Thema
UMR 8184
THéorie Économique, Modélisation et Applications

Thema Working Paper n°2008-27
University of Cergy Pontoise, France

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June 2008

UNIVERSITÉ de Cergy-Pontoise

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

DO AGRICULTURAL OUTPUTS OF PARTLY AUTARKIC PEASANTS AFFECT THEIR HEALTH AND NUTRITION?

Evidence from Rwanda

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10 399 words

June 2008

Keywords: Health and nutrition models, Agricultural Households.
Codes JEL: I12, O15.

I thank participants at conferences "les Journées PARADI" in Montreal, the Canadian Association of Economists Meeting in Toronto and at seminars in STICERD-London School of Economics, INRA-Paris and Oxford University for their remarks, particularly F. Grimard, T. Magnac and F. Teal. This research began under the auspices of the PARADI programme and has been continued thanks to a grant from the International Research Committee of Nottingham University during my visit at the University of Berkeley. I am grateful to the Ministry of Planning of Rwanda that provided me with the data, and where I worked from 1984 to 1988 as a technical adviser for the French Cooperation and Development Ministry. Finally, I am also grateful for the financial support by Spanish Ministry of Sciences and Technology, Project No. BEC2002-03097 and by the Instituto Valenciano de Investigaciones Economicas. I am solely responsible for the remaining errors.

ABSTRACT

In rural areas of Less Developed Countries because of market imperfections, the health and nutritional status of peasants may directly depend on the production levels of specific agricultural goods rather than solely on income levels. This channel of health and nutrition determination has never been studied.

In order to assess and test the empirical possibility of this channel, we estimate the responses of health and nutritional status of autarkic agricultural households in Rwanda with respect to differences in socio-demographic characteristics and the main agricultural outputs and inputs while controlling for local environment and sampling scheme. Several food outputs are found to have a positive influence on health and nutrition, whereas the production of traditional beers has a negative impact. Moreover, greater land negatively affects health and nutrition, conditionally on agricultural production, perhaps because of a larger relative workload for households who have a large farm.

An alternative interpretation of the estimates is that they inform on the validity of the common hypothesis of perfect agricultural input/output markets with no effect of agricultural inputs/outputs on health and nutrition status. This hypothesis is rejected.

1. Introduction

The effect of income on health and nutritional status (HN) of peasants is a major theme in economic development and health literatures.[1] Low levels of agricultural outputs that cause low living standards create severe nutrition and health problems for poor peasants in LDCs. However, it is often overlooked that in the presence of market imperfections, the usual separation theorems of the general equilibrium theory do not apply. Then, the effects of agricultural outputs on HN may involve not only an aggregate income effect but also a composition effect. Besides, nutritionists[2] and health specialists[3] show that different agricultural products bring different nutrients and have specific effects on HN. To our knowledge, the influence of the composition of agricultural production on health and nutrition simultaneously has not been investigated. We fill this gap.

In rural Africa, the frequent dominance of own-consumption in consumption suggests that constraints or non-price incentives affecting crop composition might be used to influence the peasants' HN. To design such policies, it is necessary to investigate the effects of specific productions on HN for agricultural households. "Does the shoemaker's son wear better shoes?" Do farmers who grew more nutritious crops have better health and nutrition statuses? In a context of incomplete markets, do different agricultural outputs have direct and specific impacts on HN? The aim of this paper is to explore these questions by estimating health and nutrition equations in rural Rwanda, which in contrast with other studies, incorporates the effects of specific agricultural productions.

1 See Smil (1986), Behrman and Deolalikar (1988), The World Bank (1986, 1993), Osmani (1992), von Braun and Kennedy (1994), Kochar (1995), Sahn (1995), Strauss and Thomas (1995, 98), Sickles and Taubman (1997).
2 Agbessi Dos Santos and Damon (1987), Gupta et al. (1992), Jacotot and Le Parco (1992).
3 Tomkins (1994).

Household behaviour could be represented by the maximisation of a utility function that depends on health, leisure and consumption for every household member, subject to technology and budget constraints (Singh et al., 1986). In this framework, when all markets of goods and outputs exist and are perfect, one could derive demand functions for the health or nutritional status of every member. In these models, consumer and producer decisions are separable. Therefore, input prices and agricultural environment affect consumption decisions and health status only through a profit effect entering the budget constraint. The effects of exogenous agricultural shocks on HN, such as bad harvests caused by adverse climates, are also conveyed through the income effect. Production composition does not matter once the profit effect is included.

When there are imperfect markets for inputs that enter in both preferences and technology, consumption and production decisions are no longer separable.[4] This is what happens in our case, first because there are no markets for health and nutritional statuses,[5] which may enter as inputs in agricultural production processes and as arguments in preferences. Of course, the absence of markets for health and nutritional status (as outputs) holds for all economies, no matter how developed are their markets. However, in the studied context, there are also market imperfections for agricultural inputs that are inputs in health and nutritional home technology.

Indeed, markets of consumption goods and agricultural output may be simultaneously missing or imperfect, since many poor peasants live in a subsistence context. In these conditions, consumption and HN demands do not depend on prices but on the characteristics of household preferences, joint HN-agriculture technology and levels of past allocations. Past allocations matter because markets do not clear output stocks. The residual output stocks are available for higher consumption than what could have occurred if only prices had mattered. Moreover, past HN directly influence present HN

4 Singh, Squire and Strauss (1986), Benjamin (1992).
5 There may be markets for health care and nutritional inputs, but there is no market for health and nutritional outputs

through biological processes. In that context, the shadow prices of particular decisions associated with the technology and preferences are endogenous and depend on all input and output allocations, as well as on characteristics coming from preferences and constraints. Then, even with a dual approach based on shadow prices, lagged effects of agricultural production should appear in HN equations.

Let us focus on the influence of agricultural products and prices on HN (in fact only incomes and nutrients have been used in this literature, in contrast with agricultural product indices). Most health and nutrition equations estimated in the development economics literature deal with children, often based on BMI (body mass index) of children. Household income, calorie intake and children's health status have been found to be related to children's nutrition status, while prices are less often significant[6]. However, Thomas, Lavy and Strauss (1996), and Higgins and Alderman (1997) found positive price effects related to adult BMI functions.

In Muller (1999), we estimated a Cobb-Douglas production function for average BMI of agricultural households in Rwanda that depends on socio-demographic characteristics and agricultural outputs. The most influential outputs are tubers, non-food products, with a positive association with nutrition, and traditional beers and non-food, both with a negative association.

