Understanding the Linkage between Agricultural Productivity and Nutrient Consumption: Evidence from Uganda

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Abstract

The prevalence of malnutrition across a predominantly agrarian country like Uganda and its potential economic implications indicate the importance of understanding the link between agricultural productivity and nutrient consumption. Such an understanding will highlight the importance of different nutrients (and foods) available across Uganda, thus guiding policymakers in prioritizing and developing appropriate programs to tackle malnutrition and improve agricultural productivity. This study contributes to the more recent literature on the linkage between nutrition and productivity by exploring the impact of various micronutrients, in addition to caloric intake, on agricultural productivity in Uganda. Using a structural equations model (SEM), estimation results clearly reveal the bidirectional relationship between productivity and nutrient intake. Labor productivity elasticity with respect to nutrient intake varies between 0.04 for vitamin B12 and 0.01 for Iron. Our findings suggest that labor productivity increases agricultural income as one would expect. We also find that nutrient intake as well as labor productivity positively affect agricultural income in Uganda. Overall, results indicate that agricultural productivity in Uganda is likely to be enhanced if nutrients intake is significantly increased.

Keywords: nutrients, agricultural productivity, malnutrition, structural equations model (SEM), production model, consumption.
Acknowledgments

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1. Introduction

Economic growth is often assumed to naturally have a positive impact on nutritional status through increased incomes and food expenditures. However, economic growth has not translated into improved nutrition in a number of developing countries (Fan and Brzeska 2011; Pauw and Thurlow 2011). Though higher incomes could allow households to consume a greater quantity of nutritious food (either from their own production or from the market), few studies quantify these effects satisfactorily, and the limited studies available offer either inconclusive or conflicting results on the link between economic growth and nutrition (Fan and Brzeska 2011).

The idea of linking food security and nutrition components into agriculture is not new. Though economists began in the 1980s to actively search for empirical evidence on the existence and shape of a function relating nutritional status to labor productivity, nutritionists and doctors have been interested in this question since before the 1920s (Strauss 1984; von Braun and Kennedy 1986). Nonetheless, effective approaches for incorporating nutrition goals into agriculture and rural development projects remained limited (Pinstrup-Andersen 1981).

Defining food security as existing when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996) makes apparent the multidimensional nature of the concept and the link between nutrition and productivity. As Skoufias pointed out (2004), the fact that adequate food intake is largely defined with an emphasis on calories taken relative to the requirements for an active, healthy life, as against simple survival, is clear evidence of this link. This view of food security creates the space for increased collaboration between agriculture and nutrition and reveals four distinct issues that are central to the attainment of food security: food availability, access, utilization, and stability of access.

Agriculture has several direct and indirect links to nutrition. Two of the most commonly discussed pathways from agriculture to good nutrition are (1) food provision via increased production and (2) increased household income from agricultural production. Increased income increases access to nutritious food, and increased agricultural productivity lowers food prices due to general increased supply while also increasing real incomes (Gillepsie and Kadiyala 2011; Kennedy and Bouis 1993; Alderman 1986). However, how income from agriculture is actually spent as well as who controls the resources within a household are also important pathways linking agriculture to good nutrition (Gillepsie and Kadiyala 2011; Kennedy 1994).

A lot of the emphasis on increased agricultural productivity to promote food security has focused on increased production of staples (largely cereals and root tubers). This approach is very important because the percentage of expenditure on food (particularly staples) among the poor is very high. Thus cost-efficient production of staples reduces prices of these items, increasing the proportion of income available to the poor for the purchase of other nonstaple foods (Oshaug and Haddad 2002). The largest relative increases in income will accrue to those who spend the highest percentage of their income on food—typically the poorest—who can use these increases to purchase a greater range of foods. Successful agriculture–nutrition programs have been associated with strategies that are well targeted to the poorest in society, who are often at most risk nutritionally (Kennedy 1994).

Just as increased agricultural productivity can translate into improved nutritional outcomes, good nutrition and consequent better health can affect agricultural productivity. This reciprocation between agricultural productivity and nutrition poses significant challenges in the empirical estimation of any of the unidirectional effects. Generally, malnutrition impairs productivity directly through poor physical health and indirectly through poor cognitive development that affects educational outcomes (FANTA-2 2010). However, in agrarian societies, where nonearned income forms an insignificant component of total income, this link is crucial.

Nutritional status of individual household members affects the intensity with which productive activities will be undertaken (Hoddinott 2011). Poor nutrition, which many researchers refer to as “hidden hunger” affects people’s health, which in turn may cause a loss of days worked or reduced
worker capacity. When family and hired labor are not perfect substitutes, these factors are likely to reduce output (Antle and Pingali 1994; Sur and Senauer 1999; Croppenstedt and Muller 2000). Poor nutrition lessens the farmer’s ability to innovate, experiment, and adopt improved technologies and practices in agricultural systems when the innovation involves additional labor, for example planting in lines (Asenso-Okyere et al. 2011). Experimental studies have analyzed this relationship between nutrient intake and agricultural productivity. Increased caloric intake may imply increased productivity, increased income, and thus improved overall nutrition. Improved nutrition is associated with sustained increments in productivity and thus with sustained access to food energy for intake (Akinleye and Rahji 2007).

While Uganda was able to significantly reduce poverty between 1992 and 2006, its success in reducing the prevalence of malnutrition has been less evident. The prevalence of underweight in children under five decreased only slightly between 1995 and 2006, from 27 percent to 20 percent (FANTA-2 2010). Interestingly, Uganda is also experiencing the double burden of malnutrition: high levels of undernutrition coexisting with a growing prevalence of overweight and obesity. The prevalence of malnutrition across a predominantly agrarian country like Uganda and its potential economic implications indicates clearly why understanding the link between agricultural productivity and nutrient consumption is important. Not only will such an understanding highlight the importance of different nutrients (and foods) available across Uganda, but the study will also assist policymakers in prioritizing and appropriately developing programs to tackle the prevailing nature of malnutrition in the country. This study contributes to the more recent literature on nutrition and productivity by exploring the importance of various micronutrients (in addition to calories) on agricultural productivity in rural Uganda.

