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Do Agricultural Outputs of Autarkic Peasants Affect Their Health and Nutrition? Evidence from Rwanda

by

Christophe Muller

Centre for Research in Economic Development and International Trade, University of Nottingham

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September 2000

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Abstract

In rural areas of LDCs, 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.

We analyse the responses of health and nutritional status of autarkic agricultural households in Rwanda, with respect to differences in socio-demographic characteristics and levels of the main agricultural outputs and inputs. The estimates account for fixed cluster-effects and the sampling scheme. The various food outputs are generally found to have a positive influence on health and nutrition, whereas the production of traditional beers has a negative impact. Thus, a policy based on incentives for substituting cultures may improve peasants' health and nutrition.

Dans les zones rurales des pays en voie de développement, en raison de l'existence d'imperfections de marchés, les états sanitaires et nutritionnels des paysans peuvent dépendre directement des niveaux de productions agricoles spécifiques, et pas seulement du niveau des revenus.

Nous estimons les changements de la santé et de la nutrition des ménages agricoles autarciques du Rwanda, dus aux différences de facteurs socio-démographiques exogènes, mais également á des différences des niveaux des principaux outputs et facteurs agricoles. Les estimations tiennent compte d'effets fixes pour les grappes et du plan de sondage. Les productions alimentaires apparaissent avoir des effets généralement bénéfiques sur la santé et la nutrition, alors que la production de bières traditionnelles a un impact négatif. Une politique basée sur des incitations à substituer des cultures pourrait améliorer la santé et la nutrition des paysans.

Outline

I INTRODUCTION

The effect of income on health and nutritional status (HN) of peasants has attracted a lot of interest in the economic development and health literatures[1]. Low levels of agricultural outputs, which are the cause of low living standards, create severe nutrition and health problems for poor peasants in LDCs. It is often overlooked that, in the presence of market imperfections, the usual separation theorems of the general equilibrium theory do not apply and the effects of agricultural output on HN may involve a composition effect and not only an aggregate income effect. From another perspective, nutritionists[2] and health specialists[3] show that different products bring different nutrients and have specific effects on HN. To our knowledge, there has been no investigation in the literature of the influence of the composition of agricultural production on HN.

A few examples will show the typical health and nutrition equations estimated in the literature. Let us focus on the influence of different agricultural products on HN (in fact only incomes and nutrients have been used in the literature) and on the role of prices. Most studies deal with children, who are characterised by biological mechanisms related to growth, different from that for adults. The authors often try to explain weight-for-height or BMI (body mass index) of children. Household income, calorie intakes and children's health status have been found to be related to children 's nutrition status. Prices are more rarely significant. Using data from Colombia, Heller and Drake (1979) find a significant impact of nutrient sources on nutritional status of children. Von Braun, Hotchkins and Immink (1989) find in Guatemala a significant effect of income per capita, and an insignificant effect of the share of income from export crops, on the weight-for-height of children aged 6-120 months. Von Braun, Puetz and Webb (1989) find in Gambia no significant effect for calories per adult-equivalent on the weight-for-height of children aged 7-120 months. Senauer and Garcia (1991) find in the Philippines that parents' wages and prices of rice and cooking oil have significant effects on the weight-for-height of pre-school children. Finally for Rwanda: von Braun, de Haen and Blanken (1991) find, in commune Giciye, significant effects of calorie intakes on the weight-for-height of children aged 6-72 months; Schnepf (1992) estimates weight-for-height

1 See recently: 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).

equations for children, in which health expenditure appear significant (though its endogeneity is not corrected); Barghava (1997) estimates weight equations for men and women, in which neither proteins nor energy are significant. In these studies of Rwanda, prices and composition of agricultural output have not been included in health and nutrition equations.

Other authors are interested in children's health as measured by the number of days of illness or inactivity. For example, Wilcox-Gok (1983) using data from USA, Deolalikar (1992) using data from Indonesia, and Appleton (1995) using data from Kenya deal mostly with the effects of socio-demographic variables, health environment and infrastructures, and family income. All these factors are found significant in the explanation of illness for children, while effects of agricultural outputs have not been investigated. Fewer authors provide results concerning adults[4], especially in LDCs.

The specification of technologies and independent variables is very varied. Using data from Indonesia (1985), Pitt and Rosenzweig (1986) estimate at household level, an illness linear production function, in which household work and twelve types of consumption are inputs. They find that worked hours are not significant, while consumption of sugar is noxious and consumptions of fish, vegetable, fruit and even tobacco-betel positively affect health. Household composition, household public good inputs and health environment are other significant determinants of illness. The effects of consumptions is directly considered rather than that of agricultural outputs. In our case, because of high own-consumption rates for the food, this distinction may be less serious that it appears, and enables us to connect agricultural and HN processes. Using data from Bangladesh, Pitt, Rosenzweig and Hassan (1990) find that the weight-for-height of household members is significantly determined by caloric intakes but also by the quality of water and especially age and sex characteristics. Foster and Rosenzweig (1994) estimate a BMI production function for adult peasants in Phillippines. The set of independent variables includes eight characteristics of the agricultural work, calorie intakes, an index for illness, lagged BMI and a dummy for male. They find that an increase of calorie intakes, net of activities, raises the BMI. The mix of activities and tasks related to different reward schemes also affect the BMI of these workers.

4 See Murray et al. (1992), Sickles and Taubman (1997) for surveys of this literature.

As a matter of fact, the relationship between HN and different types of outputs for autarkic peasants is not known at all. However, von Braun and Kennedy (1986) present a survey of the effects of level and share of the aggregate cash crop in LDCs on household food consumption and nutrition, which could be considered as a step in this direction. However, the authors were primarily interested by the impact of commercialisation of the agricultural output rather than in any output composition effect.

Several studies simultaneously consider agricultural outputs and HN [5], often in order to estimate agricultural technology or decisions. In this way, Pitt and Rosenzweig (1985, 1986) estimate agricultural and health technologies. First, the individual health production functions describe how the health of each household member depends on several vectors of: nutrients, non-food health inputs, members' characteristics, household labour, household resources that affect health, and the exogenous health endowment of the considered member. Second, the agricultural production function describes how the agricultural outputs depend on agricultural inputs and HN. We focus in this article only on relationships of the first type.

Household behaviour is often represented by the maximisation of a utility function that depends on vectors of health, leisure and consumption for every household member, subject to technology and income constraints. When all markets of goods and outputs exist and are perfect, one can derive demand functions for the health or nutritional status of every member. In these models, where consumer and firm decisions are separable, 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 crops caused by adverse climate, are also conveyed through the income effect in the budget constraint. Production composition does not matter once the profit effect is included.

When there are imperfect or missing markets for inputs that enter both in preferences and technology, consumption and production decisions are no longer separable[6]. In our case,

5 e.g. Rosenzweig and Schultz (1983), Pitt and Rosenzweig (1985, 1986), Deolalikar (1988), Croppenstedt and Muller (2000).