Other authors are interested in children's health as measured by the number of days of illness or inactivity, while effects of agricultural outputs have not been investigated[7]. Fewer authors provide

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described by a health or nutrition status.

6 Heller and Drake (1979), Von Braun, Hotchkins and Immink (1989), Von Braun, Puetz and Webb (1989), Pitt, Rosenzweig and Hassan (1990), Senauer and Garcia (1991), Cebu Study Team (1992), Dercon and Krishnan (2000). For Rwanda: von Braun, de Haen and Blanken (1991), Schnepf (1992), Barghava (1997).

7 Wilcox-Gok (1983), Deolalikar (1992) and Appleton (1998). Von Braun and Kennedy (1986) present a survey of the effects of the aggregate commercialized cash crop in LDCs on household food consumption and nutrition. Nevertheless, several studies simultaneously consider agricultural outputs and HN in order to estimate agricultural productivity, as advised by Schultz (1997)[7].

results concerning adults, especially in LDCs.[8] In Muller (2001), we estimated a Cobb-Douglas production function of the average number of days of illness for agricultural households in Rwanda, which depends on agricultural outputs. Bean output was found to have a positive link to health, while traditional beers have a negative impact.

The type of estimated equations varies. Using data from Indonesia, Pitt and Rosenzweig (1986) estimated, at household level, an illness linear production function in which household labour and twelve types of consumption are inputs. They found that worked hours are not significant, while consumption of sugar is noxious and consumption of fish, vegetable, fruit and even tobacco-betel positively affects health. In our case, because of high own-consumption rates for the food, characterising a near-subsistence economy, the distinction between consumption and production may be less serious than it appears, and enables us to connect agricultural and HN processes. Foster and Rosenzweig (1994) estimated a BMI production function for adult peasants in the Philippines. The set of independent variables included eight characteristics of agricultural work, calorie intakes, and an index for illness and lagged BMI. They found that an increase of calorie intakes, net of activities, raises the BMI. The mix of activities and tasks affected the workers' BMI. As a matter of fact, the relationship between HN and different outputs for subsistence peasants is ignored.

In contrast of the literature, our approach is important because poor peasants in LDCs often face missing or imperfect markets. In rural Rwanda, peasants mostly consume their own agricultural output.[9] The average own-consumption rate (proportion of consumption coming from own production) for the national sample used in this study is in 1983 above 66 percent overall. When focusing only on food products this ratio rises up to 80 percent. Moreover, spatial isolation of

8 See Murray et al. (1992), Sickles and Taubman (1997) for surveys of this literature, and Kahn (1992), Thomas et al. (1996) and Higgins and Alderman (1997) for estimates using adult samples.

9 Sweet potatoes, cassava and other tubers, beans, cereals, other vegetables and fruits are mainly produced and taken into consideration in the study (See Muller, 1989).

Rwandan households that are scattered in the hills makes residual monetary transactions a complex production process. During this process, which involves transport and transaction costs, the small traded part of the agricultural production is converted into purchased market goods.[10] Price effects are mediated by complicated mechanisms of missing and imperfect markets, badly described with a linear budget constraint. Markets still exist, although they may have a more limited impact on poor peasants' living standards than the size and composition of their agricultural output. This is why looking at Rwanda in 1983 is interesting. This is a context where direct effects of food production on welfare may be observable. Our deliberate choice of the data set (corresponding to a rather ancient period) is justified by: (1) the simultaneous availability of indicators for agricultural outputs, income, health and nutrition statuses, local prices and other essential indicators for the study; (2) a well identified situation of quasi-subsistence allowing us to assess and test a possible impact of agricultural productions on HN.

In this context, our modelling strategy is to consider that most consumption is explained by output levels as in subsistence economies. This empirical strategy is adapted to a case of market failure so widespread as to affect every product and factor.[11] This does not imply that markets do not play a role, but only that we neglect them as a first approximation.

[10] Von Braun, Haen and Blanken (1991) show that commercialisation may be more important in specific areas of Rwanda, the commune Giciye in their study, where markets are much denser than in most of rural Rwanda. In the Von Braun et al.'s study, the share of food consumption of the households that is own-produced is 48 percent while it is 80 percent for all of rural Rwanda (from our own estimates using the National Budget-Consumption Survey, 1983). Most households in Giciye have substantial non-agricultural incomes with a non-farm income equal to 58 percent of total income on average, while for the whole rural Rwanda, only one quarter of households regularly receive wages, generally for a small amount. Our national sample corresponds to quasi-subsistence peasants.

[11] de Janvry, Fafchamps and Sadoulet (1991) propose a model with missing markets. However, its estimation would necessitate the presence of perfect markets at least for some goods, which may not be the case in our context.

In Section 2, we discuss the theoretical model and applied specification. In Section 3, we present the data and indicators. We present in Section 4 the estimation results. Finally, we conclude in Section 5.

2. The Model

2.1. The theoretical framework

We first examine the argument of the modelling approach in an aggregate way. Then, in Section 2.2 we discuss the estimated equations.

We observe six agricultural outputs that are described in Section 3.2. Let us consider a single person agricultural household producing food outputs (Y_i, i = 1,..., 5) and non-food outputs (Y_6), from various inputs X, notably the land used and the household labour force. We assume the goods purchased using liquidities obtained from sold outputs to be of marginal importance in close-to-autarky context. This allows us to simplify the model by not incorporating what we see as a residual 'market technology'. The household is characterised with a health indicator (H) and a nutritional indicator (N). We do not consider the other agricultural inputs in the theoretical model, for they do not pertain to this issue. Instead, we focus on the household variables that are related to our subject: Y_i (i = 1, 6), X, H and N. The interactions between these variables are discussed in Section 4.2.

We have at our disposal indicators of the value of agricultural outputs and aggregate household levels of HN for a sample of households during an agricultural year. Since we have calculated the agricultural output indicators from their observed uses, the corresponding outputs may have been cropped months before and inputs have been provided still previously. In that case, the health input in the agricultural process belongs to a period exterior to the actual consumption of the agricultural output.

The information collected about the uses of agricultural production and the health and nutrition indicators correspond to the time of the enumerator's visit and the three preceding months. The harvest may have occurred in the previous season or even earlier. These considerations are important because short-run feedback of measured HN on observed agricultural output may be an issue blurring the study of the impact of agricultural production on HN, thereby generating endogeneity of the lagged agricultural production variable (Y_{t-1}) in the HN equation. Fortunately, the lags in the observed production variables mitigate the issue of reverse causation.

