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## IMPACT OF NUTRITIONAL STATUS OF SMALLHOLDER FARM HOUSEHOLDS ON AGRICULTURAL PRODUCTIVITY: PANEL DATA EVIDENCE FROM UGANDA

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## ABSTRACT

Malnourishment is a major health burden for rural smallholder farmers in many developing countries. Insufficient nutrient intake, combined with very high labor requirements limit productivity contributing to a vicious cycle of under-nutrition and poverty. While there has been significant economic growth over the past twenty years in Uganda, agricultural productivity has failed to increase at the same pace. Several measures have been put in place by the government, non-governmental organizations (NGOs) and market forces including encouraging adoption of modern agricultural technologies such as new seed varieties, use of chemical fertilizers but with limited rates of adoption. In contrast, little attention has been given to the nutritional causes of low productivity in the agricultural sector. Few studies have explored the link that connects nutrition with low labor productivity in agriculture, which employs a majority of the population. This paper aims to assess the impact of macronutrient and micronutrient intake on labor productivity and examine output composition effects for different genders using panel dataset for three waves of Uganda National Panel Surveys. Using Instrumental Fixed effects model the results show that calories, proteins, calcium, iron, vitamin C and vitamin A positively and significantly affect labor productivity. Additionally, data are disaggregated by gender type and tested for gender differences in deficiency of these nutrients and in the resulting effect on productivity. The results of the female model revealed that nutrient intake increased the value of output by almost twice the effect it had on the value of output for the male model. Although several studies have showed that the nutrient-productivity hypothesis seems not to hold in developed countries, these results show that this hypothesis still holds in developing countries. Therefore, gender sensitive policies must be taken into consideration to benefit agricultural sector.

**Key words:** Agricultural Productivity, Macronutrients, Micronutrients, Labor productivity, Fixed Effects, Developing Countries

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## INTRODUCTION

Malnutrition, in all its forms, is a severe problem in sub-Saharan African (SSA) countries [1]. SSA alone accounts for 206 million of the 806 million malnourished people in developing countries [2]. Malnutrition<sup>1</sup> can be caused by many factors operating at different levels. These include inadequate dietary intake and disease that may affect the ability of the body to absorb and utilize nutrients. Moreover, agriculture that is the economic backbone of these countries is still-labor intensive utilizing mostly high energy non-mechanical agricultural technologies. Under these conditions where manual labor is a major input in agriculture, it is particularly important for nutrient intake to be adequate if increased productivity levels are to be achieved.<sup>2</sup>

Smallholder farmers in rural areas are commonly the most malnourished populations. Women, who do the bulk of the agricultural work in many parts of Sub-Saharan Africa, are the most affected. An implication of the womenization of agriculture is that women's own nutritional status is particularly important since when their work-related energy and non-energy expenditure exceeds their intakes, the wellbeing of the entire household is compromised. The effect of nutritional intake on labor productivity and wage rates observed in earlier studies was formalized as the "efficiency wage hypothesis", which postulates a positive relationship between levels of food consumed and labor productivity at low incomes [3, 4, 5, 6].

Furthermore, the literature on the nutrition and agricultural productivity relationship in developing countries has focused predominantly on the calorie-wage relationship with little emphasis on other macro and micro-nutrient effects [7, 8]. This omission may be due to the difficulty in obtaining data on other nutrients and to the possibly unfounded assumption that other nutrients are correlated with calorie deficiency. However, households' deprivation of other nutrients may exceed that of calories and, therefore, examination of these other nutrients such as iron would be important [9, 10].

There has been significant economic growth over the past twenty years in Uganda. However, agricultural productivity has failed to increase at the same pace [11]. Several measures have been put in place by the government, non-governmental organizations (NGOs) and market forces including encouraging adoption of modern agricultural technologies such as new seed varieties, use of chemical fertilizers but with limited rates of adoption [12]. In contrast, little attention has been given to the nutritional causes of low productivity in the agricultural sector. Few studies have

<sup>1</sup> Malnutrition refers to under-nutrition in the context used here

<sup>2</sup> Nutritional status is a dimension of health relating to the macronutrient and micronutrient adequacy of an individual's diet



explored the link that connects nutrition with low labor productivity in agriculture, which employs a majority of the population. Uganda faces varying degrees and levels of adult and child malnutrition across its sub-populations. The degree of undernourishment is indicated by the depth of hunger. A study undertaken by FAO [13] showed that on average, a food-insecure Ugandan falls 240 kcal short of the minimum food needed, in terms of dietary energy. Moreover, dietary diversity remains low and tied to harvest patterns and local availability [13]. Therefore, there seems to be potential for improving labor productivity and, hence, welfare by reducing malnutrition.