This study’s approach to linking nutrient consumption to labor productivity is built on the household production theory developed by Becker (1965), wherein households are treated as producers of commodities rather than just consumers of goods and services. Grossman (1972, 1999) extended this analysis to the demand for health. We look at the demand for nutrients as a component of the demand for health, and our analysis is based on an extension of the agricultural household model developed by Pitt and Rosenzweig (1985). These authors evaluated the impact of a change in health on productivity, labor supply, and overall farmers’ income by incorporating the health variable into the utility function and introducing an explicit production technology for health. This study will take this analysis a step further to examine the effect of nutrient consumption on productivity. Unlike previous studies, we introduce into the household agricultural production framework an explicit health production function that accounts for households’ nutrient consumption. Ultimately, this approach allows us to capture the impact of the consumption of different essential nutrients on agricultural efficiency, thus moving beyond the focus on caloric needs alone to a more comprehensive approach that accounts for the importance of dietary diversity. This approach may assist in the development of appropriate food security programs that attempt to expand sustainable access to a diverse diet. A Tobit model with endogenous health production function is used to simultaneously estimate the determinants of nutritional intake and its impact on agricultural productivity.
2. Modeling the Impact of Nutrition on Farmers’ Efficiency

Micronutrients are nutrients required in small quantities by humans and other living things throughout life to orchestrate a whole range of physiological functions—nutrients the organism itself cannot produce (UNICEF Canada 2006, 67). For people, they include dietary minerals in amounts generally less than 100 micrograms per day—as opposed to macrominerals, which are required in larger quantities. The microminerals, or trace elements, include at least iron, cobalt, chromium, copper, iodine, manganese, selenium, zinc, and molybdenum. Micronutrients also include vitamins, which are organic compounds required as nutrients in tiny amounts by an organism.

The nature of agricultural production activities and the consumption of agricultural goods also have effects on health (Hoddinott 2011) and consequently on productivity. In a study of rural households in Ethiopia, Ulimwengu (2009) found a positive effect of health status on productivity. He found that production inefficiency increased significantly with the number of days lost to sickness. Strauss (1986) also found positive effects of nutrition on productivity. He used the farm household model to explore the link between nutrient intake and farm productivity. Farm output was hypothesized to be a function of effective hours of family and hired labor in addition to other inputs, such as fixed capital, nonlabor inputs, and land cultivated. Effective labor was a function of individual nutritional levels and hours worked, and nutritional level was in turn a function of household food consumption, which depended on intrahousehold distribution and biological food–calorie conversion rates. Assuming perfectly competitive markets for all inputs and outputs and using caloric intake to measure nutritional intake, Strauss found evidence to support the nutrition–productivity hypothesis. He found strong effects of caloric intake on productivity (output elasticity of 0.34); marginal productivity declined as caloric intake increased, though it remained positive over the entire spectrum of caloric intake.

In a similar study, Deolalikar (1988) analyzed the effect of average caloric intake on agricultural productivity and on wages for a rural South Indian stratified panel. He estimated an ordinary least square (OLS) and controlled for weight-for-height of workers; he found a positive effect only for weight-for-height, not for caloric intake. Sahn and Alderman (1988) regressed household caloric intake on individual wages in Sri Lanka and found a positive impact on productivity only for males. The output elasticity for calories they estimated was 0.21. Haddad and Bouis (1991), who included individual caloric intake as well as height and weight-for-height of workers in the Philippines, found an impact for the latter but did not produce robust results for the former two (caloric intake and height), when controlling for endogeneity. When they included only calories, the result was significantly positive. They also estimated an OLS and reported an output elasticity of 0.089 for calories.

Similarly, Behrman, Foster, and Rosenzweig (1997) found positive nutrition effects on productivity by estimating the effect of caloric intake during the planting stage of production on harvest profits. Distinguishing between planting and harvesting stages of production, the authors demonstrated the nonseparability of income (production) and consumption decisions, due to the relationship between caloric intake and productivity. They also highlighted the importance of distinguishing between stages of production when considering the income–nutrition relationship, since there are usually different costs of consumption during planting and harvesting due to market imperfections and also because of the effect of caloric consumption during planting on harvest-period productivity. This approach of looking at caloric intake in one stage of production on outcomes in a later stage partially addresses the simultaneity problems in estimating the effect of caloric intake on output. However, both Strauss (1986) and Behrman, Foster, and Rosenzweig (1997) do not delve beyond aggregate caloric intake to explore the potentially diverse effects of different nutrient types. This study explores the effect on productivity of the consumption of various nutrients and nutrient combinations.

Behrman, Foster, and Rosenzweig (1997) found that caloric intake effects were higher for poorer households and had little or no effect for richer households. While this reveals an expected higher effect of calories on households that are more likely to be affected by hunger (one aspect of food insecurity) and thus by any link between health and productivity, identifying the role(s) of different nutrients in
productivity might also reveal other dimensions of food security that have health and productivity effects (Hawkes and Ruel 2011). Consequently, this paper builds on the work of studies like those of Strauss (1986) and Ulimwengu (2009) to explore the impact of nutrient consumption on farmer productivity.

