their work productivity, and to compare the effects of a high energy and a low energy dietary supplement on their nutritional status and productivity" (Wolgemuth et al., p. 69). Initially 224 workers participated in the study, 138 were males and 86 were females. Then, for the experimental phase, the workers were divided in two groups: group one received a low level of energy supplementation (200 kcal/day) and group II received a high energy food supplement (1000 kcal/day). To show the consumption-production relationship prior to the intervention they regressed average productivity against age, arm circumference, hemoglobin levels, parasitic infection, sex, road site and type of task. One standard deviation in arm circumference is weakly associated with a 3.9% increase in productivity ($p<0.10$). Hemoglobin is also found to be significant at 1%. One standard deviation in this variable is associated with a change of 5.6% in productivity. Parasitic infection does not show a significant relationship but the sign is negative, it implies that the presence of illness decreases productivity. After intervention, they recorded base-line and final productivity for 47 cases among male workers. The mean change in worker productivity was 0.065 m3/mh., which is around 8.4% greater than the initial average worker productivity. In group II, with a high caloric diet, productivity increased 0.10 m3/mh., or approximately a 12.5% of increase. In the low calorie supplementation group the increase was only 0.03 m3/mh and it was not statistically significant.

The change in productivity is positively associated with supplementation and negatively associated with days worked. This suggest that calorie intake was insufficient to compensate energy expenditure. The use of a supplement as a partial substitute for food ordinarily consumed at home, the preharvest shortage of food, and the high sample attrition generate doubts to the validity of the conclusions. As before the endogeneity problem is present. Physical conditions (arm circumference), hemoglobin levels, time worked, all belong to the same group of endogenous variables. Several authors (Korjenek, 1990; Berhman, 1993; Strauss, 1986) point out they are also implicitly choice variables. They belong to group of behavioral variables which cannot be used to explain others endogenous variables, in this case average productivity unless appropriate statistical estimative techniques such a two stage least squares are used.

Imminik and Vitteri (1981a) studied sugar cane cutters in Guatemala. A group of 158 agricultural laborers constituted the subjects of this research. Workers were divided in two groups for the experiment. It was decided not to assign workers at random to either group because of strong within-community interaction among workers, both at work and in after-work activities. Therefore the treatment was given to the entire two communities. The authors state "the non-random assignment of the workers to either group admittedly weakened the internal validity of the research design" (Imminik and Vitteri, 1981a, p.257).

The treatment group received a high energy supplement and the control group received a low energy supplement. The supplementation program was given continuously for 28 months. Pre-suplementation comparison between groups did not show any significant difference between physical characteristics and expenditure of energy in the job. The high energy supplementation group workers resulted in a significant increase in their daily energy intake, unchanged energy stores, and in increased levels of daily energy expenditure. The authors tested the hypothesis that the increase in calorie intake improves labor productivity. Their results found no statistically significant differences in changes in productivity between the high energy supplement group and the low energy supplement group. The authors hypothesize that the greater level of energy is dissipated in other activities rather than additional or harder work. In a second paper related to the same topic (Imminik and Vitteri, 1981b) the authors try to estimate an efficiency curve. They use a log-inverse function for that purpose. Tons of cane (works units) produced per manday are seen as a function of daily energy intake, height and upper-arm muscle area. They found that "over wide range of daily energy intake the daily supply of work units by these workers may generally be insensitive to increased energy intake, and decreasing productivity returns set in almost immediately after daily energy intake covers basal energy requirements" (Imminik and Vitteri, 1981b).

These results can be seriously questioned for different reasons. The authors used average productivity as a dependent variable instead of marginal productivity of labor. The endogeneity problem is present in their Ordinary Least Square estimation of parameters. The experiment provided inadequate control to avoid problems like a substitution of food at home apart from the problem of non-randomly selected sample. Both groups knew the type of treatment they were receiving. This may create a motivational effect, leading to spurious correlation.

Long-term effects of better nutrition on productivity are reported by Martorell (1993) based on the Institute for Nutrition of Central America and Panama (INCAP) longitudinal study (1969 to 1977). This study was designed to assess the impact of intrauterine and preschool malnutrition on behavior. Two liquids were prepared and distributed in four poor villages between 1969 and 1977. One, the treatment, was called Atole and it provided 163 kilocalories and 11.5 grams of protein. It also was a rich source of vitamins. The Atole was distributed and consumed in a centrally located feeding hall twice a day, every day, during mid-mornings and mid-afternoons. The target group were pregnant women, mothers of young children(< 2 years) and children up to 7 years of age. All of the consumers who belonged to this group were recorded. The other liquid was called Fresco and it contained 59 kilocalories, later vitamins and minerals were added. The study observed positive effects in early childhood: significant reduction in infant mortality (66% in Atole villages compared with 24% of reduction in Fresco villages). In the follow up study (1987-1988) they cover 72% of their original subjects (89% of the subject who did not migrate). The results support their initial hypothesis that "better nutrition during early childhood leads to adults with a greater potential for leading healthy, productive lives" (Martorell 1993, p.10). Adolescents who ingested Atole regularly during the first 3 years of life were taller, had a greater work capacity and had better intellectual performance. Work capacity was significantly improved in Atole villages. Atole males had maximal oxygen consumption at the level which was 0.7 standard deviations greater than that of Fresco males, which may be considered a large effect. These improvements can lead to a better employment opportunities and greater earnings in the future. The study did not test the wage-efficiency hypothesis, but it provides an interesting proof of the effects of nutrition on work capacity in the long run. Similar to the Imminik and Vitteri (1981) study, the experience was non-randomly assigned because Atole and Fresco were distributed to all the participants in each type of village. The loss of subjects almost one third of the original participants raises questions about the validity of the results.

A good summary of the problems of consumption-production experimental studies is given by Berhman (1993), when he says "experimental studies are often based in a small and sometimes selected samples because the high costs, have difficulties in assuring good controls...in assuring that there are not household reallocations that partially offset the effects of the experiment ,may suffer for selective attrition, a usually do not have sufficient duration to learn to what extent the results are transitory or permanent" (Berhman, 1993, p.1763).

Nevertheless the recurrent positive results in these of experiments tend to support the consumption-production relationship for low income level populations.

Studies based in socio-economic surveys

In this section we review studies based on cross sectional and longitudinal socio-economic surveys . With this type of surveys we do not need to be worried about control groups but problems such endogeneity are common in both types of studies.

Hersch's (1985) study found a positive relationship between quantity of available energy and output in a sample of 135 workers, 68 male and 67 female, in a clothing factory in Rochester, New York, where all workers were paid on a constant piece rate basis. In Hersch's approach, income from work depends on effort exerted as well as time spent on the job. Effort on the job has two components, psychological and physiological. The physiological or physical component is limited by calorie intake. The total level of energy chosen and the allocation of this energy between market and non-market activities constrains the amount of energy that can be exerted on the job. Hersch uses calorie intake as a 'proxy' for intensity of effort. He defines a model with an utility function which includes calories available from the dietary intake and the level of energy expenditure off the job. This utility function is maximized subject to a budget constraint and a production function. The latter is a function of energy available on the job, determined by the calories available after subtracting basic metabolic rate requirements. Hersch estimates the derived demand for calories and found that this quantity demanded is positively related to the piece rate and negatively related to the cost- per-calorie. As Hersch (1985) notes "one implication of this study is that an increase in available energy will increase worker productivity" (Hersch 1985, p.880).

The principal problem with this study is the lack of instrumental variables to control the problem of endogeneity. As noted before, productivity, income, consumption and calories are all endogenous variables. The interesting feature of the study is that it is a complete behavioral model for the consumption-worker choices. It focuses on the trade-off consumption-production relationship. It therefore implies that the allocation of consumption is also related with the payment that the worker is going to receive. Basta (1979) found that only workers on piece-rate paid were sensitive to change in energy supplementation. Workers paid by the hour wage did not exhibit such price sensitivity. Foster (1995) presents a model in which he tried to analyze if caloric allocations efficiently capture potential returns in productivity. The model assumption is that caloric intake affects both health and productivity. The dominant form of employment is that of casual labor compensated on a piece or time-rate basis (depending on the nature of the activity) Part of the compensation can be provided in the form of meals. Workers choose calories and labor allocations so as to maximize utility subject to a budget constraint. Health, which is a component of the utility function, is a function of calorie intake and the time worked under (a) piece-rate paid rates (b) straight time wages (c) with and without meals.

Optimal caloric intake will be affected by labor force participation, particularity in the piece-rate sector. Foster (1995) mentions that in the Foster and Rosenzweig (1994) "an individual working full time at piece rates is allocated 23 percent more calories per day on average than when undertaking the reference non labor-market activity, while those working under time wages receive only 5 percent more calories per day" (Foster, 1995, p.150). If incentive effects affect allocation of calories then time-rate employers may try to compensate workers using meals. A study by Berhman (1994), found a significant association between use of meals and cultivation of high-yielding varieties, requiring the use of more labor, fertilizer and pesticides. Foster concludes that "meal -based contracts influence worker productivity either directly, by augmenting calories, or indirectly, by screening out low productivity workers" (Foster, 1995, p.151). Foster's model offers direct testable evidence in support of the presumably positive relationship between consumption and production. Here also wages, productivity, and consumption of meals are simultaneously determined.

In a study of sugar cane cutters in Guatemala, Imminik, Vitteri and Helms (1982) try to answer the question whether increased energy intake by the rural work force in developing countries can be expected to be a form of human capital formation. The baseline study collected information from 158 sugar-cane cutters on the coast of Guatemala, 4 months prior to the start of the supplementation program whose results were summarized earlier (Imminik and Vitteri, 1981a, 1981b). Regressions of daily average productivity against height, upper-arm muscle, ratio of weight to height and the ratio of daily intake to body weight yielded low coefficients of determination. Nevertheless all variables, except the ratio of weight to height are statistically significant. Interestingly an increase in adult stature is associated with an increase in tonnage of sugarcane harvested. This study confirms Martorell's results (Martorell, 1995), where better nutrition enhanced the physical capability to work. A persistent methodological problem is that all variables are endogenous determined.

Two studies assessed the relationship between disease and worker productivity based on socio-economic data. Baldwin and Weisbrod (1974) assessed the quantitative impact of parasitic diseases on labor productivity. In a follow up study Weisbrod and Helminiak (1977) examined if productivity is affected according to a time lag reflecting the duration and severity of different infections for a same sample of 466 workers (men and women), performing different kinds of manual work on a banana plantation in Santa Lucia in the Lesser Antilles . In the first study the hypothesis was that schistosomiasis, ascariasis, trichuriasis, strongyloidiasis and hookworm infection, debilitated their victims and diminished workers' productive potential as well as worker productivity. A change in productive potential means an inward shift in the marginal labor productivity curve. The authors regressed earnings per week and days worked on the number of diseases and other personal characteristics of the workers. They expected to find negative coefficients for disease variables on earnings, surprisingly no single disease showed a statistically significant effect in depressing earnings. As a group the five diseases mentioned above showed a statistically significant negative effect earnings for males only. Days worked per week were not affected by any disease for males and for females only in the case of strongyloides. The authors concluded that:

> parasitic infection appears to cause few statistically significant adverse effects on agricultural labor productivity. The analysis does show some evidence of an effect of

schistosomal infection on daily labor productivity; however, even this effect is tempered by the finding that infected workers work more, so that their lower daily earnings are offset and weekly earnings are maintained (Baldwin and Weisbrod, 1974, p. 432).

In a follow up study three years later they again could not find any significant negative effect of severity of disease on marginal productivity. Surprisingly they found that the magnitude of negative effects decreased with an increase in the severity of the disease. The authors did not use instrumental variables or other methods to avoid the problem of endogeneity, apart from the problem associated with the sample attrition.

Sahn and Alderman (1988) analyzed the determinants of labor supply using date from the 1980/81 Labor Force and Socioeconomic Survey of Sri Lanka. They used wages as a measure of marginal productivity. They correct for selection bias using Heckman procedure (Heckman, 1974), which estimates a probit model for wage earnings. They then derived the Mills ratio which is included it in the Ordinary Least Square equations of their model. The study tried to test the link between better nutrition and worker productivity, using predicted calories availability as an indicator of nutrition. To eliminate the potential problem of reverse causality predicted calories rather than actual calories were derived using a set of exogenous variables such as prices and demographic variables. The procedure was limited to rural areas because of the limited variances in prices in urban areas. Their results show a positive and statistically significant effect of predicted calories on wages for males only. This is the first study based on socioeconomic survey which tests for sample bias. It uses a Two Stage Least

Square procedure to predict calories as an indicator of nutritional level and thereby avoids the endogeneity problem.

In another study in the Philippines, Haddad and Bouis (1991) addressed the impact of the workers' nutritional level on agricultural wage rates. They used three different measures for nutritional status calorie intake, weight divided for height and height respectively. Using panel data they estimated the wage relationship using Ordinary Least Squares (OLS) and Two Stage Least Squares (2SLS), with fixed effects and random-effect techniques. Using this methodology they found height to be significant and positive. The elasticity of height relative to the wage rate equals 1.0 . They found that "an individual 15 centimeters taller than an individual of mean height may expect to achieve a 13 percent increase in the wage rate" (Haddad and Bouis, 1991, p.59). The effects of the other two indicators of nutritional status were not significant when tested using 2SLS and fixed effects. Martorell's study (1995) showed that better nutrition in early childhood has a long term effect, particularly height, confirm the results of the present study. It is not obvious how height acts so to have a positive effect on wages. Possibly taller workers choose piece-rate jobs which are physically more demanding but also better paid.

Pitt, Rosenzweig and Hassan (1990) worked with a sample of 385 households in Bangladesh. The observations are part of the 1982-82 Nutrition Survey of Rural Bangladesh which was undertaken to assess the impact of intrahousehold distribution of food on agricultural labor productivity. The daily average of calorie intake of a male 12 years old or older was 2,672 Kilocalories versus 2,063 Kilocalories for a female in the same age range.

One hypothesis explaining this disparity is that males are engaged in higher energy-demanding activities than females reflecting differences in labor-market opportunities. The authors postulate a utility function with health, food consumption and effort as variables. This is to be maximized subject to a budget constraint such that wage and non-wage income must equals to food expenditure. Health is positively related to food consumption and negatively related to effort. The wage rate as a measure of labor productivity is therefore a function of effort and health. In this approach food consumption will increase labor-market productivity via increased health status. An important characteristic of this model is that "while the nutrition-based efficiency wage literature assumes a purely technological relationship between effort and health (or food consumption), here both food consumption and effort are choice variables" (Pitt et al., 1990, p.1142). The authors estimated a health production function considering weight divided by height as a measure of health status and calorie intake and the level of activity in the respective occupation as explanatory variables with other individual characteristics. They use OLS and 2SLS for the health production function using schooling, age and food price as instrumental variables. The elasticity of calorie intake with respect to health using either OLS or 2SLS was positive and significant. The level of activity is negatively related with health status when using 2SLS but not when using OLS. The authors derive health endowments (weight divided by height) for each individual. They use these values in the estimation of calorie consumption per capita. They report "the results indicate that 10-per cent increase in a male's endowment increases his calorie allocation by 6.8 percent; the own endowment effect for females is one-tenth that of males" (Pitt et al., 1990, p.1151). An interesting result of this study is that households exhibit aversion to inequality. Male adults voluntarily pay most of the cost of this equalization.

Berhman and Deolalikar (1989) analyzed how seasonality affected nutritional and health levels and seasonal wages using a panel data of 240 agricultural workers in rural South India. Using prices and assets as instruments for calorie intake and weight divided by height, as short and long run measures of nutritional status respectively, they estimated semilogarithmic wage equations for the peak and slack seasons using dummy variables for that purpose. For the sample as a whole they found that wages were only 5% higher in the peak season. Calorie intake had a larger impact on wages rates in the peak season but weight divided by height had a smaller effect on wages for the same season. During the slack season the level of calorie intake was not a significant determinant of wage rates but weight divide by height was. There are striking differences between the female and male sub-samples. Wage rates received by females are not related to calories intake and weight for height in either peak or slack season. A possible explanation is the gender division of work between men and women in the agricultural activity. Men are involved in a physical demanding activities, so they are better paid. The study shows that food intake has an immediate productivity impact in adult males, supporting thereby the wage-efficiency hypothesis.

Korjenek (1990) tested the wage-efficiency hypothesis for a sample of urban and rural workers in the region of Bicol in Philippines using panel data with base-line data from 1977 and a follow up study for 1981. As a measure of health the author used weight divided by height. Hours worked per day are a function of experience, education, weight divided by height, the daily wage and assets. The daily wage in turn is a function of experience, education, weight divide by height and hours worked per day. The author uses a 2SLS to estimate this two equation system because calories intake, health, the wage rate and hours worked are all endogenous variables in the model. Instrumental variables used were prices, household characteristics and community health facilities. The sample is divided into three groups: landowners, tenants farmers and wage laborers. The study did not find a significant relationship between wages and weight divided by height or between hours worked and the same nutritional-health variable for the landowner group. This is consistent with the wage-efficiency hypothesis implications analyzed by Bliss and Stern (1978) implying that landowners receive lower wage than landless workers. In the tenant farmers sub-sample the long term health nutritional variable, i.e. weight divided by height has a positive impact on wages rates. Wage laborers also receive efficiency wages. These results fit with the wage-efficiency theory developed and summarized previously . Korjenek also found evidence of a positive relationship between nutrition, wage rates and hours worked for urban workers.

We now turn to two studies that postulate an agricultural production function using effective labor as an explanatory variable. Effective labor is a function of calorie intake and the number of hours worked. Strauss (1986) in Sierra Leone, Africa, estimated such a production function using a cross section survey sample of 134 rural households. The author used calorie availability rather than calorie intake because of the type of data collected. Effective family labor and effective hired labor show positive and statistically significant coefficients. To estimate the production function and the effective labor function the author used instrumental variables to avoid endogeneity. We discuss the details of the model in Chapter 3.

Deolalikar (1988) using panel data for 240 households in rural South India simultaneously estimated a semilog equation for wages and a double log equation representing farm production function using a 2SLS procedure to correct for endogeneity. In the wage equation the author uses average daily energy intake and weight divided by height as measures of short and long term nutritional status respectively. He tested the equation for fixed and random effects. In both cases energy intake is not a significant determinant of the wage rate or marginal productivity, but weight divided by height is significant at 5% level. Farm output is modeled as a Cobb-Douglas function defining effective labor as the product between the average daily energy intake and the average of weight divided by height of on farm family workers. The author found that for random and fixed effects, average household weight divided by height has a very strong and positive effect on farm production, but average calorie or energy intake does not. The author concludes that nutritional status is an important determinant of labor productivity in the agricultural sector of developing countries. His results also support the wage-efficiency hypothesis.

Berhman points out, "studies based on socioeconomic surveys often have difficulty in controlling for simultaneous choices, unobserved fixed effects, selectivity, and intrahousehold allocations, and, in exploring some longer run effects" (Berhman, 1993, p. 1763). The studies reviewed above addressed these problems (Sahn and Adelrman, 1988; Deolalikar, 1988; Strauss, 1986; Berhman and Deolalikar, 1989; Haddad and Bouis, 1991;

Pitt et al., 1990; Korjenek, 1990). Their results are supportive of the consumption-production relationship as well as the wage-efficiency hypothesis for rural workers in developing countries. A redistribution of income which increase nutritional levels for rural workers would have a two parallel effects: it would improve equality and increase productivity to the benefit of society as a whole.

CHAPTER III. NUTRITIONAL REALITY IN THE PERUVIAN ANDES

Rural areas located within the Andes are considered the poorest region of Peru (Webb and Figueroa, 1975; Banco Central de Reserva, 1995). We therefore have focused our research on a region which is considered to be chronically poor with high levels of malnutrition. What are the implications of this nutritional reality from the perspective of wage-efficiency theory? The latter is based on the assumption of a biologically determined relationship between consumption and effort, with better nourished workers receiving higher wages or efficiency premiums. On the other hand if more effort would be forthcoming without additional consumption then the wage-efficiency hypothesis does not make sense. Additional questions are those of the effects of chronic malnutrition at high altitudes.

We therefore divide this chapter in two parts. First, we discuss the process of energy intake and energy expenditure in the human body given chronic malnutrition in a high altitude environment. In the second part of this chapter we present the current nutritional situation in the subject area of research.