This study, therefore, assesses the impact of nutrition on agricultural productivity and, hence, labor productivity and examine output composition effects for different gender. The hypothesis tested is whether higher per capita nutrient intake for various nutrients increases labor productivity. Additionally, data are disaggregated by gender type and tested for gender differences in deficiency of these nutrients and in the resulting effect on productivity.

## MATERIALS AND METHODS

### Theoretical Model

The study employs the standard agricultural household model where a typical household is assumed to maximize its utility given the production function and effective labor constraint. The model is slightly modified from the model by Becker [14] and Strauss [7] in which allocation of time is incorporated. Each farmer is assumed to maximize a utility function of the following form:

$$U = U(C_a, C_m, l) \quad (1)$$

where the commodities consumed are an agricultural crop ( $C_a$ ), a market-purchased good ( $C_m$ ), and leisure ( $l$ ).  $U$  represents the utility function. The farm household production function is expressed as:

$$Q_a = F(L^{*f}, L^{*d}, V, K, A) \quad (2)$$

where  $Q_a$  is farm output,  $L^{*f}$  is effective hours of family labor and  $L^{*d}$  is effective hours of hired labor,  $V$  is variable non-labor inputs,  $K$  is fixed capital and  $A$  is cultivated land. Every farmer also faces a time constraint with total amount of time ( $T$ ) available that consists of labor hours working on farm  $L^{*f}$ , labor working off farm  $L^{*d}$ , and consumption of leisure  $l$ :

$$T = L^{*b} + l \quad \text{where } L^{*b} = L^{*f} + L^{*d} \quad (3a)$$

According to Grossman [15], total time available is a function of health. Current health status is represented by nutrient intake of macro and micronutrient. The time constraint can then be rewritten as:

$$T(C_a) = L^{*b} + l \quad (3b)$$



However, effective labor, both family and hired, is a function of macro- and micro-nutrient intake (calories, proteins, iron, calcium, vitamin A and vitamin C intake) and hours worked. The time available function  $T(C_a)$  represents the effect of consumption in enabling individuals with fewer sick days to increase the total available time for leisure and work. Individual levels of macro- and micro-nutrient intake, in turn, are a function of household food consumption. Effective labor follows the effective wage literature in which effective labor is the product of labor hours and a function relating efficiency per hour worked to macronutrient and micronutrient intake [16]:

$$L^{*b} = L^b * h(C_a), \quad b = f, h \quad f = \text{family labor}, h = \text{hired labor} \quad (4)$$

where  $h$  is the efficiency per hour worked function composed of consumption of calories, proteins, iron, calcium, vitamin A and vitamin C.  $L^{*b}$  is the efficiency per hour worked for both family and hired labor while  $L^b$  represents actual hours worked by either family or hired laborer. The efficiency labor function  $h(C_a)$  to be estimated represents the productivity-enhancing effect of consumption of macro- and micro-nutrients. Assuming competitive markets exist for land and labor, and that prices and wages are fixed, the full income constraint is given by:

$$p_m C_m + p_a C_a + w_e^f h(C_a)l = p_a Q_a - w_e^f L^{*f} - w_e^d L^{*d} - p_v V + E + w_e^f h(C_a)T \quad (5)$$

where  $w_e^d$  is hired wage per effective hour. The variable  $w_e^f$  is wage per hour of effective labor hired out and  $w_e^f h(C_a)$  is the wage per clock hour following the assumption for the same efficiency labor function applied to labor hired out and family farm labor,  $p_m$  is price of marketed commodity,  $p_a$  is price of agricultural commodity,  $p_v$  is the price of the variable input such as fertilizer,  $V$  is the variable input and  $E$  is exogenous income.