Following Singh, Squire, and Strauss (1986), we assume that each farmer chooses optimal levels of agricultural staple ($C_a$), market-purchased good ($C_m$), and leisure ($C_l$) to maximize his utility,

$$U = U(C_a, C_m, C_l),$$

under the following cash constraint:

$$p_mC_m = p_a(Q_a - C_a) - w(L - L_f) - w_x X + E,$$

where $p_m$ is the price of the purchased good; $p_a$, the price of the agricultural staple; $Q_a$, the farmer’s production; $w$, the market wage; $X$, various inputs (e.g., fertilizer) with price $w_x$; and $E$, nonlabor income (remittance, social transfer, etc.). $L$ is the total labor input and $L_f$ is family labor, so that if $L - L_f > 0$, the farmer needs to hire additional labor from the market. Inversely, if $L - L_f < 0$, the farmer can allocate the labor surplus to off-farm work activities. To capture actual productive effort (effective labor) instead of time spent, family labor is expressed as follows:

$$L_{fe} = m(N)L_f,$$

where $m$ is a measure of farmer’s efficiency, with $0 \leq m(N, z; \theta) \leq 1$, and $N$ represents nutritional intake. It follows that the farmer’s production is

$$Q_a = Q(X, L_{fe}) = m(N, z)Q(X, L_f).$$

In this paper, to explain the farmer’s productivity, given nutritional intake, we use structural equations model as described in Diagram 1.

Diagram 1: Structural representation of nutrient intake and labor productivity relationship

In Diagram 1, nutrient intake, labor productivity and agricultural income are endogenous. Production cost (Prod cost), access to agricultural information (Ag info), household health indicator (health), location

1 We assume that a change in labor productivity also affects other inputs’ productivity.
(rural), age, education, gender and regions are all treated as exogenous. Arrows indicate the sense of relationship. For simplicity, symmetry is imposed to relationship between endogenous variables as indicated by “a” and “b” on their respective arrows. Estimation of relationship described in Diagram 1 is conducted using structural equation model.

Structural equation models are multivariate regression models, combining elements of analysis of variance and factor analysis (Fox, 2002). Structural equation modeling (SEM) can be used to examine the effects of both manifest (observed) and latent (unobserved, inferred) variables (Hox and Bechger, 1998; Maccallum and Austin, 2000), both of which can be either exogenous or endogenous (STATA, 2011). SEM is an especially useful method where Ordinary Least Squares (OLS) regression analysis is impossible because multi-directional causality among variables violates the assumption of zero covariance between the residual and the independent variable (Fox, 2002). Because SEM involves relationships between variables that are not necessarily causal, correlations and covariances between variables are an essential feature. In recent years, SEM has enjoyed great popularity in the social sciences (Fox, 2002); its antecedents, including factor analysis, regression analysis, and path modeling have been used in psychology, genetics, biology, economics, and statistics. SEM has grown in importance in social sciences because it provides researchers with a method of determining the validity of models and adjusting them accordingly (Anderson and Gerbin, 1988).

Here, we present the main specification of a SEM (see STATA, 2011 for details).

Let the vector of all endogenous variables be \( Y = \begin{pmatrix} y \\ \eta \end{pmatrix} \), vector of all exogenous variables be \( X = \begin{pmatrix} x \\ \xi \end{pmatrix} \), and the vector of all error terms be \( \zeta = \begin{pmatrix} \epsilon_y \\ \epsilon_\eta \end{pmatrix} \). Thus, the structural equations model can be formulated as follow

\[
Y = BY + \Gamma X + \alpha + \zeta
\]  

where \( B = \begin{pmatrix} \beta_{ij} \end{pmatrix} \) is the matrix of coefficients on endogenous variables predicting other endogenous variables, \( \Gamma = \begin{pmatrix} \gamma_{ij} \end{pmatrix} \) is the matrix of coefficients on exogenous variables, \( \alpha = [\alpha_i] \) is the vector of intercepts for the endogenous variables, and \( \zeta \) is assumed to have mean 0 and \( \text{Cov}(X, \zeta) = 0 \).

Let

\[
\kappa = [\kappa_j] = E(X)
\]

\[
\Phi = [\phi_{ij}] = \text{Var}(X)
\]

\[
\Psi = [\psi_{ij}] = \text{Var}(\zeta)
\]

The mean vector of the endogenous variables \( Y \) is given by

\[
\mu = E(Y) = (I - B)^{-1}(\Gamma \kappa + \alpha)
\]

with variance equal to

\[
\Sigma_{YY} = \text{Var}(Y) = (I - B)^{-1}(\Gamma \Phi \Gamma^\prime + \Psi)(I - B)^{-1}
\]

and the covariance given by

\[
\Sigma_{YX} = \text{Cov}(Y, X) = (I - B)^{-1}\Gamma \Phi
\]

Now if \( Z = \begin{pmatrix} z' \\ x \end{pmatrix} \) is the vector of all variables, its mean \( \mu = (\mu_Y \kappa) \) and variance \( \Sigma = \begin{pmatrix} \Sigma_{YY} & \Sigma_{YX} \\ \Sigma_{YX} & \Phi \end{pmatrix} \).