Energy intake and energy expenditure process

To perform physical work we need to lift a load against the force of gravity which requires the expenditure of energy conventionally measured by calories. One calorie equals to the amount of heat required to raise the temperature of 1 gram of water by one Celsius degree at the sea level. One kilocalorie (kcal.) is 1,000 calories. The average daily energy expenditure for adults females equals 1,792 - 2,389 kcal /day. The corresponding range for adult males equals 1,911 - 2,866 kcal / day for men (Bender, 1993).

The sources of metabolic energy are carbohydrates, fats, protein and alcohol. Energy yields of the metabolic sources are shown in Table 3-1. There is not special nutrient source requirement for calories except for essential fatty acids. There is no specific requirement for fat either. However there is a dietary protein requirement. In early childhood this requirement is extremely important because of the growth process. Adults also require proteins in the diet because there is a continuous small loss of protein from the body. Vitamins also need to be provided trough the diet because the body cannot synthesized them.

Table 3-1. Kilocalories per source of metabolic energy

	Kilocalories / g.
Carbohydrate	4.063
Protein	3.824
Fat	8.843
Alcohol	6.931

Source: Bender, 1993, p. 3.

Energy balance requires that the intake of metabolic fuels be equivalent to the energy expenditure of the body. To calculate the energy expenditure of a person we need to take in account the different components of the expenditure of energy by the body: Resting Metabolic Rate (RMR), the thermic effect of the exercise, the thermic effect of food and facultative thermogenesis. RMR is equal to the energy necessary to maintain normal body function and homeostasis and additionally a component for activation of the sympathetic nervous system. RMR is the highest (60 - 75%) component of the total energy expenditure of the body. It is measured when the individual is lying down in a comfortable environment several hours after the last meal or significant physical activity. Basal Metabolic Rate (BMR) is a somewhat lower than RMR, and its measurement is not easy, so nowadays RMR is the most common measure. The thermic effect of exercise (TEE) explains on average 15 to 30% of the total energy requirement. It is the cost of physical activity above the basal level. It is the most variable component of energy expenditure and depends most on personal decisions. The thermic effect of food (TEF) counts for the increase in energy expenditure above RMR for several hours after the meal is ingested. It counts for around 10% of total energy expenditure. The last component of energy expenditure is that of facultative thermogenesis. It represents the change in energy expenditure induced by changes in environmental temperature, food intake, emotional stress, etc. It counts for less than 10% of total daily energy expenditure (Devlin and Horton, 1990).

If the intake of metabolic fuels is greater than required to balance energy expenditure reserves will accumulate in the form of adipose tissue. When the diet does not meet energy requirements, the body converts its reserves of fat, carbohydrates (glycogen) and protein to meet energy needs. Protein-energy malnutrition occurs when the body uses protein for fuel rather than for replacement of tissue loss. The obvious result is loss of weight and muscular mass. If a person is exposed to long periods of low food intake expending the same amount of energy expenditure the body will exhaust its reserves of fat and protein (muscles). Eventually there must be a loss of protein from heart, liver and kidneys, and finally will generate marasmus. The immune system is concurrently debilitated so that undernourished people are likely to be ill. The regeneration of intestinal tissue is hampered with a decreased absorption of food worsening the problem (Bender, 1993). Severe and long periods of undernutrition reduce the capacity of the human body to work. In the wage-efficiency framework the point of minimum or subsistence wage would correspond to BMR or RMR levels. Below such real wage equivalent they will face starvation and the biological process already described will progress.

In the short run the body can convert the reserves of fat or proteins to balance energy requirements given the absence of carbohydrates. This process cannot continue indefinitely. In less developed areas fuel reserves are low. After a short period of time, work performed must decrease because of workers' fatigue. In the presence of chronically low energy intake three adaptive mechanisms will commence: the metabolic, the genetic-biological, and the socio-behavioral (Waterlow, 1984). Ferro-Luzzi (1984) mentions that the main metabolic adaptation to low energy intake is represented by a decrease up to a maximum of 15% in the BMR, which is less than 10% of the body energy expenditure. The genetic-biological mode of adaptation to low energy intake takes the form of a smaller body size, lowering the BMR. The hypothesis of 'small but healthy' is criticized by other authors. Waterlow observes that this adaptation implies reduced capacity for work and less employment opportunities. Such individuals may be classified as handicapped rather than adapted individuals (Waterlow 1984). This author criticizes the term adaptation for the behavioral response of reducing physical activity to deal with a low energy intake. He concludes "I regard these two examples as responses to environmental stress, rather than adaptations, because they do not depend on a physiological mechanism for maintaining relative constancy within a definable preferred range" (Waterlow, 1984, p.9). Korjenek cites a paper of Sukhatme (1981) where it is suggested that individuals can adapt to intakes as low as -30% or as high as +30% of the average requirement without any negative functional effect (Korjenek,1990). In a later paper Sukhatme reiterates his earlier views "in the current literature a man's requirements for energy for a given status and pattern of physical activity and body mass are fixed. Available experimental data on the other hand show that it is variable and self-regulated over a considerable range…Below the lower limit of this range man is under energy stress, growth is retarded and man adapts to small body size" (Sukhatme, 1989, p.75). Some studies do not confirm this thesis. McNeill et al. (1987) found no metabolic adaptation in populations chronically exposed to a low food intake. Evidence therefore is not conclusive about the range beyond which individuals will experience energy stress and their capacity to do physical work. This in turn may reflect itself in socio-cultural characteristics of the subject population.

Undernutrition and energy requirements in Peruvian Andes

The selected study area is a large region of 420,000 square kilometers approximately, between 2,000 and 4,500 meters above sea level. The lack of oxygen affects the metabolism of humans at high altitudes. In a study of 17 healthy adults residing up to 14,900 feet above sea level in Peru, Picon-Reategui (1960) found that using body surface area as a standard of reference, the Basal Metabolic Rate (BMR) of the high altitude resident is within the limits considered normal for healthy adults at sea level. Varene et al. (1973) found that the individuals exposed to moderate exercise can function at high altitudes as efficiently as at sea level. There is however a higher consumption of O_2 per kilogram of fat-free mass for the high altitude resident reflecting adaptation to a low oxygen environment. The rate of aerobic energy production is the same at high altitude as at sea level. Heat loading is the same for both cases.

In rural areas of developing countries food availability is strongly seasonal. It is abundant in the post-harvest period and scarce in the pre-harvest period. Payne (1984) shows for a farming community in West Africa the existence of a surplus of energy in some periods of the year and in others energy deficit. Corresponding weight body adjustments are easy to observe throughout the year. This is an example of socio-behavioral strategy to deal with food stress in rural communities. Leonard and Thomas (1989) worked with a sample of 26 households from the town of Nuñoa located to 4,000 meters above sea level in the southern highlands of Perú. They analyzed the biological and social response of seasonal food stress in this sample of households. The study, confirming similar studies elsewhere, found large and statistically significant differences between per-capita energy intakes in the pre- and post-harvest period. A relevant comparison is shown in Table 3-2. According with the FAO model of requirements of energy (FAO/WHO/UNU, 1985) these levels are marginal for both, pre and post harvest periods. However using Leslie's guidelines (Leslie, Bindon and

Table 3-2. Estimates of per-capita nergy intake from dietary surveys conducted in the rural Peruvian hihgland

Reference	Location	Month/Year/Survey	Kcal.
Leonard and Thomas (1989)	Nuñoa	Jan-May 1985 June-Aug. 1985	1150 1519
Thomas (1973)	Nuñoa	April 1968 June 1968	1336 1571
Gursky (1969)	Nuñoa	Jul-Aug. 1967	1485
Mazess&Baker (1964)	Nuñoa	July 1962	3170
Collazos et al. (1954)	Chacan	Dec. 1951 June 1953	1194 1404

[1] Recalculated for the town sample only.

[2] Surveys monitoring household-level consumption. Individual intakes were monitoring for all other studies.

Source: Leonard and Thomas 1989, p.70

Baker, 1984) used by Leonard and Thomas (1989), the energy requirements are calculated on the basis of specific information as body size and composition, average daily activity levels, demographic structure, etc. This yields caloric requirements of 1,435 Kcal./day for females and 1,512 Kcal./day for males for this community. Therefore post-harvest intake would be adequate but pre-harvest intake would be too low.

Kashiwazaki et al. (1995) questioned these results based on an study conducted in a Bolivian Aymara agropastoral community at 4,000 meters of altitude. This study uses the doubly labeled water method (DLW) to measure the energy expenditure of 23 individuals. In the adults (18 - 65 years of age), mean Total Energy Expenditure (TEE) for males were in a range of 2,214 -3,071 Kilocalories/day. In females this range was between 2,119 - 2,548 Kilocalories. Such requirements correspond to heavy for adult females and moderately-heavy for the adult-males in the FAO/WHO/UNU (1985) classification. The Kashiwazaki results are close to other studies using the same procedure in other parts of the world (Kashiwazaki et al., 1995). The author explains the differences with the prior reported studies arguing that these studies did not properly measure energy expenditure in rural activities in free conditions, when it is purely based on tables of standard conversion factors as the Leslie calculations do. Kashiwazaki et al. (1995) questions that individuals in rural areas strongly decrease their activities in pre-harvest season (see also: Ferro-Luzzi, 1990a, 1990b; Durnin,1990a,1990b). The energy requirements estimation by DLW appear to be rigorous as Lee and Nieman (1993) mentioned and comparisons of energy expenditure determined by the DLW with reported energy intake have raised serious questions about the accuracy of reported energy intakes in dietary studies (Schoeller, 1990). Nevertheless the sources of energy expenditure remain unclear, given the seasonal availability of food in rural areas. The connection with energy storage needs to be further analyzed.

Caloric availability in rural areas of the Peruvian Andes

The "Encuesta Nacional de Hogares Sobre Medicion de Niveles de Vida 1994 (ENNIV 1994)" (National Household Living Standard Survey 1994) provides a valuable source of information about potential consumption in the area of our study: rural mountain areas. The methodology of the National Household Living Standard Surveys was developed by the World Bank to provide relevant information about the welfare and quality of life of households in developing countries (Cuánto, 1995a). The ENNIV 1994 is the fourth of this type of surveys made in Perú and it covers a sample of 3,544 households in seven domains at the national level, coast, mountain and jungle. The questionnaire explores a wide range of household characteristics among them potential consumption availability. Our study region included 720 households divided by three regions: north, central and south rural mountain.

Consumption information collected focuses on food available, not on observed food intake. It therefore measures potential consumption. The average of food available per-capita obtained from this study may overestimate the real availability of food throughout the year because of its focus on a single observed productive period, i.e. the July-August, post-harvest season.

Average potential calories per-capita equaled 1,934 Kcal. The survey does not tabulate distribution of food among the members of the household, no inferences are therefore possible about gender and age specific aspects. The average of calories available is one third higher than the majority of findings presented in Table 3-2 . On the other hand Mazes and Baker (1964) found a higher level of calorie intake. However as Leonard and Thomas (1995) observed 1962 was an unusually good harvest. It is interesting that over a period of 35 years the amount of calories requirements did not change significantly for the Nuñoa community, indicating its isolation or stationarity. According to Kashiwazaki et al. (1995) the average amount of potential calories for consumption referred to above would be inadequate for either males or for females. The deficit with respect to the lower limit of

Kashiwazaki estimates equals 13% for males and 9% for females. Limited storage capability induces food stress in pre-harvest months. Using the guidelines for moderate activity levels by Bender (1993), the average potential caloric availability would be adequate for women but very close to the lower limit recommended for men. Table 3-3 contains the regional distribution of calories available.

Table 3-3. Average available calories per-capita per-day and average household expenditure per capita per day in 1994 Soles.

	Rural Northern Andes	Rural Central Andes	Rural Southern Andes	All Rural Andes
Calories Available (Kcal.)	2,370	1,850	1,706	1,934
Index of Calories Availab.	123	96	88	100
Expenditure per-cap. S/.[1]	1.34	1.16	1.08	1.18

[1] S/. 1 = 0.5 US $

Source: "Encuesta Nacional Sobre Niveles de Vida 1994" (ENNIV 1994). Own elaboration.

The South, the poorest region of the Andes, shows the lowest index of caloric availability. The Northern Andes is the only region which meet the requirements set by Kashiwazaki (1995), for both men and women. The range in regional average is substantial. Poverty alleviation programs should take into account this heterogeneity.

Approximately 45 % of potential caloric consumption was produced by household themselves. In the rural South Andes, 55 % of the calories available came from own farm production, 40% in the rural Central Andes and 37% in the rural Northern Andes. Table 3-4 summarizes the sources of calories in the rural Andes.

Table 3-4. Sources of calories per-capita in the Rural Andes

	Rural Northern Andes	Rural Central Andes	Rural Southern Andes	All Rural Andes
Purchased	1459	1122	763	1066
Produced	911	728	943	868
Total	2370	1850	1706	1934

Source: ENNIV, 1994. Own elaboration.

Table 3-5 shows the average of income per-capita and potential calorie availability per-capita by deciles of income. There is a very large disparity in availability of calories between low and high income groups. Inequality of income is a major explanatory variable.

The highest income decile receive 7.4 times more per-capita income and 5.5 times more available calories per-capita than the lowest income decile. Only the three highest deciles reach the lower limit of the calories requirements estimated by Kashiwazaki (1995) for males at 2,214 calories. Deciles 6 to 10 can reach the lower limit of the energy requirements proposed by Bender (1993). Therefore half of the rural Andean population suffers from food stress, possibly aggravated by a seasonal lack of food availability.

Table 3-6 present calories available per-capita by source and income levels for the total rural Andes regions. Calories purchased are less than calorie produced for the lowest

Table 3-5. Potential calories available per-capita by deciles of income, all rural Andes regions

Table 3-5. Potential calories available per-capita by deciles of income, all rural Andes regions

Deciles of Income	Income Per-capita (S/.)[1]	Index of Income Per-capita (Average=100)	Calories Available (Kcal.)	Calories Available (Average=100)
1 (Lowest)	0.35	30	670	35
2	0.55	47	1048	54
3	0.71	60	1264	65
4	0.85	72	1493	77
5	1.00	85	1775	92
6	1.14	97	1919	99
7	1.30	110	2086	108
8	1.49	126	2553	132
9	1.77	150	2897	150
10 (Highest)	2.63	223	3748	194
All deciles	1.18	100	1934	100

[1] S/. 1 = 0.5 US $

Source: ENNIV 1994. Own elaboration.

Table 3-6. Calories available per-capita, by source and income levels, all rural Andes regions

Deciles of Income	Total Calories Available (in Kcal)	Calories Purchased (in Kcal)	Calories Produced in Kcal)
1	670	312	359
2	1048	531	517
3	1264	564	700
4	1493	842	621
5	1775	1063	712
6	1919	1043	876
7	2086	1117	967
8	2553	1479	1072
9	2897	1561	1334
10	3748	2212	1534
TOTAL	1934	1072	862

Source: ENNIV 1994 . Own Elaboration.

For the highest five income deciles 40% of available calories were directly produced by the household.

Table 3-7 lists six standard descriptive parameters of the distribution of per-capita food availability by regions. Within each region there exits a high degree of inequality in the distribution of calories available for consumption. Inequality of income is a major explanatory variable as we saw already above in Table 3-5.

Table 3-8 shows the distribution of available calories per-capita divided by deciles of calorie availability by regions in rural Andes. The lowest decile receives approximately only 3.5% of the total available calories in each region . The highest decile absorbs around 20%

Table 3-7. Distributional characteristics of calories available per-capita by regions

Indicators	Rural Northern Andes	Rural Central Andes	Rural Southern Andes	All Rural Andes
Mean	2370	1850	1706	1934
Median	2131	1642	1559	1766
Std.Deviation	1045	978	867	991
Range	5187	4891	4362	5187
Minimum	249	483	364	249
Maximum	5436	5374	4726	5436

Source: ENNIV, 1994. Own elaboration.

Table 3-8. Distribution of calories available per-capita, by deciles, by regions.

Deciles of calorie availability	North Andes Kcal.	North Andes %	Central Andes Kcal.	Central Andes %	South Andes Kcal.	South Andes %
1(Lowest)	842	3.5	658	3.5	530	3.2
2	1327	5.6	921	5.0	840	5.0
3	1629	6.9	1130	6.1	1083	6.3
4	1854	7.8	1315	7.1	1274	7.3
5	2040	8.6	1495	8.1	1455	8.5
6	2290	9.7	1747	9.4	1668	9.8
7	2607	11.0	1994	10.8	1946	11.1
8	2982	12.6	2355	12.7	2213	12.8
9	3625	15.3	2918	15.7	2544	15.2
10(Highest)	4499	19.0	4003	21.6	3531	21.0
Total	2370	100.0	1850	100.0	1706	100.0

Source: ENNIV 1994. Own elaboration.of available calories per region.

There is a remarkable similarity in pattern of caloric distribution among regions. The northern region has a higher level of calories available per-capita but not a more equal distribution .

Studies related to the composition of the diet in the Andes (Collazos, et al., 1954; Ferroni 1982; Mazzes and Baker, 1964) found that tubers as a botanical class, constitute the main component. Native cereals such as quinoa, tarhui or cañihua, are also part of the regular diet. Meat and other animals products are present in lesser proportions. Chuño and moraya, a freeze dried form of the potato, are also important elements of the diet. Leonard and Thomas found the distribution of caloric contribution shown in Table 3-9. According to this study almost half of available calories came from fresh tubers in the post-harvest season.

Our estimates however show a very different pattern of consumption as we can see in Table 3 -10. For the whole rural Andes only 10.3% of calories available came from tubers which is the second food in importance in caloric availability per-capita in the rural Andes. The most important contributor of calories based on the ENNIV 1994 survey data is rice. It contributes 16.5% of the total calories available per-capita, in comparison with 5.2% in

Table 3-9. Percent Caloric Contribution of Seven Foods During the Pre- and Post-Harvest Periods for a Sample of Households from Nuñoa Peru.

Food Item	Pre-Harvest	Post-Harvest
Fresh Tubers	11.7	44.6
Chuño/Moraya	12.9	5.5
Flour	15.6	8.9
Rice	10.5	5.2
Bread	8.2	5.5
Sugar	8.2	5.2
Animal Products	6.6	10.6
Totals	73.7	85.5

Source: Leonard and Thomas, 1989, p. 71.

Nuñoa community study. Animal products in our study, using ENNIV survey data, contribute 5.4% to total calories available. Table 3 -10 presents additional details . One is impressed by the variety of the diet. The relative uniformity diet among different regions is tested and the results are presented in Table 3-11. We test if there are statistically significant differences in the average of calories available per-type of food among regions. In the first column we compare the average of calories available between the northern and the central rural Andes and the hypothesis equality of means is tested. If the probability of finding a difference as large as seen in each case is smaller than the 0.05, the null hypothesis (equal means between the two regions), is rejected. In the second column we tested the same hypothesis for the the north with the southern region and the third column test a possible differences between central and the southern region.

In 40 of 57 cases the null hypothesis was rejected. The largest number of differences were founded between the northern and the southern regions, respectively the richest and the poorest regions. Table 3-12 summarizes the cases where the null hypothesis of equal means is rejected. Notice that the null hypothesis is always rejected for rice, poultry, fish, beans and sugar but for wheat the null hypothesis is always accepted. The two regions with greatest similarities in the diet were the Northern and the Central rural Andes.