### Optimization Problem

The farmer then maximizes utility in equation 1 subject to equation (5). Assuming the utility function is convex and a continuously differentiable function, the first order conditions are:

$$L: U(C_a, C_m, l) - \lambda [ p_m C_m + p_a C_a + w_e^f h(C^f)l - ((p_a Q_a - w_e^f L^{*f} - w_e^d L^{*d} - p_v V + E) + w_e^f h(C^f)T(C) ] \quad (6a)$$



$$\frac{\partial U(.)}{\partial C_a} - \lambda \left[ p_a - p_a \left( \frac{\partial Q_a}{\partial C_a} \right) + w_e^f \frac{\partial h(C^f)}{\partial C_a} l + w_e^f \frac{\partial h(C^f)}{\partial C_a} \frac{\partial hT(C)}{\partial C_a} \right] = 0 \quad (6b)$$

$$\frac{\partial U(.)}{\partial C_a} - \lambda p_a \left[ 1 + \left( \frac{\partial Q_a}{\partial L^{*f}} \right) - w_e^f \frac{\partial h(C^f)}{\partial C_a} - w_e^f \frac{\partial h(C^f)}{\partial C_a} \frac{\partial hT(C)}{\partial C_a} \right] - \lambda \left[ w_e^f p_a \left( \frac{\partial Q_a}{\partial L^{*f}} \right) \left( \frac{\partial L^{*f} h(C^f)}{\partial L^{*f}} \right) \right] = 0 \quad (6c)$$

$$\frac{\partial U(.)}{\partial l} = \lambda w_e^f h(C^f) \quad (6d)$$

where  $\lambda$  is the lagrangian multiplier for the full income constraint. Other first order conditions with respect to  $C_m$  and  $K$  can be obtained from equation 6d. Equation 6b enables us to demonstrate the link between nutrition and productivity.

### Sampling Strategy

The Uganda Bureau of Statistics (UBOS) followed a stratified random sampling technique to select households for the four waves of 2005/06, 2009/10, 2010/11 and 2011/12 used. In 2009/10, the UNPS followed up with 3,123 households distributed over 322 Enumeration Areas (EAs), selected from the 783 EAs of the Uganda National Household Survey (UNHS) in 2005/06. The 322 EAs included all 34 EAs in Kampala District, and 72 EAs (58 rural and 14 urban) in each of the other regions i.e. Central excluding Kampala, Eastern, Western and Northern which make up the strata. Within each stratum, the EAs were selected with equal probability with implicit stratification by urban/rural and district; thus, allowing for reliable estimates at the national, rural-urban and regional levels. At EA level, ten households were randomly sampled from each EA for tracking and interviews. Therefore, this study utilizes the Uganda National Panel Surveys (UNPS) dataset of 2005/06, 2009/10, 2010/11 and 2011/12. We utilized 1,634 observations from each wave considering those observations with complete data for all the variables used in our analysis.

### Data

Data collected on four main modules, namely, the household module, the agricultural module, the women module and the community module were used in this study. The household module has data on all the socioeconomic characteristics of the household such as education, household asset holdings, consumption and access to microcredit services. The agricultural model has information on land cultivation, labor and non-labor input use, shocks and land ownership among others. Areas of owned and/or cultivated agricultural plots were measured by Global Positioning Systems (GPS) and validated with farmer-supplied area estimates. Crop cards were used to quantify the production of continuously harvested as well as staple crops.



The dataset also has variables at the individual level such as education, age, and whether member migrated or not.

### Measurement of the Macronutrient and Micronutrient Intake

Household consumption information was collected through the use of interview schedules/questionnaires that were administered by field assistants and supervisors. Each time households were visited, they were asked how much they had consumed in the previous seven days for 2005/06 wave or how many days the food item was consumed out of the last seven days for 2009/10, 2010/11 and 2011/12 waves. The consumption information is collected for both the household (males, females and visitors by gender type). Information on a total of 61 food items consumed was collected. Using the food conversion factors of the World Food Dietary Assessment System (FAO 2010) for sub-Saharan Africa, food composition table for central and eastern Uganda by Hotz *et al.* [17] and Tanzania<sup>3</sup> food composition tables by Lukmanji *et al.* [18], food quantities were converted into the constituent nutrients for each household. Total quantity of nutrient  $C_i$  consumed by household  $i$  was obtained on per capita and per day basis as follows:

$$C_i = \sum_{j=1}^m q_{ij} k_j \quad (7)$$

where  $q_j$  is the weight in grams of the average daily intake of food commodity  $j$  while  $k_j$  is the standard measure of nutrients (calories, proteins, etcetera) found in each type of food commodity  $q_j$ .

### Empirical Approach

As stated earlier, this study aims at: 1) assessing the impact of nutrition on agricultural productivity and, hence, labor productivity and, 2) examining output composition effects for different gender.