6 Singh, Squire and Strauss (1986), Benjamin (1992).

because there is no market for health and for nutrition status[7], and because they may enter as inputs in agricultural production process and as arguments in preferences, the household behaviour is not separable.

Moreover, markets of consumption goods and markets of agricultural outputs may be simultaneously missing or imperfect, since many poor peasants live in quasi-autarky. This means that consumption and HN demands do not depend on prices but on the characteristics of household preferences, the characteristics of the joint HN-agriculture technology and levels of past allocations (because of lagged effects in HN processes and since markets do not clear output stocks). Sometimes, shadow prices can be used to help the interpretation. In that context, the shadow prices of particular decisions associated with the technology and the preferences are endogenous and depend on all input and output allocations, and on characteristics coming from preferences and constraints.

These considerations are important because poor peasants in LDCs often live in areas with missing or very imperfect markets. In rural Rwanda, peasants mostly consume their own agricultural output[8]. The average own-consumption rate in 1983 (proportion of consumption coming from own production) for the national sample used in this study is above 66% overall and almost 80% for food. Moreover, Rwandan households are scattered in the hills. Consequently, their spatial isolation makes the residual monetary transactions a complex production process, involving transport and transaction costs, during which a small part of the agricultural production is converted into bought market goods[9]. As a matter of fact, the effects of prices are mediated by highly complicated mechanisms of missing and imperfect markets, which cannot be accurately described with a linear budget constraint. Of course, markets still exist, but they may have a more limited

7 There may be markets for health care and nutritional inputs but there is no market for health and nutritional outputs described by health and nutrition status.

8 See Muller (1989). This is also the case in the very similar context of Burundi as described in Cochet (1993) and Sindayizeruka (1993).

9 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 the rural Rwanda. In the Von Braun et alii study, the share of food consumption of the households that is own-produced is of 48% while it is 80% for the whole rural Rwanda (from our own estimates uaing the National Budget-Consumption Survey 1983). The great majority of households in Giciye has substantial non agricultural incomes with an off-farm income equal on average to 58% of total income, while for the whole rural Rwanda, only one quarter of households regularly receives wages, and generally for a small amount. Our national sample corresponds to peasants very oriented to subsistence activities.

impact on living standards of poor peasants than the size and composition of agricultural output.

In this context, our modelling strategy is to consider that most of consumption is explained by output levels. This polar case contrasts with considering consumption decisions given a budget constraint and perfect markets. This empirical strategy is adapted to situations where market failure may be so widespread as to affect every good and factor[10].

In Rwanda, the extreme dominance of own-consumption in consumption suggests that constraints or non-prices incentives oriented towards the composition of the agricultural output might be a useful way of influencing peasants' HN. To design such policies, it is necessary to investigate the effects of specific productions on HN of agricultural households. "Does the shoemaker's son wear better shoes?" Do farmers who grew more nutritious crops have better health and nutrition status? This is possible if they eat most of the nutrition crops themselves, although the labour effort required by the different crops may also have implications for health and nutrition outcomes. In a context of missing or incomplete markets, do different agricultural outputs have direct and specific impact on HN? The aim of this paper is to answer these questions by estimating health and nutrition equations, which in contrast with other studies, incorporate the effects of specific agricultural productions, in rural Rwanda. We discuss in section 2 the theoretical model and the applied specification. In section 3, we present the data and the indicators. We show in section 4 the estimation results of equations for health and nutrition status, with and without fixed cluster-effects, and weighted by the sampling scheme. Finally, we conclude in section 5.

II THE MODEL

II.i The theoretical framework

a) General discussion

We first examine in this section the general argument of the modelling approach in an aggregate way in order to focus on the main features of our problem. Then, in section 2.2

10 de Janvry, Fafchamps and Sadoulet (1991) propose a model with missing markets but its estimation would necessitate the presence of perfect markets at least for some goods, which may not be the case in our context. They do not consider situations when all markets are imperfects.

we shall discuss the estimated Cobb-Douglas forms. Let us consider a single person agricultural household producing food outputs (Y_i,(i = 1,...,5))[11] and non-food output (Y_6), from various inputs X, notably the land used by the household, and the household labour force. We consider the goods that are obtained from markets to be of marginal importance. They can generally be bought using monetary income from residual sold outputs. To simplify, we do not enter into the description of this residual ‘market technology’. The household is characterised by a health indicator (H) and a nutritional indicator (N)[12]. We do not consider the other agricultural inputs in the theoretical model as they do not pertain to the issue here. We rather focus on the variables at the household level that are related to our subject: Y_i (i = 1,...,6), X, H and N. The interactions between these variables are discussed in details in section 4.2.

On the one hand, all the considered interactions involve delays. Part of the labour input corresponding to observed agricultural outputs may have been supplied a long time before, for example for seeding or ploughing. Indeed, the harvest may occur several months and sometimes more than one year after the beginning of the agricultural work. Once the harvest is gathered, the product must be treated - e.g. beer bananas, which have to be crushed and mixed with water and honey, before being left for fermentation. The product is then stocked, sometimes for several weeks or months before its final consumption. If we now consider the possibility of an agricultural productivity fall caused by illness, we must account for that illness might be anterior to the execution of the work. In that case, the health input in the agricultural technology corresponding to the final consumption of the agricultural output clearly belongs to a past period.

On the other hand, we have available indicators for agricultural outputs and HN for the agricultural year 1982-83. However, since we have calculated the agricultural output indicators from the value of their observed uses, the corresponding outputs may have

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11 We observe 6 agricultural outputs that will be described in section 3.2.

12 One sometimes finds a set of health and nutrition indicators in applied work. Generally, the health and nutrition status of different household members are separated. To simplify, we only consider the global indicators at the household level. Furthermore, economic variables are generally observed at the household level (consumption, labour, production, etc) and their attribution to individual members is problematic. For household behaviour models with individual allocations: Pitt, Rosenzweig and Hassan (1990), Chiappori (1992), Udry (1994).

been cropped several months before[13]. In contrast, the health and nutritional indicators are specific to the period of the enumerator visit. The sequentiality involved in the definition of these indicators reduces the short-run feedback effect of measured HN on observed agricultural output.

Under the assumptions, we can ignore the feedback effect of agricultural production on the biological processes. However, we treat a possible residual endogeneity of Y_{t-1} by using instrumental variable methods. This type of approximation is similar to that used for the estimation of agricultural production functions in the literature when neglecting the feedback effects of agricultural production on health status considered as an input in the production function (Strauss (1986), Deolalikar (1988)). The sequentiality involved in the studied indicators adds some credibility to this approach.

