Does Livestock Ownership Affect Animal Source Foods Consumption and Child Nutritional Status? Evidence from Rural Uganda

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Abstract

In many developing countries consumption of animal source foods (ASF) among the poor is still at a level where increasing its share in total caloric intake may have many positive nutritional benefits. This paper explores whether ownership of different livestock species increases consumption of ASF and helps improving child nutritional status, finding some evidence that both food consumption patterns and nutritional outcomes may be affected by livestock ownership in rural Uganda. Our results are suggestive that promoting (small) livestock ownership has the potential for affecting human nutrition in rural Uganda, but further research is needed to more precisely estimate the direction and size of these effects.

1. Introduction

The role of livestock and livestock products in contributing to household income and consumption is becoming increasingly important in developing countries as the level of development improves. According to FAO data, in the last five decades per capita milk consumption in developing countries almost doubled, meat consumption tripled, and egg consumption increased by a factor of five, whereas consumption of cereals increased only slightly and that of root and tubers declined (Gerosa & Skoet, 2013). While this growth rate is likely to slow down somewhat in the coming decades, it is still likely to remain higher than growth for other food groups particularly in Sub-Saharan Africa as populations increase, become richer, move to urban areas, and change dietary preferences (Alexandratos & Bruinsma, 2012; Fischer, 2003).

Livestock can improve food security through consumption of livestock and livestock by-products, generation of livestock-related income, improved cereal productivity due to the use of manure and traction, and reduced prices of livestock by-products (Smith et al., 2013; Kariuki et al., 2013). While the potential role of livestock in directly contributing to better nutrition for households keeping livestock is often mentioned, surprisingly little rigorous analysis exists to document these linkages, and the channels through and the conditions under which they operate. The purpose of this paper is to analyze if ownership of livestock and production of livestock goods alter household-level consumption of meat and other animal products, collectively referred to as animal-source foods (ASF). In addition, the paper examines the effect of livestock ownership on child nutritional outcomes.

Increased consumption of ASF could have numerous nutritional benefits for both poor and non-poor households. Compared to foods from non-animal sources, ASF are nutritionally dense sources of energy, protein, and other essential micronutrients. As such, ASF can make it possible for children and for pregnant and breastfeeding women to obtain calories in adequate quantities as well as high quality protein, micronutrients and better nutrition (Sigman et al., 1991; Grosse, 1998b). The lack of ASF in the diet has been associated with micronutrient deficiencies (Allen, 2003). ASF are a major source of iron, zinc, calcium, riboflavin, vitamin A, vitamin B-12, and retinol, and increasing the intake of ASF and the micronutrients they contain may have numerous positive benefits including on linear growth, improved educational attainment and health status, leading to long term improvements in income and productivity (Allen, 2003; Black, 2003; Brown, 2003; Bwibo & Neumann, 2003; Demment, Young, & Sensenig, 2003; Hop, 2003; Neumann, Harris & Rogers, 2002). Milk in particular contains several critical micronutrients such as calcium, vitamin A, riboflavin and vitamin B12 that are essential for growth and development of children older than 12 months (Iannotti, 2012; Dror & Allen, 2011; Wiley, 2009; Sadler & Catley, 2009; Hoppe et al., 2008).

Ownership of livestock can give households more opportunities to increase the consumption of ASF if it translates into cheaper or more reliable access to ASF supplies. This may be likely when markets are poorly developed, and more so for highly perishable products such as milk and dairy, which require investments in refrigeration and other equipment which may not be economically justified in the presence of sparse effective demands for such goods

Whether a link between ownership of livestock and consumption of ASF exist, and under what conditions, is therefore an empirical question. We are aware of few studies[1] that attempt to rigorously establish the existence of such a link, and most of them are based on small samples, and rely on data that make it hard to carefully identify the existence of a causal relationship between animal ownership, increased ASF consumption, and nutrition. In a large-scale randomized evaluation study of targeted asset transfer (largely livestock) and skill development program in rural Bangladesh, Bandiera et al. (2013) find a positive impact of the program on earnings, (food and non-food) consumption, and household food security. In another evaluation study of a livestock transfer and training program in India, Banerjee et al. (2011) find a significant positive effect on consumption, nutritional intake, and food security. Pimkina et al. (2013) find a dairy cow and meat goat donation program in Rwanda to have a positive impact on dairy and meat consumption, respectively. The study also found dairy cow and meat goat acquisition to improve stunting and wasting measures, respectively. In their evaluation of a women-focused goat development program in Ethiopia, Ayele and Peacock (2003) find a positive effect on milk consumption among recipients, especially among children 6-72 months old. A positive association between livestock ownership and nutritional outcomes has also been documented in Uganda (Vella, Nviku, & Marshall, 1995) and Rwanda (Grosee, 1998a).

On the other hand, ownership of livestock can adversely affect the wellbeing of children through untimely substitution of breast milk with animal milk (Grosse, 1998b), and through the spread of animal-borne diarrheal diseases (Pickering et al., 1986). For example, Griffin & Abrams (2001) find that consumption of fresh, unheated cow milk by infants younger than 12 months is associated with fecal blood loss and lower iron status. Livestock ownership in general and dairy production in particular could also impact (child) nutrition and health negatively if it increases labor demand on childcare providers, encourages milk marketing, and increases the incidence of zoonosis (Iannotti, 2012). When household resources are under stress, livestock may also start competing with humans for the allocation of foodstuffs with implications on the availability of food for household consumption.

Using nationally representative data for Uganda, the present paper aims to contribute to building an evidence base on the existence of such linkages between livestock ownership, ASF consumption and nutrition. Uganda offers a promising environment for this analysis due to a combination of high prevalence of livestock ownership, recent growth in the livestock sector, and high level of malnutrition – 33 percent of stunting and 50 percent of anemia prevalence in children under 5 (DHS, 2011).

The paper is organized as follows: Section 2 outlines the conceptual framework against the backdrop of the relevant literature; Section 3 describes the dataset used in the empirical analysis; Section 4 outlines the empirical strategy; Section 5 discusses the estimation results; Section 6 concludes.

2. Conceptual Framework

In examining the role of livestock ownership and its effect on consumption of ASF it is useful to first lay out the mechanisms through which ownership (and production) may alter dietary composition. In considering the household as both a producer and a consumer of livestock products, a well-established microeconomic framework is offered by the agricultural household model. In this framework, a household is jointly engaged in production and consumption and maximizes utility that is a function of consumption goods (agricultural and market good) and leisure, subject to constraints on cash, labor, time, and overall production (Bardhan & Udry, 1999; Singh, Squire, & Strauss, 1986). Joint decision making begs the question of whether the two decisions are taken independently of each other (‘separable’ model) or are made simultaneously (‘non-separable’ model). Separability implies that a household first maximizes profits from production and then maximizes utility from consumption.

Separability requires that markets for agricultural inputs and outputs function perfectly, prices be exogenous, and goods be tradable without transaction costs. If markets work, then a separable household would be indifferent between own consumption and market purchased goods (Taylor & Adelman, 2003) and consumption may be viewed as the household purchasing goods from itself. With separability, consumption levels should depend on income and preferences and not vary with (the type of) livestock ownership after controlling for income and preferences. When market failures are present and some markets are missing, consumption and production decisions become non-separable and consumption decision would influence production decision (Key, Sadoulet, & de Janvry, 2000).

For livestock, non-separability implies that livestock ownership and management decisions would be made simultaneously with consumption decisions and ownership may be a strategy to ensure availability of ASF at affordable prices. The possible role of livestock ownership in providing better nutrition through increased ASF consumption has been documented in the reviews by Murphy & Allen (2003) and Randolph et al., (2007). The latter offers a careful discussion of the complex causal linkages between livestock keeping and nutrition, and warns against simplistically assuming that promoting livestock ownership among the poor will readily result in higher ASF consumption and better nutrition.

While intra-household allocation may impact the distribution of resources within the household, by altering individual-level consumption, household-level consumption may also be affected by who controls income (Senauer, 1990; Villa, Barrett, & Just, 2010). Co-ownership or female-ownership of livestock could be associated with improved child ASF consumption and health outcomes if, for example, women spend more of the livestock income on food, health, clothing and education of children than men do (Jin & Iannotti, 2014; FAO, 2011).