### Impact of Nutrition on Agricultural Productivity and, hence, Labor Productivity

Estimating the nutrient productivity relationship has a number of methodological pitfalls including unobserved fixed effects, multi-directional causality, and hidden intra-household allocation. Unobserved fixed effects include factors such as management skills, ability of the household head, genetic endowment, high metabolic rate of some individuals that may be problematic in estimating the nutrition productivity relationship.

Causality that can run in both directions i.e. Better nourished workers may be more productive and, hence, earn higher wages and higher income that may be spent on

<sup>3</sup> Tanzania food composition table was used to supplement nutrient values that were not available in other tables. This is possible since foods eaten within East Africa are quite similar



more nutrients. Failure to account for this form of endogeneity results in biased and inconsistent estimates [19, 20, 21, 22]. Furthermore, failure to control for unobserved individual-specific differences in innate abilities, management skills, ability of the household head, genetic endowment, and high metabolic rate of some individuals can result in an overestimate of the effect of nutrition on productivity since such endowments may be correlated with nutrition.

The third pitfall, hidden nature of intra-household allocation is a situation in which there is unequal sharing of nutrients if consumption data are not collected at the individual level. This pitfall is not addressed in this study because data were collected at household level and not at the individual level. Below, the study discusses how the other two pitfalls were addressed.

Unobserved time-invariant heterogeneity such as differences in innate abilities, management skills, ability of the household head, genetic endowment, and high metabolic rate of some individuals that may be problematic in estimating the nutrition productivity relationship are addressed using panel data. The two standard models used in econometric analyses of panel data are random effects and fixed effects models. The random effects model makes the strong assumption that the unobserved effect,  $\mu_i$  in equation (8) is not correlated with any of the other covariates. This assumption is strict and likely to be violated. The fixed effects model allows correlation between the individual effects and the explanatory variables which can be differenced out in the estimation process of panel data. Fixed effects approach is, therefore, employed in the estimation procedure after testing for suitability of both models.

To control for endogeneity of nutrients' variable due to reverse causality, the study uses instrumental variables. The instruments used include prices of consumption goods in the market, value of assets, and demographic characteristics such as household size. These instruments are highly correlated with the endogenous variables but exogenous to the outcome variable. The price of consumption goods varies widely over space and time. Other studies have used these variables as instruments [22]. The F test is used to test for exogeneity of these instruments. Therefore, the study adopts a Fixed Effects Instrumental Variable (FEIV) approach to obtain consistent and unbiased estimates. The exclusion restrictions are satisfied by the household characteristics in the nutrient equations. The exclusion restrictions are not expected to affect the productivity outcome directly but are highly correlated with nutrient intake. The Sargan Hansen test of over identifying restrictions is used as a post-estimation test for validity of the instruments.



## Estimated Models

The study estimated a Cobb Douglas production function to allow for comparison of results for calories with other studies, especially [7, 12]. Effective family labor, hired labor, capital, acreage under cultivation and other inputs are included in the production estimation model. The farm production function is specified as follows:

$$\ln Q_{ait} = \alpha_0 + \alpha_1 \ln L_{it}^{*f} + \alpha_2 \ln L_{it}^h + \alpha_3 \ln K_{it} + \alpha_4 \ln V_{it} + \alpha_5 \ln A_{it} + \mu_i + \varepsilon_{it} \quad (8)$$

where  $Q_a$  is the value of farm output,  $L^{*f}$  is effective hours of family labor and  $L^h$  is hours of hired labor,  $V$  is the value of variable non-labor inputs such as fertilizers, pesticides and improved seed,  $K$  is fixed capital,  $A$  is cultivated land,  $i$  indexes the household,  $\alpha_i$  are the parameters for the production function,  $t$  indexes time,  $\mu$  is an unobserved household-specific effect, and  $\varepsilon$  is an i.i.d error term.