The Cuánto Institute S.A. (1995) systematically collects retail prices of food items for mayor cities located in the Andes region. This information can be used to construct an approximate price index of the cost per-available calorie. The results are shown in Table 3-13 and in Figures 3-1, 3-2 and 3-3. Analysis of the graphs immediately shows a high degree of negative correlation between the relative calorie cost of food items and their contribution to

Table 3-10. Average of calories available per-capita, by type of food by rural Andes regions

Type of Food	Rural Northern Andes Kcal.	Rural Northern Andes %	Rural Central Andes Kcal.	Rural Central Andes %	Rural Southern Andes Kcal.	Rural Southern Andes %	Total Rural Andes Kcal.	Total Rural Andes %
Rice	532	22.4	311	16.8	183	10.7	319	16.5
Tuber.	184	7.8	183	9.9	224	13.1	199	10.3
Sugar	241	10.2	180	9.7	185	10.8	198	10.2
Barley	105	4.4	160	8.6	231	13.5	173	8.9
Bread	178	7.5	229	12.4	126	7.4	172	8.9
Oil	241	10.2	139	7.5	128	7.5	162	8.37
Corn	166	7.0	96	5.2	131	7.7	129	6.7
Beans	265	11.2	94	5.0	49	2.9	123	6.4
Wheat	125	5.3	123	6.6	98	5.7	112	5.8
Noodles	126	5.3	99	5.4	68	4.0	93	4.8
Dairy p.	39	1.6	58	3.1	60	3.5	54	2.8
Quinoa	14	0.6	28	1.5	90	5.3	49	2.5
Meats	33	1.4	44	2.4	53	3.1	45	2.3
Eggs	37	1.6	24	1.3	21	1.2	26	1.3
Fruits	24	1.0	22	1.2	16	0.9	20	1.0
Poultry	25	1.1	25	1.4	12	0.7	20	1.0
Vegetab.	14	0.6	20	1.1	15	0.9	16	0.8
Fish	20	0.8	16	0.9	11	0.6	15	0.8
M.Sub[1]	1	0.0	0	0.0	0	0.0	1	0.0
Average	2370	100.0	1850	100.0	1706	100.0	1934	100.0

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration.

Table 3-11. Comparison of differences in diet among regions in rural Andes

Type of Food	$H_0: \mu_1 = \mu_2$		$H_0: \mu_1 = \mu_3$		$H_0: \mu_2 = \mu_3$	
	t value	significant	t value	significant	t value	significant
Rice	4.81	0.000	10.00	0.000	3.57	0.000
Corn	4.07	0.000	1.81	0.071	-2.26	0.024
Wheat	0.11	0.914	1.56	0.120	1.65	0.099
Barley	-1.74	0.082	-4.08	0.000	-2.44	0.015
Quinoa	-.172	0.086	-6.64	0.000	-6.24	0.000
Bread	-1.90	0.059	2.57	0.011	4.37	0.000
Noodles	1.88	0.061	5.11	0.000	2.57	0.011
Meat	-1.31	0.192	-2.14	0.033	-1.01	0.311
Poultry	0.05	0.962	3.02	0.030	3.25	0.001
SubpM.	0.88	0.378	0.83	0.406	-0.24	0.811
Fish	1.33	0.186	2.94	0.004	1.98	0.048
Milk	-1.87	0.063	-2.88	0.004	-0.32	0.749
Eggs	3.05	0.002	4.48	0.000	1.08	0.280
Oil	5.82	0.000	7.76	0.000	0.83	0.408
Tuberous	0.11	0.909	-2.20	0.029	-2.48	0.014
Beans	7.47	0.000	9.95	0.000	3.25	0.001
Vegetable	-2.97	0.003	-0.52	0.601	2.55	0.011
Fruits	0.43	0.664	2.46	0.015	1.99	0.047
Sugar	2.80	0.005	2.65	0.009	-0.23	0.820

Table 3-12. Test results of equality of means of calories available by type of food among regions.

Northern vs. Central rural Andes		Northern vs. Southern rural Andes		Central vs. Southern rural Andes	
Rejected	No-rejected	Rejected	No-rejected	Rejected	No-rejected
Rice	Wheat	Rice	Corn	Rice	Wheat
Corn	Barley	Corn	Wheat	Corn	Meat
Meat	Quinoa	Meat	SubpM.	Poultry	SubpM.
Poultry	Bread	Poultry	Vegetables	Barley	Milk
SubpM.	Noodles	Barley		Fish	Eggs
Fish	Milk	Fish		Beans	Oil
Eggs	Tuberous	Eggs		Quinoa	
Oil	Fruit	Oil		Sugar	
Beans		Beans		Bread	
Vegetables		Quinoa		Noodles	
Sugar		Sugar		Tuberous	
		Bread		Fruit	
		Noodles			
		Milk			
		Tuberous			
		Fruit			

Source: Table 3-11

potential calorie consumption.

Only barley is relatively cheaper per-calorie than rice. It is also the most important contributor to potential consumption in the Southern Andes, the poorest region of the sample. For all other regions rice is relatively the cheapest food and also the largest contributor to those regional diets. Tubers show a high relative price but their consumption is nevertheless important in all three regions. We need to keep in mind that rural households are consumers as well as producers of potatoes, and the substitution effect, which is negative, can be offset by the income effect of higher prices, which is positive. Furthermore rural Andean households make chuño freeze dried potatoes as a way of storing calories for consumption during the pre-harvest season. Its off-season value is thereby increased.

Table 3-13. Average of Calories Available per-capita, per day and relative retail price per calorie by region

Type of Food	Rural Northern Andes Kcal.	Rural Northern Andes Index[2]	Rural Central Andes Kcal.	Rural Central Andes Index[2]	Rural Southern Andes Kcal.	Rural Southern Andes Index[2]
Rice	532	1.00	311	1.00	183	1.00
Tuber.	184	4.25	183	2.42	224	3.16
Sugar	241	1.36	180	1.16	185	1.18
Barley	105	.70	160	0.61	231	.63
Bread	178	2.48	229	1.74	126	1.68
Oil	241	1.29	139	1.11	128	1.13
Corn	166	2.04	96	1.51	131	2.02
Beans	265	2.12	94	1.31	49	1.82
Wheat	125	1.77	123	1.44	98	1.92
Noodles	126	2.31	99	1.94	68	1.90
Dairy p.	39	4.29	58	6.92	60	4.92
Quinoa	14	2.55	28	1.67	90	2.07
Meats	33	11.79	44	9.77	53	10.93
Eggs	37	8.31	24	7.39	21	7.36
Fruits	24	7.46	22	5.63	16	6.99
Poultry	25	10.94	25	9.07	12	8.08
Vegetab.	14	10.95	20	6.51	15	8.20
Fish	20	8.12	16	6.96	11	7.34
M.Sub[1]	1	17.26	0	13.65	0	12.40
Average	2370		1850		1706	

[1] Sub-products from the meat.

[2] The relative cost per-calorie if rice equals 1.00 in each region.

Source: ENNIV 1994. Own elaboration.

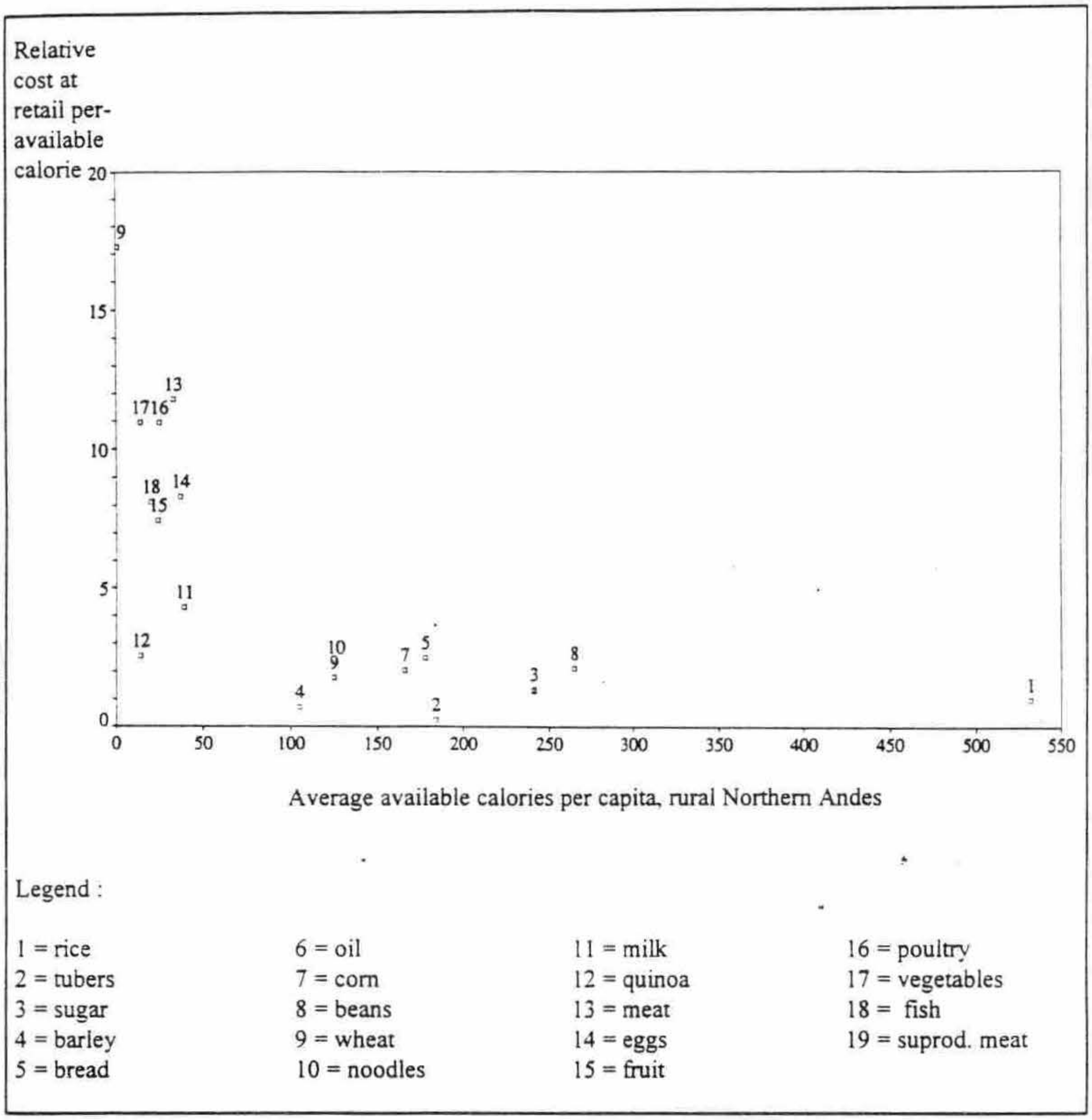

Figure 3-1. Plot of relative cost of calorie per type of food and potential consumption of calories per capita by type of food, rural Northern Andes

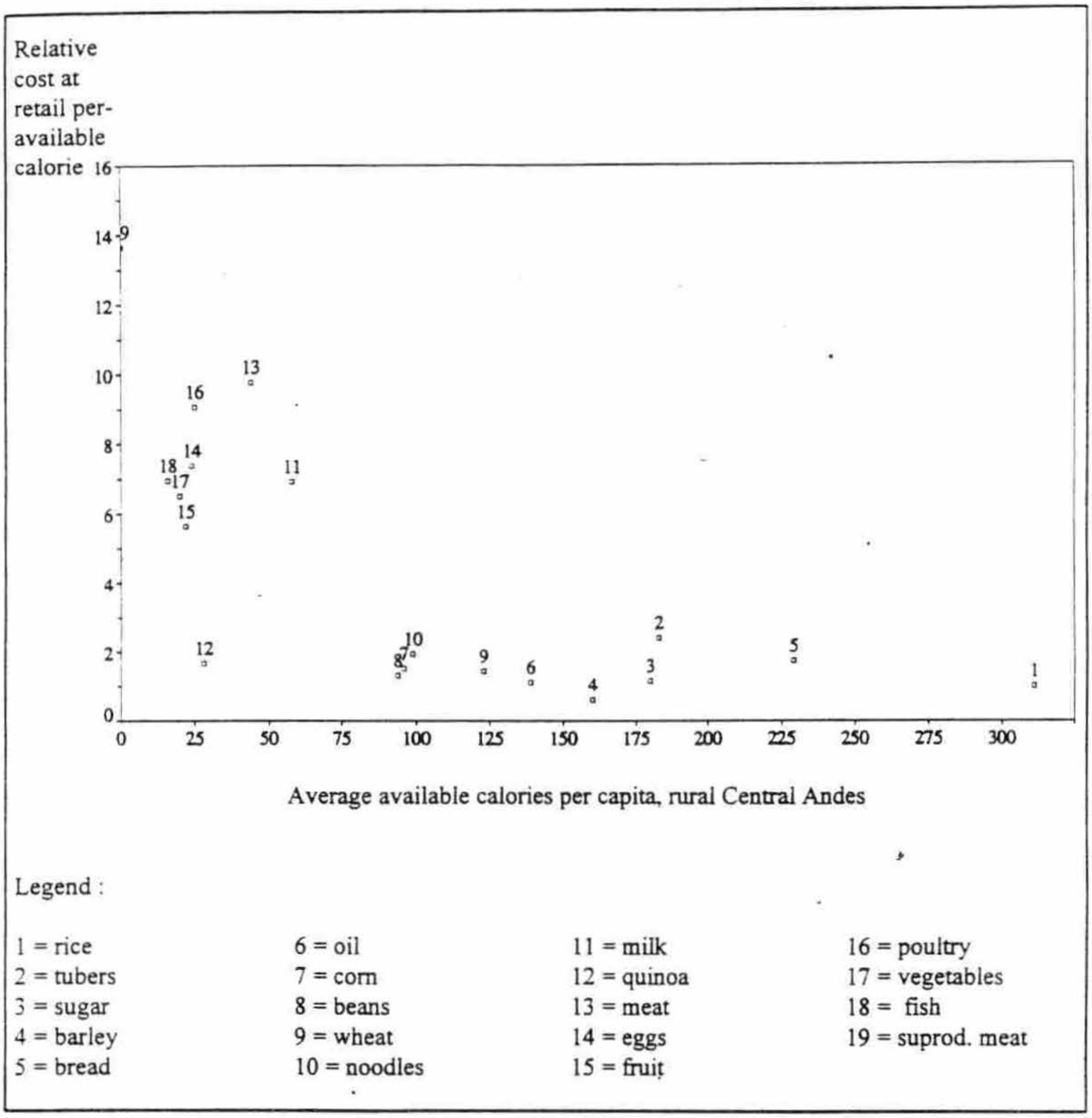

Figure 3-2. Plot of relative cost of calorie per type of food and potential consumption of calories per capita by type of food, rural Central Andes

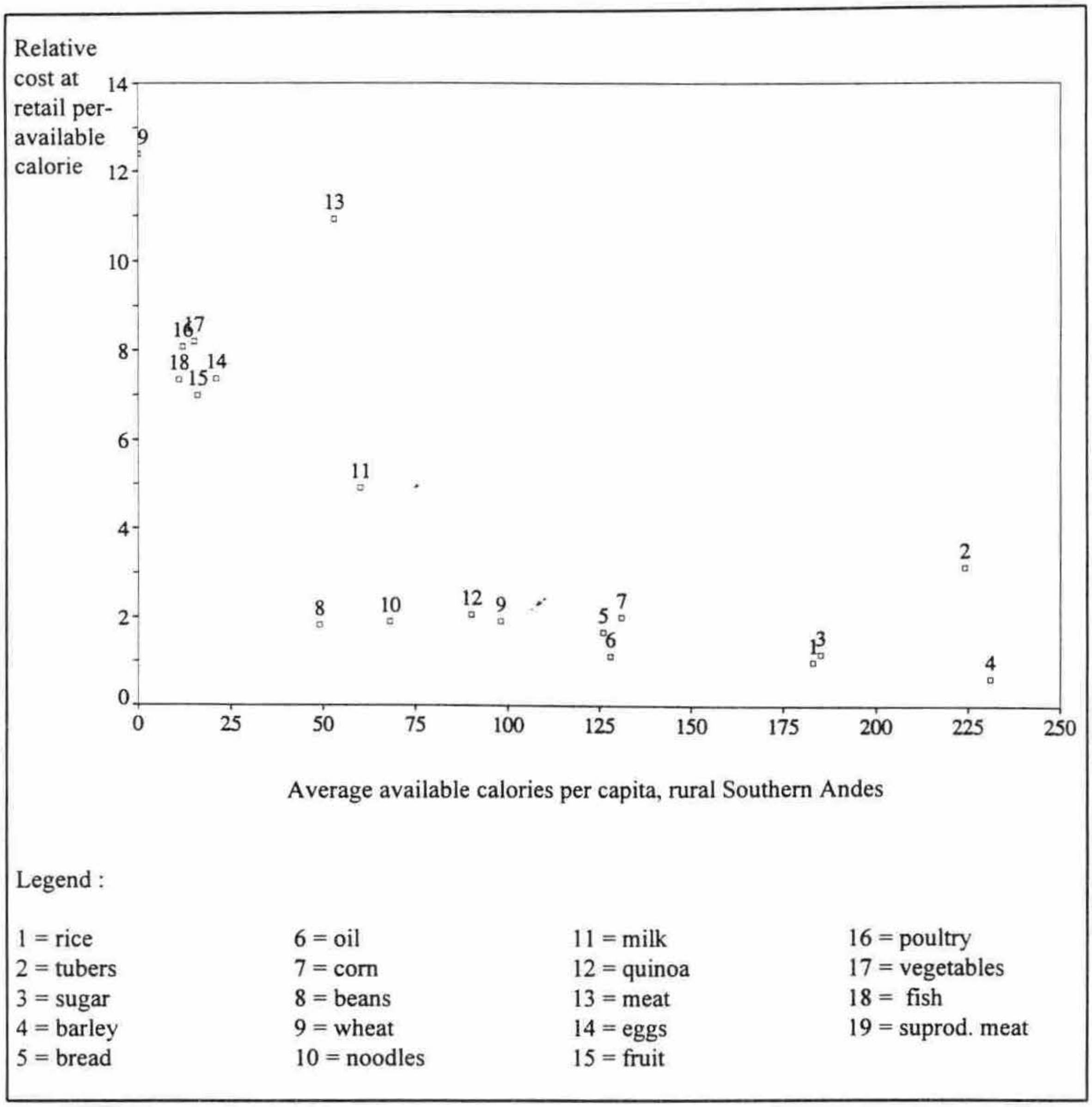

Figure 3-3. Plot of relative cost of calorie per type of food and potential consumption of calories per capita by type of food, rural Southern Andes

Table 3-14 lists the average of calories available per capita per day by type of food by source for the total rural Andes. For the rural Andes as a whole 55 percent of potential consumption of calories were purchased, the remainder being produced by the household . Typical of the latter are tubers, barley, corn and whole grain wheat. On the other hand processed or non-regionally produced foods such a rice, sugar, bread (loaves), oil, noodles, . fruits, vegetables and fish are predominantly purchased items. Tables 3-15, 3-16, 3-17, confirm above observations for each of the three rural sub-areas of the rural Andes. The south, the poorest region in the Andes, is the region which is closest to the traditional image of the rural Andes. Barley and tubers are the two main crops providing calories, mostly homegrown. However products produced elsewhere are also important. We note that sugar, rice and oil, occupy the third, fourth and sixth place in calories-per capita providers, mostly obtained through purchases. Household produced corn is also important in the southern rural Andes.

There are however minor intraregional differences to the produced percentage on a per item basis. The rural areas of the Central Andes are commercially integrated with Metropolitan Lima area. Self-production, on a per item basis, tends to be displaced by purchases. The Northern Andes border the major rice producing areas of the jungle. Correspondingly the percentage of the household produced rice increases. Quinoa is predominantly grown in Southern Perú. Home production accounts for most of potentially available calories for that item. Livestock is the predominant supplementary agricultural activity in Southern Perú. On an intraregional comparative basis, one would expect the self

Table 3-14. Average of calories available per-capita, per-day by type of food by by source, total rural Andes

Type of Food	Rural Andes Total Kcal.	Rural Andes Total %	Rural Andes Purchased Kcal.	Rural Andes Purchased %	Rural Andes Produced Kcal.	Rural Andes Produced %
Rice	319	100	280	88	39	12
Tuber.	199	100	34	17	165	83
Sugar	198	100	189	95	9	5
Barley	173	100	20	12	153	88
Bread	172	100	157	91	15	9
Oil	162	100	154	95	8	5
Corn	129	100	10	8	119	92
Beans	123	100	36	29	87	71
Wheat	112	100	12	11	100	89
Noodles	93	100	85	91	8	9
Dairy p.	54	100	9	17	45	83
Quinoa	49	100	10	20	39	80
Meats	45	100	17	38	28	62
Eggs	26	100	4	15	22	85
Fruits	20	100	18	90	2	10
Poultry	20	100	5	25	15	75
Vegetab.	16	100	12	75	4	25
Fish	15	100	14	93	1	7
M.Sub[1]	1	100	0	0	1	100
Average	1934	100	1066	55	868	45

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration.