The decisions of the household relative to HN are likely to be complex. Health and nutrition status can be viewed as conditional demands derived from an optimisation programme where the household utility depends on consumption, time use, HN and where the constraints incorporate biological technologies describing the health and nutrition processes. As we indicated before, the various agricultural outputs and the stress of agricultural work are inputs in the biological technologies. However, our purpose is not to enter in the details of the specification of such a model that can have various forms. Indeed, little is known about the complete specification of such an optimisation programme and we observe only a partial set of indicators. Nonetheless, it is clear that HN conditional demands should depend on the characteristics of preferences and HN technologies, and on agricultural outputs and inputs corresponding to a past period.

These corresponding HN equations are described in eq. 1. Y_t denotes the vector of usual agricultural outputs, X_t is the vector of the main agricultural inputs (land and labour force) in period t, which affect the stress of the agricultural 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 biological processes. Z_t^{U} denotes the exogenous characteristics of preferences.

13 The information collected about the uses of agricultural production corresponds to the period of the enumerator's visit (at each quarter) and to the three previous months. The harvest at the origin of these uses may have occurred at the previous season.

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

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

Under our assumptions, we can estimate system (1) separately from the agricultural technology. However, production must be treated as endogenous. Indeed, Y_{t-1} and HN_t may be affected by common unobserved variables. For example climatic shocks such as high level of rains can both damage crops and food stocks, and help future multiplication of anopheles mosquitoes conveying malaria, or future diarrhoea epidemics (Drasai, Tomkins and Feachem (1981)).

II.ii The applied specification

Because of the small sample size, we specify reduced-form conditional demands for health and nutrition status that are defined at the household level, by using Cobb-Douglas type functions for h and n in system (1). Indeed, Cobb-Douglas type functions are parsimonious in parameters to estimate. This yields:

$$(2)\ \text{Log } H_t = \sum_{i=1}^{6} b_{2i}\ \text{Log } Y_{i,t-1} + d_2\ \text{Log } X_{t-1} + Z_t^{HN\,'} a_2 + Z_t^{U\,'} c_2 + \lambda + \varepsilon_H$$

$$(3)\ \text{Log } N_t = \sum_{i=1}^{6} b_{1i}\ \text{Log } Y_{i,t-1} + d_2\ \text{Log } X_{t-1} + Z_t^{HN\,'} a_1 + Z_t^{U\,'} c_1 + \mu + \varepsilon_N$$

where Y_i (i = 1,...,5) are the values of food production for the five observed food outputs, respectively: beans (Y_1), other fruit and vegetables (Y_2), tubers (Y_3), other food output (Y_4), traditional beers (Y_5). Note that banana for beers (in Y_5) and banana for food (in Y_2) are different varieties and come from different trees. Y_6 is the value of non-food production. Non-food output is included on the grounds that firstly its consumption may directly contribute to the efficiency of health and nutrition processes, such as for equipment goods. Secondly, the money coming from residual sales of this output can be used to purchase consumed goods that affect HN. b_{1i}, b_{2i} (i = 1,..., 6) and a_1 , a_2 , c_1, c_2, d_1 , d_2 are vectors of parameters. $(\varepsilon_{H}, \varepsilon_N)'$ is the vector of error terms. μ and λ are fixed cluster-effects varying with the cluster (μ and λ are identical for all households in the same cluster). They account for local unobserved fixed characteristics that may influence the preferences and the HN technology, and are included in our preferred specification.

III DATA AND INDICATORS

III.i The data

The population of Rwanda is estimated at 5.7 million in 1983, nearly half under 15 years of age. Per capita GDP is around US $ 270 per annum. More than 95% of the population live in rural areas and agriculture accounts for 38% of GDP. The educational level of the population is low with half the adult population illiterate. In our application we study a peaceful situation corresponding to the agricultural year 1982-1983 (i.e. mostly 1983). General health status is very precarious, with a life expectancy of 44 years. The perinatal mortality rate is 86 (per 1000 births); the juvenile mortality rate is 222; the adult mortality rate is 395, and 34% of children under five years are too small for their age, indicating a prevalence of malnutrition.

3.5 % of GDP is spent on health services (US $ 74 million), of which international aid finances 40 %. Demographic growth is very high, with an average of 8.3 children per fertile woman, possibly the highest fertility rate in the world. This results in great pressure on land (the average farm covers around 1 ha), and food production per capita has fallen between 1980 and 1991 by 1.8% per year[14]. These few numbers illustrate the potential role of policies directed to HN. The recent civil war dramatically increases the need for such policies. Besides, health and nutrition problems have been a permanent concern of public decision makers since the independence of the country (Colloque FOMETRO (1966), ONAPO (1985), Ministère du Plan (1985, 1988)).

Data for the estimation is extracted 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[15] from November 1982 to

14 Source: World Development Report 1991, The World Bank, 1992.
15 95% of the population according to the census of 1978, Bureau National du Recensement (1984).

December 1983 (Ministère du Plan (1986)[16]). 270 households were surveyed over a period of twelve months about their demographic characteristics, their budget, their food own-consumption and their agricultural sales. We dispose of anthropometric measures and records of the number of forced rest days due to illness, for all household members over 14 years old[17].

The survey involved an intense preparation work. Indeed, every household was visited at least once a day by an enumerator collecting the information during two weeks for every quarter. Also, every household had to register for himself much repetitious information in a booklet during the absence of the enumerator. The set of surveyed topics was very broad and several aspects have been treated as redundant by using different collection methods. This enabled an excellent quality of the collection and we were able to supervise a thorough cleaning of the data that was carried out by more than thirty ex-enumerators. Sophisticated verification algorithms have been designed and applied using the many redundancies that are present in the data. Finally, we calculate the indicators with algorithms deliberately aiming at reducing the measurement errors from the combination of several questionnaires. However, some data contamination is certainly still present, particularly for anthropometric measures and especially for the number of days of illness that are known to be delicate information to obtain in household surveys.

III.ii The indicators

a) Household variables

Table 1 shows some descriptive statistics for the main variables. We use only 157 observations in the estimation because of missing or invalid values for the information about illness duration and anthropometric measures[18]. Health and nutritional indicators are based respectively on the number of forced rest days caused by illness and BMI, for all members between 18 and 50 years old inside the household. The health indicator H is defined as the inverse of the average number of forced rest days caused by illness (plus

16 The collection has been designed by INSEE (French National Statistical Institute).

17 See Cox and Cohen (1985) for methodological issues associated with these measurements.

18 This missing value problem leads to a strong selection of the sample. However, we do not dispose of relevant information to correct it. Then, we shall assume that this sample selection is random and does not affect the estimation results. Moreover, to keep comparable the estimated equations for health and nutrition indicators, we choose to use the same sample of households for estimating both equations.

one) 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.[19] That is: each individual ratio is calculated and we take the average of these ratios for all active adults.