Effective family labor is the product of family labor hours and a function relating efficiency per hour worked to macronutrient and micronutrient intake.<sup>4</sup>

$$L^{*f} = h(C_a) L_{it}^f \quad (9)$$

The efficiency per hour worked function is assumed to be exponentially related to the effective family labor function and can be specified as:

$$h = C_{it}^{\beta_1} P_{it}^{\beta_2} Cl_{it}^{\beta_3} I_{it}^{\beta_4} V_{C_{it}}^{\beta_5} V_{A_{it}}^{\beta_6} \quad (10)$$

where  $h$  is the ratio of effective to actual labor input,  $C$  is calories,  $P$  is proteins  $C_a$  is calcium,  $I$  is iron,  $V_C$  is vitamin C,  $V_A$  is vitamin A,  $i$  indexes the household,  $t$  indexes time, and  $\beta_i$  are parameters for the  $h$  function. Putting equations (8) - (10) together gives

$$\ln Q_{ait} = \varphi \ln C_{it} + \gamma \ln P_{it} + \phi \ln Cl_{it} + \Gamma \ln I_{it} + \theta \ln V_{C_{it}} + \zeta \ln V_{A_{it}} + \alpha_1 \ln L_{it}^f + \alpha_2 \ln L_{it}^h + \alpha_3 \ln K_{it} + \alpha_4 \ln V_{it} + \alpha_5 \ln A_{it} + \mu_i + \varepsilon_{it} \quad (11)$$

where  $\varphi = \beta_1 \alpha_1$ ;  $\gamma = \beta_2 \alpha_1$ ;  $\phi = \beta_3 \alpha_1$ ;  $\Gamma = \beta_4 \alpha_1$ ;  $\theta = \beta_5 \alpha_1$ ;  $\zeta = \beta_6 \alpha_1$   
 Equation (11) is then estimated using the fixed effects instrumental variable approach and later used to derive labor productivity.

## Accounting for Gender Specific Differences

Equation (11) is re-estimated after gender disaggregation to account for the gender differences in consumption of nutrients and the effect on productivity.

<sup>4</sup> Data on nutrient intake for hired labor are not available therefore, only family labor input is treated in efficiency units. We do not expect the results to change significantly due to this because use of hired labor is very limited in this population

## RESULTS AND DISCUSSION

### Descriptive Statistics of Sampled Households

Descriptive statistics of variables are presented in Table 1. Sample size each year is 1,634 hence, the total number of observations in the panel is 6,536 households. The average age of the respondent in the panel is 49 years. The mean years of education of household head is about four years. The sampled households had an average of seven persons with more adults than children. Seventy one percent of the household heads were male in the overall sample for the years 2005-2012, with about 80 percent married. Across the different waves, most households lived as married couples in 2005/2009 (82 percent) while the least proportion of married couples was in 2009/2010 (79%). On average, the 2011/2012 wave had the most educated household heads with an average of 5.4 years of formal education. There was a steadily increasing number of household members for each consecutive wave such that 2005/2006 had 6.13 members, 2009/2010 had 6.93 members, 2010/2011 had 7.58 members and 2011/2012 had 8.17 members.

An examination of productivity indicators from Table 1 for the panel shows that the average cropland under cultivation was about nine acres. More family labor was utilized compared to hired labor. This may be because labor is scarce especially during the peak periods of farming in this area. Overall, panel results show that the mean value of output was about 912 million Uganda shillings against mean input cost of about 43198 Uganda shillings.

Furthermore, Table 1 shows average macronutrient and micronutrient intake per Adult Equivalent (AE). The average daily calorie intake for the overall sample in the panel is 2022 kcal which is below the 2400 kcal recommended by FAO [13]. Average protein intake is 62 g which is just about the recommended level. Average calcium, iron, and vitamin A intake were below the recommended levels of 1000 mg, 26 mg and 900 microgram per capita daily intake respectively. However, the average vitamin C intake (111 mg) was above the recommended intake of 90 mg in the four waves under study. The proportion of households consuming nutrients below the recommended daily intake was 65% for calories, 58% for proteins, 81% for calcium, 74% for iron, 45% for vitamin C and 61 percent for vitamin A. This suggests that overall, the prevalence of undernourishment is high in this population. This is not surprising since these results are for the poor rural population in Uganda that is engaged in agriculture as their main source of livelihood and income. Nonetheless, the results are similar to a range of estimates for African countries [23, 24].



## Econometric Results

### Production Function Estimation Results

The farm production results are shown in Table 2. Both fixed effects and random effects models were estimated.<sup>5</sup> The Hausman test was performed to determine which model to use. The results of the test rejected the random effects model implying that the fixed effects model is superior and, hence, it was adopted for further analysis ( $\text{Chi}^2(10) = 531.54$  and  $\text{prob} > \text{chi}^2 = 0.000$ ).