In these conditions, we shall ignore the reverse (that is: feed-back) effect of observed HN on observed agricultural outputs. This approximation is similar to that typically used for agricultural production functions when neglecting the reverse effects of agricultural production on health statuses considered as an input in the production function. What we look at is the direct effect of agricultural productions on HN considered as outputs of biological processes.

Nonetheless, household decisions relative to HN are complex. The health and nutrition statuses can be viewed as conditional demands (on agricultural output levels) derived from an optimisation program where consumption, time use and HN are attributes of the household utility; and the constraints incorporate health and nutritional biological processes. Therefore, HN conditional demands should depend on preferences, characteristics of the HN processes and past agricultural outputs and inputs.

These HN equations are described in System (1). Y_t denotes the vector of common agricultural outputs at period t, X_t is the vector of the main agricultural inputs (land and labour force) at period t, correlated with work. $(H_t, N_t)' = HN_t$ is the vector of health and nutrition indicators at period t. Z_t^{HN} describes the exogenous variables and fixed factors intervening in the biological processes described by functions *h* and *n* that are to specify. Z_t^{P} denotes the exogenous characteristics of preferences.

Finally, ε_H and ε_N are error terms accounting for missing variables, unobserved heterogeneity and measurement errors.

$$(1)\ \begin{cases} H_t = h\ (Y_{t-1}, X_{t-1}, Z_t^{HN}, Z_t^{P}, \varepsilon_H\ ) \\ N_t = n\ (Y_{t-1}, X_{t-1}, Z_t^{HN}, Z_t^{P}, \varepsilon_N\ ) \end{cases}$$

Under our assumptions, we can estimate System (1) separately from the agricultural technology.

2.2. The applied specification

Because of the small size of our observed sample (described in Section 3.1 and Appendix 2) and the difficulty to identify structural parameters from such a limited information set, we specify reduced-form conditional demands for H and N in System (1) at the household level, by using Cobb-Douglas type functions, which are parsimonious in parameters to estimate. Naturally, this functional form is only an approximation. Translog functional forms have been tested and rejected. We obtain:

$$(2)\ \mathrm{Log}\ \mathrm{N_t} = \sum_{i=1}^{6} \mathrm{b_{1i}}\ \mathrm{Log}\ \mathrm{Y_{i,t-1}} + \mathrm{d_1}\ \mathrm{Log}\ \mathrm{X_{t-1}} + \mathrm{Z}_t^{\mathrm{HN}\,'} a_1 + \mathrm{Z}_t^{P\,'} c_1 + \mu + \varepsilon_N$$

$$(3)\ \mathrm{Log}\ \mathrm{H_t} = \sum_{i=1}^{6} \mathrm{b_{2i}}\ \mathrm{Log}\ \mathrm{Y_{i,t-1}} + \mathrm{d_2}\ \mathrm{Log}\ \mathrm{X_{t-1}} + \mathrm{Z}_t^{\mathrm{HN}\,'} a_2 + \mathrm{Z}_t^{P\,'} c_2 + \lambda + \varepsilon_H$$

Where the $Y_{i,t-1}$ (i = 1,...,5) are the observed output levels (in value) for the five observed food outputs, respectively: beans (Y_1), other fruit and vegetable (Y_2), tubers (Y_3), other food output (Y_4) and traditional beers (Y_5). Although traditional beers may be noxious to health owing to their alcoholic content, all the other included outputs are expected to contribute to enhancing HN. Note that bananas used for beers (in Y_5) and bananas as food (in Y_2) are different varieties and come from different trees. Y_6 is the value of non-food output and is included on the grounds that firstly non-food consumption may directly contribute to the health and nutrition processes, such as clothes protecting against cold weather and firewood used for cooking. Secondly, the money coming from residual sales of non-food output can be used to purchase unobserved consumed goods that affect HN, such as medicines. Vectors of parameters b_{1i}, b_{2i} (i = 1,..., 6) and a_1 , a_2 , c_1, c_2, d_1 , d_2 must be estimated. μ and λ are fixed cluster effects varying with the cluster. That is: μ and λ are identical for all households in the same cluster. They account for local, unobserved fixed characteristics that may influence preferences and HN technology, and are included in our preferred specification. We now discuss the data used for estimating (2) and (3).

3. Data and Indicators

3.1 The data

The population of Rwanda was estimated at 5.7 million in 1983, while nearly half of the population was less than 15 years of age. More than 95 percent of the population lived in rural areas. In our application, we study a peaceful situation corresponding to Agricultural year 1982-83 and the data at our disposal. General health status was very precarious with a life expectancy of 44 years. The perinatal mortality rate was 86 (per 1000 births); the juvenile mortality rate was 222 and 34 percent of children less than five years of age were too small for their age, pointing at malnutrition.

Guichaoua (1989) emphasizes two stylized facts important for our study. First, the population was scattered on thousands of hills in the country, with local geographical isolation of peasant households and limited market interactions, as opposed to more intense trade in villages. Second, for many households most food consumption comes from family plots, ensuring near food selfsufficiency. This subsistence situation is qualified by the presence of markets that complemented the dominant food own-consumption with trade and off-farm work opportunities.

Data for these estimations are taken from the Rwandan National Budget-Consumption Survey, which was conducted by the government of Rwanda and the French Cooperation and Development Ministry in the rural part of the country from November 1982 to December 1983 (Ministère du Plan, 1986). 270 households were surveyed over twelve months about their demographic characteristics, budget, food own-consumption and agricultural sales. We also avail of anthropometric measures and records of the number of forced rest days caused by illness, for all household members over 14 years of age. We describe how the sample is drawn in Appendix 2. We can only use 157 household observations in the estimation because of missing or invalid information about illness duration and anthropometric measures. Moreover, to make comparable the estimated equations for health and nutritional indicators, we choose to use the same sub-sample of households for estimating both equations. However, we do not have available relevant information to correct this sample selection. The differences between the characteristics of the initial sample of 270 households and the used sample are discussed in Appendix 2. Clearly, dropping observations because of missing values may introduce selection biases in the sense that the final sample is less representative of the Rwandan rural population than the initial sample. However, the differences between the two samples are not extreme to the point that the findings would not have implications for the broader population. Mostly, the selected population corresponds to smaller households than the average. We cannot see why the conclusions of the paper would not somehow extend to larger size households too. We now discuss the indicators, starting with the health and nutrition variables.