With non-separability, households may choose to own a diverse set of livestock to serve different (consumption) needs. Large livestock, such as cattle and horses, may be viewed as a physical asset for transportation or traction and also represent major cultural and financial assets. Cattle are also generally the most highly regarded livestock species because of the quantity and value of products deriving from them. Small ruminants, such as sheep and goats, are of smaller size and value, but they breed faster and are more affordable than large ruminants (Robinson, Franceschini, & Wint, 2007). Finally, poultry and pigs require fewer inputs, are potentially more likely to be slaughtered, and may provide a steadier (if smaller) source of cash, due to their smaller size and affordability. Different livestock species may be more directly associated with management by male or female household members, thus interacting with the intra-household allocation mechanism in influencing how livestock income or by-products affect consumption patterns (Kariuki et al., 2013). A multiplicity of factors beyond food consumption, however, contribute to determining nutritional outcomes so that finding a positive impact of livestock ownership on ASF consumption would not guarantee a similar impact on nutrition. Even if it does, the impact may not be homogeneous among population groups, and not necessarily concentrated among the key demographic groups of interest from a nutritional perspective (children under 2 years, children under 5 years, women of reproductive age, lactating mothers).

For instance, the increased ASF consumption by the household may not be equally shared among members, and may not benefit the groups to which it may be nutritionally more valuable. Or, if the presence of animals in or around the dwelling is associated with a deterioration of hygienic conditions and increased sickness spells, the nutritional effect of increased ASF consumption may be offset by such episodes. Or yet when family resources come under stress, households may decide to reduce the availability of food crops for human consumption or increase the use of crop residues for animal feed with implications for human nutrition. It is therefore necessary to carry the empirical investigation beyond the mere ASF consumption onto the question of whether livestock ownership ultimately translates into improved nutritional outcomes.

Decomposing ASF into subgroups allows for the analysis of whether different forms of ASF consumption are impacted differently by livestock ownership and herd composition. Dairy may be separated from meat because it is a high quality source of protein that is generally lower in cost, and its consumption may be less sensitive to economic insecurity (Dore, Adair, & Popkin, 2003). Dairy consumption may also be more frequent than meat consumption, since slaughtering of animals (except possibly poultry and other small animals) for household meat consumption is rather infrequent, occurring when animals become sick or unproductive, or for festivities and special social occasions (Randolph et al., 2007).

Decomposing ASF is also important because of the differential nutritional value of ASF. Iron, vitamin A, and iodine deficiencies are the most widespread deficiencies that can be mitigated through the consumption of ASF (Muehlhoff et al., 2013; Kennedy et al. 2003; Herbert 1994). Among non-fortified foods, Vitamin B12 is only available in animal products, particularly in meat but also in dairy (Randolph et al., 2007; Murphy & Allen, 2003).

Foods like beef, poultry and fish are rich sources of heme iron (which is more easily absorbed by the human body compared to the iron contained in plants), while cow milk contains little iron and can in fact contribute to iron deficiency among infants and toddlers (Ziegler, 2011). Vitamin A and retinol can be sourced from dairy, but not from most meat products with the notable exception of liver. Meat and meat products on the other hand are rich in Vitamin B12, which is available in smaller amounts in milk. Milk and eggs also provide small amounts of iodine, which is necessary for proper synthesis of thyroid hormones (Kennedy et al. 2003). Like for iron, ASF vary in terms of contents of other minerals, with dairy products good for calcium intake, and meat more dense in zinc and selenium (Biesalski. 2005; Siekmann et al., 2003).

The nutrient content of meat varies by species, quality of feed, cut of meat and extent of fat trimming, and some meat types (for example, goat meat) generally have lower fat and cholesterol than others (for instance, pork) (Gebhard & Thomas, 2002). Similarly, the nutritional composition of milk depends on the species and breed, management practice, season, and quality of feed with, for example, goat milk generally having higher vitamin A than cow milk (Wijesinha-Bettoni & Burlingame, 2011; Pandya & Ghodke, 2007).

Given the above, it is important in any analysis of nutritional outcomes to consider that different products have different potential of addressing specific nutritional deficiencies. We acknowledge that in this paper by breaking down both ASF consumption and livestock ownership in different categories. The nature of the data (which we describe in the next section) does not however allow us to exploit that to a full extent as we do not have detailed information on nutrient deficiencies, and there are no clear, prior hypotheses that can be made on the differential impact of different ASF on the nutritional outcome measures we do have: children height and weight.

Based on the above conceptualization of the linkages between livestock ownership and animal production, ASF consumption, and nutrition, the remainder of the paper will investigate how these relationships are at play in Uganda.

3. The Data

This paper uses household survey data from the 2005/06 Uganda National Household Survey (UNHS) and the 2009/10 Uganda National Panel Survey (UNPS), both implemented by the Uganda Bureau of Statistics. The surveys have a similar design, collecting information on a range of socioeconomic and demographic characteristics of the household, including extensive information on agricultural activities and, in 2009/10, also anthropometric information on children under 5 years of age. Both are nationally representative, and are based on a stratified random sample of the Uganda population.

The 2005/06 UNHS covered all the districts in Uganda surveying 7,421 households from 783 Enumeration Areas. The 2009/10 UNPS collected information on 2,975 households in 322 enumeration areas nationally, selected among those interviewed for the 2005/06 UNHS. Data was collected over a twelve month period. The sample used in this paper is restricted to the rural domain and is therefore representative of rural Uganda.

Both surveys include detailed food and non-food consumption expenditure modules, as well as extensive agricultural sector modules, covering both crop and livestock activities (animal inventories, by-products, and sales). The data also allow separating consumption expenditure into different types of meat categories, which can mapped to the different livestock species. We examine four categories of ASF (beef, chicken, dairy, and sheep and goat meat) and an aggregate of the four categories. To align the herd composition with the different ASF types considered, we define three livestock categories - large ruminants (bulls, cows, calves), small ruminants (goats and sheep), and poultry (chickens, turkeys, and ducks).

To capture the effect of livestock ownership on ASF consumption and child nutritional outcomes, we exploit the longitudinal nature of the data from 2005/06 and 2009/10. For each ASF type, we compute the annual value of per capita consumption as price times quantity consumed (expressed in 2005 Purchasing Power Parity (PPP) US dollars). The per capita value of ASF is then computed as the sum of the per capita consumption value of beef, sheep and goat meat, chicken, and dairy.

Since the analysis in this paper focuses mainly on differences in consumption between livestock owners and non-owners, it is important to understand how other relevant characteristics also differ between the two groups. Table 1 summarizes relevant socio-economic and child anthropometric variables by ownership and per capita consumption expenditure terciles for the 2005/06 UNHS and the 2009/10 UNPS.[2] Descriptive statistics on all the variables included in the regression analyses are provided in the online appendix (Tables A1 & A2).

There are significant differences between livestock owners and the average household both in 2005/06 and 2009/10. Livestock owners generally have a higher value as well as share of consumption of different ASF than the average household in the sample. Livestock owners consume more sheep and goat, and chicken meat per capita, and have higher shares of income from crop production and lower shares of income from wages. The number of animals owned and ASF consumption both increase with the level of expenditure.

The empirical analysis of child nutritional outcomes uses standardized anthropometric indicators. Z-scores for height-for-age (HA), weight-for-age (WA), weight-for-height (WH) are computed based on the 2006 World Health Organization's new Child Growth Standards. A child is defined as stunted, underweight, or wasted if her HA, WA, or WH z-scores respectively are below -2. Under-five children in households that own livestock have higher WA, and WH z-scores, on average, than their counterparts in households without livestock. Average HA and WA z-scores are also found to vary by expenditure levels, with children in the lower tercile having a lower z-score (lower panel in Table 1).