According to the results in Table 2, calories, proteins, calcium, iron, vitamin C and vitamin A positively and significantly affect the value of output. The result obtained for calories corroborates the conclusion of Strauss [7] that calories have a significant effect on productivity measure. On the other hand, the results suggest that protein intake remains important even in later life for farmers' productivity. Not surprising was the effect of iron per capita daily intake on the value of output. This finding is similar to earlier studies that found that iron intake positively influences the value of output [25].<sup>6</sup> Other control variables such as hired labor and family labor positively and significantly affected the value of farm output. These results are in conformity with other studies that report that when family and hired labor are not perfect substitutes, inadequate nutritional intake is likely to reduce output [26]. The size of land under cropland had a positive and significant effect on productivity. Value of inputs such as fertilizers, pesticides, and bullock positively and significantly affected the value of output.

### The Effect of Nutrient Intake on Labor Productivity

From equation (10), the  $h$  function which transforms person days of labor into efficiency person days is identified as:

$$\ln h = \frac{L^*}{L} = 2.743 \ln C_{it} + 3.005 \ln P_{it} + 2.395 \ln Cl_{it} + 4.768 \ln I_{it} \\ + 1.579 \ln Vc_{it} + 2.884 \ln Va_{it}$$

The results show that the elasticity of  $h$  with respect to calories, proteins, calcium, iron, vitamin C and vitamin A is significantly different from zero. This implies that nutrient intake plays a significant role in enhancing labor productivity, a similar observation by Berha *et al.* [1]. The calorie result we find does not agree with that of Deolalikar [20] who found that calorie intake had no effect on output or labor productivity. The positive calorie-productivity relationship shows that the efficiency wage hypothesis is relevant in rural smallholder farmers who often operate below the required minimum nutrient. Productive activities are affected by the level of

<sup>5</sup> Results for the random effects estimation are not shown here but are available from the author

<sup>6</sup> Different specifications were estimated with demographic variables and assets excluded as instruments but the results did not change significantly



nutritional intake by household members. These findings are not surprising given that the agricultural sector in Uganda relies heavily on rudimentary tools such as hand hoes that require high levels of energy.

### **Comparison of Nutrient Productivity Estimates for Male and Female Models**

After disaggregating the data by gender, equation (11) is re-estimated for female and male models separately. The results are shown in Table 3. For both the male and female models, the coefficients on calories, proteins, calcium, iron, and vitamin C were all positive and significant. However, the magnitudes of the coefficients for the female model for all the macronutrients and micronutrients were greater than for the male model. For example, the elasticity of the value of output with respect to calories for male-headed households was 3.06 for calories, 3.40 for proteins, 2.70 for calcium, 5.71 for iron, and 1.41 for vitamin C. On the other hand, the elasticity of value of output with respect to calories was 4.90, for proteins was 5.50, for calcium was 5.03, for iron was 10.28 and for vitamin C was 3.78 for female-headed households. Vitamin A had no significant effect on value of output for male headed households but was positive and significant for female-headed households. Across all the nutrients, female-headed households experience elasticities that are twice that of male-headed households. This is probably because most agricultural activities such as planting, pruning, weeding, and harvesting are undertaken mainly by women in Uganda. Therefore, households experience the greater loss if women get inadequate macronutrients and micronutrients. The calorie result contrasts with that of Sahn & Aldermann [27] who found that per capita calorie intake has a positive and significant impact on productivity for men but not for women. The exception was vitamin A which negatively and significantly affected the value of output among male-headed households. Women gained more than men from all nutrients. Most importantly, per capita iron intake had a huge effect on the value of output. This further emphasizes the need for increasing intake of nutrients by women, who do the bulk of the work in the agricultural rural setting.

Other control variables for the production function such as crop land, family labor, hired labor, input cost were all positive and significant.

### **CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT**

Understanding the nutrition-agriculture relationships remains an important aspect of increasing productivity among low-income households that rely on agriculture for their livelihood. The nutrient-productivity relationship has a potential beneficial economic impact on the overall productivity of subsistence-based populations. The results from this study show that macronutrient and micronutrient intake (calories, proteins, calcium, iron, vitamin C) positively and significantly affect the value of output and hence, labor productivity. Furthermore, the results of the female model



revealed that nutrient intake increased the value of output by almost twice the effect it had on the value of output for the male model. The results demonstrate that policy interventions that aim at enhancing macronutrient and micronutrient intake can be regarded as investments that lead to improved productivity and higher household incomes. Enhancing necessary nutrient intake will contribute significantly to overall poverty alleviation, economic growth and development.