3.2. The indicators

(a) Household health and nutrition variables: Table 1 shows some descriptive statistics for the main variables.[12] Health and nutritional indicators are based respectively on the number of forced rest days caused by illness and BMI, for all members inside the household between ages 18 and 50 ("the active adults"). The health indicator H is defined as 1/(1 + *Illness*), where *Illness* is the average number of forced rest days caused by illness per month, for adults over 18 and under 50 in the household. N is defined as the average ratio of weight to height squared (BMI), for adults over 18 and under 50 in the household.[13] That is: each individual ratio is calculated, and we take the average of these ratios for all active adults. Using the average household health and nutrition enables us to aggregate the issues at the household level without entering in the complex and unobserved intra-family phenomena about food and work sharing, health care and other types of member interactions. Only the global results of the influence of these factors are taken into account. The counterpart of this simplification is that average health and nutritional indicators may be sensitive to household composition. We control for this by focusing on adult members only, and including a wide range of demographic variables in the household equation.

The mean member height is 1.35 m (1.61 m for active adults). The mean weight of all household members is 38 kg (55 kg for active adults). The nutritional indicator (BMI) is 21.08 $kg.m^{-2}$ on average with very little dispersion across households (standard deviation of 1.48, first quartile of 19.7 and third quartile of 22.37). The average number of forced rest days is 1.95 per month per

[13] We consider only adult members in calculating health and nutritional indicators. Mausner and Kramer (1985) recommend using different health indices in relation to stages of life-cycle. Indeed, the growth curve and the type of disease are sensitive to the children's age. Including children in health and nutritional indicators would give too much importance to the household's gender and age structure and would cloud the relationships. For similar reasons, people over 50 years are not included in the health indicator since they may be chronically constrained to rest and their BMI is hard to interpret (Tomkins, 1994).

capita with a standard deviation of 3.1. Only 3.5 percent of households do not spend a day in forced rest, and we therefore neglect this truncation. Let us now turn to the independent variables is the equations to estimate, excluding the output variables that we discuss later.

(b) Non-output independent variables: exogenous variables are incorporated in the model through vectors Z^P, Z^{HN} and X_{t-1}. They include land area, household composition, other socio-demographic characteristics and cluster dummies. The land and number of active members are the main inputs in agricultural production. However, land would not appear in HN demand equations with a separable model based on complete markets. The land market is almost non-existent in Rwanda. Moreover, the main exploitation system is direct exploitation of owned land obtained from inheritance (Guichaoua, 1989). Less than 10 percent of the land is share-cropped. So, the land variable can reasonably be considered as exogenous. Here, land influences HN in that it affects the stress of agricultural work and because, as a determinant of shadow prices, it influences the household decisions. Similarly, the size of the household labour force affects shadow prices and household decisions.

In such context, individual health and nutrition statuses can be negatively affected by activity levels (Osmani, 1992). Even if we do not accurately observe the workload, given workforce and output levels, households with large farms should generally supply higher effort. This is caused by higher work burden for seeding, weeding and harvest tasks, and larger travel time and transport loads. Thus, fixing the number of workers and the outputs, a larger amount of land owned should have a negative effect on HN, since it requires more energy expenditure per household. It is therefore useful to introduce land in the equations since the actual labour input and effort are not observed, but only the number of active members.

Since the labour force is almost entirely made of household members, the presence of many active members should contribute to reducing the average workload of individuals, first by sharing tasks among workers exploiting scale economies, second because it allows further specialisation. Then, the direct effect of the number of active members on HN should be positive.

The number of active members is not the sole demographic variable that matters. The number of children may influence how the household deals with nutrition and health problems, although the direction of the resulting effect is not obvious a priori. First, scale economies may exist in cooking, food processing and health care. Second, households with many children may be more experienced in nutrition and health domains since adults had many opportunities to practice on their children. However, the opposite could be true as with many children to look after, parents cannot dedicate much time to their siblings' health. Third, children participate in HN processes and agricultural production, which contributes to diminishing adult workload. For example, they care for their younger siblings or help prepare meals. Fourth, young children are a burden for the family. They require female members' time that may be diverted from the management of HN processes for adults. Many young children are breastfeeding. Therefore, they require direct care from some adult females. Some of these resources from adult female members cannot be substituted by older dependent or younger household members. Fifth, they are more likely to be ill than other members and their presence raises contagion risks amongst the family. Finally, socio-demographic characteristics are major determinants of preferences, which we discuss now.

A few regressors in HN equations account for differences in age, education and gender of members of different households to capture differences in preferences and labour force. In particular, the age and education of the head of the family may partly determine household experience and household efficiency in health and nutritional processes. The ethnic group is a special demographic characteristic upon which we now comment. In Rwanda of 1983, households from the Tutsi ethnic group were overly excluded from public decisions. Tutsi families may have had a harder time accessing public health and nutrition centres than the average household. A dummy variable for Tutsi household heads is therefore included.

Last, we include dummies for sampling clusters to account for unobserved local characteristics that matter for HN, such as health and nutritional services, and environment healthiness (including sanitation and proximity of breeding sites of parasites). We now conclude the discussion of the variables with the agricultural production.

(c) Agricultural outputs: the agricultural products are measured from interviews. Household agricultural production is calculated from records of own-consumption, agricultural sales and other uses of production (gifts, reimbursements…). They are grouped in such a way as to isolate three major categories in Rwandan food (beans, tubers, traditional beers), and to separate nutritional goods that are: bad (traditional beers), poor (tubers), rich (beans, fruit and vegetables), and excellent (other food). Beans are a good source of calories, proteins, vitamins and minerals (calcium, iron). As a source of protein, they are much cheaper than meat. However, many vitamins are lost during meal preparation as beans are only boiled in Rwanda. Moreover, their cultivation requires a great deal of labour effort.

The group "Other fruit and vegetables" is composed of different products, mostly bananas and peas, but also leafy vegetables (cassava leaves) that are rich in vitamins and minerals. Plantain bananas supply fibres that contribute to normal functioning of the colon. They contain more than 15 percent of glucides, although they are low in proteins (1 percent).

Tubers cultivated in Rwanda mostly include sweet potatoes, cassava and some other potatoes. They are less nutritious than other food (less than 1 percent of proteins, almost no lipids or cellulose). They play a crucial nutritional role as staple food bringing a lot of carbohydrates (20 percent of their weight). Sweet potatoes are kept in a separate group because of their importance in Rwanda.