4. Estimation strategy

4.1 Household ASF consumption

To examine the relationship between livestock ownership and ASF consumption, we examine the value of consumption of different categories of ASF discussed in Section 3. Several empirical issues arise when assessing the relationship between livestock ownership and ASF consumption. First, households that own livestock may have unobservable characteristics that also influence ASF consumption. In addition, there may be simultaneous causality resulting from increased ASF consumption leading to increased livestock production or choice of ownership. Finally, while controlling for a measure of household welfare (such as total household per capita expenditure) can help control for differential ASF consumption due to differences in wellbeing across households, including such variable in the analysis may introduce potential endogeneity if there are omitted variables that affect both per capita household expenditure and ASF consumption simultaneously (simultaneity bias).

In this paper, we exploit the panel nature of our data and employ the Tobit model to estimate the effect of ownership of different types of livestock on ASF consumption. The use of a censored model is justified in that a significant proportion of households do not show any expenditure in ASF, while the rest show a positive level.[3] The latent variable will then be a mixture of zero and positive values, and the standard OLS model would not yield consistent estimates, as the censored sample will not be representative of the whole universe of households. To test the first hypothesis, that is whether the number of different types of livestock owned by households affects ASF consumption, we estimate the following household-specific effects model for different types of ASF using panel random effects:

$$(1) \quad BD_{it} = \beta_i + \beta_1 LargeRuminants_{it} + \beta_2 {LargeRuminants^2}_{it} + \beta'_3 \mathbf{H}_{it} + \beta_4 P_{it} + \beta_5 I_{it} + \beta_6 \boldsymbol{D}_i + u_i + \varepsilon_{it}$$

$$(2) \quad O_{it} = \alpha_i + \alpha_1 SmallRuminants_{it} + \alpha_2 {SmallRuminants^2}_{it} + \alpha'_3 \mathbf{H}_{it} + \alpha_4 P_{it} + \alpha_5 I_{it} + \alpha_6 \boldsymbol{D}_i + u_i + \varepsilon_{it}$$

$$(3) \quad C_{it} = \gamma_i + \gamma_1 Chickens_{it} + \gamma_2 Chickens_{it}^2 + \gamma'_3 \mathbf{H}_{it} + \gamma_4 P_{it} + \gamma_5 I_{it} + \beta\gamma_6 \boldsymbol{D}_i + u_i + \varepsilon_{it}$$

$$(4) \quad ASF_{it} = \delta_i + \delta_1 LargeRuminants_{it} + \delta_2 {LargeRuminants^2}_{it} + \delta_3 SmallRuminants_{it} + \delta_4 {SmallRuminants^2}_{it} + \delta_5 Chickens_{it} + \delta_6 Chickens_{it}^2 + \delta_7 \boldsymbol{H}_{it} + \delta_8 P_{it} + \delta_9 I_{it} + \delta_{10} \boldsymbol{D}_i + u_i + \varepsilon_{it}$$

Where *i* and *t* are indices for household and time, BD measures the value of beef or dairy consumption; *O* measures the value of consumption of sheep and goat meat, *C* measures of the value of chicken consumption, ASF is the total value of beef, dairy, chicken, and sheep and goat meat consumption. $LargeRuminants$ and $LargeRuminants^2$ are the number of large ruminants and its squared term, respectively; $SmallRuminants$ and $SmallRuminants^2$ are the number of small ruminants and its squared term, respectively; $Chickens$ and $Chickens^2$ are the number of chickens and other poultry and its squared term, respectively. The random effects are $u_i \sim N(0, \sigma_u^2)$ and $\varepsilon_{it} \sim N(0,\ \sigma_\varepsilon^2)$, with ε_{it} independent of u_i, so this model relies on the assumption of homoscedastic normally distributed error terms.

$\boldsymbol{H}$ is a vector of household characteristics, including the age of the head of the household, whether the head was female, whether any female member of the household owned or managed cattle, average adult years of education, the share of children under 10 years old and the share of elderly (over 60) in the household. Inclusion of composition variables should help control for household preferences. The variables $\boldsymbol{P}$ and $\boldsymbol{I}$ measure agricultural land and poverty, proxied by dummy by lower, middle and upper tercile of total per-capita household consumption expenditure, respectively. $\boldsymbol{D}$ is a vector of fixed effects for interview month, stratum of residence, agro-ecological zones (AEZ)[4], Normalized Difference Vegetation Index (NDVI)[5], and travel time from the community to the nearest town with at least 20,000 people, which summarizes the dimension of market access. $\alpha_i,\ \beta_i,\ \gamma_i, and\ \delta_i$ are our parameters of interest and u_{it} and ε_{it} are random error terms.

In each model, the squared term of each livestock type is included to detect possible non-linearity in the response of ASF consumption to increased numbers of livestock, with coefficient estimates expected to be negative. Consumption of households with low numbers of livestock should be affected significantly by a marginal increase of herd size, with a decreasing impact for households with large herds. In other words, we expect ASF consumption to increase at a decreasing rate with the number of livestock.

The use of the random effect Tobit model modifies the latent variable y_{it}^* in:

$$\boldsymbol{Y_{it}^* = X_{it}'\beta + u_i + \varepsilon_{it}}$$

where u_i and ε_{it} have the same statistical properties, while

$$Y_{it} = \begin{Bmatrix} Y_{it}^* & if\ Y_{it}^* > L \\ L & if\ Y_{it}^* \le L \end{Bmatrix}$$

for the left censoring point $L=0$.

The scalar $\rho = \sigma_u^2/(\sigma_u^2 + \sigma_\varepsilon^2)$ measures the proportion of the total variance $\sigma_u^2 + \sigma_\varepsilon^2$ explained by the random effect u_i. As ρ approaches zero, the panel-level variance component progressively becomes negligible, and the panel estimator reduces to the pooled estimator.

The assumption of zero correlation between the observed explanatory variables and the unobserved effect required by the random effects estimates are, however, very difficult to satisfy. For that reason, we re-estimated the same specification using the fixed effects Honorè’s estimator (Honorè, 1992). It is useful to present random effects and fixed effects results side by side, because while the assumptions behind the random effects are very strong and hard to satisfy in practice, fixed effects estimates may not be appropriate when there is little over-time variability within individuals (Wooldridge, 2010). In our case, we do not observe large variability in livestock ownership overtime: Households that were raising livestock in 2005/06, are likely still raising livestock in 2009/10. The risk is that a fixed effect model will be washing away the variability in livestock ownership across households, by lumping it in the fixed effects.

To further check a possible omitted variable bias, we run the same set of regressions a second time including controls for the ownership of livestock types that are not relevant for the production of a class of ASF (for example, large ruminants on the 'poultry meat' regression). We interpret the results of these regressions as akin to a "placebo" test. If only the relevant livestock types are statistically significant or positively correlated to each component of ASF, whereas the others are not, we interpret that as an indication that the effects picked up in the main regressions are not picking up a general wealth effect associated with livestock ownership. The implications and results of this approach are discussed in Section 5.

4.2 Child Nutritional Status

In order to test the second hypothesis, according to which ownership of livestock improves child nutritional outcomes, we estimate a Probit model for the stunting, wasting, and underweight child nutritional outcome measures discussed in Section 3. Through this model we aim to assess whether and how owning livestock of different types may relate to the odds of children under-5 being malnourished. The model can be written as:

$$(5) \quad \Pr(Y_i = 1|X_i) = \Phi(X_i\beta)$$

where $X_i = (C_i\,,\ P_i,\ H_i,\ O_i,\ D_i)$ and Φ is the standard cumulative distribution function.

We estimate three separate versions where the dependent variable is an indicator equal 1 if a child is either stunted, wasted, or underweight, and 0 otherwise. **C** is a vector of child characteristics (gender, age in months and its squared term, child of multiple birth, whether child is 24 months younger than older sibling, whether child slept under mosquito net last night, and whether child suffered some illness during the last 30 days), **P** is a vector of parental characteristics (age of the mother and its squared term, education of the mother, whether father is present in the household), **H** is a vector of household characteristics (per capita consumption expenditure, dependency ratio, number of females 20-59 years old, whether any female member of the household owned or managed cattle, whether the household suffered a drought during the last 12 months).