A number of policy implications for rural smallholder farmers are drawn from these results. Whereas studies have shown that the nutrient-productivity hypothesis seems not to hold in developed countries, the results in this study point to this hypothesis still being indeed relevant in poor low-income countries. This is probably because most households are still consuming nutrients below the recommended daily intake. Since the study finds strong significant effects of macronutrients and micronutrients intake on productivity and hence, labor productivity, policies that focus on enhancing intake of these nutrients have a great potential for delivering considerable benefits to poor rural households in Uganda. In addition, policies that take into consideration gender of farmer will greatly benefit especially women who provide the bulk of agricultural labor.

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**Table 1: Socio-Economic Characteristics of Sampled Population for Years 2005/06, 2009/10, 2010/11 and 2011/12**

	2005/06	2009/10	2010/11	2011/12	Panel
	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
<b>Socio-demographic</b>					
Age of head (years)	43.9 (15.0)	47.9 (14.9)	48.5 (14.8)	49.4 (14.5)	47.4 (15.0)
Education of head (years)	3.2 (3.5)	2.8 (3.2)	3.2 (3.6)	5.4 (4.1)	3.6 (3.7)
Education of spouse (years)	2.8 (3.3)	2.4 (2.79)	2.6 (3.1)	3.4 (3.3)	2.8 (3.2)
Sex of head (1=male, 0 otherwise)	0.7 (0.4)	0.7 (0.4)	0.7 (0.5)	0.7 (0.5)	0.7 (0.4)
Household size (numbers)	6.1 (3.0)	6.9 (3.2)	7.6 (3.5)	8.2 (3.7)	7.2 (3.4)
Married (1= married, 0 otherwise)	0.8 (0.4)	0.8 (0.4)	0.8 (0.4)	0.8 (0.4)	0.8 (0.4)
<b>Productivity</b>					
Cropland (acres)	11.4 (15.0)	8.7 (9.8)	9.3 (11.7)	6.9 (6.9)	9.1 (11.3)
Hired labor (person days)	26.3 (75.7)	38.6 (370.8)	21.7 (42.4)	17.7 (40.7)	26.1 (191.6)
Family labor (person days)	138 (153)	871 (1225)	817 (878)	1606 (10605)	858.2 (5380)
Annual total input cost (US\$)	41648 (347584)	48743 (131249)	39287 (98753)	43117 (139729)	43198 (204505)
Annual value of output (000000) (US\$)	2.9 (7.4)	162 (3700)	5.8 (576)	3400 (11800000)	912 (5920000)
Value of productive assets (US\$)	123551 (283644)	1193782 (5753802)	1015921 (3188013)	512003 (9126678)	711315 (5641345)
<b>Nutrients (Per AE)</b>					
Calories (g)	1892.6 (859.5)	2084.2 (1392.1)	1989.1 (881.0)	2120.8 (1006.4)	2021.7 (1060.1)
Proteins (g)	42.3 (15.7)	70.8 (53.6)	67.7 (30.1)	69.1 (36.2)	62.5 (38.3)
Calcium (mg)	621.1 (245.1)	649.9 (719.7)	727.7 (646.5)	679.9 (634.7)	669 (592.5)
Iron (mg)	12.8 (5.7)	22.7 (16.7)	8.0 (1.3)	7.8 (1.1)	12.8 (10.8)



Vitamin C (mg)	181.8 (137.1)	73.6 (51.2)	103.79 (58.97)	86.4 (54.2)	111.4 (93.4)
Vitamin A (micrograms)	463.1 (245.8)	885.3 (387.5)	1114.3(1417.2)	725.7 (975.5)	797.1 (921.0)
Observations	1634	1634	1634	1634	6536

Note: Figures in parentheses are standard deviations. Nutrients are measured per adult equivalent per day