Let \( \Theta = \begin{pmatrix} \text{vec}(B) \\ \text{vec}(\Gamma) \\ \text{vech}(\Psi) \\ \text{vech}(\Phi) \\ \alpha \\ \kappa \end{pmatrix} \) be the vector of all parameters, the log likelihood for \( \theta \) is
\[ \log L(\Theta) = -\frac{\omega}{2} \{ k \log(2\pi) + \log(\det(\Sigma_0)) + \text{tr}(D\Sigma_0^{-1}) \} \]  \hspace{1cm} (12)

where \( k \) is the number of observed variables, \( \Sigma_0 \) is the submatrix of \( \Sigma \) for observed variables, and \( D = fS + (\bar{z} - \mu_0)(\bar{z} - \mu_0)' \)  \hspace{1cm} (13)

where
\[
\bar{z} = \frac{1}{\omega} \sum_{t=1}^{N} \omega_t z_t
\]
\[
S = \frac{1}{\omega - 1} \sum_{t=1}^{N} \omega_t (z_t - \bar{z})(z_t - \bar{z})'
\]
\[
f = \begin{cases} 
\frac{\omega - 1}{\omega}, & \text{if sample variance rather than ML variance} \\
1, & \text{otherwise}
\end{cases}
\]

\( \omega_t \) is the corresponding weight value, with \( \omega \) the sum of the weights; and \( \mu_0 \) is the subvector of \( \mu \) for observed variables.

**DESCRIPTIVE ANALYSIS**

Data are from the Uganda National Household Survey 2005–2006, a comprehensive survey with five modules: socioeconomic, agriculture, community, market, and qualitative. The survey covered about 7,400 nationally representative households. Household food consumption was surveyed in the socioeconomic module using a 7-day recall. It collects information on consumed quantities and values for more than 50 food items (including beverages other than water), which are recorded separately according to their sources such as from own production, market purchases, and free food received in kind. To calculate nutrient consumption amounts from the reported food quantities, we applied conversion factors of the World Food Dietary Assessment System (FAO, 2010) for sub-Saharan Africa. For each household, we aggregated food consumption quantities and nutrient amounts into 11 food groups and converted them on a per-capita and per-day basis. Our choice of food group aggregation takes account of the typical composition of Ugandan meals and the nutritional characteristics of foods. The estimation of required and recommended levels of nutrients followed Ecker and Qaim (2011).

To explore the relationship between agricultural productivity and nutrient deficiency, we model the effect of nutrient consumption on labor and land productivities. Labor productivity is defined as the ratio of total household production to household agricultural labor, which is the total number of all household members’ days of labor utilized during the second season of 2004 (July through December 2004) and the first season of 2005 (January through June 2005). Land productivity is defined as the ratio of total household production to household harvested land area.

Plantain, sweetpotato, cassava, and maize account for most nutrient consumption, except for vitamin B12 (see Table 3.1). Together they represent 74.3 percent of caloric intake, 55.4 percent of protein, 94.4 percent of vitamin A, 80.3 percent of vitamin C, 76.8 percent of riboflavin, 81.2 percent of vitamin B6, 64.3 percent of folate, 58.9 percent of iron, and 59.6 percent of zinc. Ugandan households receive 18.1 percent of their protein from maize, followed by other cereals (17.3 percent), sweetpotatoes (13.9 percent), cassava (11.8 percent), plantain (11.6 percent), and legumes and nuts (11.3 percent).

Regarding vitamin A, 93 percent comes from sweetpotatoes alone. Meat, fish, and poultry, combined with dairy, fats, and oils, provide 100 percent of Vitamin B12.

**Table 3.1—Sources of nutrients**

<table>
<thead>
<tr>
<th></th>
<th>Calories</th>
<th>Protein</th>
<th>Vitamin A</th>
<th>Vitamin C</th>
<th>Riboflavin</th>
<th>Vitamin B6</th>
<th>Folate</th>
<th>Vitamin B12</th>
<th>Iron</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantain</td>
<td>19.2</td>
<td>11.6</td>
<td>0.7</td>
<td>13.2</td>
<td>31.9</td>
<td>43.9</td>
<td>22.5</td>
<td>0.0</td>
<td>8.4</td>
<td>11.9</td>
</tr>
<tr>
<td>Sweetpotato</td>
<td>15.4</td>
<td>13.9</td>
<td>93.0</td>
<td>26.2</td>
<td>28.7</td>
<td>12.8</td>
<td>20.1</td>
<td>0.0</td>
<td>11.1</td>
<td>12.0</td>
</tr>
<tr>
<td>Cassava</td>
<td>25.7</td>
<td>11.8</td>
<td>0.5</td>
<td>40.9</td>
<td>4.6</td>
<td>20.3</td>
<td>16.6</td>
<td>0.0</td>
<td>21.1</td>
<td>15.4</td>
</tr>
<tr>
<td>Product</td>
<td>13.9</td>
<td>18.1</td>
<td>0.0</td>
<td>0.0</td>
<td>11.5</td>
<td>4.1</td>
<td>5.1</td>
<td>0.0</td>
<td>18.3</td>
<td>20.3</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------</td>
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<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Irish potato</td>
<td>7.7</td>
<td>9.2</td>
<td>0.0</td>
<td>7.5</td>
<td>3.0</td>
<td>9.1</td>
<td>4.4</td>
<td>0.0</td>
<td>3.9</td>
<td>8.3</td>
</tr>
<tr>
<td>Other cereals</td>
<td>10.1</td>
<td>17.3</td>
<td>0.2</td>
<td>0.0</td>
<td>7.5</td>
<td>2.8</td>
<td>4.0</td>
<td>0.0</td>
<td>23.8</td>
<td>20.5</td>
</tr>
<tr>
<td>Meat, fish, and poultry</td>
<td>0.1</td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>12.8</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Dairy, fats, and oils</td>
<td>0.6</td>
<td>1.5</td>
<td>0.2</td>
<td>0.1</td>
<td>2.3</td>
<td>0.2</td>
<td>0.3</td>
<td>87.2</td>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Fruits</td>
<td>2.7</td>
<td>1.7</td>
<td>2.9</td>
<td>6.9</td>
<td>4.1</td>
<td>3.0</td>
<td>3.3</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Vegetables</td>
<td>1.2</td>
<td>3.0</td>
<td>2.3</td>
<td>4.6</td>
<td>3.4</td>
<td>2.6</td>
<td>8.2</td>
<td>0.0</td>
<td>3.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Legumes and nuts</td>
<td>3.3</td>
<td>11.3</td>
<td>0.2</td>
<td>0.6</td>
<td>2.9</td>
<td>1.1</td>
<td>15.5</td>
<td>0.0</td>
<td>9.1</td>
<td>7.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Authors’ computation.