The group "Traditional beers" is composed of sorghum beer and banana beer. Banana beer has a higher level of alcohol. Sorghum beer contains more nutrients and is rare in the East region which is low altitude, ill-adapted to sorghum cultivation. A dummy variable for the East region is crossed by the traditional beer output level. It accounts for the higher prevalence of banana beer in the East. Beers are a minor source of calories. They are less liable to contamination than water, but their impact on HN can still be harmful. Alcohol consumption injures the liver, which severely disturbs digestion and therefore harms nutrition. It affects the brain and increases the rate of cholesterol. Alcoholics cannot properly absorb folic acid, which leads to anaemia and mental sluggishness. It has been found (Mullahy and Sindelar, 1993) that alcoholism reduces labour participation and productivity.

The group "Other food" includes, among other products, cereals, milk, meat and palm oil. It is a heterogeneous grouping of goods with generally high contents of proteins and fats. Cereals (mostly sorghum and corn, and some wheat and rice) are good sources of proteins, fats and carbohydrates. Milk, eggs and meat are exceptional sources of proteins, although generally expensive. Palm oil is an important source of fats in Rwanda. "Non-food" is a heterogeneous group composed of coffee, tea and other industrial crops and craftwork products. Agbessi Dos Santos and Damon (1987) and Gupta et al. (1992) analyse carefully the effects of every given food on nutritional status. However, the effects on HN of consuming particular products are hypothetical and must be empirically investigated.

These crops are grown on farms that have a mean area of 1.3 ha and produce a mean food value of 61 352 Frw (Rwandan Francs[14]). The larger food outputs are traditional beers, tubers and beans. Using prices for the aggregation of products does not mean that we assume perfect markets, but only

[14] In 1983, the average exchange rate was Frw 94.34 for US $ 1 (source: Penn Tables).

that it is the most obvious procedure. However, the estimation may be biased if the observed prices do not accurately represent the marginal rates of substitution between outputs. We use local quarterly prices. The price levels have been found inversely related to living standards in Muller (2001), suggesting market imperfections. Shadow prices accounting for market imperfections would be more appropriate for some households and some goods, but they are not available. The gaps between sale prices and purchase prices are often close to 10 percent, showing that the market prices may be a suitable approximation if, as in de Janvry, Sadoulet and Fafchamps (1991), shadow prices are between selling and buying prices.

The assumption that markets little matter rests on the observation that own-consumption rates, especially when remittances are included, are very high (subsistence ratio of 66.4 percent on average) for the completed household sample (sample not truncated for missing values on HN indicators). They are even higher for specific food products: 80.6 percent for beans, 94 percent for other fruits and vegetables, 89.4 percent for tubers, 62.2 percent for traditional beers and 43.5 percent for other foods. These figures are consistent with the exclusion of the budget constraint from our approach. This is also in agreement with findings by Laure (1982) and Damez (1987). We now present the estimation results.

4. Estimations

4.1. The estimation methods

We use Ordinary Least-Squares (OLS) estimation method, weighted by the sample scheme. The residual effects of the geographical differences in prices, if these effects exist, and other local effects are picked up by the cluster dummies and are therefore under control. So, the effect of other variables can be estimated using within-cluster OLS. It is not possible to estimate HN demand equations with food prices and food outputs since we use cross-section data. We now comment the results.

4.2. The results

(a) Generalities and tests

An alternative way of considering the estimation is that it is a device to check if markets are really imperfect or absent. Indeed, HN should be influenced by production composition if the markets for agricultural inputs and outputs were imperfect, while they would only be affected by household income if markets were performing well. Then, one must first show that the observed impact on HN is not simply an income effect. For this purpose, we test if the coefficient of the total consumption value is zero when this variable is added to both equations. The test results at 5 percent level show that this coefficient is always non-significant in OLS estimates with Student-t respectively of 1.80 and 1.33 in the nutrition and health equations separately. The joint F-test of the hypothesis of an effect of the log per capita consumption coefficient in both equations together also leads to the rejection of this hypothesis, even at 1 percent level. We comment later the differences in estimates when introducing log per capita consumption as a regressor in the equations.

By contrast, the hypothesis of the nullity of the coefficients of the agricultural outputs is rejected. This indicates that the output composition is a better explanation of HN than the total consumption value. This result supports the omission of the budget constraint and indicates that food outputs are not simply picking up income effects.

We present in Table 2 "within-cluster" estimates that are defined by the inclusion of cluster fixed effects for equations (2) and (3).[15] In Table 2, columns (b) and (d), we show the estimation results including the logarithm of total per capita expenditure as regressor. On the whole, introducing this variable little affects the estimated coefficients of the logarithms of outputs. The goodness-of-fit measured by the R^2 in the nutrition and health equations is much higher for the within-cluster estimates than when excluding cluster dummies. This implies that much of the explanatory power comes from unobserved variables at the cluster level and excluding the hypothesis of absence of cluster effects.

We now examine the estimated effects of the correlates of HN in the within-cluster estimates, starting with non-output variables. As expected the found elasticities are small. This is because there is limited variation range for typical health and nutrition indicators by construction. One cannot improve health beyond good health, overweight is physically limited and survival threshold imply stringent lower bounds for our health and nutrition indicators.

(b) Results for the non-output variables

The coefficients of the number of active members, the number of adolescents and non-food outputs are not significant. All other included variables show significant effects. Conditionally on output levels, land area negatively affects nutrition and health status, probably because of a greater workload for households who have a large farm with a fixed number of active members. Indeed, in the development literature about nutrition, hard work correlates with poorer health and nutrition (Osmani, 1992). This result confirms the hypothesis of missing markets at the core of our model. Controlling by adding land per capita (or land per number of adults, or per number of active members) as a proxy for wealth may also help to convince that the negative effect is robust. Indeed,

15 The sample used is further reduced to 111 observations in the case of within-cluster estimates, in order to consider only clusters for which the relevant information is available for all the surveyed households in the cluster. Using reduced

if the impact of land after such correction were positive, then a traditional explanation in terms of income might look possible. If on the contrary the impact of land stays negative, then the interpretation that more land drains on human resources would reinforce the results suggesting features of a subsistence economy. Because we estimate double-logarithmic equations, adding log(land/number of active members) = log(land) –log(number of active members) to the regression amounts to recalculate the coefficients of log(land) and log(number of active members). These coefficients would not be identified in such a case because of the exact co-linearity between log(land), log(land/number of active members) and log(number of active members). If it were possible to introduce the three variables (for example because one coefficient is exactly known), one would expect the coefficient of log(land/number of active members) to be positive if it corresponded to a wealth effect. In that case, the coefficient of log(land) in this equation would be the coefficient of land in the estimated equation minus the coefficient of log(land/number of active members), still making it more negative. Thus, the relevance of the subsistence situation is reinforced as opposed to explanations in terms of income or wealth.