O is a vector of dwelling characteristics (whether the household has a good toilet, piped or protected water source, and sand or smoothed mud floor) and total rainfall between 2008 and 2009 (in centimeters). In the literature (Fewtrell & Colford, 2004) find a positive relationship has been documented between presence of basic hygiene and diarrhea, good water quality and flushing toilet facilities with better health outcomes (Strauss & Thomas, 1995). ***D*** is a vector of fixed effects for interview month, stratum, Normalized Difference Vegetation Index and its squared term, and agro-ecological zones. Robust standard errors are clustered at household level to account for potential intra-household correlation in the outcome measures.

It is widely accepted in nutrition studies (Sahn & Alderman, 1997; UN ACC/SCN, 1997; Garrett & Ruel, 1999) that the underlying causes of undernutrition for infants may differ from those of older children. Typically, nutritional and resource requirements vary with age in response to changes in diet and activities, and with gender due to biological reasons (FAO-WHO, 2004). For example, the importance of the mother's care and nurturing practices has an age dimension: food choice and preparation maters more for older children than for infants, who are more likely to be breastfed. We incorporate age differences in the analysis in two ways: by controlling for age of the child; and by splitting the sample into two groups and run separate regressions for children between zero to twenty-three and twenty-four to fifty-nine months of age.

As suggested in the literature (Deaton & Grosh, 2000), we use per capita expenditure to proxy for income (Y) in the two-stage least squares specification to test (and correct) for potential endogeneity.[6] We instrument per capita expenditure[7] by the highest level of educational attainment in the household if not the mother's (and the second highest level of educational attainment in the household if the highest is the mother's), whether the household head is polygamous, and the total rainfall in 2008-9. We maintain that our chosen excluded instruments fulfill the conditions of instrumental relevance and exogeneity, as they are good predictors of the endogenous regressor, while not being related to the child nutritional status variables.

While maternal education is strongly associated to child undernutrition, the mother being the main decision-maker on child nutrition and care practices, the education of adults in the household other than the mother is strictly correlated to income generation potential, but is often found to have limited or no direct impact on nutrition if not through income (Sahn & Alderman, 1997; Kabubo-Mariara, Ndenge, & Mwabu, 2009; Miller & Rodgers, 2009). Similarly, while the polygamy of the household head and the amount of rainfall are good predictors of household wellbeing, we argue that they do not directly affect child nutritional status, if not through income. This argument is also supported by previous studies using Uganda data. Vella et al. (1992) find no association between polygamy and child nutrition in North Uganda, while Asiimwe & Mpuga (2007) point to the large, direct impacts of rainfall on income in rural Uganda. Taken together with the results of the standard tests, this evidence provides robust support to the exogeneity claim of our choice of instruments.

5. Results

5.1. Tracking the Impacts of Livestock Ownership on ASF Consumption

Table 2 presents the results of the random effect panel Tobit model presented in equations (1) to (4) and of its fixed effect equivalent (Honorè estimator). The dependent variable changes as indicated in the column headings and is the annual household per capita value in PPP dollars for different classes of livestock products: beef, sheep and goat meat, poultry meat, dairy, and ASF. Table 3 presents the results of a similar set of models estimated through standard linear regression, for comparison. For each dependent variable and each estimator, the specification was gradually augmented with additional controls (total income, expenditure terciles, and expenditure tercile with different income types, with and without interaction). The basic idea in doing this is that, given the endogeneity concerns outlined in the previous section (and the difficulties in using an instrumental variable approach in Tobit models), gradually introducing controls for income, expenditure terciles, and their interaction would allow gauging the extent to which the observed effect on the relevant ASF consumption is a general wealth effect as opposed to an effect due to the other channels highlighted in the conceptual framework above. The tables present the specification with the complete set of controls (except the interactions), while the complete set of specifications is available in the online appendix (Tables A3-A7).

The first specification displays the association of the dependent variable to ownership of the relevant livestock type(s), conditional on basic household characteristics and dummies for expenditure terciles. Next, following Villa et al. (2010), we include variables for the different income components. If markets were perfect and income was fully fungible, the elasticity of the different income components should not differ. If the coefficients differ by income components, we then have reason to believe that this is linked to the existence of market imperfections[8], or mental accounting.

The random effects coefficient on the number of livestock owned are mostly significant in the parsimonious specifications, become substantially lower in magnitude when income levels are controlled for, but remain significant as additional control are added in the poultry meat, dairy, and ASF regressions. That is expected as these are the ASF items that are more frequently consumed and sourced from own consumption, whereas it is quite unusual for a household to slaughter a cattle for beef consumption. To quantify the effect of the right-hand side variables, the semi-elasticities shown for total ASF consumption need to be interpreted as a proportionate increase of one in the number of large ruminants (a doubling of large ruminants), being associated with 3.5 additional PPP international dollars of ASF consumption. It is to note that this quantitative impact is unconditional on the actual ownership of cows, and refers to the whole universe of households, including those not owning any large ruminants. None of the fixed effects coefficients on the number of livestock owned are significant.

A more consistent pattern can be traced in the magnitude of the coefficients on the other main variable of interest, income from livestock. In the random effect specifications this coefficient is positive and significant for all dependent variables except beef. In the fixed effects model it is significant in the poultry meat regression but also, more importantly, in the ASF regression. These results confirm the findings in Villa et al. (2010) on the differential dietary impact of different income components. Besides providing confirmation of those results, we maintain that these findings improve on that study which could not rely on detailed consumption expenditure data, but only on discrete information on whether or not households consumed certain food groups. Also, our study is based on a large, nationally representative sample as opposed to a relatively small scale study of specific regions and livestock systems. This makes our conclusions relevant for rural policy at a national level, and while specific to Uganda, we believe that the externally validity is both more likely, as well as more readily testable in future studies that will use nationally representative samples. The increasing availability of data of a similar nature across Sub-Saharan Africa holds promise for replicating this approach in other countries in the continent.

The endogeneity concern related to the possible income effect of the number of different livestock types owned on the consumption of ASF can be further tested assuming that the number of specific types of livestock owned does not affect the consumption of ASF not related to the specific type of livestock. For example, if no statistically significant (or statistically negative) relationship between number of large ruminants owned and chickens consumption is found, this result further corroborates the hypothesis that the impact of large ruminants does not materialize through an indirect income effect, but rather it has a direct effect on specific ASF consumption. These “placebo” tests indeed provide a strong indication of an independent impact, and are reported in an online appendix (Tables A8-A12). The number of large ruminants has a positive and significant effect only on beef, dairy and total ASF consumption, but no (or negative) effect on chicken and sheep and goat meat consumption. The number of chickens owned show a similar effect in all regressions except on sheep and goat meat consumption, an indication of a potential co-ownership of chickens and small ruminants. These findings confirm that the herd size bears a significant effect on ASF consumption after controlling of confounding factors, potentially endogenously correlated with our variable of interest.

Finally, we tried to account for differential gender roles by including a variable on whether any livestock are managed by female members. The information is however available only for cattle and only for the 2009/10 survey, and even there the variable is highly correlated to the gender of the household head. The estimated coefficient has the expected positive sign throughout, but is only significant in the more parsimonious specifications in the chicken, dairy, and ASF regressions. We conclude that the lack of significance in the estimated coefficient is inconclusive and likely due to the data limitations, and flag this issue for future research.

5.2 Child Nutritional Status

Tables 4 to 6 show the results of the Probit model specified as in equation (5) and report the probability that a child be stunted, wasted or underweight, respectively. Endogeneity test results from child outcome regressions show insignificant test statistics, except for underweight and for the 6-23 months wasting, suggesting absence of sufficient information in our sample to reject the null of exogeneity. Thus, a regular Probit provides unbiased and consistent estimates for all the other child nutritional outcomes and age groups. First-stage regression results are reported in the online appendix (Table A13).

The role of livestock appears to be restricted to underweight, rather than stunting. It is worth recalling that stunting is an indicator of long term malnutrition, wasting an indicator of acute weight loss, while underweight may result from different combinations of long and short term factors. All have been linked to increased risk of death (WHO, 2010). None of the livestock ownership coefficients is significant in the stunting regression. The ownership of small ruminants, on the other hand, appears to significantly reduce the probability of being wasted or underweight among children in the older age group, with the coefficient being stable across the Probit and Instrumental Variables (IV) Probit model. The coefficient is smaller but still significant for the entire 6 to 59 month sample (except for the instrumented underweight specification), but is never significant for the 6-24 month age bracket - which is consistent with the expected greater role for animal source food in the diet of relatively older children (Dror & Allen, 2011).