Overall, Table 3.2 suggests that the majority of Ugandan households are deficient in vitamin B₁₂ (79.7 percent), iron (77.2 percent), and zinc (69.2 percent). Nutrient deficiency varies across regions; Northern Region appears the most affected, with the highest rates of deficiency in calories (49.8 percent), protein (34.5 percent), zinc (76.7 percent), vitamin A (36.4 percent), vitamin C (17.0 percent), vitamin B₆ (19.0 percent), riboflavin (47.5 percent), and folate (35.2 percent). Female-headed households are more affected than those headed by males, except for vitamin B₁₂. Nutrition deficiency does not systematically single out urban or rural households; deficiencies for each location vary by nutrient.

**Table 3.2—Nutrition deficiency by nutrient (%)**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>All</th>
<th>Central</th>
<th>Eastern</th>
<th>Northern</th>
<th>Western</th>
<th>Female</th>
<th>Male</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>34.3</td>
<td>28.7</td>
<td>34.4</td>
<td>49.8</td>
<td>29.9</td>
<td>35.1</td>
<td>32.2</td>
<td>28.6</td>
<td>35.7</td>
</tr>
<tr>
<td>Protein</td>
<td>20.5</td>
<td>17.4</td>
<td>21.3</td>
<td>34.5</td>
<td>13.0</td>
<td>20.6</td>
<td>20.2</td>
<td>19.9</td>
<td>20.7</td>
</tr>
<tr>
<td>Iron</td>
<td>77.2</td>
<td>80.7</td>
<td>79.2</td>
<td>78.3</td>
<td>71.7</td>
<td>78.4</td>
<td>74.1</td>
<td>81.0</td>
<td>76.9</td>
</tr>
<tr>
<td>Zinc</td>
<td>69.2</td>
<td>70.0</td>
<td>73.2</td>
<td>76.7</td>
<td>60.2</td>
<td>70.5</td>
<td>65.9</td>
<td>67.9</td>
<td>69.9</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>25.2</td>
<td>20.2</td>
<td>20.1</td>
<td>36.4</td>
<td>27.8</td>
<td>25.8</td>
<td>23.4</td>
<td>23.1</td>
<td>25.8</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>10.1</td>
<td>10.5</td>
<td>8.0</td>
<td>17.0</td>
<td>6.1</td>
<td>10.6</td>
<td>8.7</td>
<td>12.0</td>
<td>9.7</td>
</tr>
<tr>
<td>Vitamin B₆</td>
<td>9.7</td>
<td>10.0</td>
<td>7.2</td>
<td>19.0</td>
<td>4.6</td>
<td>10.1</td>
<td>8.8</td>
<td>12.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>79.7</td>
<td>73.3</td>
<td>82.9</td>
<td>83.2</td>
<td>83.7</td>
<td>79.3</td>
<td>80.8</td>
<td>74.2</td>
<td>81.3</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>25.3</td>
<td>19.8</td>
<td>24.4</td>
<td>47.5</td>
<td>16.1</td>
<td>25.8</td>
<td>23.8</td>
<td>23.9</td>
<td>25.7</td>
</tr>
<tr>
<td>Folate</td>
<td>23.5</td>
<td>21.6</td>
<td>28.8</td>
<td>35.2</td>
<td>12.4</td>
<td>24.0</td>
<td>22.3</td>
<td>24.0</td>
<td>23.6</td>
</tr>
</tbody>
</table>

Source: Authors’ computation.

Labor productivity, in Uganda shillings (UGX) per person-day, and land productivity, in UGX per hectare, are reported in Figures 3.1 and 3.2, respectively, comparing the mean values between nutrient-deficient households and nondeficient households.
Figure 3.1—Labor productivity by nutrient in deficient and nondeficient households

Source: Authors’ computation.

Note: To estimate nutrient deficiencies, per-capita nutrient consumption amounts were compared with per-capita household-specific nutrient recommendation levels. Nutrient deficiencies are binary variables equal to one if the household is nutrient deficient and zero otherwise.
We applied the paired Student’s t-test to analyze the significance of difference in agricultural productivity between the two groups of households. The results show that, with the exception of vitamin A and vitamin B₆ for labor productivity and iron for land productivity, differences among deficient and nondeficient households are statistically significant, suggesting that calories, protein, iron, zinc, and vitamin B₁₂ are important factors in labor productivity and that all but iron are likely determinants of land productivity.

**Estimation Results**

The study sample is predominantly rural households in Uganda. The typical household is headed by a male member of about 45 years (Table 4.1). Average land and labor productivity in the sample are about 11.8 UGX per hectare and 7.7 UGX per person day respectively. Access to productivity enhancing information appears scarce as less than 50 percent of all households had access to these. Though variables considered for identifying the determinants of land and labor productivity are described in Table 4.1, this study focuses only on labor productivity in the consequent empirical estimations.