The average height of members is 1.35 metre (1.61 metre for active adults). The average weight of 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 (standard deviation of 2.04, first quartile of 19.7 and third quartile of 22.37). The number of forced rest days is 1.95 per month per capita on average with a standard deviation of 3.1. Only 3.5 percent of households spent no day in forced rest, and we therefore neglect this truncature in the estimation.

b) Non-output independent variables

A set of exogenous variables is incorporated in the model through vectors Z^U, Z^{HN} and X_{t-1}. It includes: land area, household composition, other socio-demographic characteristics and cluster dummies[20]. The land and the number of active members are the main inputs in the agricultural technology. However, land would not appear in HN demand equations with a separable model based on a set of complete markets[21]. Here, land influences HN in that it affects the quantity and the stress of agricultural work and also because it influences the household decisions as a determinant of shadow prices. The same is valid for the size of the household labour force. Clay, Reardon and Kangasniemi (1998) provide a more detailed picture of agricultural inputs in Rwanda. However, it is unclear how minor inputs would affect HN and anyhow we do not dispose of this information in our dataset.

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19 We consider only adult members in calculating health and nutritional indicators. Mausner and Kramer (1985) recommend to use different health indices in relation to stages of life-cycle. Indeed, the growth curve and the type of disease are very sensitive to the age of children. Including children in the health and nutritional indicators would give too much importance to the households sex 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 difficult to interpret (Tomkins (1994)).

20 However, some of these variables are not significant in the estimations and we have excluded them to save on degrees of freedom. For instance, neither the place of birth nor the date of settlement of the head in the surveyed sector play any role in the estimation, which suggests that the selectivity of the sample by migration, sometimes observed in health studies (Strauss and Thomas (1995)), is not important in Rwanda. The religion of the head is also non-significant.

21 The land market is almost inexistent in Rwanda, and the main exploitation system is direct exploitation (see Guichaoua (1989)). Less than 10 percent of the land is share-cropped.

The number of children may substantially influence how the household deals with nutrition and health problems. 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 practise on their children. Third, children participate in the HN processes (for example by caring for their younger sisters or brothers, or preparing meals), and in agricultural production, which contribute to diminish the workload for adult. Fourth, young children are a burden for the family. They take a lot of time of female members that may be diverted from the HN process for adults. Fifth, they are more likely to be ill than other members and their presence increases the risk of contagion in the family. Sixth, the household composition is a major determinant of preferences.

These variables are also important determinants of household preferences. The age and education of the head may partly explain experience and efficiency in health and nutrition processes. Age and gender of members are potentially important determinant of HN, although their effects are attenuated by the fact that we use averages calculated only for adult household members. 2.1 adult members over 18 and under 50 years old were selected on average, as a basis for nutritional and health indicators. Nonetheless, several variables account for differences in age and gender of members of different households, as an attempt to capture differences in preferences and labour force.

The households from the Tutsi minority ethnic group, in Rwanda of 1983, have sometimes been excluded from political and public decisions. Some Tutsi families may have a worse access than the average households to public health and nutrition centres that provide support in health and nutrition domains. A dummy variable for a Tutsi head of household is therefore included. Finally, dummies for sampling clusters account for unobserved local characteristics that could matter for HN, such as health and nutritional services, and the healthiness of the environment.

c) Agricultural outputs

The agricultural products are gathered so as to isolate three major groups in the Rwandan alimentation (beans, tubers, traditional beers), and to separate bad nutritional goods (traditional beers), poor nutritional goods (tubers), good ones (beans, fruit and vegetables), and excellent ones (other food). Beans are a good source of calories, proteins, vitamins and mineral (calcium, iron). As a source of protein, they are much cheaper than meat. However, a lot of vitamins are lost during preparation since beans are generally boiled in Rwanda. Their cultivation requires also a great deal of labour.

"Other fruit and vegetables" are composed of different products, mostly banana and peas, but also leafy vegetables (manioc leaves) that are rich in vitamins and minerals. The plantain banana supplies fibres that contribute to the normal functioning of the colon. They contain more than 15 percent of glucides, although they are poor in proteins (1 percent).

Tubers are mostly composed of sweet potatoes and cassava, and some potatoes. They are less nutritive than other food (less than 1 percent of proteins, almost no lipids nor cellulose), although they have a notable nutritional role as staple food bringing a lot of carbohydrates (20 percent of their weight).

"Traditional beers" are composed of sorghum beer and banana beer. Banana beer has a higher alcohol degree. Sorghum beer contains more nutrients and is rare in the East region that has a low altitude, ill adapted to the culture of sorghum. A dummy variable for East crossed by the level of traditional beer output accounts for the higher prevalence of banana beer in the East. The beers are a source of calories, but are very noxious for HN because of their alcohol content. Excess consumption entails health problems related to liver and brain. It provokes apathy, anaemia and loss of memory.

"Other food" includes, among other products, cereals, milk, meat and palm oil. It is a very heterogeneous grouping with generally high contents in proteins and fats. Cereals (mostly sorghum and corn, and also some wheat and rice) are good sources of proteins and fats. They also contain a lot of carbohydrates. Milk, eggs and meat are exceptionally good sources of proteins, although generally expensive. Palm oil is an important source of fats in Rwanda. "Non-food" is a heterogeneous good composed of coffee and tea and other industrial cultures, although also of various craft works.

Enquête Nationale Agricole (1986) shows how household nutrient intakes come from the different crops. On average, calories are brought by different crops with the following proportions: banana (19 percent), pulses (22.5), cereals (26.5), tubers (32). Proteins are brought as follows: banana (6 percent), pulses (55) among which 48.5 percent from beans, cereals (24.8), tubers (14.5).

The average agricultural exploitation area is 1.3 ha (13003 m^2) for a mean food production value of 61 352 Frw (Rwandan Francs[22]). The larger food outputs in value are traditional beers, tubers, and beans. The value of household agricultural production is calculated from records of own-consumption, residual agricultural sales and other uses of production (gifts, reimbursements,…). We stress again that if prices are used for this aggregation, this does not mean that we consider that there exist perfect markets. Using prices is only the most obvious procedure in this context since there is no other observed anchor for defining aggregation procedures. However, if observed prices do not represent accurately enough the marginal rates of substitution between outputs, this may introduce a bias in the estimation. The prices used are most of the time local and correspond to the consumption quarter. Shadow prices accounting for market imperfections would be more appropriate for some households and some goods, but they are not available. Differences in sales prices and purchases prices are often around 10 percent, showing that market prices may be a suitable approximation if, as in de Janvry, Sadoulet and Fafchamps (1991), shadow prices occupy an intermediate position.