Table 3-15. Average calories available per capita, per day by type of food by by sources, Northern rural Andes.

Type of Food	Rural Northern Andes Total Kcal.	Rural Northern Andes Total %	Rural Northern Andes Purchased Kcal.	Rural Northern Andes Purchased %	Rural Northern Andes Produced Kcal.	Rural Northern Andes Produced %
Rice	532	100	425	80	107	20
Tuber.	184	100	62	34	122	66
Sugar	241	100	228	95	13	5
Barley	105	100	32	30	73	70
Bread	178	100	173	97	5	3
Oil	241	100	232	96	9	4
Corn	166	100	12	7	154	93
Beans	265	100	76	29	189	71
Wheat	125	100	14	11	111	89
Noodles	126	100	120	95	6	5
Dairy p.	39	100	7	18	32	82
Quinoa	14	100	6	43	8	57
Meats	33	100	16	48	17	52
Eggs	37	100	5	14	32	86
Fruits	24	100	17	71	7	29
Poultry	25	100	4	16	21	84
Vegetab.	14	100	11	79	3	21
Fish	20	100	19	95	1	5
M.Sub[1]	1	100	0	0	1	1
Average	2370	100	1459	62	911	38

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration.

Table 3-16. Average calories available per capita, per day by type of food by by sources, Central rural Andes.

Type of Food	Rural Central Andes Total Kcal.	Rural Central Andes Total %	Rural Central Andes Purchased Kcal.	Rural Central Andes Purchased %	Rural Central Andes Produced Kcal.	Rural Central Andes Produced %
Rice	311	100	295	95	16	5
Tuber.	183	100	40	22	143	78
Sugar	180	100	169	94	11	6
Barley	160	100	29	18	131	82
Bread	229	100	192	84	37	16
Oil	139	100	124	89	15	11
Corn	96	100	11	11	85	89
Beans	94	100	38	40	56	60
Wheat	123	100	19	15	104	85
Noodles	99	100	87	88	12	12
Dairy p.	58	100	18	31	40	69
Quinoa	28	100	15	54	13	46
Meats	44	100	19	43	25	57
Eggs	24	100	7	29	17	71
Fruits	22	100	22	100	0	0
Poultry	25	100	8	32	17	68
Vegetab.	20	100	15	75	5	25
Fish	16	100	14	88	2	13
M.Sub[1]	0	100	0	0	0	0
Average	1850	100	1122	61	728	39

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration.

Table 3-17. Average calories available per capita, per day by type of food by by sources, Southern rural Andes.

Type of Food	Rural Southern Andes Total Kcal.	Rural Southern Andes Total %	Rural Southern Andes Purchased Kcal.	Rural Southern Andes Purchased %	Rural Southern Andes Produced Kcal.	Rural Southern Andes Produced %
Rice	183	100	172	94	11	6
Tuber.	224	100	11	5	213	95
Sugar	185	100	177	96	8	4
Barley	231	100	7	3	224	97
Bread	126	100	119	94	7	6
Oil	128	100	126	98	2	2
Corn	131	100	9	7	122	93
Beans	49	100	6	12	43	88
Wheat	98	100	4	4	94	96
Noodles	68	100	61	90	7	10
Dairy p.	60	100	6	10	54	90
Quinoa	90	100	11	12	79	88
Meats	53	100	15	28	38	72
Eggs	21	100	2	10	19	90
Fruits	16	100	15	94	1	6
Poultry	12	100	3	25	9	75
Vegetab.	15	100	9	60	6	40
Fish	11	100	10	91	1	9
M.Sub[1]	0	100	0	0	0	0
Average	1706	100	763	45	943	55

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration.

purchased percentage for that item to be high, which it is at 88 percent. Fruits are an inter - Andean valley crop. Correspondingly rural area residents living at 2,000 meters above the sea level must purchase, rather than produce, most fruits.

Table 3-18 tabulates calories available per capita per day by type of food and income deciles for the total for the total rural Andes. The calculated nutritionally adequate average of 1,984 Kcal./day hides a great disparity with the lowest income decile having a calorie availability of only 670 Kcal./day and with the highest decile registering on availability of 3,748 Kcal./day. Table 3-19 translates the information of Table 3-18 into the percentage composition of the diet, stratified by deciles of calories. Inspection reveals that the percentage composition of the diet remains nearly constant for the whole range of deciles. It is indicative of near unitary calorie-income elasticities. If no substitution effect were to take place, for different income levels, then all Marshallian calorie cross price elasticities would equal zero and direct price elasticities, by inference, would have to equal negative unity. This would imply that a plot of the relative cost of caloric availability would reveal an approximately rectangular hyperbolic relationship, as previously revealed in Figures 3-1, 3-2 and 3-3.

Closer inspection of Table 3-19 reveals substantial income substitution in the cereal group. With increasing income deciles, manufactured cereals (bread and noodles) tend to substitute for home grown cereals (barley, wheat and quinoa). Other substitution effects are also apparent.

Table 3-18. Calories available per capita per day by type of food and income deciles.

Type of Food	Average Kcal.	1st Decile Kcal.	2nd Decile Kcal.	3rd Decile Kcal.	4th Decile Kcal.	5th Decile Kcal.	6th Decile Kcal.	7th Decile Kcal.	8th Decil Kcal.	9th Decil Kcal.	10th Decil Kcal.
Rice	319	97	152	185	245	311	296	317	490	482	631
Tuber.	199	81	126	140	177	175	216	248	225	265	352
Sugar	198	91	112	118	188	151	193	226	249	255	410
Barley	173	94	162	163	99	125	162	154	236	347	213
Bread	172	19	75	87	104	170	181	176	227	252	450
Oil	162	55	96	97	133	263	162	205	209	195	322
Corn	129	53	60	94	130	134	144	165	145	166	212
Beans	123	51	51	88	85	128	111	112	174	218	211
Wheat	112	62	69	98	83	141	161	115	128	154	129
Noodles	93	18	38	38	58	111	81	102	148	171	180
Dairy p.	54	13	26	33	41	42	46	57	62	78	144
Quinoa	49	11	36	53	35	28	38	54	85	74	86
Meats	45	6	11	23	24	17	34	49	45	74	164
Eggs	26	7	8	17	21	22	27	30	27	45	61
Fruits	20	3	6	8	14	16	20	20	31	33	52
Poultry	20	2	4	8	9	13	15	17	26	36	71
Vegetab.	16	4	8	9	10	9	15	22	25	28	35
Fish	15	5	7	7	8	21	16	17	22	24	23
M.Sub[1]	1	0	0	0	0	0	0	1	0	0	0
Average	1934	670	1048	1264	1493	1775	1919	2086	2553	2897	3748

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration

Table 3-19. Dietary composition by type of food and by income deciles.

Type of Food	Average %	1st Decile %	2nd Decile %	3rd Decile %	4th Decile %	5th Decile %	6th Decile %	7th Decile %	8th Decil %	9th Decil %	10th Decil %
Rice	16	14	15	15	16	18	15	15	19	17	17
Tuber.	10	12	12	11	12	10	11	12	9	9	9
Sugar	10	14	11	9	13	9	10	11	10	9	11
Barley	9	14	15	13	7	7	8	7	9	12	6
Bread	9	3	7	7	7	10	9	8	9	9	12
Oil	8	8	9	8	9	15	8	10	8	7	9
Corn	7	8	6	7	9	8	8	8	6	6	6
Beans	6	8	5	7	6	7	6	5	7	8	6
Wheat	6	9	7	8	6	8	8	6	5	5	3
Noodles	5	3	4	3	4	6	4	5	6	6	5
Dairy p.	3	2	2	3	3	2	2	3	2	3	4
Quinoa	3	2	3	4	2	2	2	3	3	3	2
Meats	2	1	1	2	2	1	2	2	2	3	4
Eggs	1	1	1	1	1	1	1	1	1	2	2
Fruits	1	0	1	1	1	1	1	1	1	1	1
Poultry	1	0	0	1	1	1	1	1	1	1	2
Vegetab.	1	1	1	1	1	1	1	1	1	1	1
Fish	1	1	1	1	1	1	1	1	1	1	1
M.Sub[1]	0	0	0	0	0	0	0	0	0	0	0
Average	100	100	100	100	100	100	100	100	100	100	100

[1] Sub-products from the meat.

Source: ENNIV 1994. Own elaboration

In this chapter we presented and discussed important aspects of the current nutritional status in the Andean Mountains. The evidence shows the area to be in deficit to calories available for consumption for most of its rural area population. A high percentage of the calorie available to consumption comes from self-production, especially for the poor. Wage-efficiency theory predicts that better nourished people will be more productive. The Rural Andes seems to be an area where the wage efficiency hypothesis might work because of observed low levels of income and consumption. The next step is to test the relationship between nutrition and production in this area.

CHAPTER IV. THE MODEL, THE DATA BASE AND ECONOMETRIC ESTIMATION

Strauss (1986) modified the standard farm household model to analyze the impact of a worker's nutritional level on farm output. In the standard farm household model farm family members are simultaneously workers, producers and consumers (De Janvry and Saudelot, 1995). The farm family chooses a consumption bundle of food, nonfood and leisure, as well as labor and non-labor variable inputs to maximize a household utility function subject to a farm production function, a time endowment, a production credit constraint and other fixed household characteristics. In addition to the above, the research focuses on effective labor, rather than labor time. Farm output will therefore be a function of the sum of effective hours of family and hired labor, variable non-labor inputs, fixed capital and land cultivated. Effective labor, hired or family, is a function of the nutritional level (measured as the level of calorie intake) and the numbers of hours worked. Calorie intake in turn, depends on household food consumption. We assume that the current year inflow of calories affects annual effective labor.

Effective labor (L_i^*) is the product of labor hours (L_i) and a function relating efficiency per hour worked to caloric intake:

$$L_i^* = h(X^i_c)\, L_i \qquad i = \text{family, hired} \qquad (1)$$

The efficiency per hour worked function, $h(X^i_c)$, is often hypothesized to have a range with increasing returns followed by a range with decreasing returns (Mirrless, 1975; Stiglitz, 1975; Bliss and Stern ,1988a). We also make the important assumption of perfect competition in all markets. Formally households try to maximize the utility (assumed to depend on food, non-food products and leisure), subject to a farm production function, income and time constraints:

$$\text{Max. } U = U(X_a, X_m, X_l) \qquad (2)$$

s.t: $p_m X_m = p_a(Q - X_a) - w^*(L^* - L_f^*,)$ cash income constraint (3)

$X_l + L_f = T$ total time available (4)

$Q = Q(L_f^*, L_h^*, A, K, V)$ production function (5)

Where:

X_a = food consumption bundle.

X_m= non - food consumption bundle.

X_l = leisure.

p_a = food product prices.

p_m= non-food product prices.

p_v = price of another variable inputs.

w = market wages.

w* = effective wages.

Q = farm output.

L_f^* = effective family labor.

L_h^* = effective hired labor.

L^* = total effective labor demand.

T = Total time available for the family.

A = land cultivated.

K = capital.

V = non-labor variable inputs.

Inserting equations (4) and (5) in to equation (3) we obtain:

$$p_m X_m = p_a(Q(L_f^*, L_h^*, A, K, V) - X_a) - w^*((L^* - T) + X_l) \qquad (6)$$

Equation (1) specifies the effective labor function for family and hired labor. Total effective labor demand (L^*) is the sum of effective family labor plus effective hired labor. Inserting these two identities in equation (6) one obtains:

$$p_m X_m + p_a X_a + w^* h(X_c) X_l$$
$$= w^* h(X_c) T + (p_a Q(L_f^*, L_h^*, A, K, V) - w^* L_f^* - w^* L_h^* - p_v V) \quad (7)$$

Equation (7) is a simplified full income constraint, because it excludes non-farm income. The effective wages rate (w^*) is the ratio between the wage market (w) and the effective labor function ($h(X_c)$):

$$w^* = w \ / \ h(X_c) \qquad (8)$$

We assume an identical effective labor function for family and hired labor. We define net profits as follow:

$$\pi = (p_a Q(L_f^*, L_h^*, A, K, V) - w^* L_f^* - w^* L_h^* - p_v V) \qquad (9)$$

In order to solve the restricted maximization problem defined by the equations (2) to (9) we construct the Lagrangian function:

$$\boldsymbol{L} = U(X_a, X_m, X_l) + \lambda ((p_m X_m + p_a X_a + w^* h(X_c) X_l - w^* h(X_c) T$$
$$- (p_a Q(L_f^*, L_h^*, A, K, V) - w^* L_f^* - w^* L_h^* - p_v V)) \quad (10)$$

The first order conditions for labor effective family and hired equal the marginal value products of efficiency labor to the uniform efficiency wage:

$$p_a \ (\delta Q \ / \ \delta L_f^*) = w^* \qquad (11)$$

$$p_a \ (\delta Q \ / \ \delta L_h^*) = w^* \qquad (12)$$

Equations (11) and (12) highlight an important difference from the standard household model. With the standard case marginal value product equals market wage per-clock hour. In our case the marginal value product of labor (family or hired) equals the efficiency wage. The demand for labor (family and hired) is derived by solving equations

(11) and (12), in terms of prices pa and w*, the technological parameters of the production function and fixed factors of production as land, capital, etc.:

$$L_f^* = L_f^*\,(w^*, p_a, A, K) \qquad (13)$$

$$L_h^* = L_h^*\,(w^*, p_a, A, K) \qquad (14)$$

The derived demand for labor (family and hired) give us a set of possible decisions associated with a profit maximization behavior in a farm household as a production unit.

The first order conditions for the other variables are:

$$\delta \boldsymbol{L} / \delta X_a = \delta U / \delta X_a - \lambda\, p_a\, [\, 1 - p_a\, L_f\, \delta Q / \delta L_f^*\, dh(X_c)/dX_a - w^*/\, p_a[T - L_f - X_l]\, dh(X_c)/dX_a\,] = 0 \qquad (15)$$

$$\delta \boldsymbol{L} / \delta X_m = \delta U / \delta X_m - \lambda\, p_m = 0 \qquad (16)$$

$$\delta \boldsymbol{L} / \delta X_l = \delta U / \delta X_l - \lambda\, (w^*\, h(X_c)) = 0 \qquad (17)$$

$$\delta \boldsymbol{L} / \delta \lambda = (p_m X_m + p_a X_a + w^*\, h(X_c) X_l - w^*\, h(X_c) T - (p_a\, Q(L_f^*, L_h^*, A, K, V) - w^*\, L_f^* - w^*\, L_h^* - p_v\, V)) = 0 \qquad (18)$$

The first three equations (15, 16 and 17) combined with the constraint (18) when solved yield the demand functions for food, non-food and leisure.

The real marginal price of food is less than its market price because of the incorporation of nutritional levels in the model. As Strauss observed "from the first order conditions it is clear that the real marginal price of foods is less than the market price to the extent that on-farm (and off-farm) labor productivity varies positively with calorie intake" (Strauss 1986, p.303).

The Data Base

Our data are derived from the "Encuesta Nacional de Hogares Sobre Medicion de Niveles de Vida 1994 (ENNIV 1994)" (National Household Living Standard Survey 1994). The methodology of the National Household Living Standard Surveys was developed by the World Bank . The primary objective is to provide relevant information about the welfare and quality of life of households in developing countries. Four successive data surveys were implemented in 1985-86, 1991 and 1994, and in 1990 for Metropolitan Lima only. All aspects of the survey were implemented by the private sector Peruvian research institute Cuánto S.A., with the technical and financial support of the World Bank and the InterAmerican Development Bank (Cuánto, 1995).

The following paragraph describes the main characteristics of the statistical design and population covered by the 1994 survey (ENNIV 1994, Basic Information, Cuánto, 1995).

The survey questionnaire asks for socio-economic information at the household level. A household is defined as the person or set of persons, relatives or not, who live in the same house, occupy it totally or partially and attend to their basic needs. The unit of analysis is the individual. Topics about housing, consumption, agricultural activity and household enterprise activities use the household as unit of analysis. The variables and sections of the questionnaire are listed in appendix 2.

The total geographical extension of Peru equals 1,285,217 square kilometers. Figure 4-1 provides a map locating the study area and Table 4-1 contains the domains of the survey. There are three natural regions, Coast, Mountain (over 1,200 meters above the sea level) and Jungle. The size of sample equaled 3,544 houses, that were distributed over seven domains (i.e. urban coast, rural coast, urban mountain, rural mountain, urban jungle, rural jungle and Metropolitan Lima). Of these, 1,344 houses were in the rural areas and 2,200 houses were in the urban areas. Table 4-1 shows the distribution of the sample by domains and sub-domains. The sample is probabilistic, multistage and independent in each domain of study. In the urban area it is stratified and three-stage. In the rural area it is a three-stage design in villages with population between 500 and 2,000 inhabitants, and a two-stage design in the rest of the rural area. A total of 3,544 houses were visited, where reviewed 3,623 households. A house can have more than one household.

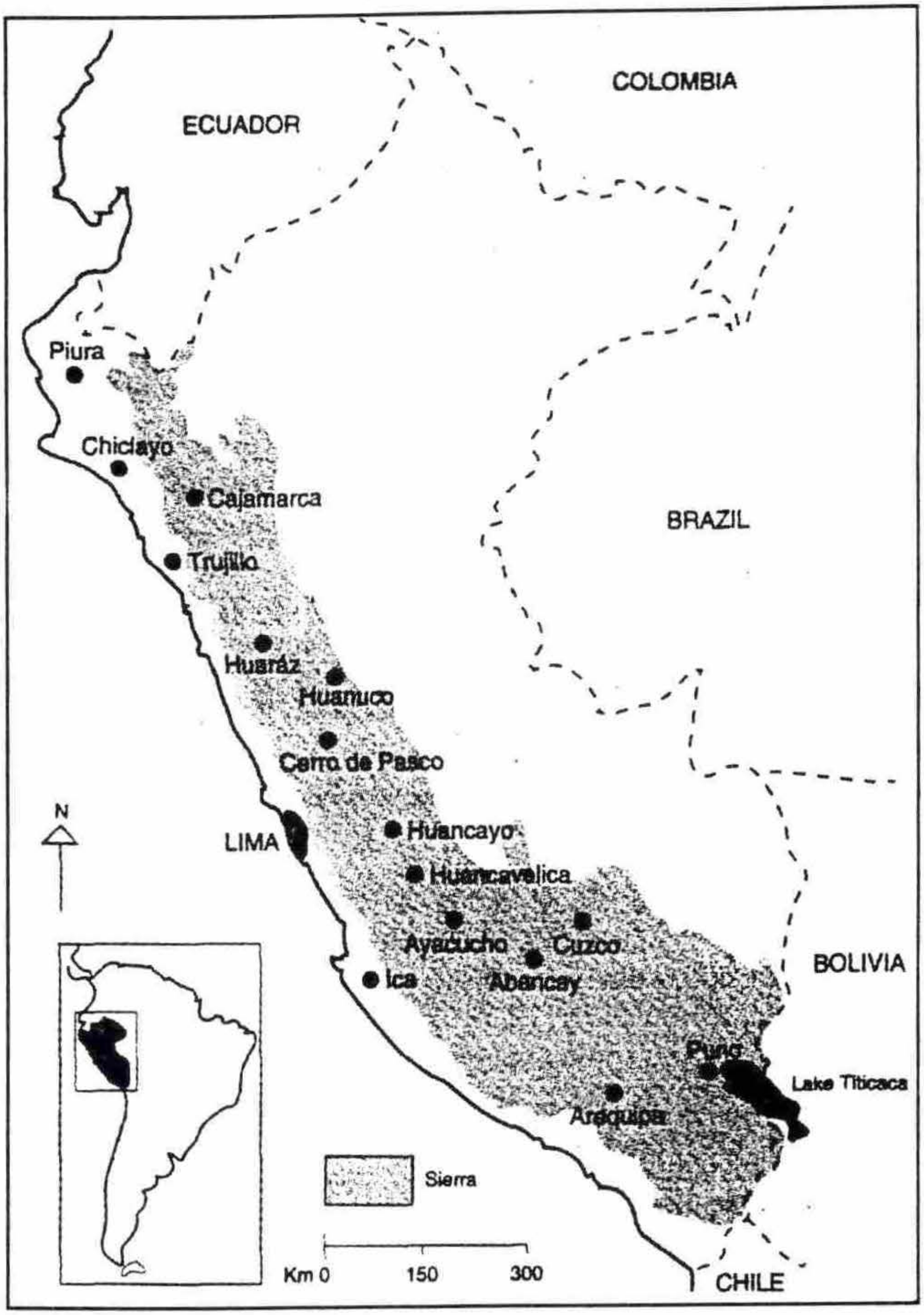

Figure 4-1: Map of Peru and the region of study (rural Andes or Sierra)

Table 4-1. Encuesta Nacional de Hogares Sobre Medicion de Niveles de Vida 1994 (ENNIV 1994), Sample Distribution according with domains of study

Region	Domains	Agglomerations	Houses
Coast	Urban North	27	324
	Rural North	12	144
	Urban Central	11	132
	Rural Central	8	96
	Urban South	4	48
	Rural South	2	24
Mountain	Urban North	4	48
	Rural North	18	216
	Urban Central	19	228
	Rural Central	21	252
	Urban South	18	216
	Rural South	21	252
Jungle	Urban	32	384
	Rural	30	360
LIMA	Metropolitan Lima	137	820
Total		364	3544

Source: ENNIV 1994, p. 8 .