What is less straightforward to interpret is the positive association between the ownership of large ruminants and the probability of being underweight, also among children between 3 to 5 years of age. As recalled earlier, hygiene problems linked to livestock, livestock-borne disease, and the competition for foodstuff between human and livestock consumption may lead to a perverse effect of livestock on nutritional outcomes. Here we can just speculate that one of these explanations (or some combination) might be at play.

Regarding the lack of statistical significance on the variable on livestock management by female household members, the discussion on data limitation in the previous section still applies. Instrumented per capita expenditure is found to be significantly and negatively associated with wasting and underweight only for children under 2 years of age, with the value of estimated parameters of the IV model much larger than in the simple Probit estimate. This jump in size of the coefficient of the instrumented variable is common in the literature, and is consistent with measurement error in the consumption variable.

All in all, there appears to be some relationship between livestock ownership (particularly small ruminants) and child nutrition, but this relationship is not as clear cut as in the case of ASF consumption, and to some extent even points to a possible detrimental effect of large ruminant ownership on child weight gains. This finding confirms the existence of complex linkages between livestock and nutrition, which go beyond the simple effect on food consumption.

6. Conclusion

Increased consumption of ASF has many positive benefits, especially the addition of necessary micronutrients to the diet which have been shown to lead to long term improvements in income and productivity. This paper explored whether the type and number of livestock owned increase ASF consumption and improve child nutritional outcomes. Our results clearly indicate that there are significant differences in the consumption patterns of ASF between livestock owners and non-owners: The number of large ruminants owned or managed bears a positive effect on dairy consumption but insignificantly affects beef consumption. While the number of small ruminants has no statistically significant effect on consumption of goat and sheep meat, ownership of poultry affects chicken consumption positively. In particular, our results highlight a positive effect of the number of poultry on chicken consumption and of the number of large ruminants on diary consumption above and beyond the indirect effect of these livestock types through livestock income, controlling for welfare level (proxied by total per-capita consumption expenditure tercile).

Given the impact found on the structure of household consumption, our study goes a step further investigating whether the effect translates into better nutritional outcomes, focusing on children under 5 years of age. Beyond food consumption there are many other factors that affect child nutrition, including care, health, and sanitation elements. Some of these characteristics can also be adversely affected by the presence of livestock around the household (for instance when that leads to a higher incidence of livestock-borne diseases). It is therefore not guaranteed that an increase in household ASF consumption would translate into better nutritional outcomes for its members.

Indeed, we find only a weak association between livestock ownership and child nutritional status, specifically on the probability of being underweight and wasted (limited to children between 2 and 5 years of age), but no association to stunting. Also, while we find evidence that ownership of small ruminants reduces the probability of children of age 2 to 5 being underweight, we also find that ownership of large ruminants partly counters that effect.

One limitation of our results on child nutrition, is that we were not able to test the effect on other age groups that are also of concern from a nutritional point of view, such as women of reproductive age and lactating mothers. Moreover, we were not able to look at the impacts of livestock on other health outcomes related to nutrition, such as anemia and other outcomes related to micronutrient deficiencies. A possible hypothesis on the weak causality mechanism between increased household ASF consumption and improvements in child nutrition is linked to the competition on ASF consumption within the household. An alternative explanation is our missing focus on other important outcomes (for example a reduction in the prevalence of anemia) that the higher consumption of ASF could also affect. In terms of methodological insights, these two hypotheses call for future studies to look also into adult nutritional outcomes, individual level food consumption, and anemia prevalence.

Our results contribute to the rather slim literature on the relationship between livestock and human nutrition in that they rely on a large national panel dataset, with good level of detail on livestock ownership and food consumption, and good quality anthropometric data. We are not aware of previous studies on the topic that could rely on this suite of information. We also maintain that our results on the impact of type and number of livestock on ASF consumption are quite strong in suggesting that these links do materialize in a developing country context, likely characterized by pervasive market failures, such as rural Uganda.

In terms of relevance for policy and programming, the results suggest that promoting (small) livestock ownership has the potential for affecting human nutrition in Sub-Saharan African countries, but that direction and size of the effect is still controversial. In context where markets are imperfect, supporting livestock ownership may be conducive to improving diets by a direct access channel, as well as providing further livelihood opportunities and increased income. Any intervention posited on such goals should however carefully consider the possibility of site-specific adverse effects, to the extent that livestock may compete with humans for food resources, and that it may (if not adequately managed) contribute to an increase in the incidence of diseases among the human population. The effects on child nutrition seem also limited to children above 2 years of age, so that livestock does not seem to a reliable means for targeting younger children.

Further research is needed to investigate more fully the impacts on nutritional indicators other than child weight and height, and to explore the possible adverse effects livestock might have on nutritional outcomes through channels other than ASF consumption. Also, any intervention will likely have to factor in how gender role within the households play out in terms of the livestock/nutrition interaction, something we were not able to adequately disentangle with the data at hand. Finally, our conclusions are based on a national sample of Ugandan households, and their applicability to other contexts (in Africa and beyond) is limited in the absence of a broader set of studies confirming our findings. Within

Uganda, however, our results can be generalized, and therefore have some advantage in terms of external validity when compared to possible experimental, but smaller scale studies.

From a methodological point of view, our results point to the importance of being able to differentiate both animal types and ASF product types in order to gauge whether and to what extent herd size can lead to higher consumption of ASF. We were able to look into our main research question because of the complex design of the survey, which incorporated detailed information on livelihoods, livestock ownership, food consumption and anthropometric measurement within a panel design. Other data collection efforts for studies aimed at exploring this relationship ought to achieve at least the same level of complexity in survey design. Better still, future studies should incorporate more detailed information on gender roles in livestock ownership and management, as well as nutritional information on other key subgroups in the population, and on other nutritional outcomes.

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Tables and Figures

Table 1 Descriptive statistics

	2005/06						2009/10					
	All	Livestock Ownership		Expenditure Terciles			All	Livestock Ownership		Expenditure Terciles		
		Nonowners	Owners	Poorest Tercile	Second Tercile	Richest Tercile		Nonowners	Owners	Poorest Tercile	Second Tercile	Richest Tercile
Household-level variables												
Per capita value of Beef(PPP)[ǂ]	13.09	12.25	13.34	4.56***	12.23	19.24***	14.83	15.61	13.55	5.82***	12.36	22.49***
Per capita value of Chicken(PPP)	4.88	2.81***	5.67***	1.86***	4.53	8.45***	5.30	3.56**	6.43**	1.59***	5.55	8.79***
Per capita value of Goat and Sheep Meat(PPP)	3.83	2.86*	4.17*	2.18***	3.39	5.83***	3.69	1.61**	4.54**	1.34***	3.87**	3.08
Per capita value of Dairy(PPP)	11.19	10.76	11.23	3.94***	7.77***	19.71***	11.89	10.67	12.06	4.47***	11.2	17.20***
Per capita value of ASF(PPP)[#]	32.64	28.69**	34.41**	12.54***	27.92**	53.23***	35.00	31.45*	36.59*	13.23***	32.98	51.57***
Number of Large Ruminants	1.51		2.09***	1.12***	1.29***	3.41***	1.85		2.36***	0.82***	1.85***	4.48***
Number of Small Ruminants	2.37		3.30***	2.37**	2.40**	3.47***	2.41		3.24***	1.82***	2.79	4.02***
Number of of chickens, turkeys, ducks	5.01		6.92***	3.85***	6.73***	7.03***	5.55		7.39***	4.19***	5.99*	9.48***
Income from livestock	26.09	3.73***	34.64***	20.69**	22.58	31.21***	50.58	7.73***	64.94***	30.76***	47.65	52.56***
Income from crop	115.72	90.60***	124.10***	85.68***	113.07***	116.78***	151.17	110.56***	168.24***	127.16**	160.41***	120.81***
Income from agr. wage	48.40	93.28***	30.99***	58.59***	18.22	12.23**	27.98	56.96***	23.98***	30.87***	22.15	15.90***
Income from non-agr. wage	97.24	176.17**	65.89**	31.91	57.31	139.82**	95.09	241.51***	59.03***	48.24***	52.35**	128.53***
Income from self-employment	118.39	169.33	98.02	37.88***	67.74*	239.30***	97.11	102.23	97.49	47.57***	62.09	144.26***
Income from transfers	14.20	19.33***	12.17***	8.83*	9.82	13.67***	23.83	38.82***	20.67***	13.61***	15.60*	29.35***
Income -other-	0.41	0.24	0.47	0.21	0.2	0.64***	6.08	6.83	4.37	1.15***	2.18***	13.07***
Total Income	420.45	552.69***	366.31***	243.79***	288.95*	553.66***	451.84	564.64***	438.75***	299.36***	362.44	504.49***
Number of observations	*1923*	*510*	*1413*	*913*	*585*	*425*	*1926*	*465*	*1461*	*826*	*642*	*458*
Child-level variables												
Height-for-Age(Z-score)							-1.47	-1.52	-1.46	-1.70***	-1.5	-1.04***
Weight-for-Age(Z-score)							-0.89	-1.03**	-0.84**	-1.08***	-0.86	-0.58***
Weight-for-Height(Z-score)							-0.07	-0.25***	-0.02***	-0.13	-0.03	-0.01
Number of observations							*1225*	*235*	*990*	*459*	*454*	*312*