The own-consumption rates, especially when remittances are included, are very high (66.4 percent on average). They are even higher for specific food products: 80.6 percent for beans, 94 percent for other fruit and vegetables, 89.4 percent for tubers, 62.2 percent for traditional beers, 43.5 percent for other foods. The importance of the consumption from own production is consistent with the exclusion of the budget constraint from our approach. This is also consistent with Laure (1982), who finds that in commune Kanama of Rwanda, the frequencies of consumptions of beans and corn are very dependent on their respective harvests. Using a socio-demographic survey in commune Giciye, Damez (1987) finds that there exists often no serious management of the agricultural output, which is eaten by household members after the harvest without a clear commercialisation strategy. Leurquin (1960) and Vis et al. (1975) have also shown that in the past the diet of rural populations in Rwanda depended closely on local productions. This situation does not seem to have fundamentally changed.

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

III.iii The Sampling Scheme

The sampling scheme (described in Roy (1983)) has four sampling levels (communes, sectors, districts and clusters of households). The drawing of the communes has been stratified by prefectures, agro-climatic regions and altitudes zones. One sector has been drawn in each commune, and one cluster of three households have been drawn in each district.

We calculate sampling weights that reflects the probabilities of drawings at every level of the sampling plan and that we use in Horwitz-Thompson estimators (e.g. Gouriéroux (1981)). These weights also account for missing values. When the information of a sample unit cannot be used, we modify the drawing probability of the sample units of the same level, but only for that included in the same sample unit of the preceding level. This implies that different weights have to be used for the direct and the within-cluster estimations since only complete clusters are kept for the last case. The sampling weights make the weighted sample representative of the whole population of rural households in Rwanda. Using sampling weights substantially improves the results of descriptive statistics and estimations.

IV ESTIMATIONS

IV.i The estimation methods

We use OLS and 2SLS estimation methods (weighted by the sample scheme) in which instrumental variables are regional dummies, socio-demographic characteristics, household composition and prices.[23] Prices and regional dummies reflect the local heterogeneity of economic environment that guide agricultural processes.

Four characteristics of the household head that are used as IV (matrimonial status, religion, settlement year, place of birth), are important for the identification of 2SLS estimates. Indeed, these variables should significantly affect HN decisions, while they are correlated with levels of agricultural outputs on various grounds. Matrimonial status is

23 The geographical variability of prices (measured by the standard deviation across 5 regions) is half of the temporal variability (measured by the standard deviation across 4 quarters) which is large due to seasonal variations in aggregate agricultural output. Since we possess cluster prices, we may expect a good quality of these instruments in the equations without cluster effects. The price indicators have been collected in the closest market and are exogenous. We do not take position about the complex mechanism through which they may influence the production composition and levels. Here, prices are merely used as instrumental variables and are not associated with a budget constraint.

useful to distinguish married heads from bachelors and widows. Indeed, in Rwanda, to be married is the warrant of better social insertion[24] and better access to collective agricultural resources. To be an (old) bachelor might also be the signal of unfavourable past events correlated with a lower productivity, such as an illness or accident making him crippled. Widows are generally old women unable to cope alone with the agricultural production. They rely on the help of family members and neighbours.

Similarly, to be Christian rather than Animist or Muslim, and particularly to be Catholic, is associated with better public support and access to a larger social network. This may have consequences in terms of access to privileged information (about new cultural methods, local organisation of crops rotations,...), that is correlated with levels and composition of production. An old settlement year is related to specific experience in the area, which would increase the agricultural productivity. Indeed, knowledge about annual climatic hazards and properties of land plots is crucial for the organisation of daily agricultural works. In contrast, households recently settled in observed districts have generally access to land of inferior quality since the best lands had already been occupied.

Finally, the birth place of the head is used to separate heads born out of the observed sector. These heads benefit less from mutual help in agricultural tasks. Thus, heads born outside the sector may have a sub-optimal timing of their agricultural tasks and a different composition of their agricultural output.

All these arguments are supported by over-identifying restriction tests for these IV (Davidson and McKinnon (1993), Hwang (1980)). The results[25] imply that for all considered equations at traditional significance levels, the null hypothesis of the validity of instruments is never rejected.

Table 4 shows the Fisher's statistics for the tests of identifying instrumental variables (IIV). The hypothesis of no effect of the IIV in the prediction of the possibly endogenous

24 See Codere (1979), Crépeau and Bizimana (1979), Crépeau (1985).

25 The test proposed in Davidson and McKinnon amounts to compare the statistics $\xi = n R^2$ (where n is the sample size and R^2 the non-centered R-square calculated from the ancillary regression of the IV residuals on the instruments), with the appropriate quantile of χ^2 (dl), where the degree of freedom, dl, is the number of total instruments minus the number of explanatory variables. For the direct specification, the value of (ξ,

output variables is rejected for the traditional beer output in the East region in the case of direct estimates (with or without sampling correction). This hypothesis in the case of within-cluster estimates is rejected for fruit and vegetables, tubers, traditional beers, other food and non food outputs, without sampling correction; and for all outputs when the sampling correction is implemented. The 2SLS estimates with sampling correction are therefore supported by the IIV test.

IV.ii The results

a) Generalities

We present two different sets of estimates: "Within-cluster" estimates[26] corresponding to the inclusion of fixed cluster-effects and "Direct" estimates without these fixed effects. Tables 2 and 3 show respectively the direct and within-cluster estimates of system (1).[27]

The GR^2 in the nutrition and health equations for the direct estimates, respectively 0.046 and 0.067, are small.[28] Moreover, the $\overline{GR}^2$ for these equations are still lower

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dl) are (53.006; 53) in the nutrition equation and (61.557; 53) in the health equation. For the within-cluster specification, they are (58.499; 61) in the nutrition equation, and (63.4522; 61) in the health equation.

26 The used sample 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 surveyed households. Indeed, using reduced and unbalanced clusters with such a small sample would yield to meaningless estimates of fixed effects.

27 Because of the low sample size, the 2SLS estimates are sensitive to the number and the explanatory power of the instrumental variables. Following Davidson and McKinnon (1993), we use an intermediate set of instruments to both limit the bias of the estimates and the proximity with inconsistent OLS estimates. The set of identifying instruments includes: regional dummies; matrimonial status and religion of the head; settlement year; birth place of the head; masculinity ratio; household composition by age and sex classes; dummy for heads who can write; local prices of beans, sweet potatoes, banana beer and soap powder. Note that prices and region dummies cannot be used to identify within-cluster equations. The predictive equations for the outputs can be obtained by request to the author.

28 In 2SLS estimation, R^2 and adjusted R^2 are deficient measures of goodness-of-fit, and inappropriate criteria for model selection. Pesaran and Smith (1994) provide a better measure, generalised R^2, (denoted GR^2) which is an asymptotically valid criterion of model selection. We extend this criterion by calculating an adjusted generalised R^2.