A total of 720 households were interviewed in the rural Mountain areas, our chosen area of interest. Because we want to estimate an agricultural production function we discarded households which did not register agricultural production. This implies a final sample for our study equal to 503 households.

The survey was conducted in June, July and August of 1994. All monetary values in the survey are expressed in prices as of June 1994. All the stages of the survey were the responsibility of Cuánto S.A.

The Variables

Calories per-capita

Calories per-capita are estimated from the registers of consumption and self-consumption in the survey. Households were asked about the amount spent on food in the last 15 days and if self-provided this was valued at the local market price. We used a list of regional prices collected by Cuánto S.A. (1995a) for the three regions of the rural Andes: Northern, Central and Southern. We divided expenditures on food by these prices to estimate the availability of food in kilograms or liters. The Cuánto Institute also provided food item specific conversion factors which were used to transform data on food availability into availability of calories per-household. The household total was divided by the number of family members and by the number 15 to estimate the availability of calories per capita per day. The histogram showing the distribution of calories per capita per day is shown in Figure 4-2.

Output

Gross agricultural product is taken as a measure of aggregate agricultural output. As ENNIV 1994 was a cross sectional survey all prices are as of June 1994. Because the estimation of the farm production function is going to be done in log-linear form, a histogram of the natural logarithm of agricultural output is shown if Figure 4-3.

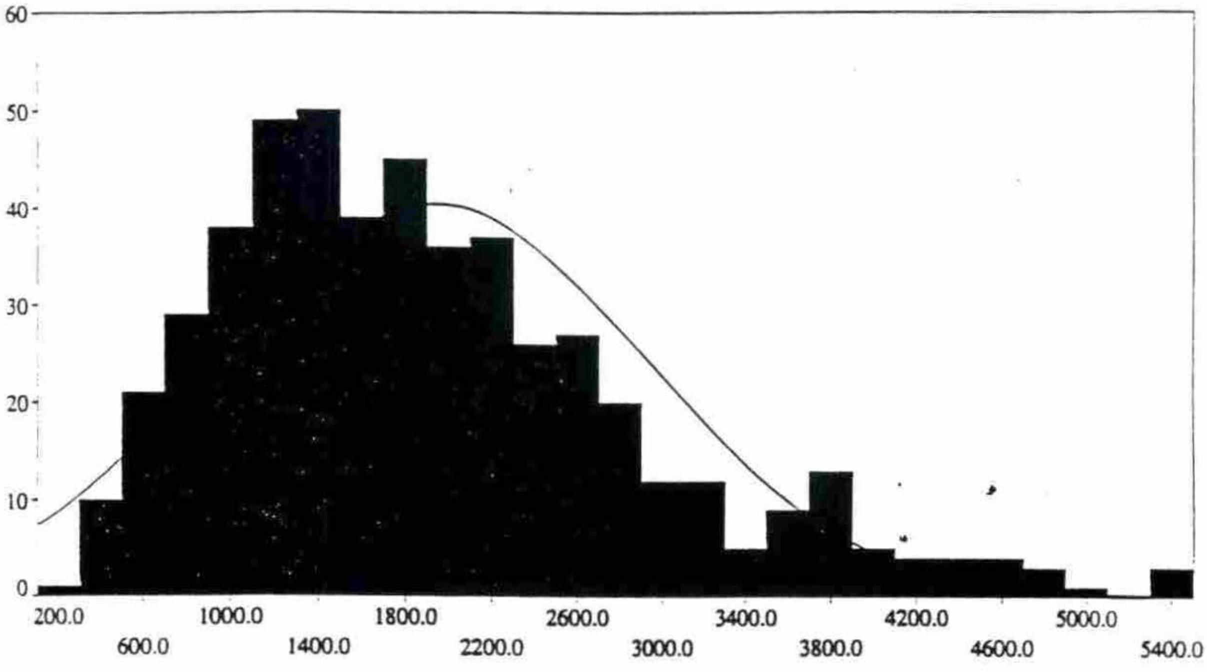

Figure 4-2. Histogram of calories available per capita, per day in rural Andes

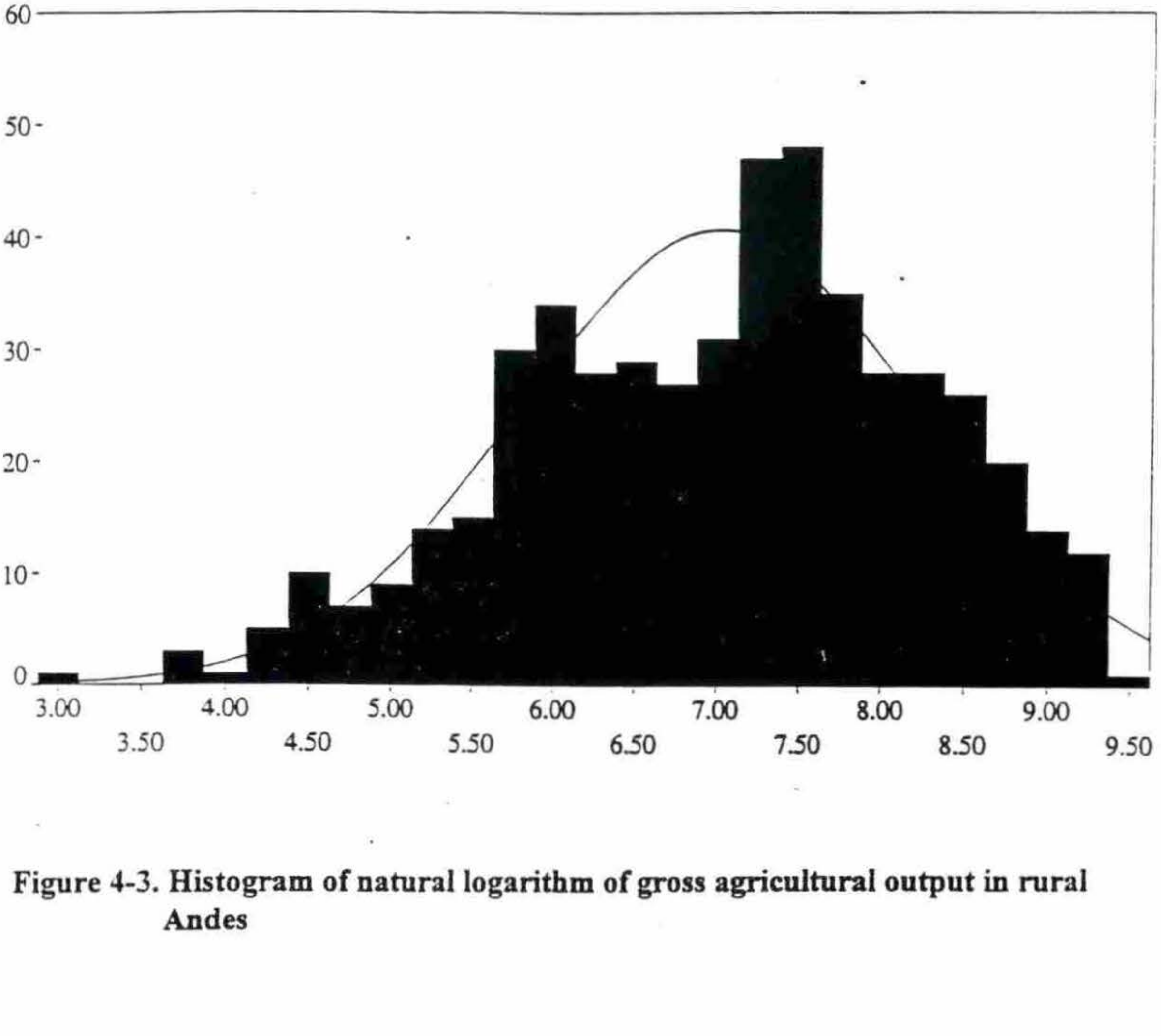

Figure 4-3. Histogram of natural logarithm of gross agricultural output in rural Andes

Family Labor

The family labor variable measures the number of hours worked by the family members on their own farm . The estimates for this variable are really an approximation of its value, in the sense that the survey simply asked family members if they worked the week before the survey, how many hours, how many days and how many months. On the basis of these answers we estimated the number of hours the family worked on their own farm. A histogram of the distribution of the natural logarithm of number of family hours worked is shown in Figure 4-4.

Hired Labor

Hired labor was taken from the annual amount spent on hired labor given, by the farmer at the time of the survey divided by the average wage at the local level. Only 215 from 503 households used hired labor force. A natural logarithm histogram of this variable is shown in Figure 4-5.

Land

Cultivated land is taken as an indicator of the land variable. It was not possible to find an indicator of land quality in order to isolate this factor in our estimations. We therefore assume a homogenous distribution of land quality in the area of study. A natural logarithm histogram of this variable is presented in Figure 4-6.

Capital

Capital measured as the value of equipment used in agricultural activity. The value was taken from the farmer's declaration for how much he was willing to sell that equipment.

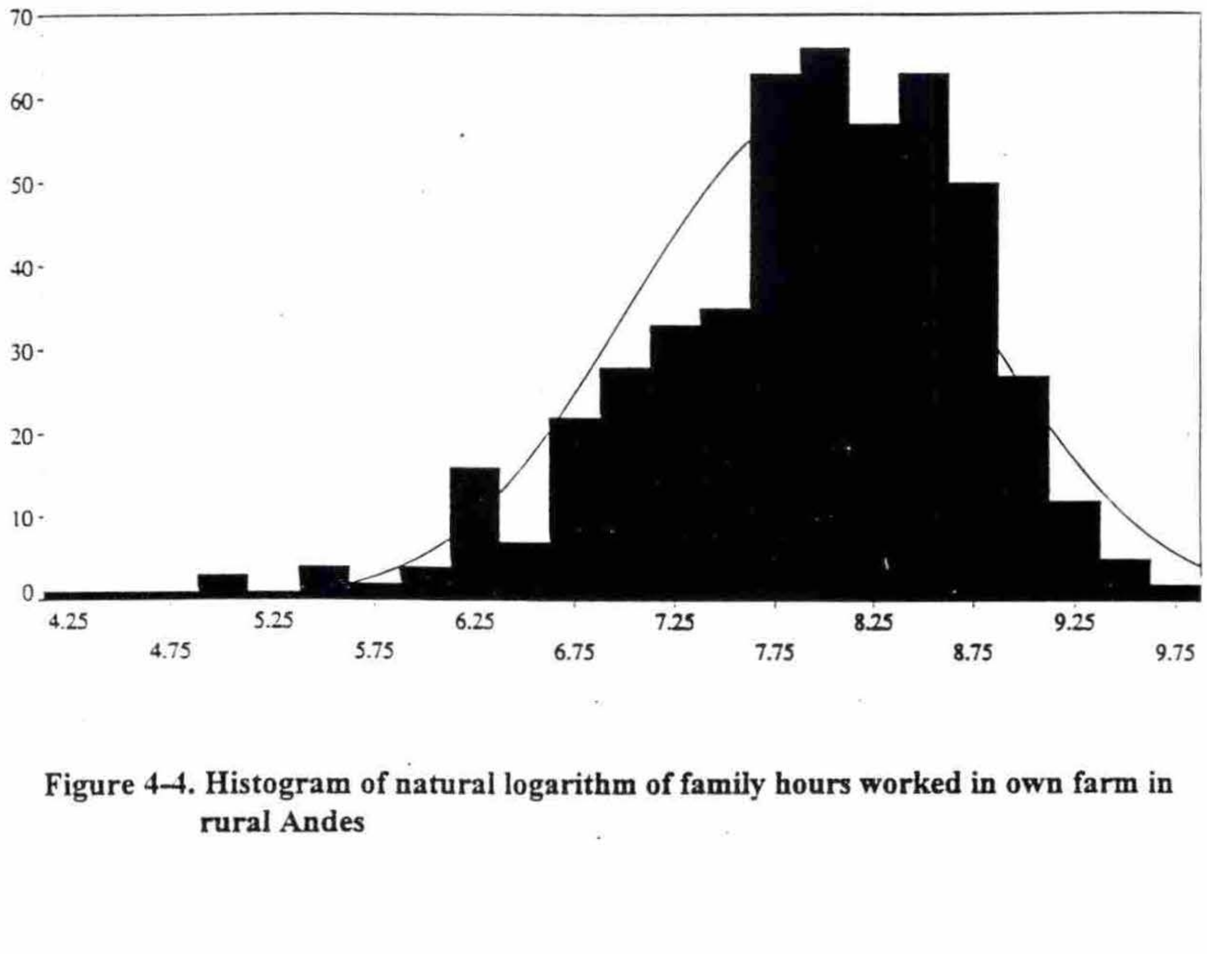

Figure 4-4. Histogram of natural logarithm of family hours worked in own farm in rural Andes

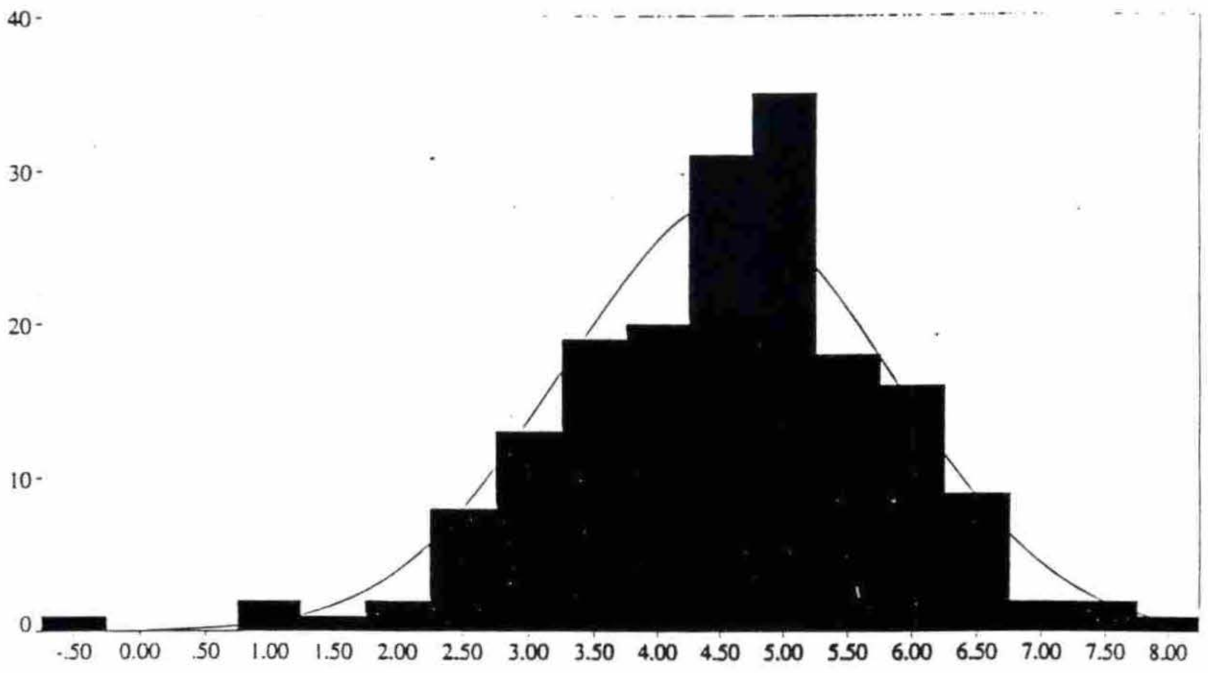

Figure 4-5. Histogram of natural logarithm of hired labor in rural Andes

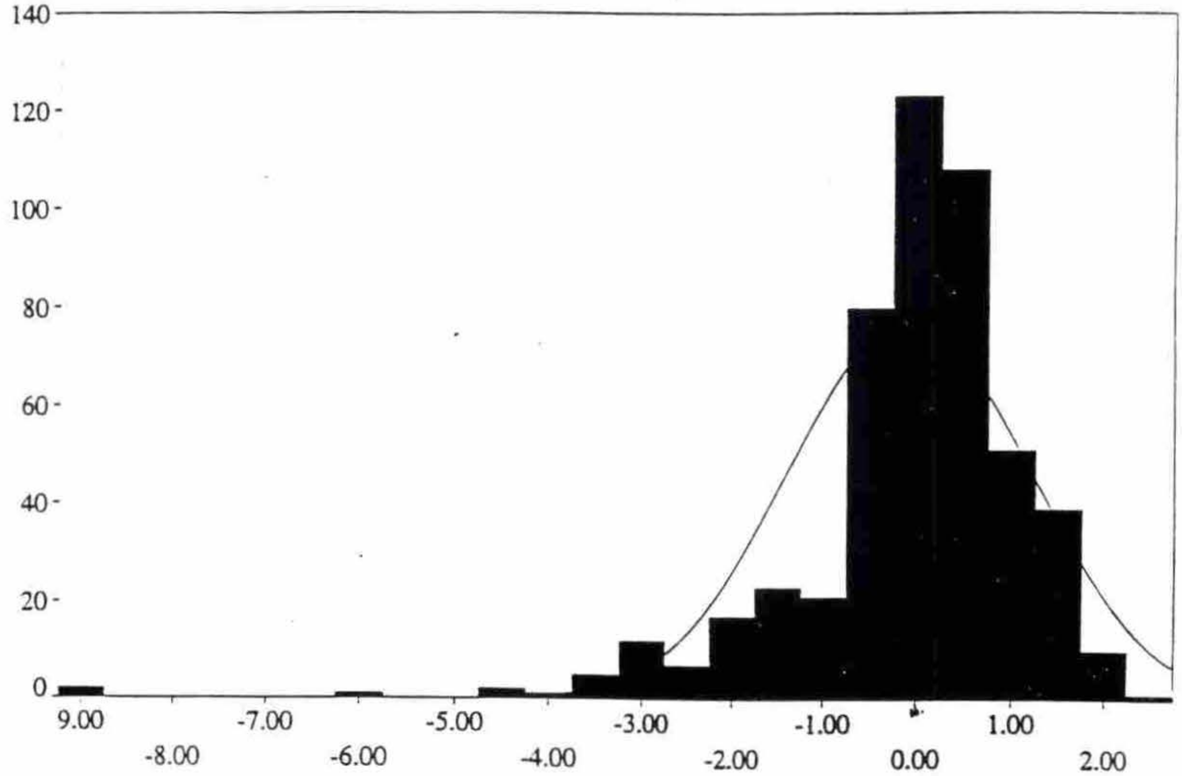

Figure 4-6. Histogram of natural logarithm of land in rural Andes

A histogram of the natural logarithm of capital is shown in Figure 4-7.

Wages

Wages are taken as measure of marginal product of labor under the assumption of perfect competition. They represent the average wage in agricultural activities at the time of the survey. Figure 4-8 represents the histogram of this wage rate. Figure 4-9 represents the histogram of the natural logarithm of this wage rate. Furthermore Figure 4-10 represents the wage rate for the family members 11 years or older. This variable is used as instrumental variable for family hours to overcome the endogeneity problem mentioned several times in this study.

Econometric Estimation

Following Strauss (1986) we estimate a Cobb-Douglass farm production function without and with effective labor. If the parameters of effective labor are different and statistically significant between these two types of production functions then the nutritional level affects the productivity of labor of the households in our chosen study area.