note: * significant at 10%; ** significant at 5%; *** significant at 1%

[ǂ] PPP stands for Purchasing Power Parity

[#] ASF stands for animal source foods. The per capita value of ASF is the sum of the per capita value of beef, chicken, dairy, and goat and sheep meat consumption

Table 2 Tobit panel semi-elasticity estimates on beef, chicken, sheep and goat meat, dairy, and animal source foods expenditure/year/capita (in Purchasing Power Parity)

	Beef		Goat and sheep meat		Chicken meat		Dairy		Animal source foods	
Variables	Random Effects Tobit	Fixed Effects Honore	Random Effects Tobit	Fixed Effects Honore	Random Effects Tobit	Fixed Effects Honore	Random Effects Tobit	Fixed Effects Honore	Random Effects Tobit	Fixed Effects Honore
Number of Large Ruminants	-0.18	1.98					5.71***	1.06	3.47***	0.25
	(1.12)	(1.50)					(0.60)	(1.59)	(0.92)	(5.00)
Number of Large Ruminants (squared)	-0.35	-0.96***					-0.96***	-0.34	-0.59**	-0.24
	(0.46)	(0.27)					(0.16)	(0.53)	(0.24)	(2.28)
Number of Small Ruminants			2.7	-6.15					0.47	-3.1
			(2.74)	(15.76)					(1.39)	(2.50)
Number of Small Ruminants (squared)			-0.33	0.59					0.02	0.12
			(0.71)	(2.98)					(0.36)	(0.77)
Number of of chickens, turkeys, ducks					9.88**	-11.21			-2.21	-4.99**
					(4.30)	(8.76)			(1.42)	(2.25)
Number of chickens, turkeys, ducks (squared)					-2.17	2.76			0.56*	0.73***
					(1.83)	(2.58)			(0.32)	(0.26)
Income from livestock	0.09	1.07	4.59***	12.24	4.36***	7.32*	1.85***	1.14	4.88***	5.19**
	(0.53)	(1.24)	(0.87)	(17.11)	(0.94)	(3.91)	(0.32)	(1.43)	(0.48)	(2.36)
Number of observations	3803	3803	3803	3803	3803	3803	3803	3803	3803	3803
Uncensored observations	1064		299		333		1275		2031	
Left-censored observations	2739		3504		3470		2528		1772	
Std dev time-level	65.65***		101.04***		107.31***		42.83***		71.95***	
Std dev panel-level	25.66***		30.13***		22.18***		22.58***		25.78***	
Log-likelihood	-7184.29		-2429.34		-2645.04		-7747.41		-12737.5	
Chi-squared	329.26		124.32		194.12		756.64		891.87	
Chi-squared for comparison test	11.93		1.27		0.31		38.53		15.11	
Rho	0.13		0.08		0.04		0.22		0.11	
Significance	0		0		0		0		0	

Note: All regressions control for agricultural land (hectares), average adult years of education, household (HH) head age, HH head gender, percentage (%) of HH members 4 years or younger, % of HH members between 5 and 10 years of age, percentage of HH members 60 years or older, indicator for ownership of cattle by female in the HH, travel time to the nearest town of 20,000 people, indicators for expenditure tercile group, and income from different sources (crop, agricultural wage, non-agricultural wage, self-employment, transfers and other sources). All regressions include fixed effects for interview month, stratum, normalized difference vegetation index, and agro-ecological zone.

* p<.1, ** p<.05, *** p<.01

Cluster-robust standard errors in parentheses

Table 3 Linear panel semi-elasticity estimates on beef, chicken, sheep and goat meat, dairy, and animal source foods expenditure/year/capita (in Purchasing Power Parity)

Variables	Beef		Goat and sheep meat		Chicken meat		Dairy		Animal source foods	
	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects	Fixed Effects
Number of Large Ruminants	-0.11	0.1					1.66***	0.47**	1.22***	0.35
	(0.17)	(0.31)					(0.15)	(0.24)	(0.33)	(0.56)
Number of Large Ruminants (squared)	0	-0.01					-0.02***	-0.01***	-0.01**	-0.01
	(0.00)	(0.00)					(0.00)	(0.00)	(0.01)	(0.01)
Number of Small Ruminants			-0.19	-0.21					-0.42	-0.69
			(0.12)	(0.22)					(0.33)	(0.53)
Number of Small Ruminants (squared)			0	0					0.01	0
			(0.00)	(0.00)					(0.01)	(0.01)
Number of of chickens, turkeys, ducks					0.07	-0.13			-0.40***	-0.62***
					(0.06)	(0.10)			(0.16)	(0.23)
Number of chickens, turkeys, ducks (squared)					0	0			0.01***	0.01**
					(0.00)	(0.00)			(0.00)	(0.00)
Income from livestock	0.01	0	0.04***	0.03***	0.02***	0.02***	0.03***	0.02***	0.10***	0.07***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Constant	1.87	-5.68	3.84	8.67*	-0.19	6.42	3.47	9.16*	8.34	21.05*
	(6.28)	(6.62)	(4.31)	(4.94)	(4.50)	(5.03)	(5.79)	(5.06)	(11.34)	(11.60)
Number of observations	3803	3803	3803	3803	3803	3803	3803	3803	3803	3803
Adj R-squared		-0.97		-0.97		-0.95		-0.94		-0.83
R-squared within	0.03	0.05	0.03	0.05	0.05	0.06	0.04	0.06	0.1	0.11
R-squared between	0.13	0.03	0.13	0.05	0.1	0.04	0.29	0.13	0.28	0.21
R-squared overall	0.09	0.04	0.08	0.04	0.07	0.04	0.21	0.11	0.21	0.17
Ancillary parameter	28.01	34.84	20.11	24.7	20.52	25.49	23.98	29.81	49.61	61.22
Std dev time-level	26.96***	26.96***	20.11***	20.11***	20.42***	20.42***	20.61***	20.61***	47.00***	47.00***
Std dev panel-level	7.61***	22.07***	0.00***	14.34***	1.95***	15.25***	12.26***	21.54***	15.88***	39.23***
Chi-squared	338.46		335.28		297.32		805.47		934.71	
Probability	0	0	0	0	0	0	0	0	0	0
Hausman-Chi-squared		39.64		60.57		30.02		140.48		80.94
Hausman-Chi-squared probability		0.06		0		0.27		0		0
Rho	0.07	0.4	0	0.34	0.01	0.36	0.26	0.52	0.1	0.41
F		3.06		3.02		3.71		3.84		7.01
F for error term		1.17		0.94		1.06		1.8		1.25

Note: All regressions control for agricultural land (hectares), average adult years of education, household (HH) head age, HH head gender, percentage (%) of HH members 4 years or younger, % of HH members between 5 and 10 years of age, percentage of HH members 60 years or older, indicator for ownership of cattle by female in the HH, travel time to the nearest town of 20,000 people, indicators for expenditure tercile group, and income from different sources (crop, agricultural wage, non-agricultural wage, self-employment, transfers and other sources). All regressions include fixed effects for interview month, stratum, normalized difference vegetation index, and agro-ecological zone.