Source: Author's own computations from the data



**Table 2: Fixed Effects Instrumental Variable Results for Productivity and Nutrient Intake**

Variables	Calories	Proteins	Calcium	Iron	Vitamin C	Vitamin A
Nutrients	3.541*** (0.422)	3.880*** (0.484)	3.092*** (0.442)	6.156*** (0.874)	2.038*** (0.394)	3.723*** (1.349)
Cropland (ln)	1.233*** (0.093)	1.165*** (0.091)	1.207*** (0.096)	1.310*** (0.095)	1.294*** (0.091)	1.221*** (0.117)
Family labor (ln)	1.291*** (0.074)	1.321*** (0.073)	1.492*** (0.082)	1.332*** (0.074)	1.323*** (0.069)	1.205*** (0.097)
Hired labor (ln)	0.347*** (0.047)	0.302*** (0.049)	0.244*** (0.056)	0.394*** (0.047)	0.445*** (0.043)	0.579*** (0.074)
Input cost (ln)	0.055*** (0.018)	0.049*** (0.018)	0.047** (0.019)	0.060*** (0.018)	0.064*** (0.017)	0.107*** (0.027)
Constant	-23.58*** (3.145)	-12.53*** (1.924)	-17.20*** (2.860)	-12.38*** (2.159)	-6.788*** (1.847)	-16.97** (7.094)
R <sup>2</sup> overall	0.074	0.053	0.051	0.039	0.130	0.06
Prob > chi <sup>2</sup>	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.157	0.238	0.123	0.275	0.106	0.234
Observations	6,536	6,536	6,536	6,536	6,536	6,536
Number of years	4	4	4	4	4	4

Note: \*P < 0.1; \*\*p < 0.05; \*\*\*p < 0.01; Figures in parentheses are standard errors

**Table 3: Production Function Estimation Results after Gender Disaggregation**

	Calories	Proteins	Calcium	Iron	Vitamin C	Vitamin A
<b>Results of the Male Model</b>						
Nutrients	3.062*** (0.472)	3.396*** (0.559)	2.698*** (0.499)	5.705*** (1.037)	1.413*** (0.490)	1.617 (1.172)
Cropland (ln)	1.129*** (0.104)	1.048*** (0.102)	1.080*** (0.108)	1.176*** (0.108)	1.134*** (0.102)	1.117*** (0.115)
Family labor (ln)	1.212*** (0.086)	1.233*** (0.085)	1.365*** (0.093)	1.200*** (0.087)	1.228*** (0.080)	1.163*** (0.096)
Hired labor (ln)	0.386*** (0.052)	0.352*** (0.053)	0.279*** (0.061)	0.417*** (0.052)	0.455*** (0.048)	0.510*** (0.068)
Input cost (ln)	0.043** (0.020)	0.041** (0.020)	0.035 (0.021)	0.049** (0.021)	0.052*** (0.019)	0.073*** (0.025)
Constant	-19.04*** (3.513)	-9.597*** (2.215)	-13.44*** (3.180)	-9.891*** (2.493)	-2.823 (2.254)	-4.907 (6.153)
R <sup>2</sup> overall	0.067	0.05	0.049	0.033	0.118	0.022
Prob > chi <sup>2</sup>	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.148	0.215	0.112	0.251	0.116	0.280
Observations	4,633	4,633	4,633	4,633	4,633	4,633
<b>Results of the Female Model</b>						
Nutrients	4.904*** (0.861)	5.500*** (0.932)	5.028*** (0.977)	10.280*** (1.843)	3.775*** (0.681)	8.321** (3.897)
Cropland (ln)	1.382*** (0.195)	1.386*** (0.195)	1.463*** (0.222)	1.613*** (0.214)	1.655*** (0.194)	0.893** (0.429)
Family labor (ln)	1.270*** (0.149)	1.334*** (0.149)	1.668*** (0.184)	1.459*** (0.161)	1.394*** (0.142)	1.354*** (0.294)
Hired labor (ln)	0.187* (0.110)	0.098 (0.116)	0.081 (0.133)	0.267** (0.111)	0.379*** (0.095)	0.637*** (0.217)
Input cost (ln)	0.065* (0.036)	0.045 (0.036)	0.051 (0.041)	0.054 (0.038)	0.076** (0.034)	0.166** (0.084)
Constant	-34.40*** (6.381)	-19.75*** (3.713)	-31.12*** (6.436)	-23.98*** (4.676)	-16.09*** (3.288)	-42.17** (20.59)
R <sup>2</sup> overall	0.070	0.040	0.032	0.021	0.127	0.010
Prob > chi <sup>2</sup>	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.111	0.262	0.104	0.383	0.050	0.262
Observations	1,903	1,903	1,903	1,903	1,903	1,903
Number of years	4	4	4	4	4	4

Note: \*P < 0.1; \*\*p < 0.05; \*\*\*p < 0.01. Figures in parentheses are standard errors



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