Finally, another possible interpretation of the negative coefficient of land could be that the measure of land is heterogeneous due to unobserved differences in land quality. Ministère de l'Agriculture (1985) shows that there was a negative correlation of land area with productivity per ha at the studied period.[16] However, the cluster fixed-effects should largely cope with this potential problem. Direct correlations of land and HN are positive in this sample. A negative coefficient for land is not as surprising as it would be for simple correlations (or for coefficients of land in agricultural production functions), since we control for output levels and composition. Here, there is

and unbalanced clusters with such a small sample would yield to meaningless estimates of fixed effects.

16 For example, for beans we obtain the following pairs of land surface class and average production by ha (in kg). Below 0.25 ha: 961.6 kg/ha; from 0.25 to 0.5 ha: 397.6 kg/ha; from 0.51 to 0.75 ha: 320.8 kg/ha; from 0.76 to 1 ha: 279.6 kg/ha; from 1.01 to 1.50 ha: 200.24 kg/ha; from 1.51 to 2 ha: 167.8 kg/ha; above 2 ha: 124 kg/ha. Clearly, productivity per ha decreases with land surface. Some of the decline may be attributed to fixed factors, although there are not many

no reason why land and labour should be expected to have a positive effect on HN *conditionally* on productions.

Alternative interpretations of the effect of land through its relationship with labour could be proposed in terms of household composition. Households with more land may attract additional members, notably dependent members). This may contribute to explain why the coefficient of land on health status is substantially negative. Sick family relatives may seek help from households seen as able to provide it. Here, land would act as a signal of help capacity. Despite these effects being partly controlled by the introduction of the household composition variables, they may generate correlations between household composition and land variables. However, this does not matter from the estimation results. Such a situation may slightly blur the interpretation of the effect of these variables, although that is also the case for agricultural production functions and should not stop us.

The number of children between 4 and 10 years old is associated with a better adult nutrition, while the number of children under 4 is associated with worse adult health. Several interpretations could be proposed for these effects. Firstly, as already mentioned, some children may distract some of the resources and time from healthy adult care. Secondly, the number of infants and children could partly be endogenous since families with good HN may be more likely to have babies and a lower infantile mortality. Finally, families with bad HN may also have more children due to replacement or insurance motives.

Clearly, if these phenomena are important, the long-term endogeneity of household demographics, reflecting behaviour, may be an issue when estimating HN equations. Unfortunately, we have no IVs to instrument this behaviour, and we are led to neglect these factors. However, it may be helpful to separate long-term and short-term HN determination, the latter being our focus since we considered only outputs of the latest harvest. In the short term, household composition is

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such factors in Rwanda. However, it is believed that most of the decline is related to poorer land quality.

almost fixed and endogeneity issues should be mild. Finally, we are less interested in causal interpretations of demographic effects, than in controlling for demographic differences in studying the impact of agricultural outputs on HN. In that sense, we believe that omitting demographics would yield worse estimation results.

The household head's age negatively affects nutritional status and positively affects health status. In contrast, the average age of members has opposite effects. The education of the head has negative effects on health and nutrition conditionally on production levels. Finally, Tutsi heads are associated with worse nutritional and health statuses. As we mentioned above, household's socio-demographic characteristics simultaneously influence household preferences, HN domestic processes and agricultural technology. It comes as no surprise that their estimated effects on HN are ambiguous. Admittedly, the sign of the education variable looks unfamiliar as one usually expects better education associated with better knowledge and control of HN processes. However, two elements contribute to qualify such statement. First, household heads in Rwanda are generally male, while the literature found positive effects of the education for female adult members, but no significant effects for male adult members. Second, the education effect is here conditional on agricultural output levels in a complex decision model, which makes the interpretation of education coefficients less obvious. A few calculations of comparative statics will clarify this matter.

Let us consider a drastically simplified model described by the following optimisation program excluding agricultural production considerations:

$$\mathrm{Max}_{\{H,N\}}\ U(H, N; E) \text{ subject to: } H = G(N; E) \text{ and } N = J(H; E),$$

where E is the education variable that appears as a parameter of preferences described by utility function U, health production process described by function G and nutrition production process described by function J. Note that health production depends positively on nutrition status and nutrition production depends positively on health status.

Assuming usual concavity and derivability properties, the solution to this optimisation problem, describing health and nutrition decisions, is characterised by the first-order and second-order optimisation conditions. Hatta (1980) shows how to derive dual conditions involving the derivatives of functions with respect to parameters, that is: E in our case. He also derives generalised Slutsky conditions which we can calculate for our problem. We obtain:

$$H_E = S_E^H - H_G\, G_E - H_J\, J_E \text{ and } N_E = S_E^N - N_G\, G_E - N_J\, J_E,$$

where the sub-indices denote partial derivatives with respect to the index variable, S_E^H and S_E^N denote generalised Slutsky matrix terms. The latter terms partly characterise the concavity of the dual gain function at the optimum. Then, their values are determined by the optimum, while unknown a priori. All quantities in the equations are calculated at the optimum. The derivatives with respect to G and J indicate derivatives with respect to the levels of these functions. They are akin to income effects in consumer theory.

Likely conjecture can be done about the signs of some derivatives: $H_G > 0$, $N_J > 0$, $H_J < 0$, $N_G < 0$, $G_E > 0$, $J_E > 0$. Indeed, health and nutrition status are expected to vary positively with the levels of their respective production functions. In contrast, they should vary inversely with the level of the other production function where they appear as an input. For example, the higher the exogenous variation of the health production capacity, at given health status level, the lower the needed nutrition input to reach this health status level. Moreover, one expects the education variable to improve the efficiency of health and nutrition production processes.

In these conditions, it is easy to see that the signs of H_E and N_E are ambiguous, irrelevantly from the signs of the Slutsky terms. This implies that the effect of exogenous education on health and nutrition can be positive or negative.

Let us now consider the effect of our main variables of interest, the agricultural outputs.

(c) Results for the output variables

The results confirm the assumptions made about the expected effects of the output variables. Beans, tubers and other food outputs positively affect nutrition. This is consistent with the fact that beans and tubers in Rwanda are the main food basis. As mentioned above, all these products not only have important nutrient contents but also amount to a major share of food consumption. The effect of 'Other food outputs', which are heterogeneous and rich in proteins, lipids and vitamins, is significantly positive for nutrition and non-significant for health.