**Table 4.1—Variables used for estimation**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor productivity (UGX/person-day)</td>
<td>5,639</td>
<td>7.66</td>
<td>1.24</td>
<td>1.98</td>
<td>18.07</td>
</tr>
<tr>
<td>Land productivity (UGX/ha)</td>
<td>5,606</td>
<td>11.78</td>
<td>1.28</td>
<td>4.87</td>
<td>16.06</td>
</tr>
<tr>
<td>Access to information (1 if yes, 0 otherwise)</td>
<td>5,598</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to soil fertility management information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Access to crop protection information  5,596  0.00  1.00  
Access to farm management information  5,593  0.00  1.00  

Total cost of input (UGX, million)
Log total cost  5,639  0.09  0.38  0.00  16.31  
Log total cost squared  5,639  0.15  4.58  0.00  266.02  

Education of the household head  (1 if attended, 0 otherwise)
Junior and secondary  4,430  0.00  1.00  
Post-secondary  4,430  0.00  1.00  

Region (Default = Central Region)
Eastern  5,639  0.00  1.00  
Northern  5,639  0.00  1.00  
Western  5,639  0.00  1.00  

Gender of the household head  (1 if male, 0 if female)  5,639  0.00  1.00  
Age of the household head (years)  5,639  43.76  15.68  13.00  99.00  
Location (1 if rural, 0 otherwise)  5,639  0.00  1.00  
Number of household members with disability/malaria that impacts functioning  5,639  0.41  0.69  0.00  6.00  
Log of agricultural income (UGX)  4,556  11.50  1.63  2.57  16.63  
Log of protein (g)  5,566  4.06  0.79  -2.64  8.35  
Log of vitamin A (μg, retinol equivalent)  5,414  7.65  1.85  -3.11  12.01  
Log of iron (mg)  5,585  2.88  0.88  -5.82  7.96  
Log of calories (kcal)  5,586  7.77  0.72  1.59  11.28  
Log of zinc (mg)  5,557  2.12  0.74  -3.33  6.79  
Log of vitamin B6 (μg)  5,565  1.57  0.92  -4.94  4.92  
Log of vitamin B12 (μg)  4,224  -0.64  1.84  -12.83  4.55  

Source: Authors' computation.

Estimation results clearly reveal the bidirectional relationship between productivity and nutrients intake. Results in Table 4.2 show that more productive farmers tend to consume more nutrients and vice versa. The elasticities across nutrients are relatively higher for vitamin B6, B12 and proteins. On the other hand, results indicate that agricultural income does not only increase caloric intake but also significantly increases household intake of all nutrients. While education generally increases household consumption of vitamin B12, only post secondary education increases the consumption of all other nutrients except folate and iron. Where significant, male headed households consume less nutrients than female headed households. This finding has important policy implication for gender-based targeting of nutritional programs by national governments as well as development agencies. The results also show that having an older household head increases household consumption of iron and zinc and households with more people who cannot function because of disease tend to consume less of nutrients. This is
expected as such households will tend to have less income to guarantee the consumption of these nutrients.
## Table 4.2 The determinants of nutrient intake

<table>
<thead>
<tr>
<th></th>
<th>Vitamin B12</th>
<th>Calorie</th>
<th>Folate</th>
<th>Vitamin B6</th>
<th>Riboflavin</th>
<th>Vitamin A</th>
<th>Vitamin C</th>
<th>Protein</th>
<th>Iron</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor productivity (UGX/ person-day)</td>
<td>0.0434</td>
<td>0.0197</td>
<td>0.0221</td>
<td>0.0389</td>
<td>0.0279</td>
<td>-0.0068</td>
<td>0.0048</td>
<td>0.0319</td>
<td>0.0143</td>
<td>0.0280</td>
</tr>
<tr>
<td>Agricultural income (UGX)</td>
<td>0.0226</td>
<td>0.0483</td>
<td>0.0313</td>
<td>0.0543</td>
<td>0.0477</td>
<td>0.0309</td>
<td>0.0558</td>
<td>0.0282</td>
<td>0.0284</td>
<td>0.0310</td>
</tr>
<tr>
<td>Education (1 if attended, 0 otherwise)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior and secondary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-secondary</td>
<td>0.5083</td>
<td>0.0440</td>
<td>0.0614</td>
<td>0.0146</td>
<td>-0.0150</td>
<td>0.1368</td>
<td>0.1263</td>
<td>0.1075</td>
<td>-0.0546</td>
<td>0.0794</td>
</tr>
<tr>
<td>male (1 for male, 0 for female)</td>
<td>-0.0522</td>
<td>-0.0298</td>
<td>-0.0429</td>
<td>-0.0328</td>
<td>-0.0407</td>
<td>-0.0159</td>
<td>-0.0583</td>
<td>-0.0436</td>
<td>-0.0272</td>
<td>-0.0388</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.0005</td>
<td>0.0015</td>
<td>0.0017</td>
<td>0.0015</td>
<td>0.0015</td>
<td>-0.0012</td>
<td>-0.0019</td>
<td>0.0017</td>
<td>0.0025</td>
<td>0.0019</td>
</tr>
<tr>
<td># persons can’t because of disease</td>
<td>-0.1704</td>
<td>-0.0309</td>
<td>-0.0045</td>
<td>-0.0119</td>
<td>-0.0077</td>
<td>0.0304</td>
<td>0.0119</td>
<td>-0.0371</td>
<td>-0.0485</td>
<td>-0.0195</td>
</tr>
<tr>
<td>Eastern Region</td>
<td>-0.2314</td>
<td>0.0014</td>
<td>-0.0852</td>
<td>-0.1609</td>
<td>-0.1070</td>
<td>-0.0161</td>
<td>-0.0167</td>
<td>-0.0181</td>
<td>0.0346</td>
<td>-0.0153</td>
</tr>
<tr>
<td>Northern Region</td>
<td>-0.4795</td>
<td>-0.2802</td>
<td>-0.1608</td>
<td>-0.4891</td>
<td>-0.5699</td>
<td>-0.6978</td>
<td>-0.2716</td>
<td>-0.1428</td>
<td>-0.2220</td>
<td>-0.2724</td>
</tr>
<tr>
<td>Western Region</td>
<td>-0.4258</td>
<td>0.0322</td>
<td>0.2040</td>
<td>0.2697</td>
<td>0.1090</td>
<td>-0.4570</td>
<td>-0.1662</td>
<td>0.0694</td>
<td>0.1767</td>
<td>0.1616</td>
</tr>
</tbody>
</table>

Source: Authors’ calculation

Notes: bold, italic and underlined means significant at 1%, 5% and 10% respectively.