In the classical linear regression model, we have $Y_i = X_i b + u_i$ where $E(u_i | X) = 0$ and $E(u_i^2 | X) = \delta^2$, $\forall$ i = 1 to n, where Y_i is the value of the independent variable for observation i, X_i is the transposed vector of the explanatory variables for observation i and b is a vector of parameters. Applied across n observations, we obtain $Y = X\ b + u$. If W is the matrix of instrumental variables,

$\tilde{b} = [X' W (W' W)^{-1} W' X]^{-1} X' W (W' W)^{-1} W' Y$ is the 2SLS estimator. The vector of prediction errors from 2SLS is $\hat{u} = Y - W (W' W)^{-1} W' X\ \tilde{b}$ and $GR^2 = 1 - \frac{\hat{u}' \hat{u}}{S}$. The adjusted GR^2 can be defined by

$1 - \overline{GR}^2 = \frac{n}{n-k} . (1 - GR^2)$, where k is the number of explanatory variables.

(respectively -0.013 and 0.0085). Indeed, it is common in the health literature to obtain a weak goodness-of-fit from nutrition and health equations. One reason is the importance of missing explanatory factors in the data, including genetic factors. Even calorie intakes are not always significant in cross-sections (Deolalikar (1988)). The values of total R^2 and total GR^2 are much larger for the within-cluster estimates (GR^2 = 0.30 for the nutrition equation and GR^2 = 0.41 for the health equation)[29], showing that much of the explanatory power is in cluster unobserved variables.

Table 5 shows the Fisher's statistics for the hypotheses of nullity of the coefficients of fixed cluster-effects. Only a restricted sample can be used for this test so as to consider exclusively households belonging to complete observed clusters. The null hypothesis is not rejected in OLS estimates but is always rejected in consistent 2SLS estimates for all sets of equations. This indicates, as did the GR^2 tests, that the within-cluster estimates corresponds to the best specification once the correction for endogeneity is made.

Because the data comes from a cross-section, we can only investigate short-run effects and our estimates must be considered as a first step towards the resolution of a difficult question. It is possible that long-term effects would be smaller than short-term ones since households may adapt to an unfavourable environment, for example by changing the organisation of production.

b) Expected effects

We now discuss the expected effects of independent variables. Non-toxic food consumptions generally improve nutritional status, whereas appropriate non-food consumption such as health services and household equipment (e.g. cooking and health material, lodging), may improve health and nutritional status. Alcoholic beverages have a specific effect, often neglected in HN studies. They bring valuable nutrients, mainly calories, but in small quantities. They are also less vulnerable to contamination than water, but their impact on HN can be very harmful. Alcohol consumption injures the liver,

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29 Note that they cannot be directly compared with the corresponding statistics for the direct estimates since both the samples and the variables are different. However, the within-cluster estimates correspond certainly to a better goodness-of-fit since for a random sample with the same number of degree of freedom., the OLS direct estimates on a selected sample yields only R^2 = 0.21 and $\overline{R}^2$ = -0.033 for the nutrition equation and R^2 = 0.31 and $\overline{R}^2$ = 0.098 for the health equation.

affects the brain and increases the rate of cholesterol. Alcoholics cannot properly absorb folic acid, which leads to anaemia and mental sluggishness. One cannot wipe out the possibility that specific food could sometimes be associated with diseases or intoxication, implying bad HN[30]. Agbessi Dos Santos and Damon (1987) and Gupta et al. (1992) provide a detailed analysis of the effects of every specific type of food on nutritional status. However, the effects of consumption of particular products on HN are more or less hypothetical and must be empirically investigated.

Moreover, there also exist direct effects on HN of the main agricultural inputs, land and labour. Indeed, health and nutrition status of individuals strongly depend on the activity level (Osmani (1992)). Even, if we do not observe the workload, we know that large agricultural exploitations for given workforce generally imply a higher effort level. This is caused by the larger amount of seeding, weeding and harvest tasks, and larger travel and transport burden. Thus, when output levels, number of workers and work organisation are kept constant, one expects a negative effect of the land area on HN.

By contrast, since the labour force is almost entirely constituted of household members, the presence of many active members in the household may contribute to reduce the workload of individuals, first by sharing tasks among workers exploiting scale economies, second because of the possibility of specialisation. Then, the direct effect of the number of active members on HN should be positive.

We only fully comment on the 2SLS-Within estimates, which are our best estimates. However, we first briefly discuss preliminary results with 2SLS-Direct estimates. The coefficient of masculinity ratio and the gender of the head are never significant (nor in within estimates) and these variables have been excluded. The coefficients of the following variables are not significant: land area, number of children for the two categories of children, age and education of the head, output of beans, output of other fruit and vegetables, output of traditional beers (in and out of the East region). The number of active members has a negative impact on nutrition that is compensated by the positive effect of the number of adolescents and the average age of members. Thus, family composition seems to matter for nutrition status. Households led by a Tutsi head

30 see Salvato (1982), Lilienfeld and Stolley (1994), Tomkins (1994) for studies on such effects.

are more likely to have bad nutritional and health status. Tubers and other food output positively affect nutrition, while non-food output is associated with worse nutrition but better health.

c) Non-output variables in Within-2SLS

The picture obtained with the 2SLS-Within estimates is substantially different, which suggests that 2SLS-direct estimates are biased. The coefficients of the number of active members, the number of adolescents and the non food output are no longer significant in any equation. All other included variables show significant effects. Land area negatively affects nutrition and health status, as expected because of a greater workload for households with a large farm. The number of children between 4 and 10 years old is associated with a better nutrition of adults, while the number of children under 4 is associated with a worse health of adults. Several interpretations could be proposed for these effects. The number of infants and children is partly endogenous since families with good HN may be more likely to have babies and a lower infantile mortality. Families with bad HN may also have more children due to replacement or insurance motivations. However, the lack of appropriate instrumental variables and the small sample size do not enable us to correct for possible endogeneity of household composition.

Moreover, the age of the head negatively influences the nutrition status and positively the health status, although the average age of members has an opposite effect. As we mentioned above, the household composition is likely to have effects on preferences, HN domestic processes and agricultural technology. It comes as no surprise that their estimated effects on HN is complex.

Similarly to the direct estimates, the Tutsi ethnic group of the head is associated with worse nutrition and health status. The education of the head has similar and unexpected effects. This surprising result may be related to special tastes for some characteristics of the consumed goods. Indeed, more educated households have a tendency to consume some varieties of goods for their 'social status' rather than their dietetic properties. The popularity of Coca-Cola drinks in Rwanda among educated classes in Rwanda is one example of this.

d) Output variables in Within-2SLS

Beans, tubers and other food outputs have a positive effect on nutrition. This is consistent with the nutritional importance of beans and tubers in Rwanda, which are considered as the food basis. The interpretation of the effect of other food output, which is a very heterogeneous good, is more doubtful. However, its average nutritional quality is very high with a rich content in proteins, lipids and vitamins.

In contrast, the traditional beer output has a significant negative impact on nutritional status. Here, the noxious effect of banana beer and sorghum beer consumptions overrides its possible positive energetic effect[31]. The fact that consumption of banana wine is much higher in the East may explain the more negative coefficient of traditional beer output in the East. These results imply that a study based only on nutrient intakes would miss an important influence channel. In designing health and nutrition policies aimed at poor peasants, fighting alcoholism may be as crucial as bringing nutrients to households.