In contrast, traditional beer output has a significantly negative impact on nutritional status. The noxious effect of banana beer and sorghum beer consumption overrides its positive energetic contribution.[17] This is not necessarily obvious as in Rwanda traditional beers often look like porridge rather than beverage. So, they incorporate non-negligible nutrient amounts. Some precautions are still necessary since the brewed beer is only partly consumed by the household and instead used for gifts, sales and loans. The fact that consumption of banana wine is much higher in the East may explain a more negative coefficient of the traditional beer output in the East region. The mechanisms through which beer production harms nutritional status are not well known. However, malnutrition is known to be common in those with an alcoholic addiction (Eddleston, 1990). Excessive alcohol ingestion perturbs normal digestion. Alcoholism is known as an important cause of hypoglycaemia and diabetes (Williams and Monson, 1990). Alcoholism also diminishes an appetite by substituting less nutritious alcoholic beverages in place of nutritional food. An issue in other populations could have been that of overweight, such as 'beer bellies', as an outcome of excessive beer consumption in contrast with nutrient deprivation. However, such overweight is rare for the studied rural households who are extremely poor. In these data, less than 1 percent of

[17] It has been suggested that the production of banana beer could be endogenous in the nutrition equation; since households are producing a large surplus of bananas compared to their own consumption and if unable to trade them, could make banana beer with this surplus. This hypothesis is to be rejected because bananas used for food consumption and bananas used for beer are different species coming for different trees. The exogeneity of the banana beer output is

households have mean adult BMI over 23 percent, the threshold defining overweight in Higgins and Alderman (1997). Although, this effect would certainly be important for better off urban households, it is unlikely to matter much for the poor rural Rwandan households that we study. Another possibility is that alcoholism may often degrade health without causing acute illnesses forcing the ill person to stay in bed. In this situation, the effect of beer production on health would be largely unobserved with our health indicator. Moreover, the part of the beer production being sold, given or loaned may blur the relationship between brewing and health. Thus, our results suggest that nutritional studies based only on nutrient intakes would miss an important influence channel of food. In designing nutritional policies aimed at poor peasants, fighting alcoholism may be as vital as bringing nutrients to households.

As opposed to the nutrition equation, the health equation has few significant coefficients for the agricultural outputs. The 'other fruit and vegetables' output, mainly composed of peas and plantain bananas, has a positive significant effect on the health status. This is consistent with the rich content in vitamins and mineral salts of these products.

The fact that there is no significant relationship between brewing beer and health is unexpected. In particular, one would have thought that diabetes and other alcohol-related illnesses would have an impact on health. However, remember that the health status of members is measured by the number of days of illness, a variable known as being often affected by answering errors (as in Schultz and Tansel, 1997). In particular, mild sickness spells due to diabetes may not be recorded. Moreover, sudden mortality fits caused by diabetes would also escape this health measures. This imperfect measurement would also explain that most effects are not significant in the health equation.

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based on the lagged agricultural output indicators as compared to HN indicators.

Finally, non-food output has no effect on nutrition and health. This is little surprising since this type of product (coffee, craftwork, etc) is generally not consumed by the household but sold and should not directly affect HN. However, since these products bring market resources, they could help generate purchases affecting HN. Thus, the fact that the corresponding coefficient is not significant is another confirmation that market interactions may not be as important for the explanation of HN as the direct effects of own-consumption in the studied context.

(d) Differences arising when including per capita consumption in the equations

Although there may be slight changes in the levels of the estimated coefficients, the introduction of per capita consumption in the estimated equation *does not change* the signs and significance of the significant coefficients of the output variables. However, there are a few differences in the coefficients of the other variables.

The coefficient of log of land area is slightly more significantly negative in the nutrition equation, and is no longer significant in the health equation. The coefficient of the age of the head (respectively average age of members) is significantly negative at 10 percent instead of 5 percent in the nutrition (respectively) health equation. The coefficient of the Tutsi head dummy (respectively education of the head) is no longer significant at 10 percent in the nutrition (respectively health) equation.

So, on the whole, there is a slight loss of significance which justifies dropping the per capita consumption whose joint significance is rejected from the equations.

5. Conclusion

In some less developed countries, market imperfections imply that the composition of agricultural production may directly affect health and nutritional status. Using lags in the observed indicators of agricultural production, as compared to the health and nutritional status indicators, we specify a model where health and nutritional statuses depend on agricultural production from a previous period. We estimate health and nutrition equations with cluster-effects for peasants of Rwanda, in which health and nutritional levels are related to the main agricultural outputs and inputs and to socio-demographic characteristics.

The estimates first indicate there may be little use for food markets in the studied environment as far as health and nutrition are concerned. Income only cannot summarise the impact of output composition and level on health and nutrition.

Beans, sweet potatoes and a category composed of heterogeneous food of high quality are found to have positive impacts of their output on nutritional statuses, while the production of traditional beers is found to be noxious for nutrition. Other fruit and vegetables output is associated with a better health status.

The results show the interest in paying attention to the case opposite to that of perfect markets: the absence of market effect. This is clearly a research line that has not been much investigated in the previous literature. Focusing on the case of quasi-autarky enables us to estimate from limited data a simple model of the effects of agricultural production on health and nutrition. The sufficiency of direct market effects to explain health and nutrition statuses is rejected by the data.

However, richer data would be necessary for a full investigation of this question, notably with several observation spells in order to decipher the multiple causality links between agricultural processes on one hand, and health and nutritional processes on the other. Also, an estimated model explaining the role of market imperfections in generating direct effects of production on health and nutrition would be useful. To estimate such a model, more data are needed that should provide a description of the market imperfections and introduce the residual role of markets in the problem.

As a whole, what we have presented is some evidence for the importance of accounting for the agricultural production composition of peasants under imperfect markets, when one is concerned for their health and their nutrition. This implies that, for the management of health and nutritional care, one should devote more attention to the agricultural activities and crop selection of peasants. Moreover, agricultural research could emphasize more on research about improved varieties with nutritional and health enhancement. Our results appeal for more studies in this direction.