Define a Cobb-Douglass farm production function which depends on effective family labor, effective hired labor, capital and land cultivated.

$$Q = \beta_1 (L_f^*)^{\beta 2} (L_h^*)^{\beta 3} K^{\beta 4} A^{\beta 5} \qquad (19)$$

where:

Q = agricultural output .

L_f^*= effective family labor.

L_h^*=effective hired labor.

K = capital.

A = land cultivated.

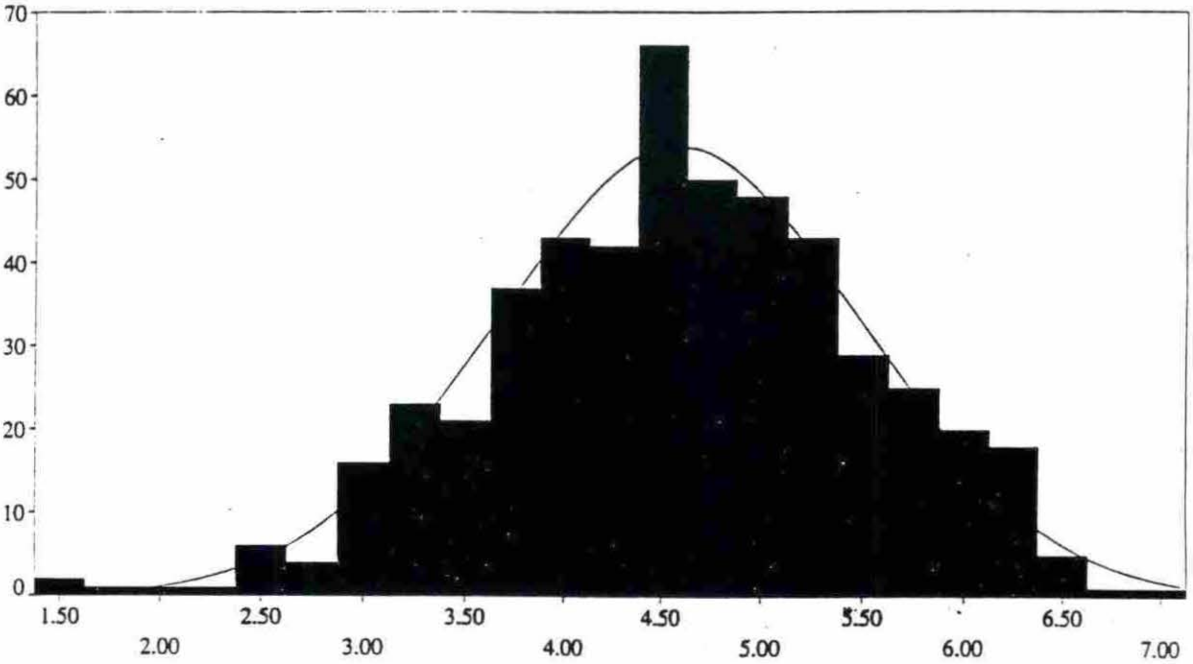

Figure 4-7. Histogram of natural logarithm of capital in rural Andes

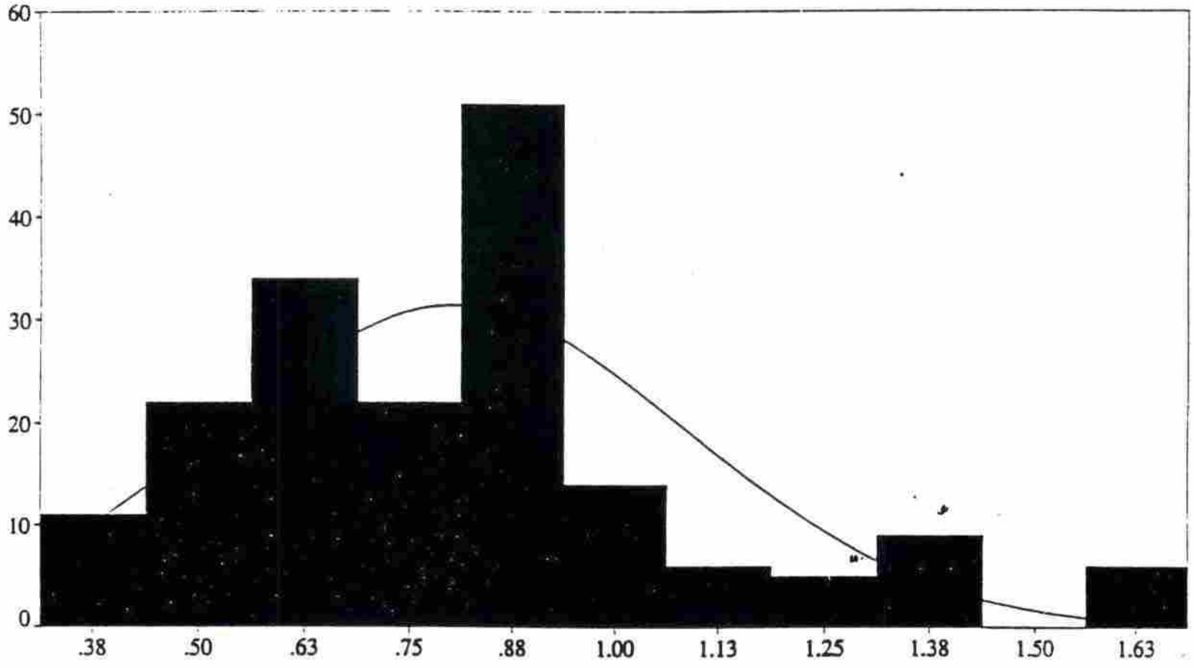

Figure 4-8. Histogram of agricultural wages in rural Andes

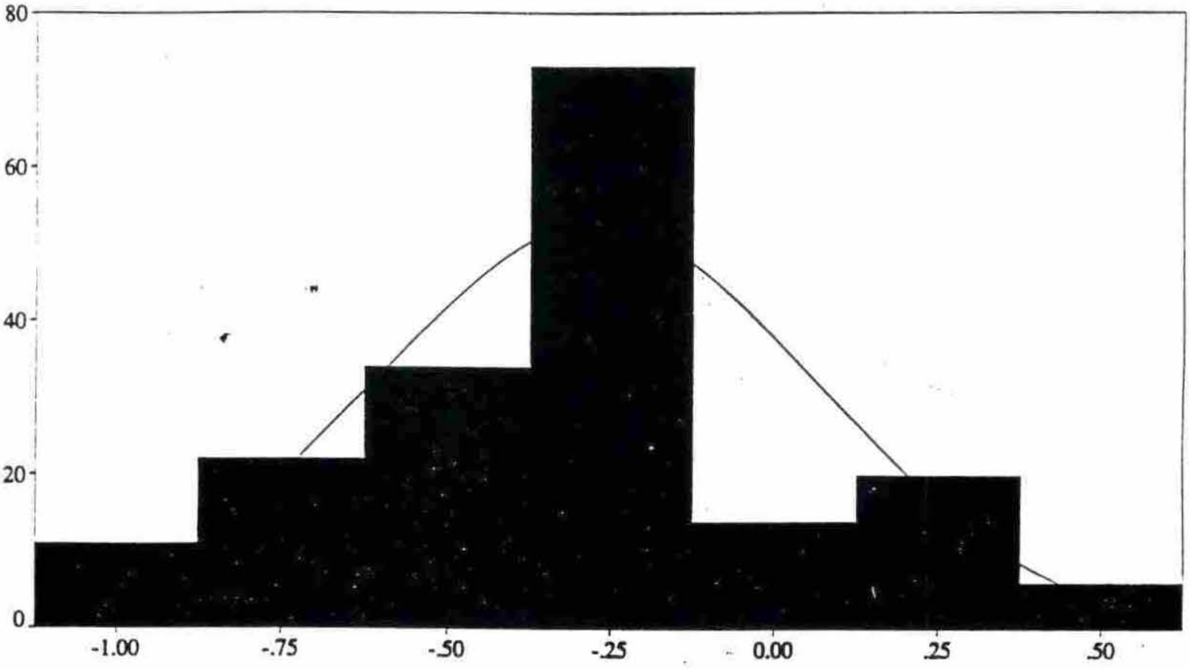

Figure 4-9. Histogram of natural logarithm of agricultural wages in rural Andes

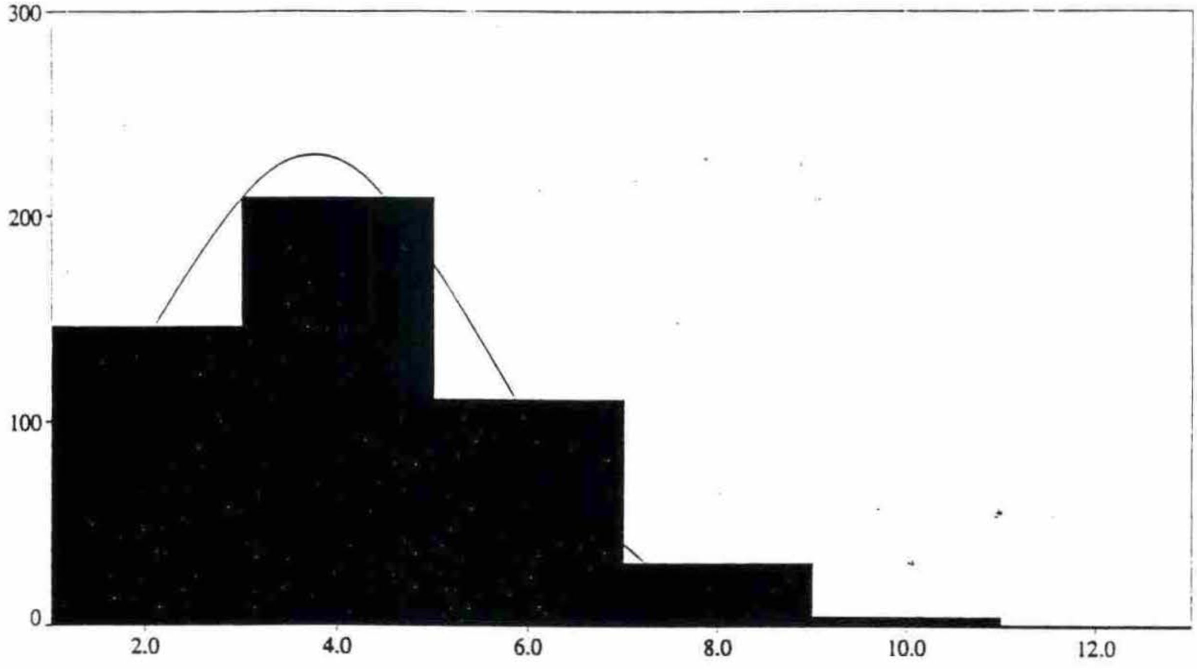

Figure 4-10. Histogram of family members older than 11 years in rural Andes

In the wage-efficiency hypothesis literature (Bliss and Stern 1988a; Stiglitz 1975; Mirrless 1975), effective labor is a function on number of hours worked and a function which related efficiency per-hour worked and calories intake. Specify the effective labor function as:

$$L_i^* = h(X^i_c)\, L_i \qquad i = \text{family, hired} \qquad (20)$$

where:

L_i^* = effective labor, family and labor hours.

$h(X^i_c)$ = efficient labor function.

L_i = number of hours worked, family and hired labor hours.

Assume that the efficient labor function is the same for both, family and hired labor. Insert (2) in (1) and obtain:

$$Q = \beta_1 (h(X^i_c) L_f)^{\beta 2} (h(X^i_c) L_h)^{\beta 3}\ K^{\beta 4}\ A^{\beta 5} \qquad (21)$$

Strauss (1986) used a non-linear econometric method to estimated simultaneously the parameters of the farm production function and the effective labor function. In our study the estimation of the relevant parameters will be divided into two steps. First we estimate the parameters of the effective labor function, then these estimates will be used to correct the family and hired labor variables to obtain the effective labor for each one of these. We then linearize the Cobb-Douglass production function by taking natural logarithms in order to use linear methods of estimation. The equation to be estimated is:

$$\ln Q = \beta_1 + \beta_2 \ln (h(X^i_c) L_f) + \beta_3 \ln (h(X^i_c) L_h) + \beta_4 \ln K + \beta_5 \ln A \qquad (22)$$

In the farm household model the demand for and supply of labor hours, as well as food consumption (measured in this study by potential calories consumption), are determined simultaneously with farm production (Strauss 1982; Singh et al. 1986). We cannot ensure that the 'independent' variables in (4) have zero correlation with the ex-ante error term. Ordinary least square can not be used because it will generate biased and inconsistent estimates (Green 1993; Pindyck and Rubinfeld 1991; Maddala 1993). To see this we will develop an intuitively explanation and then a formal solution to this problem.

The demand for a commodity can be defined as function on income, price and a stochastic error term:

$$\text{DEMAND} = \beta_0 + \beta_1 * \text{PRICE} + \beta_2 * \text{INCOME} + \text{ERROR}_1 \tag{23}$$

The stochastic error term captures all the other influences which affect the commodity demand. Figure 4-11 illustrates the hypothetical causal paths which influence demand. There is a feedback effect between production (or demand), prices and income. Production (or demand) depends on prices , -higher prices are an incentive for higher levels of production (or lower levels of demand)-, but it is equally true that prices depend on production (or demand), -an important increment of some commodity supply in the market will decrease the price of this commodity in the market. If a variable not included in the model varies, - use of a new technology, better labor organization, etc.-, and so the production of this hypothetical commodity is increased its prices will fall. Because of the feedback relationship , high values of the error term would be associated with low prices of this commodity in our demand equation. Correlation of the error with the predictor variable violates the basic assumptions of OLS regression analysis. It will generate biased coefficients, because the model originally implies that price levels cause increased production (or demand). The Ordinary Least Square algorithm used by the Linear Regression procedure treats that portion of the error that is correlated with price as being caused by price -although really the correlation arises in other direction, from the feedback effect of demand on price. Figure 4-12 emphasizes this feedback relationship from the dependent variable 'demand' to the predictor variable 'price'. It produces a correlation between the error term and price. The recommended way to overcome this problem is the use of instrumental variables. Instrumental variables are variables that are not influenced by other variables in the model but do influence those variables. To be effective, instruments need to be highly correlated with the endogenous variable but not correlated with the error term.

Figure 4-13 illustrates the relationship between instruments and other variables in the model. The Two Stage Least Square procedure uses the instruments in a first stage to regress against the predictor variable correlated with the error term and to obtain estimates of this variable. In a second stage this forecast is used to estimate the original equation (for an example see SPSS 1995c).

The problem for the econometric estimation of the farm production function with effective family and hired labor, is the simultaneity determination of production, consumption and hours worked which emerges from the farm household model. In order to give a more formal explanation of that, just work with a two equation Keynesian model of income determination as presented in Gujarati (1988):

Consumption Function: $C_i = \beta_0 + \beta_1 Y_t + \mu \qquad 0 < \beta_1 < 1 \qquad (24)$

Income identity: $Y_t = C_i + I_t \qquad (25)$

where:

C_i = consumption,

Y_t = income,

I_t = investment,

t = time,

μ = stochastic error term

β_0 , β_1 = parameters

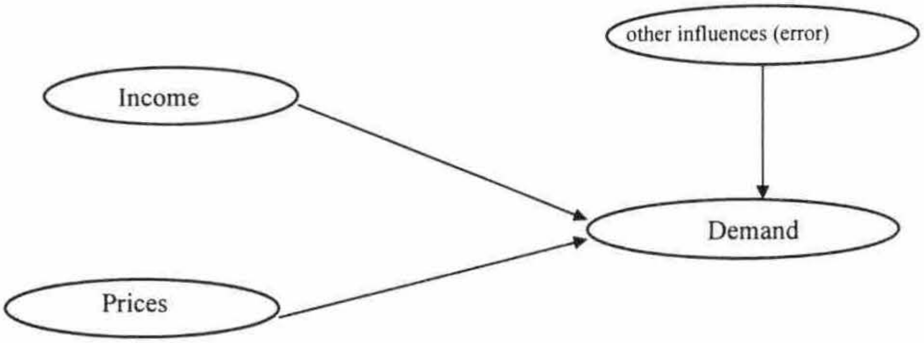

Figure 4-11. Diagram of simple model

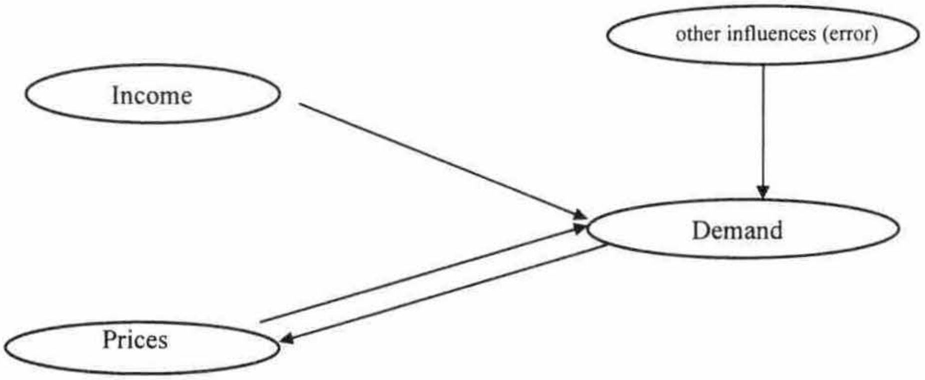

Figure 4-12. Diagram include feedback in the model

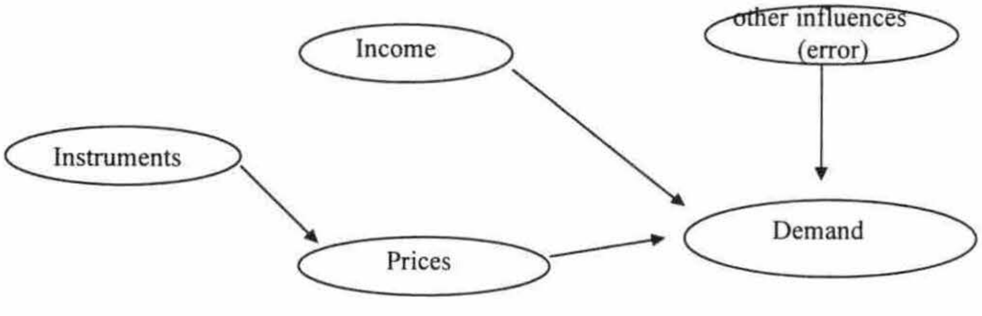

Figure 4-13. Model with instrumental variables

In this model consumption and income are endogenous variables, and only investment can be considered as exogenous variable, so in equation (24) consumption is regressed against another endogenous variable, income. Both depend on each other. In this case income is correlated with the error term μ .

To see that just substitute (24) in (25)

$$Y_t = \beta_0 + \beta_1 Y_t + \mu + I_t$$

$$Y_t = (\beta_0 / 1 - \beta_1) + (1 / 1 - \beta_1) I_t + (1 / 1 - \beta_1) \mu \qquad (26)$$

Taking expectations

$$E (Y_t) = (\beta_0 / 1 - \beta_1) + (1 / 1 - \beta_1) I_t \qquad (27)$$

because $E (\mu) = 0$ and the expected value of the exogenous variable I_t is the same I_t.