* p<.1, ** p<.05, *** p<.01

Cluster-robust standard errors in parentheses

Table 4 Probit and Instrumental Variables (IV) Probit regression estimates on stunting

	Probit						IV-Probit					
	6 to 59 months olds moderate stunting		6 to 23 months olds moderate stunting		24 to 59 months olds moderate stunting		6 to 59 months olds moderate stunting		6 to 23 months olds moderate stunting		24 to 59 months olds moderate stunting	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Number of large Ruminants	0.003	0.010	-0.016	0.021	0.014	0.012	0.006	0.011	-0.007	0.026	0.018	0.013
Number of small Ruminants	-0.003	0.011	0.003	0.021	-0.006	0.013	0.000	0.012	0.021	0.031	-0.003	0.013
Female	-0.186**	0.078	-0.439***	0.142	-0.084	0.094	-0.174**	0.078	-0.421***	0.152	-0.069	0.097
Age of Child (in months)	0.044***	0.012	0.105	0.094	-0.028	0.038	0.045***	0.013	0.060	0.101	-0.032	0.042
Age in months (squared)	-0.001***	0.000	-0.002	0.003	0.000	0.000	-0.001***	0.000	-0.000	0.003	0.000	0.001
Child of multiple birth	0.126	0.321	0.737	0.657	-0.018	0.368	0.147	0.267	0.842	0.641	0.010	0.335
Child is 24 months younger of older sibling	0.204**	0.102	0.108	0.192	0.233*	0.127	0.209*	0.107	0.218	0.228	0.225*	0.129
Age of the mother	-0.051**	0.023	-0.083**	0.040	-0.045	0.033	-0.053**	0.024	-0.069	0.049	-0.051*	0.031
Age of mother (squared)	0.001*	0.000	0.001*	0.001	0.000	0.000	0.001*	0.000	0.001	0.001	0.000	0.000
Education of the mother	-0.003	0.013	-0.002	0.022	-0.012	0.015	0.005	0.016	0.023	0.033	-0.002	0.019
Father present in the household (HH)	0.019	0.116	-0.253	0.189	0.247	0.155	0.038	0.120	-0.275	0.218	0.268*	0.160
Dependency ratio	0.004	0.048	0.086	0.090	-0.012	0.058	-0.013	0.049	0.016	0.112	-0.028	0.058
% (#/HHsize) of females 20-34	-0.539	0.667	-0.177	1.151	-0.504	0.869	-1.299	0.948	-2.086	2.099	-1.364	1.125
% (#/HHsize) of females 35-59	-0.741	0.904	-0.307	1.575	-0.599	1.088	-1.161	1.030	-1.721	2.243	-0.995	1.240
Any cattle owned/controlled by female in the HH	-0.031	0.158	0.083	0.248	-0.070	0.189	-0.045	0.147	0.119	0.289	-0.112	0.184
Drought/irregular rains (past 12 months)	-0.021	0.096	0.003	0.165	-0.012	0.114	-0.023	0.090	0.013	0.178	-0.018	0.111
Household has good toilet	-0.158	0.111	-0.495**	0.203	-0.030	0.130	-0.143	0.109	-0.489**	0.217	-0.006	0.135
Household has piped water source	-0.063	0.108	-0.327*	0.182	0.050	0.128	-0.090	0.100	-0.349*	0.193	0.012	0.124
Household has sand or smoothed mud floor	0.147	0.138	0.073	0.243	0.147	0.162	0.083	0.159	-0.155	0.343	0.086	0.186
Child slept under mosquito net last night	-0.089	0.086	-0.148	0.151	-0.115	0.103	-0.109	0.082	-0.239	0.169	-0.126	0.102
Child w/illness last 30 days	-0.035	0.084	-0.153	0.162	-0.013	0.100	-0.030	0.085	-0.149	0.172	-0.002	0.104
Log of per-capita expenditure (at constant prices)	-0.188**	0.084	-0.210	0.136	-0.179*	0.108	-0.381	0.305	-0.848	0.682	-0.389	0.349
Constant	-1.979	2.004	-1.173	3.563	-1.768	2.756	0.228	3.722	5.887	7.760	0.733	4.561
Number of observations	1,232		419		813			1,220		414		806
Number of clusters		827		398		675		827		398		675
Log-Likelihood	-744.22		-221.54		-496.73							
Chi-squared		96.320		77.243		74.883		96.786		60.033		70.157
probability		0.000		0.001		0.001		0.000		0.035		0.004
Chi-squared for exogeneity								0.448		1.019		0.390
probability of exogeneity								0.503		0.313		0.532
Pseudo R2	0.070		0.149		0.076							

note: *** p<0.01, ** p<0.05, * p<0.1

Fixed effects for interview month, stratum, normalized difference vegetation index, and agro-ecological zone included

Robust standard errors are reported to account for potential intra-household correlation.

Endogenous variable (instrumented): log of per-capita expenditure.

Excluded instrument for expenditure: highest education if not mother; household head is polygamous; rainfall in 2008-09.

Table 5 Probit and Instrumental Variables (IV) Probit regression estimates on underweight

	Probit						IV-Probit					
	6 to 59 months olds moderate underweight		6 to 23 months olds moderate underweight		24 to 59 months olds moderate underweight		6 to 59 months olds moderate underweight		6 to 23 months olds moderate underweight		24 to 59 months olds moderate underweight	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Number of large Ruminants	0.015	0.010	-0.028	0.023	0.038***	0.013	0.026**	0.013	-0.015	0.034	0.046***	0.016
Number of small Ruminants	-0.028**	0.012	0.005	0.022	-0.051***	0.017	-0.016	0.016	0.046	0.035	-0.047**	0.021
Female	-0.009	0.087	-0.285*	0.152	0.171	0.112	-0.021	0.094	-0.350*	0.179	0.172	0.123
Age of Child (in months)	-0.010	0.013	-0.004	0.097	-0.089*	0.046	-0.007	0.014	-0.079	0.117	-0.092*	0.052
Age in months (squared)	0.000	0.000	0.001	0.003	0.001*	0.001	0.000	0.000	0.003	0.004	0.001*	0.001
Child of multiple birth	0.664*	0.374	0.519	0.430	0.693	0.480	0.752**	0.297	0.536	0.649	0.814**	0.377
Child is 24 months younger of older sibling	0.206*	0.120	-0.044	0.205	0.281*	0.154	0.237*	0.129	0.226	0.281	0.234	0.162
Age of the mother	-0.043*	0.025	-0.031	0.041	-0.082*	0.042	-0.033	0.027	-0.004	0.059	-0.079**	0.036
Age of mother (squared)	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.001*	0.000
Education of the mother	-0.011	0.015	-0.005	0.024	-0.013	0.019	0.015	0.019	0.041	0.038	0.009	0.025
Father present in the household (HH)	-0.196	0.136	0.028	0.211	-0.333*	0.178	-0.201	0.136	-0.077	0.258	-0.320*	0.181
Dependency ratio	-0.031	0.052	0.021	0.089	-0.046	0.067	-0.096	0.059	-0.144	0.132	-0.091	0.074
% (#/HHsize) of females 20-34	-1.805**	0.737	-1.498	1.229	-2.513***	0.934	-3.420***	1.155	-4.708**	2.257	-3.789**	1.490
% (#/HHsize) of females 35-59	-0.649	1.027	-1.307	1.711	0.112	1.252	-1.932	1.210	-4.046	2.506	-0.834	1.500
Any cattle owned/controlled by female in the HH	-0.217	0.177	-0.164	0.284	-0.277	0.209	-0.207	0.183	-0.187	0.360	-0.267	0.236
Drought/irregular rains (past 12 months)	-0.052	0.112	-0.024	0.175	-0.041	0.140	-0.034	0.109	0.046	0.212	-0.023	0.140
Household has good toilet	-0.067	0.128	-0.480**	0.218	0.138	0.162	0.046	0.132	-0.432*	0.242	0.272	0.182
Household has piped water source	0.039	0.121	-0.181	0.193	0.190	0.141	0.014	0.118	-0.211	0.222	0.173	0.153
Household has sand or smoothed mud floor	0.097	0.151	0.002	0.238	0.139	0.197	-0.109	0.198	-0.485	0.401	0.018	0.251
Child slept under mosquito net last night	-0.157	0.100	-0.163	0.165	-0.207	0.126	-0.202**	0.100	-0.276	0.189	-0.247*	0.132
Child w/illness last 30 days	0.091	0.094	0.064	0.179	0.073	0.122	0.106	0.104	0.137	0.207	0.068	0.133
Log of per-capita expenditure (at constant prices)	-0.144	0.093	-0.138	0.138	-0.163	0.123	-0.838**	0.378	-1.551**	0.779	-0.630	0.477
Constant	-1.405	2.223	1.173	3.582	-2.331	3.664	6.997	4.602	16.375*	8.734	3.939	6.203
Number of observations	1,231		419		812			1,206		410		796
Number of clusters		821		398		668		821		398		668
Log-Likelihood	-525.46		-189.98		-307.56							
Chi-squared		87.682		64.119		79.269		73.933		38.463		65.807
probability		0.000		0.016		0.000		0.002		0.627		0.011
Chi-squared for exogeneity								3.307		3.635		1.018
probability of exogeneity								0.069		0.057		0.313
Pseudo R2	0.073		0.123		0.114							