This conference paper has not been peer reviewed. Any opinions stated herein are those of the author(s) and are not necessarily endorsed by or representative of IFPRI or of the cosponsoring or supporting organizations.
The study results also indicate the significant effect of nutrient consumption on labor productivity (Table 4.3). All nutrients apart from vitamin A, Vitamin C and Iron are significant determinants of labor productivity. This iron finding contrasts the findings of Levin (1986), who summarized eight experimental studies that analyzed the relationship between blood iron levels and productivity. Those studies found output elasticities of hemoglobin levels to be as high as between 1 and 2. Similarly, Weinberger (2004) examined the impact of iron intake on labor productivity of households in India by applying a two-stage least squares (2SLS) estimation technique and found that productivity, measured in wages, is affected by insufficient iron intake, and that wages would on average be 5 to 17.3 percent higher if households would achieve recommended intake levels of iron. Similarly, using an IV Tobit approach, we found elasticities ranging between 2.3 (vitamin B12) and 8.8 (protein). However, as pointed out earlier, only structural equations model can adequately account for the complex interactions depicted in Diagram 1 and therefore yield unbiased and efficient estimates. On the other hand, Gilgen, Mascie-Taylor, and Rosetta (2001) used a randomized clinical intervention trial to investigate the effect of iron supplementation and anthelmintic treatment on the labor productivity of adult female tea pluckers in Bangladesh. Four groups were formed: Group 1 received iron supplementation weekly, group 2 received anthelmintic treatment at the beginning and halfway through the trial (week 12), group 3 received the same iron supplementation as group 1 and the same anthelmintic treatment as group 2, and group 4 was a control group that received placebos. They found no significant difference in labor productivity among the four intervention groups over the trial period.

Vitamins B12, B6 and protein appear as the most important nutrients. This is consistent with findings of other studies like that of Hoddinott (2008), which investigated the direct effect of a nutrition intervention in early childhood on adult economic productivity in Guatemala and found that men who had received nutrition supplements (including protein) from birth to 36 months of age earned a higher hourly wage in adulthood than men who had not received the supplements. However, our results further indicate that protein consumption later in life remains important for farmers’ health and productivity.
Table 4.3. The determinants of labor productivity

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Vitamin B12</th>
<th>Calorie</th>
<th>Folate</th>
<th>Vitamin B6</th>
<th>Riboflavin</th>
<th>Vitamin A</th>
<th>Vitamin C</th>
<th>Protein</th>
<th>Iron</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients</td>
<td>0.0434</td>
<td>0.0197</td>
<td>0.0221</td>
<td>0.0389</td>
<td>0.0279</td>
<td>-0.0068</td>
<td>0.0048</td>
<td>0.0319</td>
<td>0.0143</td>
<td>0.0280</td>
</tr>
<tr>
<td>Soil Fertility</td>
<td>0.1753</td>
<td>0.1730</td>
<td>0.1733</td>
<td>0.1706</td>
<td>0.1723</td>
<td>0.1733</td>
<td>0.1728</td>
<td>0.1747</td>
<td>0.1735</td>
<td>0.1735</td>
</tr>
<tr>
<td>Access to agricultural information (1 yes, 0 no)</td>
<td>-0.0409</td>
<td>-0.0416</td>
<td>-0.0418</td>
<td>-0.0400</td>
<td>-0.0409</td>
<td>-0.0422</td>
<td>-0.0420</td>
<td>-0.0410</td>
<td>-0.0419</td>
<td>-0.0407</td>
</tr>
<tr>
<td>Crop protection</td>
<td>-0.0449</td>
<td>-0.0418</td>
<td>-0.0430</td>
<td>-0.0443</td>
<td>-0.0429</td>
<td>-0.0385</td>
<td>-0.0402</td>
<td>-0.0439</td>
<td>-0.0412</td>
<td>-0.0434</td>
</tr>
<tr>
<td>Farm management</td>
<td>0.4326</td>
<td>0.4402</td>
<td>0.4401</td>
<td>0.4386</td>
<td>0.4396</td>
<td>0.4422</td>
<td>0.4409</td>
<td>0.4397</td>
<td>0.4410</td>
<td>0.4400</td>
</tr>
<tr>
<td>Total production cost (UGX, millions)</td>
<td>0.0307</td>
<td>0.0312</td>
<td>0.0312</td>
<td>0.0311</td>
<td>0.0312</td>
<td>0.0314</td>
<td>0.0313</td>
<td>0.0312</td>
<td>0.0313</td>
<td>0.0312</td>
</tr>
<tr>
<td>Total production cost squared</td>
<td>-0.0160</td>
<td>-0.0165</td>
<td>-0.0164</td>
<td>-0.0158</td>
<td>-0.0168</td>
<td>-0.0180</td>
<td>-0.0180</td>
<td>-0.0163</td>
<td>-0.0171</td>
<td>-0.0167</td>
</tr>
<tr>
<td>Male (1 for male, 0 for female)</td>
<td>0.1961</td>
<td>0.2132</td>
<td>0.2100</td>
<td>0.2093</td>
<td>0.2122</td>
<td>0.2121</td>
<td>0.2115</td>
<td>0.2103</td>
<td>0.2116</td>
<td>0.2104</td>
</tr>
<tr>
<td>Education (1 if attended, 0 otherwise)</td>
<td>0.1768</td>
<td>0.1832</td>
<td>0.1866</td>
<td>0.1818</td>
<td>0.1828</td>
<td>0.1883</td>
<td>0.1873</td>
<td>0.1815</td>
<td>0.1857</td>
<td>0.1821</td>
</tr>
<tr>
<td>Junior and secondary</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td>Post-secondary</td>
<td>-0.3507</td>
<td>-0.3505</td>
<td>-0.3554</td>
<td>-0.3589</td>
<td>-0.3566</td>
<td>-0.3559</td>
<td>-0.3565</td>
<td>-0.3519</td>
<td>-0.3617</td>
<td>-0.3617</td>
</tr>
<tr>
<td>Age (years)</td>
<td>-0.0158</td>
<td>-0.0226</td>
<td>-0.0220</td>
<td>-0.0214</td>
<td>-0.0224</td>
<td>-0.0224</td>
<td>-0.0211</td>
<td>-0.0216</td>
<td>-0.0218</td>
<td>-0.0218</td>
</tr>
<tr>
<td>Location (1 for rural, 0 for urban)</td>
<td>-0.3364</td>
<td>-0.3418</td>
<td>-0.3394</td>
<td>-0.3329</td>
<td>-0.3408</td>
<td>-0.3481</td>
<td>-0.3465</td>
<td>-0.3406</td>
<td>-0.3449</td>
<td>-0.3440</td>
</tr>
<tr>
<td># persons can't because of disease</td>
<td>0.0996</td>
<td>0.0839</td>
<td>0.0820</td>
<td>0.0764</td>
<td>0.0836</td>
<td>0.0786</td>
<td>0.0830</td>
<td>0.0845</td>
<td>0.0829</td>
<td>0.0792</td>
</tr>
<tr>
<td>Regions (Default=Central region)</td>
<td>0.0996</td>
<td>0.0839</td>
<td>0.0820</td>
<td>0.0764</td>
<td>0.0836</td>
<td>0.0786</td>
<td>0.0830</td>
<td>0.0845</td>
<td>0.0829</td>
<td>0.0792</td>
</tr>
</tbody>
</table>