Subtracting (27) from (26) it is obtained:

$$Y_t - E (Y_t) = (1 / 1 - \beta_1) \mu$$

We know that:

$$\mu - E(\mu) = \mu$$

So: $$\begin{aligned} \text{cov} (Y_t\ \mu) &= E[Y_t - E(Y_t)] [\mu - E(\mu)] \\ &= E (\mu^2) / 1 - \beta_1 \\ &= \sigma^2 / 1 - \beta_1 \end{aligned} \qquad (28)$$

Given that σ^2 is positive by assumption, the covariance between income and the error term μ should be different from zero, i.e. income and the error term are correlated, which violates the assumption of the classical regression of linear model about the independence of the error term or at least they are not correlated with the explanatory variables. In that case the estimates are biased and inconsistent (Gujarati, 1988; Pindyck and Rubinfeld, 1991; Maddala, 1993). To demonstrate why it is inconsistent in our example of income and consumption just take the variables in deviation form from the equation (24) and (25) and estimate β^* by Ordinary Least Square (OLS). It yields the following model:

$c = \beta y + u$ and $y = c + I$, where the lower case letters indicate the same variables in the equation (24) and (25) but in deviation form. The parameter β^* will be

$$\beta^* = \sum c\, y / \sum y^2 \tag{29}$$

substituting c in equation (29) we have:

$$\beta^* = \sum (y\, (\beta y + u) / \sum y^2$$

$$\beta^* = \beta + \sum y\, u / \sum y^2 \tag{30}$$

An estimate is consistent if its plim is equal to its true population value. Taking the limit of probability (plim) of (30) yield:

$$\text{plim } \beta^* = \text{plim}(\beta) + \text{plim } (\sum y\, u / \sum y^2)$$

$$\text{plim } \beta^* = \text{plim}(\beta) + \text{plim } [(\sum y\, u / N) / (\sum y^2 / N)]$$

$$\text{plim } \beta^* = \beta + \text{plim } [(\sum y\, u / N) / \text{plim } (\sum y^2 / N)] , \tag{31}$$

where N is the total number of observations in the sample. The quantities within parentheses are the sample covariance between income and the error term and the sample variance of income, respectively. The result (31) tells us that the plim of β^* is the true β plus the ratio of the sample covariance between y and u and the plim of the sample variance of y. As the sample increase the sample covariance should be close to the true value of the population covariance which according our result is $\sigma^2 / 1 - \beta_1$, and in the same way at larger the sample N, the sample variance of y will trend to the true population variance σ_y^2. So the equation (31) can be written as:

$$\text{plim } \beta^* = \beta + (\sigma^2 / 1 - \beta_1) / \sigma_y^{2.}$$

$$\text{plim } \beta^* = \beta + (1 / 1 - \beta_1) (\sigma^2 / \sigma_y^{2.}) , \tag{32}$$

Because β^* lies between 0 and 1 and both σ^2 and σ_y^2 are positive, the plim of β^* will always be greater than the true value β , i.e. β^* overestimate the true value of β (Gujarati, 1988; Pindyck and Rubinfeld,1991). The direction of the bias is not always known as mentioned by Pindyck and Rubinfeld (1991). Even for a simple model of supply and demand the direction of the bias is usually unknown.

The use of instrumental variables can help to overcome this problem. The instrumental variable method consists of finding a variable 'z' that is not correlated with 'w', the error term, but correlated with 'x', the explanatory variable and estimating the parameters by the following formula:

$$\beta_{IV} = \sum y z \,/ \sum x z \ , \tag{33}$$

Where y is the dependent variable and 'z' is called the instrumental variable. So if we have the following model:

$$y = \beta x + w \ , \tag{34}$$

the normal equation for the OLS estimation is:

$$\sum x (y - \beta x) = 0 \tag{35}$$

it is valid under the assumption that cov (x, w) is zero. But if this assumption is violated we cannot use the normal equation in (35) to find our parameter, instead that we replace our condition by cov (z, w) = 0 and replace the normal equation (35) by:

$$\sum z (y - \beta x) = 0 \tag{36}$$

so ,

$$\beta_{IV} = \sum z y \,/ \sum z x$$

$$\beta_{IV} = \sum z (\beta x + w) \,/ \sum z x$$

$$\beta_{IV} = \beta + \sum z w \,/ \sum z x \tag{37}$$

which is the instrumental variable estimator. It is consistent because:

$$\text{plim } \beta_{IV} = \text{plim } [\sum z (\beta x + w) / \sum z x]$$

$$= \beta + \text{plim } \{[(1/n (\sum z w)] \ / \ [1/n (\sum z x)]\}$$

$$= \beta + \text{cov } (z, w) / \text{cov } (z, x) = \beta \tag{38}$$

since cov (z, w) = 0 and cov (z, x) is different from zero (Maddala, 1993).

The Two Stage Least Square Method (2SLS) method is an application of the instrumental variable method (IV). It involves in the first stage the creation of an instrument.

The second stage of 2SLS involves a variant of instrumental -variables estimation (Pindyck and Rubinfeld, 1991).

In the 2SLS method, estimates of predictor variables are used as regressor rather than as instruments (Maddala, 1992), both of them give you the same results. To see that considered the equation to be estimated:

$$y_1 = \beta_1 y_2 + \beta_2 c z_1 + u_1 \tag{39}$$

where y_1 and y_2 are endogenous variables and z_1 and z_2, z_3 , z_4 are other exogenous variables in the model. Let y_2* the predicted value of y_2 from the regression on z_1, z_2, z_3 and z_4 , then:

$$y_{12} = y_2{}^* + v_2$$

where v_2 , the residual , is no correlated with each of the regressor z_1, z_2, z_3 and z_4 and hence y_2* as well. The normal equations for the efficient IV method are:

$$\sum y_2{}^* (y_1 - \beta_1 y_2 - \beta_2 z_1) = 0$$

$$\sum z_1 \quad (y_1 - \beta_1 y_2 - \beta_2 z_1) = 0$$

Substituting $y_2 = y_2{}^* + v_2$

$$\sum y_2{}^* (y_1 - \beta_1 y_2 - \beta_2 z_1) - \beta_1 \sum y_2{}^* v_2 = 0 \tag{40}$$

$$\sum z_1{}^*(y_1 - \beta_1 y_2 - \beta_2 z_1) - \beta_1 \sum z_1 v_2 = 0 \tag{41}$$

But $\sum z_1{}^* v_2 = 0$ and $\sum y_2{}^* v_2 = 0$ since z_1 and y_2* are no correlated with v_2 . Thus equations (40) and (41) give:

$$\sum y_2{}^* (y_1 - \beta_1 y_2 - \beta_2 z_1) = 0$$

$$\sum z_1{}^*(y_1 - \beta_1 y_2 - \beta_2 z_1) = 0$$

and these are the normal equations if we replace y_2 by y_2* in equation (39) and estimate the equation by OLS (Maddala, 1992). So the 2SLS estimator are the same as the instrumental variable estimators and both give us consistent estimators. Therefore 2SLS involves two steps: -first make an estimate of the endogenous variable regressing by OLS this variable against exogenous variables in the model; and then replace the right hand side endogenous variables by y_2*(forecast of endogenous variables) and estimated the equation by OLS.

As mentioned before the estimation of the farm production will be divided in two steps, first the estimation of the efficient labor function that relates calories and labor productivity, and then this will be used to transform the number of labor hours, family and hired, in effective labor variables in the farm production function, which is our final objective.

Estimation of the efficient labor function

Strauss (1986) used a non-linear two stage least square method to estimate simultaneously the parameters of the farm production function and the effective labor function. Strauss's formulation for the effective labor function is a normalized quadratic function which "is reasonably flexible even allowing for a range of negative productivity effects at the high levels of food intake. It does not allow for both convex and concave portions , but it is likely that observed values would be on the concave portion of the curve since that is the more relevant economic region" (Strauss, 1986, p.308). In this study we use two functional forms for the efficient labor function, (a) the quadratic function and (b) the inverse logarithmic form or sigmoid form but without normalization. The functional specifications for the effective labor function will be:

$$h(X^i_c) = \alpha + \alpha_1 X^i_c + \alpha_2 (X^i_c)^2 \quad \text{(quadratic)}$$

$$\ln[h(X^i_c)] = \alpha - \alpha_1 (1/X^i_c) \quad \text{(inverse-logarithmic)}$$

where:

$h(X^i_c)$ = the marginal product of labor.

X^i_c = calorie availability per-household.

If we assume perfect competition in the labor market then wages can be considered as a good measure of the marginal productivity of labor (Korjenek 1992; Berhman 1993). The parameters of the effective labor function can then be obtained if we regress wages (or marginal labor product) against calories available per household. Because calories available (which in turn are provided by food consumption) are determined simultaneously with production it is necessary to find an instrumental variable for calories for our effective labor function. In the case of calories, both prices and income variables are the logical candidates. We face two problems. The first one is that we do not have a cross-sectional set of regional prices in order to regress these against the calories variable. We only have prices for three regions, northern, central and southern, and they do not allow us to obtain good predictions for the calorie variable. Also income is a simultaneous variable within the household model. However in this case we have an option mentioned by several authors (Maddala 1993; Johnston 1972; Greene 1993). It is the so-called grouping method used to build an instrumental variable. Three main grouping methods have been suggested in the literature, Wald (1940), Bartlett (1949), and Durbin (1954). Following Maddala (1993) use of Wald's method, we rank the X's and form those above the median X into one group and those below the median into another group. If the means in the groups are, respectively, Y1 , X1 and Y2, X2 , we estimate the slope β by:

$$\beta^* = (Y2 - Y1) / (X2 - X1)$$

This amounts to using the instrumental variable:

$$Zi = \begin{cases} 1 \text{ if } X > \text{median} \\ -1 \text{ if } X < \text{median} \end{cases}$$

and using the instrumental variable estimator

$$\beta^* = \sum YiZi / \sum XiZi$$

Johnston (1972) explained this method using a two variable linear regression model expressed in matrix form. The parameters by the instrumental variable method are:

$$b = (Z'X)^{-1} Z'y \qquad (42)$$

here Z is the matrix of the instrumental variables which is not only not correlated with the error term but also correlated with the explanatory variable X. Suppose there is an even number of sample observations and we define a Z matrix as:

$$Z' = \begin{bmatrix} 1 & 1 & 1 & \dots & 1 & 1 \\ -1 & -1 & -1 & \dots & 1 & 1 \end{bmatrix}$$

where the second elements in the second row of Z' are plus or minus one according as the corresponding value of X is above or below the median X value. The X matrix for use in the regression is: $X' = \begin{bmatrix} 1\,1 & 1 & \dots & 1 & \\ x_1 & x_2 & x_3 & \dots & x_n \end{bmatrix}$

Where $x_i = (X_i - \overline{X})$

The instrumental variable defined by (42) is then:

$$b = \begin{bmatrix} n & 0 \\ 0 & (n/2)\,(\overline{x}_2 - \overline{x}_1) \end{bmatrix}^{-1} \begin{bmatrix} n\,\overline{Y} \\ (n/2)\,(\overline{Y}_2 - \overline{Y}_1) \end{bmatrix}$$

where $\overline{x}_2$ and $\overline{x}_1$ denote the mean values of the deviations for those values of X above and below the median and $\overline{Y}_2$ and $\overline{Y}_1$ are the means of the corresponding Y values.

Thus:

$$b = \begin{bmatrix} \overline{Y} \\ \overline{Y}_2 - \overline{Y}_1 / \overline{x}_2 - \overline{x}_1 \end{bmatrix}$$

The estimated slope is:

$$\beta^* = \overline{Y}_2 - \overline{Y}_1 \Big/ \overline{x}_2 - \overline{x}_1 = \overline{Y}_2 - \overline{Y}_1 \Big/ \overline{X}_2 - \overline{X}_1 \qquad \text{and,}$$

$$\alpha^* = \overline{Y} - \beta^* \, \overline{X}$$

To find a forecast for calories we therefore regress calories against income (or expenditure per-capita as a proxy measure of income per-capita) building an instrumental variable by Wald's method. So the model to be estimated is:

CALORIES AVAILABLE = ALFA + BETA * INCOME + ERROR

The results are summarize in Table 4-2.

Table 4-2. Regression results of calories against income, using Wald method of instrumental variables.

Variable	Parameters	T-value	Significant t
Income (expenditure)	1440.82	33.506	0.0000
Constant	240.45	4.393	0.0000
R^2	0.692		
Sample size	503		

We now use these estimates of available calories as a regressor in our efficient labor function, which may be estimated using OLS:

$$h(X^i_c) = \alpha + \alpha_1 X^i_c + \alpha_2 (X^i_c)^2$$

$$\ln[h(X^i_c)] = \alpha - \alpha_1 (1/X^i_c)$$

where:

$h(X^i_c)$ = marginal product of labor measure by market wages;

X^{i}_{c} = calories available estimates,

Note that we implemented a two stage process similar to the 2SLS procedure. First we created an instrumental variable regressing calories available against income using the grouping method suggested by Wald. Second, this instrument (calories available estimates) was then used as a regressor. The results of this procedure are summarized in Table 4-3 for the quadratic labor efficiency function, and in Table 4-4 for the log-inverse form of that function. Both tables report the results when (a) calculated for the sample as a whole, (b) calculated for households that declared the use of hired labor at the time of the survey, and (c) by levels of calories availability. Grouping data may have two effects: (1) the parameter estimates will be less efficient due to loss of information, (2) the fit of the regression improves. The OLS estimates however remain unbiased (Greene 1993).

Table 4-3 shows the linear effect of the estimated calorie availability to be statistically highly significant. The quadratic effect of estimated calorie availability is only marginally significant. Table 4-4 shows the inverse logarithmic effect of the estimated calorie availability to be statistically highly significant.

In the inverse-log functional form the constant has an economic meaning. This function is asymptotic at e^{α}, where α is the constant in the equation, and it indicates that the contribution of calories to marginal product of labor reaches a saturation point as calorie consumption increases.

Table 4-3. Comparative results of the Efficient Labor Function:
$h(X^i_c) = \alpha + \alpha_1 X^i_c + \alpha_2 (X^i_c)^2$

Parameters	Effective Labor Function (quadratic) [1]	Effective Labor Function (quadratic) [2]	Effective Labor Function (quadratic) [3]
Calories	1.5859	1.7930	1.8235
t-value	3.2150	3.2670	3.4610
significance	0.0014	0.0013	0.0008
Calories Square	-0.00010	-0.00016	-0.00016
t-value	-1.162	-1.810	-1.7640
significance	0.2459	0.0718	0.0890
Constant	3737.0000	5064.3700	4929.1700
t-value	6.2710	6.9120	7.5420
significance	0.0000	0.0000	0.0000
R^2 (%)	8.42	12.7	26.3
Sample Size	503	215	101

[1] Calculated for the whole sample

[2] Calculated for those households which declared hired labor at the time of the survey.

[3] Calculated grouping by calories levels.

Note: all the parameters were multiply by 10,000, including the constant)

Table 4-4. Comparative results of the Efficient Labor Function:
$\ln[h(X^i_c)] = \alpha - \alpha_1(1/X^i_c)$

Parameters	Effective Labor Function (inverse-logarithm) [1]	Effective Labor Function (inverse-logarithm) [2]	Effective Labor Function (inverse-logarithm) [3]
1 / Calories	-140.82	-383.51103	-318.7985
t-value	-3.42	-4.928	-4.6470
significance	0.0007	0.0000	0.0000
Constant	-0.2453	-0.055197	-0.0827
t-value	-8.173	-1.119	-1.6510
significance	0.0000	0.2643	0.1019
R^2 (%)	2.2	10.2	18.1
Sample size	503	215	101

[1] Calculated for the whole sample

[2] Calculated for those households which declared hired labor at the time of the survey.

[3] Calculated grouping by calories levels.

Estimation of the farm production function

The next step is to estimate the farm production function with hired and family labor adjusted by the efficient labor function. Again the endogeneity problem presents itself. For example labor hours demanded and family labor supplied are determined simultaneously with production. Again it will be necessary to use an instrumental variable for hired and family labor. We use two such variables, family members 11 years or older and market wages. Table 4-5 summarizes the results using the whole sample of 503 observations for few alternative specifications,

(1) Ordinary Least Squares, without an efficiency labor function.

(2) Two Stage Least Squares, without an efficiency labor function.

(3) Two Stage Least Squares, with a quadratic efficiency labor function.

(4) Two Stage Least Squares, with an inverse logarithmic efficiency labor function.

Comparison of the alternative specifications leads to the following observations. The productive elasticity of land as an input is statistically significant for all four cases and approximately equal to 0.30. The productive elasticity of hired labor is small but highly statistically significant for all four statistical estimation procedures. On the other hand, as anticipated, the production elasticity of family labor is large when allowing for efficiency labor and endogeneity. Without these two considerations the production elasticity of family labor equals 0.12 indicating a low marginal productivity of this input. On the other hand the simple OLS procedure gives a high marginal productivity to capital, its productive elasticity being equal to 0.28 and statistically highly significant. Allowing for efficiency and endogeneity the apparent importance of capital in the production process decreases, such that it became statistically insignificant. The above results observe that the proper calculation of inputs used in the agricultural production process and the proper statistical estimation procedure are of convergence in estimating the parameters of aggregate agricultural production functions, in this case a conventional unconstrained Cobb-Douglass production function within the context of the rural household production-consumption model.

Table 4-5. Summary Estimates of Farm production Function in the Rural Andes

Variable	OLS	2SLS, no ELF	2SLS, ELF quadratic	2SLS,EFL inv.logarithm.
FAMILY LABOR	0.122	0.245	0.492	0.496
(t value)	(2.285)	(1.349)	(2.343)	(1.743)
significant T	0.0227	0.1781	0.0195	0.0820
HIRED LABOR	0.0489	0.095	0.095	0.165
(t value)	(6.818)	(3.531)	(3.777)	(2.773)
significant T	0.0000	0.0005	0.0002	0.0058
LAND	0.341	0.315	0.294	0.269
(t value)	(9.505)	(7.52)	(6.884)	(4.531)
significant T	0.0000	0.0000	0.0000	0.0000
CAPITAL	0.283	0.185	0.144	0.022
(t value)	(5.495)	(2.336)	(1.798)	(0.148)
significant T	0.0000	0.0199	0.0728	0.8824
constant	5.00	4.671	2.919	3.728
(t value)	(11.004)	(3.694)	(1.937)	(2.198)
significant T	0.0000	0.0002	0.0533	0.0284
R **2	0.33	0.29	0.28	0.22
Sample size	503	503	503	503

CHAPTER V. ANALYSIS OF RESULTS AND SUGGESTIONS FOR FURTHER RESEARCH

The Peruvian Andes is a region with sufficient characteristics to test the wage-efficiency hypothesis, because a chronically a high proportion of its population experiences a per capita calorie availability below the minimal requirements of food consumption to sustain moderate physical labor. Using Kashiwazaki's (1995) calories requirements for the rural Andes we estimate that 70 % of the rural Andean population is below the minimal level of calories required during post-harvest season, and 90 % during the pre-harvest season. In this context the level of nutrition matters as a productivity factor. Nevertheless to show the impact of calories intake on the marginal product of labor is not an easy task because of the difficulties of correct specifications and econometric procedures.

The efficient labor function for rural Andes

The efficient labor function (EFL) is the key of our analysis because it shows the relationship between nutritional level and marginal productivity of labor. Assuming perfect competition in the labor market we used wages as the measure of marginal product of labor, however the aggregation of the data does not permit to distinguish between different types of tasks within the agricultural activity in the rural Andes, we therefore used average wage for the set of agricultural activities at the local level.

For the whole sample the best fitting model was obtained using the inverse-logarithm functional form. Both parameters are highly statistically significant. The quadratic functional form appears more suitable for the sub-sample of 215 households and the grouped sample of 101 levels of calories. The inverse logarithm form for the grouped sample indicates an asymptotic level of that function which is significant statistically at only the 10% level.

Summarizing the results for the relevant parameters in our effective labor functions (calories and calories square in the quadratic functional forms and calories-inverse and constant in the inverse-logarithm functions), we find seven of these to be significant at the 0.01 level of significance and three to be significant statistically at the 10% level. In only two cases are the relevant parameters not statistically significant (see Tables 4-3 and 4-4). We conclude that the results shows a positive relationship between calorie consumption (potential or available consumption in our particular case) and the marginal product of labor. The nutritional level matters as a productive input in the rural Andes.

Calorie consumption and efficient labor units

With the estimation of the Effective labor function (ELF) we can stratify the labor force according the level of its efficiency as measured by the quantity of effective labor units forthcoming. To estimate the efficient labor units according to calorie consumption we are going to use the parameters of two of our calculated EFLs: the inverse-logarithm functional form for the whole sample (503 observations) and the quadratic form for the grouping classification by calorie levels (101 observations). The results are presented in Table 5-1 and in Figures 5-1 and 5-2.