The equation describing the health status response has few significant coefficients of agricultural outputs. Other fruit and vegetables output, mainly composed of peas and plantain bananas, has a positive effect on health status. This is consistent with the rich content in vitamins and mineral salts of this category of products (Gupta et al. (1992)).

Note finally, that non-food output has no effect on nutrition and health. Indeed, this type of product (coffee, craftwork, etc), which is generally not consumed by the household but sold, may have little direct impact on HN. This also confirms that, since these products are sometimes sold, the markets interactions may not be as important for the explanation of HN as the direct effects of own-consumption.

IV.iii Policy consequences

The estimation results suggest that a policy of providing incentives to substitute crops used in beer production with crops containing missing nutrients may be beneficial to HN. In particular, the substitution for banana trees of tubers and beans cultures would produce

31 It has been suggested that the production of banana beer could be endogenous in the nutrition equation since households producing a large surplus of banana compared to their own consumption and unable to commercialise them, could make banana beer with this surplus. This hypothesis is to be rejected because banana for food consumption and banana for beer are different varieties coming for different trees. The exogeneity of the banana beer output is based on the sequentiality of agricultural output and HN indicators and in case it would not be sufficient, we control for endogeneity by using instrumental variable methods.

positive effects. If we consider only the estimation results, which do not incorporate various side-effects attached to the behaviour or the situation of peasants, the positive impact of a reduction of banana beer output is apparently even more important than the positive effect of increases in other agricultural outputs. The agronomic conditions required for this policy are satisfied because the land occupied by crops used in beer fabrication is generally of the highest available quality to the household, especially for banana trees.

Such a policy appeals for Rwanda where land is very scarce and the consumption of traditional beers is widespread. Alcoholism has been known for a long time to be a very serious problem among Rwandan peasants (Colloque FOMETRO (1966)). Several strategies to reduce its prevalence have been discussed during the preparation of the Plan of Rwanda in which we were involved (Ministère du Plan (1985, 1988)). Unfortunately, their implementation is generally difficult. For example, an increase in the taxation of banana beer would attract strong political opposition from peasants who are very attached to the consumption of traditional beers, in part because it plays a major social and ceremonial role. Furthermore, banana trees contribute to the feeding of animals, and provide green fertilisers, straw and even fire material. In these conditions, it is not surprising that Bezy (1990) considers that banana tree cultivation is the main obstacle to change in Rwanda.

More radical policies might be possible at the moment because firstly, after the 1994-95 war, development agencies and public authorities are more aware of the political consequences of widespread poverty. The obligation of cultivation of tea or coffee for many peasants in Rwanda is an example of a centrally planned constraint on the output composition. This policy has been implemented with some success in the past, in a situation were peasants considered that the return to industrial crops was very inferior to food crops (Laure (1982)). A similar policy may be possible for limiting the cultivation of banana trees used in beer production.

V CONCLUSION

The presence of market imperfections in some LDCs implies that the composition of agricultural production may directly affect health and nutrition status. Using the presence of lags in the observed indicators of agricultural production, compared with health and nutrition status indicators (HN), we specify a model where HN depend on agricultural productions from a previous period.

We estimate HN equations for peasants of Rwanda, in which HN levels are related to the main agricultural outputs and inputs and to socio-demographic characteristics. We incorporate fixed cluster-effects and account for the sampling scheme.

Beans output, sweet potatoes output and an output corresponding to heterogeneous food of high quality are found to have positive impacts on nutrition status, while the production of traditional beers is found to have a very noxious effect on nutrition. Other fruit and vegetables output is associated with better health status. These results suggest that health and nutrition policy could take advantage of substitution for the cultivation of banana beer trees with other agricultural products, such as beans or tubers. However, consideration of other side-effects and a macroeconomic framework would be necessary for a complete policy analysis.

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Table 1: Descriptive statistics for the main variables

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)	10133	9968	7375
Other fruit and vegetables output (Frw)	7775	8504	10596
Tubers output (Frw)	13361	12873	9998
Traditional beer output (Frw)	18893	20032	18046
Other food output (Frw)	6359	6922	12704
Non food output (Y) (Frw)	749	707	1524
Land area (m^2)	13003	12876	14206
Number of infants (under 4 years of age)	1.02	1.01	0.8
Number of children (over 3 and 11 years of age)	1.15	1.19	1.08
Number of adolescents	0.78	0.82	0.97
Proportion of selected members	0.37	0.37	0.16
Household size	5.75	5.73	2.16
Number of active members	3.49	3.52	1.65
Average age of members	20.7	20.4	7.9
Age of the household head	44.6	44.1	14.3
Years of education of the household head	2.11	2.03	2.39
Dummy for female household head	0.17	0.16	0.37
Dummy for Tutsi household head	0.15	0.14	0.35
Masculinity Ratio	1.30	1.28	0.98
Dummy for North-West Region	0.15	0.13	0.34
Dummy for East Region	0.28	0.24	0.42
Average height of members (cm)	136	136	15.6
Average height of selected members (cm)	161	162	6.7
Average weight of members (kg)	37.9	37.7	7.9
Average weight of selected members (kg)	55.0	54.9	6.0
Total production	61351	60295	30248
Total consumption	56529	56795	20865
Subsistence ratio	0.658	0.655	0.15
Food subsistence ratio	0.747	0.741	0.15

157 observations. Frw is Rwandan Francs.

Table 2: Estimation results

(Direct estimates weighted by sampling scheme)