Table 4.4. Determinants of Agricultural income in Uganda

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Vitamin B12</th>
<th>Calorie</th>
<th>Folate</th>
<th>Vitamin B6</th>
<th>Riboflavin</th>
<th>Vitamin A</th>
<th>Vitamin C</th>
<th>Protein</th>
<th>Iron</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor productivity (UGX/ person-day)</td>
<td>0.4674</td>
<td>0.4712</td>
<td>0.4711</td>
<td>0.4670</td>
<td>0.4670</td>
<td>0.4734</td>
<td>0.4741</td>
<td>0.4707</td>
<td>0.4709</td>
<td>0.4700</td>
</tr>
<tr>
<td>Nutrients</td>
<td>0.0226</td>
<td>0.0483</td>
<td>0.0313</td>
<td>0.0543</td>
<td>0.0477</td>
<td>0.0309</td>
<td>0.0558</td>
<td>0.0282</td>
<td>0.0284</td>
<td>0.0310</td>
</tr>
</tbody>
</table>

Source: Authors’ calculation
Notes: bold, italic and underlined means significant at 1%, 5% and 10% respectively.
Other important factors that improve labor productivity are soil quality and production costs. We find an increasing return to production costs indicating that the rate of increase in labor productivity increases with higher levels of production costs. This relationship between costs and productivity may be reflecting the use of improved technologies that require certain investments that increase costs but which have a larger effect on the productivity of labor. The results also suggest that male headed households are less productive than female households. In addition, our study shows that education increases labor productivity. Both, junior and secondary education of the household head as well as post secondary education improves labor productivity. Compared to the central region, the Eastern and Northern regions are less productive, while the Western region appears to be more productive.

As pointed out by Latham, “There can be no doubt that nutrient intake and nutritional status influence physical fitness as well as work capacity and work output. This relationship exists in housewives, factory workers, and in those engaged in agriculture, be it subsistence peasant farming or agricultural labor for wages. The problem is to define, for groups of individuals, what levels of nutrient intake or what degree of undernutrition, or malnutrition, are likely to have what effects on work output” (1988, 147).

Finally Table 4.4 reveals the relationship between labor productivity and the consumption of calories and various nutrients on one hand and agricultural income on the other. We find that labor productivity increases agricultural income as one would expect. We also find that calories as well as nutrient intake also positively affect agricultural income in Uganda.

Concluding Remarks
As established by previous studies, there are many channels through which nutrient consumption may affect human productivity. Not only do food nutrients serve as fuel for the human body, but they also play a major role in maintaining adequate health while preventing certain diseases and infections. Hence, poor nutrition in childhood is more likely to lead to stunting, weakness, or body deformation that may prevent human organs from functioning at their full potential. Poor nutrition affects people’s health, which in turn will cause a loss of days worked or lead to reduced worker capacity. Poor nutrition also lessens the farmer’s ability to innovate, experiment, and adopt improved technologies and practices in agricultural systems. This study contributes to the more recent literature on nutrition and productivity by exploring the importance of various micronutrients, in addition to caloric intake, on agricultural productivity in Uganda. We also find a strong relationship of protein and vitamin B6 intake with labor productivity. Overall, results indicate that agricultural productivity in Uganda is likely to be enhanced if emphasis is placed on micronutrients (particularly protein). The productivity implication of malnutrition calls for more research-based evidence on the link between agricultural productivity and nutrient consumption to inform the design of appropriate programs to tackle malnutrition and improve agricultural productivity which in turn will increase household income.
References