Table 5-1. Calorie available for consumption and efficient labor units

Calories available for consumption (in Kcal.)	Effective labor units, inverse-logarithm ELF (sample = 503)	Effective labor units, quadratic ELF (sample = 101)
500	0.83	0.76
1000	0.96	0.86
1500	1.00	0.95
1782	1.01	1.00
2000	1.03	1.03
2500	1.04	1.11
3000	1.05	1.17
3500	1.06	1.22
4000	1.06	1.26
4500	1.07	1.29
5000	1.07	1.31

In the case of the inverse-logarithmic functional form, one unit of efficient labor is obtained at the level of 1,500 Kcal. At this level of calorie consumption, one hour of labor time is equal to one hour of effective labor. Calorie consumption below this level corresponds to an effective labor of less than unity, i.e. one hour of labor time is less than one hour measured in effective units. Conversely, calorie consumption above this level yields effective units greater than unity, so one hour of labor time is greater than one in effective units of labor.

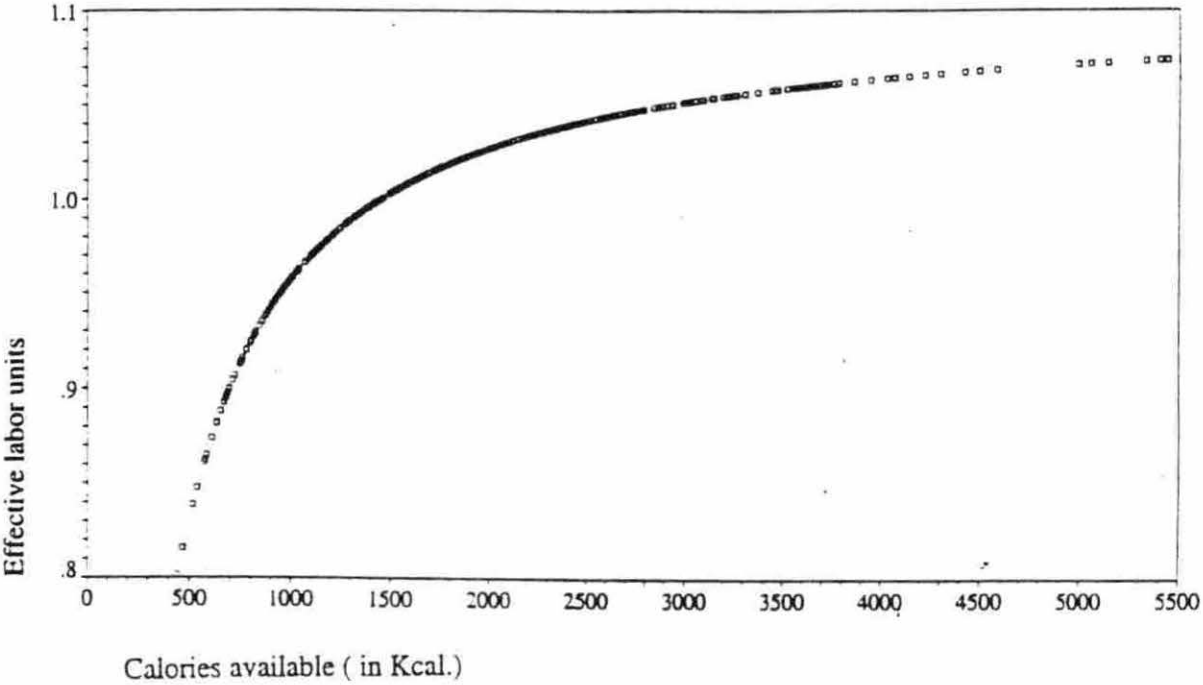

Figure 5-1. Effective labor function for the rural Andes, inverse-logarithmically functional form, whole sample.

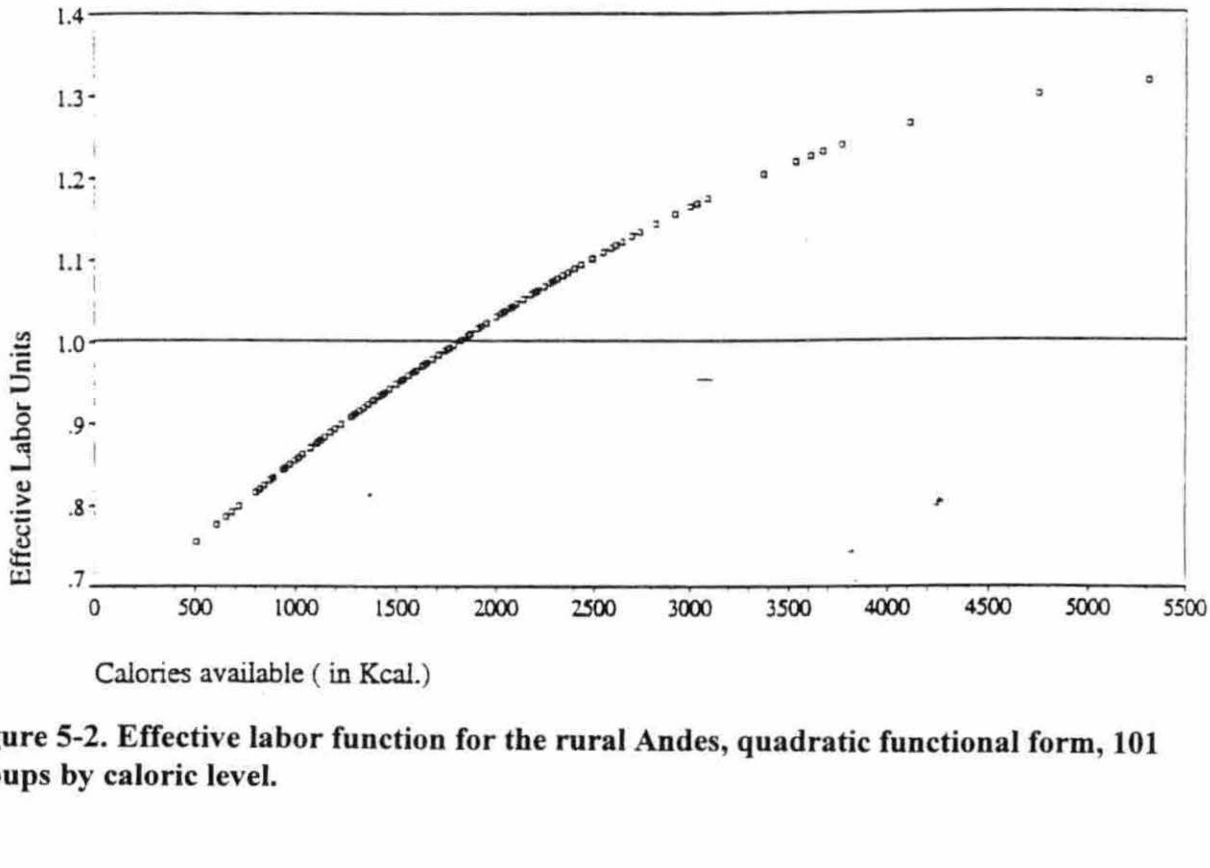

Figure 5-2. Effective labor function for the rural Andes, quadratic functional form, 101 groups by caloric level.

In the quadratic form estimated by grouping by level of calories, the unit of effective labor is reached at the 1,782 Kcal./day. Levels above and below this level will have the effects already mentioned. In this functional form however the effective labor units are larger than in the with inverse-logarithmic form for each level calories over 1,781 Kcal./day. For example at the level of 4,000 Kcal./day the inverse-logarithmically form yields 1.06 units of effective labor but 1.26 units using the quadratic form. On the other hand for low levels of calorie consumption, i.e. between 500 to 1,500 Kcal./day, the inverse-logarithmic function shows more effective labor units than does the quadratic functional form.

Productivity-calorie elasticity

The productivity-calorie elasticity tells us by how many percentage points the marginal product of labor (assumed equal to the market wage) changes when calories consumed increase by one percent. For the inverse-logarithm the elasticity is defined as:

$$(d \,\mathrm{Ln}\,(w) \;/\; d\,\mathrm{Calories}) * (\,\mathrm{Calories} / \;w\,) = \;-\beta \;/\; \mathrm{Calories},$$

where: β = parameter belongs to (1/ Calories) in the corresponding function.

For the quadratic functional form the elasticity is:

$$(d\,\mathrm{Ln}\,(w) \,/ d\,\mathrm{Calories}) * (\,\mathrm{Calories} \;/\; w\,) = \;(\beta 1 + 2\,\beta 2\,\mathrm{Calories}\,) * \;\mathrm{Calories}/ w,$$

where: $\beta 1$ and $\beta 2$ are the parameters belonging to calories and to calories squared in the quadratic functional form. Table 5-2 presents successive numerical point estimates of this elasticity. They will be used to analyze the impact of an hypothetical nutritional program in the rural Andes.

Table 5-2. Productivity-calorie elasticity in rural Andes at different levels of calorie consumption.

Calories available for consumption (in Kcal.)	Productivity-calorie elasticity (inverse-logarithm ELF)	Productivity-calorie elasticity (quadratic ELF)
500	0.282	0.161
1000	0.141	0.242
1500	0.094	0.275
1782	0.079	0.279
2000	0.070	0.278
2500	0.056	0.261
3000	0.047	0.233
3500	0.040	0.196
4000	0.035	0.154
4500	0.031	0.110
5000	0.028	0.064

The inverse-logarithm function shows a high elasticity for the lowest level of calories (between 500 to 1,000 Kcal./day). At the sample mean (1,500 Kcal./day) the point elasticity for this functional form equals 0.094. As the level of calorie intake reaches 4,500 Kcal./day the productivity-calorie elasticity falls to 0.031, but for the level of 500 Kcal./day the productivity-calorie elasticity equals 0.282. Strauss (1984) found an elasticity equal to 0.18 at the sample mean using the same functional form.

For the quadratic functional form, the elasticity at the sample mean is 0.279. Strauss (1986) found an elasticity of 0.33 at the sample mean using the same functional form. At the level of 4,500 Kcal./day the elasticity drop to 0.11.

The farm production function with effective labor in rural Andes

Table 5-3 compares our results with those of Strauss (1986). Using the quadratic functional form, Strauss found an elasticity of 0.60 for the effective family labor hours, our estimates are 0.49 and 0.495 for the same variable using the quadratic ELF and the inverse-logaritmically ELF. In the later case the parameter is significant only at the 8.2 percent level.

Table 5-3. Comparing Strauss's results and this study

Variables	Strauss study (quadratic EFL)[1]	Our study (quadratic EFL)	Our study (inv.-logarithm.)
Effective Family Labor	0.60*	0.49*	0.50[2]
Effective Hired Labor	0.13*	0.10*	0.17*
Capital	0.03*	0.14	0.02
Land	0.26*	0.29*	0.27*
R^2	0.52	0.28	0.22
Sample size	134	503	503

* Significant at 0.05.

[1] Taking at the sample mean.

[2] Significant at 0.082

Sources: Strauss (1986), p.314 and Table 4-5 of this study

The elasticity for hired labor is 0.095 for the ELF quadratic and 0.165 for the inverse-logarithmically ELF, in both case statistically significant. Strauss found an elasticity of 0.13, which is close to our results.

Using 2SLS the variable capital is marginal significant under the quadratic ELF and not significant at all with the inverse-logarithm ELF. In Strauss (1986) the output-capital elasticity is small, 0.03, as in our inverse-logarithmically. As we are working with poor small farmers operating at a low technological level the possibility of non significance of the capital variable may be high.

Land maintains in all results its significance and its value is very close to the value found by Strauss (1986).

The results show that the nutritional level, measured as potential calorie intake, increases current farm labor productivity and agricultural output in the selected area of study.

Suggestions for further research

Studies reviewed in the second chapter show the difficulties of this type of research. Finding good measures for the marginal product of labor and finding a good set of instrumental variables, especially regional prices and regional wages by different tasks, are among the problems to be solved. Also some variables are difficult to measure such as hours of family labor. In cross sectional studies with one or two visits per year, the calculation of the number of hours worked in the field is a matter of guess at best. It is necessary therefore to improve the collection of the data. A repeated cross sectional survey at the national level may will be too expensive. The alternative is to develop a sharply focused continuos field study. A new set of variables needs to be incorporated in order to have a better picture of the situation and to make credible inferences.

Anthropometric measures for the whole family height, weight, circular arm, hemoglobin, etc., are an important variables to be included. Two other aspects need to be taken into account in the design of this type of study: the seasonal effect of provision of food and the intra-household distribution of food. A field study can cover these aspects in order to differentiate the effect of the nutritional status on productivity, by sex and seasons.

The quality of land also can affect the results of this type of research. In our study we assume implicitly a homogenous distribution of land quality, however this assumption may not hold throughout the rural Andes. There remains the question as to the level of real sustainable requirements of calories in high-land populations. Kashiwazaki's (1995) findings bring into serious question the findings of the studies developed for the selected study area.

APPENDIX 1

CALORIES PER-CAPITA BY TYPE OF FOOD, BY DECILES OF INCOME AND ORIGIN, IN KILOCALORIES AND PERCENTAGE

Decil Income	Total Purch.	Total Produ.	Rice Purch.	Rice Produ.	Corn Purch.	Corn Produ.	Wheat Purch.	Wheat Produ.
1	312	359	97	0	0	5	4	58
%	46	56	100	0	0	100	6	94
2	531	517	150	2	8	52	33	66
%	51	49	99	1	13	87	4	96
3	564	700	157	28	8	86	88	90
%	45	55	85	15	9	91	8	92
4	842	621	242	4	11	118	115	68
%	58	42	98	2	9	91	18	82
5	1063	712	281	30	17	117	1919	122
%	60	40	90	10	13	87	14	86
6	1043	876	294	0	2	142	33	158
%	54	46	100	0	1	99	2	98
7	1117	968	259	58	20	145	115	100
%	54	46	82	18	12	88	13	87
8	1479	1073	455	35	5	140	1414	114
%	58	42	93	7	3	97	11	89
9	1561	1335	362	120	23	143	2525	129
%	54	46	75	25	14	86	16	84
10	2212	1535	510	120	10	202	1313	116
%	59	41	81	19	5	95	10	90

Decil Income .	Barley Purch.	Barley Produ.	Quinoa. Purch.	Quinoa Produ.	Bread Purch.	Bread Produ.	Noodle Purch.	Noodle Produ.
1	1	92	3	8	19	0	18	0
%	1	99	25	75	100	0	100	0
2	2	159	4	33	70	5	36	2
%	1	99	10	90	93	7	95	5
3	7	156	9	45	80	7	37	1
%	4	96	16	84	92	8	98	2
4	2	97	7	28	100	3	55	2
%	2	98	21	79	97	3	96	4
5	42	83	6	22	150	19	104	8
%	33	67	22	78	89	11	93	7
6	11	152	7	31	179	2	77	4
%	7	93	19	81	99	1	96	4
7	21	133	7	46	166	10	89	13
%	14	86	14	86	94	6	88	12
8	15	221	20	64	194	33	117	31
%	6	96	24	76	85	15	79	21
9	54	293	13	61	211	41	166	6
%	16	84	17	83	84	16	97	3
10	53	161	32	54	409	40	161	19
%	25	75	37	63	91	9	89	11

Decil Income	Meat Purch.	Meat Produ.	Poultry Purch.	Poultry Produ.	MeatS. Purch.	MeatS. Produ.	Fish Purch.	Fish Produ.
1	1	5	0	2	0	0	5	0
%	20	80	0	100	0	0	94	6
2	6	5	1	3	0	0	5	2
%	51	49	26	74	0	0	75	25
3	4	19	2	6	0	0	6	0
%	19	81	20	80	0	0	100	0
4	7	17	2	6	0	0	7	1
%	30	70	27	73	0	0	93	7
5	12	5	5	8	0	0	18	3
%	70	30	37	63	0	0	86	14
6	17	17	4	11	0	0	16	0
%	50	50	28	72	0	0	100	0
7	25	24	6	11	0	1	14	3
%	51	49	36	64	0	100	83	17
8	16	29	6	21	0	0	19	3
%	35	63	22	78	0	0	90	10
9	33	41	10	26	0	0	24	0
%	44	56	28	72	0	0	100	0
10	46	118	11	60	0	3	23	0
%	28	72	16	84	0	100	100	0

Decil Income	DairyP. Purch.	DairyP. Produ.	Eggs Purch.	Eggs Produ.	Oil Purch.	Oil Produ.	Tuber. Purch.	Tuber. Produ.
1	2	11	0	7	54	1	10	71
%	17	83	4	96	98	2	13	87
2	4	22	1	7	96	0	6	120
%	17	83	9	91	100	0	5	95
3	3	30	2	15	94	3	15	125
%	10	90	13	87	97	3	11	89
4	6	35	3	18	132	2	21	157
%	14	86	16	84	99	1	11	89
5	7	35	5	17	152	12	51	124
%	17	83	23	77	93	7	29	71
6	14	33	3	24	143	19	24	192
%	29	71	12	98	88	12	11	89
7	18	39	2	28	190	15	35	214
%	32	68	6	94	93	7	14	86
8	19	44	4	23	199	10	53	172
%	30	70	14	86	95	5	23	77
9	13	65	6	39	191	4	60	206
%	17	83	13	87	98	2	22	78
10	14	130	17	44	303	18	74	278
%	10	90	28	72	94	6	21	79

Decil Income	Beans Purch.	Beans Produ.	Hotalz. Purch.	Hortalz . Produ.	Fruit Purch.	Fruit Produ.	Sugar Purch.	Sugar Produ.
1	1	50	2	1	3	0	92	0
%	3	99	60	40	100	0	100	0
2	16	35	7	1	6	0	110	2
%	31	69	84	16	100	0	98	2
3	4	85	6	2	8	0	114	4
%	4	96	75	25	100	0	97	3
4	27	57	8	2	13	1	183	5
%	32	68	84	16	92	8	97	3
5	31	97	8	1	15	1	143	8
%	24	76	90	10	92	8	95	5
6	27	84	11	4	16	3	191	2
%	25	75	75	25	83	17	99	1
7	23	89	14	8	15	4	198	28
%	20	80	65	35	79	21	88	12
8	73	101	20	4	28	3	225	24
%	42	58	82	18	90	10	90	10
9	70	148	19	9	31	2	252	3
%	32	68	69	31	93	7	99	1
10	85	126	21	14	45	7	384	26
%	40	60	60	40	86	14	94	6

Notes: Produ. = produced. Purch. = purchased.
Source: ENNIV 1994, own elaboration.

APPENDIX 2
SECTIONS AND VARIABLES OF ENNIV 1994

Variable / Section	Part	Description	Period of reference
0		Identification of House	
Features of members			
1		Age, Sex, Marital Status, …	Day of the survey
Housing			
2	A	Features of housing	Day of the survey
	B	Expenditures in Housing	1 month
Education			
3		Education	7 days-12 months
Health			
4	A	Health all	4 weeks-15 days.
	B	Women 15-49 years old	4 weeks-15 days
Economic Activity			
5	A	Economic Activity of members of household	7 days - 12 months
	B	main occupation	7 days
	C	secondary occupation	7 days
	D	search supplementary job	7 days
	E	main occupation	12 months
	F	occupational history	12 months
	G	secondary job	12 months

Variable/Section	Part	Description	Period of reference
Migration			
6		Migration	Day of the survey
Self-employ activity, non-agropecuarian			
7	A	Self-employ act.no-agrop.	12 months
	B	Expenditures	12 months
Variable, Section	Part	Description	Period of Reference
	C	Capital and Inventories	Day of the survey
Expenditures and Inventories			
8	A	Dairy expenditures	15 days
	B	Exp. in semi-durable goods	3 months
	C	Inventory of durable goods	Day of the survey
	D	Transference	12 months
Expenditures and Self-consumption of food			
9	A	Exp. in food	15 days
	B	Expenditures and self-consumption	15 days
Other sources of income			
10		Other sources of income	12 months
Credit and Saving			
11		Credit and Saving	12 months
Exp. in Food dairy			
12		Exp. in Food	Day of the survey

Variable / Section	Part	Description	Period of reference
Agropecuarian Activity			
13	A	Land cultivated	12 months
	B	Agricultural production	12 months
	C	Sub-products	12 months
	D	Forestry production	12 months
	E	Agropecuarian Equipment	12 months
	F	Agricultural Inputs	12 months
	G	expenditures in agricultural and forestry activities	12 months
	H	pecuarian production	12 months
	I	Pecuar. products and subp.	12 months
Variable, Section	Part	Description	Period of Reference
	J	Expenditures in pecuarian activities	12 months
Antropometric			
14		Infant health and Antropometric.	

Source: ENNIV 1994, pp. 4-6.

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