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Appendix 1: Tables

Table 1: Descriptive statistics

Variable	Mean (with sampling weight)	Mean (without sampling weights)	Standard Deviation
Nutritional indicator (N) (kg.m^{-2})	21.07	20.97	2.03
Inverse Health Indicator (1/ H) (days per month)	1.94	2.32	3.12
Bean output (Frw)	10 133	9 968	7 375
Other fruit and vegetables output (Frw)	7 775	8 504	10 596
Tubers output (Frw)	13 361	12 873	9 998
Traditional beer output (Frw)	18 893	20 032	18 046
Other food output (Frw)	6 359	6 922	12 704
Non food output (Y) (Frw)	749	707	1 524
Years of education of the household head	2.11	2.03	2.39
Average height of members (cm)	136	136	15.6
Average height of active members (cm)	161	162	6.7
Average weight of members (kg)	37.9	37.7	7.9
Average weight of active members (kg)	55.0	54.9	6.0
Total production	61 351	60 295	30 248
Subsistence ratio	0.658	0.655	0.15
Food subsistence ratio	0.747	0.741	0.15
Body Mass Index (x 10^4)	20.97	21.08	1.487
Single Head	0.0191	0.0185	0.137
Animist head	0.152	0.144	0.361
Head who can write	0.484	0.509	0.501

157 observations. Frw is Rwandan Francs. The subsistence ratio is the proportion of produced consumption. The food subsistence ratio is the proportion of produced food consumption. The masculinity ratio is the number of male members over female household members. The other regions used as reference basis of the included region dummies are: Southwest, Centre north, Centre south.

Variable	Mean (with sampling weight)	Mean (without sampling weights)	Standard Deviation	Mean (complete sample of 270 observations)
Land area (m^2)	13 003	12 876	14 206	12 398
Number of infants (under 4 years of age)	1.02	1.01	0.8	0.83
Number of children (4-10)	1.15	1.19	1.08	1.05
Number of adolescents (11-15)	0.78	0.82	0.97	0.72
Proportion of selected members	0.37	0.37	0.16	
Household size	5.75	5.73	2.16	5.21
Number of active members	3.49	3.52	1.65	2.50
Average age of members	20.7	20.4	7.9	23.86
Age of the household head	44.6	44.1	14.3	46.57
Dummy for female household head	0.17	0.16	0.37	0.20
Dummy for Tutsi household head	0.15	0.14	0.35	0.11
Masculinity Ratio	1.30	1.28	0.98	1.13
Dummy for the Northwest Region	0.15	0.13	0.34	0.14
Dummy for the East Region	0.28	0.24	0.42	0.24
Total consumption	56 529	56 795	20 865	51338
Year of arrival in the area (till present time)	39.22	37.86	35.80	40.02
Head born off sector	0.382	0.402	0.487	0.42

Table 2: Estimation results

(Within-cluster estimates weighted by sampling scheme)

Dependent Variable	*Nutrition*	*Health*	*Nutrition (with total expenditure)*	*Health (with total expenditure)*
Independent variables:				
Logarithm of number of active members	-0.0571 (-1.45)	-0.328 (-0.90)	-0.0296 (-0.71)	-0.519 (-1.32)
Logarithm of land area (m^2)	-0.0294* (-1.92)	-0.230* (-1.61)	-0.0361** (-2.31))	-0.183 (-1.25)
Number of infants (0-3)	0.0156 (1.03)	-0.230* (-1.63)	0.0204 (1.34)	-0.263* (-1.84)
Number of children (4-10)	0.03377** (2.97)	-0.03851 (-0.36)	0.0486** (3.49)	-0.141 (-1.08)
Number of adolescents (11-15)	0.0268 (1.58)	-0.0879 (-0.55)	0.0259 (1.49)	-0.0756 (-0.48)
Age of head	-0.003188** (-2.22)	0.0494** (3.70)	-0.00271* (-1.88)	0.0461** (3.41)
Average age of members	0.00727** (2.78)	-0.0524** (-2.15)	0.00585** (2.16)	-0.042* (-1.67)
Dummy for Tutsi head	-0.0513* (-1.60)	-0.997** (-3.33)	-0.0484 (-1.52)	-1.017** (-3.41)
Education of head	-0.0129** (-2.47)	-0.0891* (-1.82)	-0.0163** (-2.96)	-0.0657 (-1.27)
Bean output (Frw)	0.0229** (2.53)	0.0553 (0.66)	0.0206** (2.28)	0.0715 (0.84)
Other fruit and vegetables output (Frw)	-0.00852 (-0.88)	0.221** (2.45)	-0.0134 (-1.35)	0.255** (2.73)
Tubers output (Frw)	0.0608** (2.90)	-0.240 (-1.23)	0.0493** (2.28)	-0.160 (-0.79)
Traditional beer output (Frw)	-0.0250** (-2.46)	-0.0370 (-0.39)	-0.0297** (-2.87)	-0.00425 (-0.04)
(Traditional beer output) x (Dummy for East)	-0.0793** (-2.94)	-0.260 (-1.03)	-0.0783** (-2.93)	-0.267 (-1.07)
Other food output (Frw)	0.00538 (1.33)	0.0159 (0.42)	0.00567 (1.40)	0.0142 (0.38)
Non food output (Frw)	0.00385 (1.38)	0.0181 (0.70)	0.00302 (1.08)	0.0239 (0.92)
Log of Total Per Capita Expenditure			0.0874* (1.80)	-0.606 (-1.33)
R^2	0.3383	0.4189	0.3380	0.4180

Student's t is in parentheses. * = Significant at 10% level. ** = Significant at 5% level.

Appendix 2: The Sampling Scheme

The sampling scheme has four sampling levels: communes, sectors, districts and households (Roy, 1984). The drawing of the communes was stratified by prefectures, agro-climatic regions and altitude zones. Several sectors were drawn in each commune. One district was drawn in each sector and one cluster of three neighbouring households was drawn in each district. From this information, we have calculated sampling weights that are the inverse of the household drawings probabilities.

There are in total 90 clusters of three households each. The three households constituting each cluster were randomly selected after a full census of the households living in the selected district at the time of the survey.

Table 1 shows the means of a few characteristics for both the initial sample of 270 households and the final sample of 157 households remaining after removing missing values. Many means are relatively similar across the two samples (for land, children, household size, age and birth year of the head, masculinity ratio, year of settlement, geographical dummies). However, these samples differ substantially by the following characteristics.

The selected sample corresponds to households of often smaller size and fewer members for most demographic categories. In the selected sample, the average age of the head is on average higher than for the whole sample, and fewer heads are Tutsi, while more numerous heads are female. Finally, the mean total consumption is lower for the selected sample. On the whole, the occurrence of missing values slightly makes the used sample deviate from the mean rural household characteristics in Rwanda, while not in an extreme fashion.