	Log of nutritional status		Log of health status	
Estimation method	OLS	2SLS	OLS	2SLS
Independent variables:				
Constant	-6.314** (-39.9)	-6.414** (-30.5)	-0.743 (-0.52)	-0.839 (-0.45)
Logarithm of number of active members	-0.0771** (-2.19)	-0.0908** (-2.41)	-0.357 (-1.13)	-0.468 (-1.39)
Logarithm of land area (m^2)	-0.00243 (-0.23)	-0.00673 (-0.61)	0.03404 (0.36)	0.0282 (0.29)
Number of infants	0.00763 (0.61)	0.00858 (0.65)	-0.186** (-1.64)	-0.167 (-1.43)
Number of children	-0.003902 (-0.43)	-0.00474 (-0.49)	-0. 0771 (-0.94)	-0.0715 (-0.83)
Number of adolescents	0.03791** (2.52)	0.0424** (2.63)	0.0400 (0.29)	0.0866 (0.60)
Age of head	-0.000869 (-0.80)	-0.000966 (-0.84)	0.0154 (1.57)	0.0159 (1.55)
Average age of members	0.003679* (0.0020)	0.00427** (1.96)	-0.0187 (-0.99)	-0.0167 (-0.86)
Dummy for Tutsi head	-0.0478** (-2.30)	-0.0530** (-2.45)	-0.398** (-2.13)	-0.378** (-1.96)
Education of head	-0.00405 (-1.11)	-0.00450 (-1.15)	0.03667 (1.11)	0.03548 (1.02)
Bean output (Frw)	-0.00273 (-0.41)	0.000763 (0.07)	0.0252 (0.42)	0.114 (1.19)
Other fruit and vegetables output (Frw)	-0.00931 (-1.40)	-0.00921 (-0.99)	-0.0159 (-0.26)	-0.0457 (-0.55)
Tubers output (Frw)	0.0263** (2.63)	0.03216** (2.01)	0.03642 (0.40)	-0.0298 (-0.21)
Traditional beer output (Frw)	0.003319 (0.44)	0.00690 (0.68)	-0.0368 (-0.55)	-0.0185 (-0.19)
(Traditional beer output) x (Dummy for East)	0.003591* (1.66)	0.003324 (1.35)	-0.0242 (-1.24)	-0.030739 (-1.40)
Other food output (Frw)	0.003753 (1.42)	0.00926** (2.49)	-0.00697 (-0.29)	-0.00886 (-0.27)
Non food output (Frw)	-0.00122 (-0.55)	-0.00522* (-1.67)	0.03147 (1.57)	0.0603** (2.16)
R^2	0.186	-	0.109	-
$\bar{R}^2$	0.092	-	0.0067	-
GR^2	-	0.046	-	0.066
$\overline{GR}^2$	-	-0.0133	-	0.0085

Student's t in parentheses. 157 observations. * = Significant at 10% level. ** = Significant at 5% level

The set of identifying instruments includes: regional dummies; matrimonial status and religion of the head; settlement year; birth place of the head; masculinity ratio; household composition for age and sex classes; dummy for heads who can write; local prices of beans, sweet potatoes, banana beer and soap powder.

Table 3: Estimation results

(Within-cluster estimates weighted by sampling scheme)

	Log of nutritional status		Log of health status	
Estimation method	OLS	2SLS	OLS	2SLS
Independent variables:				
Logarithm of number of active members	-0.0571 (-1.45)	-0.0531 (-1.28)	-0.328 (-0.90)	-0.303 (-0.79)
Logarithm of land area (m^2)	-0.0294* (-1.92)	-0.03407** (-2.11)	-0.230* (-1.61)	-0.254* (-1.71)
Number of infants	0.0156 (1.03)	0.0121 (0.78)	-0.230* (-1.63)	-0.239* (-1.66)
Number of children	0.03377** (2.97)	0.03271** (2.67)	-0.03851 (-0.36)	-0.03471 (-0.31)
Number of adolescents	0.0268 (1.58)	0.0213 (1.19)	-0.0879 (-0.55)	-0.109 (-0.66)
Age of head	-0.003188** (-2.22)	-0.003262** (-2.19)	0.0494** (3.70)	0.0486** (3.54)
Average age of members	0.00727** (2.78)	0.00694** (2.57)	-0.0524** (-2.15)	-0.0526** (-2.11)
Dummy for Tutsi head	-0.0513* (-1.60)	-0.0603* (-1.82)	-0.997** (-3.33)	-1.040** (-3.41)
Education of head	-0.0129** (-2.47)	-0.0126** (-2.22)	-0.0891* (-1.82)	-0.0942* (-1.79)
Bean output (Frw)	0.0229** (2.53)	0.0277** (2.66)	0.0553 (0.66)	0.100 (1.05)
Other fruit and vegetables output (Frw)	-0.00852 (-0.88)	-0.00958 (-0.89)	0.221** (2.45)	0.270** (2.73)
Tubers output (Frw)	0.0608** (2.90)	0.0595** (2.55)	-0.240 (-1.23)	-0.238 (-1.11)
Traditional beer output (Frw)	-0.0250** (-2.46)	-0.0275** (-2.42)	-0.0370 (-0.39)	-0.0790 (-0.75)
(Traditional beer output) x (Dummy for East)	-0.0793** (-2.94)	-0.0852** (-2.60)	-0.260 (-1.03)	-0.246 (-0.82)
Other food output (Frw)	0.00538 (1.33)	0.0120** (2.21)	0.0159 (0.42)	0.040 (0.80)
Non food output (Frw)	0.00385 (1.38)	0.00216 (0.68)	0.0181 (0.70)	0.00994 (0.34)
R^2	0.3383	-	0.4189	-
$\overline{R}^2$	0.2327	-	0.3261	-
GR^2	-	0.301	-	0.405
$\overline{GR}^2$	-	0.180	-	0.303

Student's t in parentheses. 111 observations. * = Significant at 10% level. ** = Significant at 5% level.

The set of identifying instruments includes: matrimonial status and religion of the head; settlement year; birth place of the head; masculinity ratio; household composition for age and sex classes; dummy for heads who can write.

Table 4: F Statistics for the tests of identifying instrumental variables

(weighted by sampling scheme)

Variable	Direct estimates	Within estimates
Logarithm of traditional beer output) x (dummy for east region)	2.31	1.83
Logarithm of bean output	1.007	1.59
Logarithm of other fruit and vegetables output	1.416	2.16
Logarithm of tubers output	1.10	1.99
Logarithm of traditional beer output	1.23	2.06
Logarithm of other food output	1.26	1.67
Logarithm of non food output	1.30	2.36

$F_{1-\alpha}(63,147) = 1.301$ for $\alpha=10\%$, $F_{1-\alpha}(63,147) = 1.402$ for $\alpha=5\%$, $F_{1-\alpha}(63,147) = 1.611$ for $\alpha=1\%$,

$F_{1-\alpha}(32,102) = 1.411$ for $\alpha=10\%$, $F_{1-\alpha}(32,102) = 1.557$ for $\alpha=5\%$, $F_{1-\alpha}(32,102) = 1.866$ for $\alpha=1\%$.

Table 5: F Statistics for the tests of fixed cluster-effects

Estimation methods and equations

Null hypothesis	Estimates		OLS	OLS	2SLS	2SLS
			N	H	N	H
Fixed Cluster-effects	Each equation	Test statistic	0.867	0.552	1.880	1.5126
		Degrees of freedom	(34,94)	(34,94)	(34,94)	(34,94)
		Result	A	A	R	R
Fixed Cluster-effects	Both equations	Test statistic	0.557		1.5176	
		Degrees of freedom	(68,188)		(66,188)	
		Result	A		(R)	

The result of the test is denoted as follows: R = rejection of the null hypothesis at 5% level; (R) = rejection of the null hypothesis at 10% level; A = non-rejection of the null hypothesis at 10 % level.

The formula of the F statistic for 2SLS is different from the ones used for OLS. Indeed, some of the sums of squared errors intervening in the formula are calculated from prediction errors rather that from 2SLS residuals.

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