note: *** p<0.01, ** p<0.05, * p<0.1

Fixed effects for interview month, stratum, normalized difference vegetation index, and agro-ecological zone included

Robust standard errors are reported to account for potential intra-household correlation.

Endogenous variable (instrumented): log of per-capita expenditure.

Excluded instrument for expenditure: highest education if not mother; household head is polygamous; rainfall in 2008-09.

Table 6 Probit and Instrumental Variables (IV) Probit regression estimates on wasting

	Probit						IV-Probit					
	6 to 59 months olds moderate wasting		6 to 23 months olds moderate wasting		24 to 59 months olds moderate wasting		6 to 59 months olds moderate wasting		6 to 23 months olds moderate wasting		24 to 59 months olds moderate wasting	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Number of large Ruminants	-0.011	0.023	-0.042	0.036	0.009	0.026	0.001	0.023	-0.021	0.049	-0.004	0.036
Number of small Ruminants	-0.056**	0.024	0.004	0.029	-0.154***	0.044	-0.047*	0.028	0.055	0.051	-0.158***	0.060
Female	-0.176	0.118	-0.364**	0.179	0.053	0.181	-0.187	0.133	-0.454*	0.241	0.044	0.215
Age of Child (in months)	-0.057***	0.017	0.159	0.121	-0.017	0.073	-0.057***	0.020	0.108	0.154	-0.011	0.091
Age in months (squared)	0.001**	0.000	-0.007	0.004	0.000	0.001	0.001*	0.000	-0.005	0.005	0.000	0.001
Child of multiple birth	0.546	0.387	0.472	0.687	0.522	0.489	0.631*	0.377	0.340	0.843	0.310	0.594
Child is 24 months younger of older sibling	-0.030	0.160	-0.032	0.240	-0.003	0.233	0.044	0.192	0.334	0.376	-0.059	0.308
Age of the mother	0.130	0.080	0.150	0.108	0.095	0.106	0.135*	0.081	0.166	0.142	0.077	0.128
Age of mother (squared)	-0.002	0.001	-0.002	0.002	-0.002	0.002	-0.002	0.001	-0.002	0.002	-0.001	0.002
Education of the mother	0.034	0.021	0.039	0.032	0.017	0.029	0.055**	0.027	0.110**	0.051	-0.011	0.047
Father present in the household (HH)	0.105	0.190	0.205	0.258	0.224	0.275	0.093	0.203	0.077	0.365	0.212	0.357
Dependency ratio	-0.038	0.071	0.090	0.103	-0.281**	0.109	-0.086	0.091	-0.106	0.171	-0.236	0.156
% (#/HHsize) of females 20-34	-0.731	1.022	-1.402	1.576	-1.612	1.662	-2.112	1.741	-5.693*	3.170	-0.084	2.842
% (#/HHsize) of females 35-59	0.887	1.319	-0.225	2.013	0.854	2.103	-0.241	1.811	-4.222	3.487	1.874	3.088
Any cattle owned/controlled by female in the HH	-0.001	0.298	0.241	0.417	-0.113	0.414	0.010	0.290	0.178	0.489	-0.163	0.548
Drought/irregular rains (past 12 months)	-0.070	0.144	0.027	0.208	-0.165	0.199	-0.046	0.158	0.151	0.280	-0.163	0.252
Household has good toilet	-0.479***	0.155	-0.739***	0.245	-0.529**	0.220	-0.403**	0.175	-0.639*	0.326	-0.628**	0.296
Household has piped water source	-0.139	0.168	0.016	0.233	-0.337	0.262	-0.189	0.175	-0.044	0.284	-0.257	0.333
Household has sand or smoothed mud floor	0.116	0.200	0.157	0.278	0.098	0.294	-0.086	0.285	-0.520	0.545	0.303	0.466
Child slept under mosquito net last night	-0.257*	0.134	-0.093	0.199	-0.691***	0.191	-0.270*	0.142	-0.206	0.251	-0.653**	0.268
Child w/illness last 30 days	0.120	0.127	0.294	0.210	0.076	0.187	0.179	0.156	0.454	0.302	0.015	0.240
Log of per-capita expenditure (at constant prices)	-0.063	0.125	-0.369**	0.164	0.339*	0.192	-0.717	0.538	-2.335**	1.038	1.071	0.870
Constant	-11.596***	3.142	-11.623**	4.788	-12.995***	4.699	-4.473	6.999	6.768	11.689	-20.615*	12.034
Number of observations	1,214		413		801			1,202		408		794
Number of clusters		816		392		663		816		392		663
Log-Likelihood	-235.84		-112.91		-97.68							
Chi-squared		123.236		66.359		113.937		64.925		34.937		29.534
probability		0.000		0.010		0.000		0.013		0.772		0.926
Chi-squared for exogeneity								1.631		4.870		0.882
probability of exogeneity								0.202		0.027		0.348
Pseudo R2	0.154		0.206		0.217							

note: *** p<0.01, ** p<0.05, * p<0.1

Fixed effects for interview month, stratum, normalized difference vegetation index, and agro-ecological zone included

Robust standard errors are reported to account for potential intra-household correlation.

Endogenous variable (instrumented): log of per-capita expenditure.

Excluded instrument for expenditure: highest education if not mother; household head is polygamous; rainfall in 2008-09.

Notes

[1] Examples are papers in a 2003 Supplement of the *Journal of Nutrition*, and Villa et al. (2010).

[2] Child anthropometrics data are only for 2009/10 since the 2005/06 survey did not collect this information.

[3] The percentage of households with no expenditure is 71-73% for beef (depending on the year), 91-93 % for chicken, 90-94 % for goat and sheep meat, 65-68 % for dairy, and 45-49 % for animal source food.

[4] AEZs are geographical areas sharing similar climate characteristics (for example, rainfall and temperature) with respect to their potential to support (usually rainfed) agricultural production. They are often used to identify land suitable for rainfed cultivation and for the production of specific crops.

[5] It is a variable assessing the degree of live green vegetation in the observed area. Negative values of NDVI (approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Lastly, low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1). Here the NDVI is expressed as ten year average over the period 2000-2010 (NASA, 2011).

[6] We have also estimated linear models (ordinary least squares and two-stage least squares) for comparison, and provide these in an online appendix (Tables A14-A16)

[7] Per-capita expenditure is considered endogenous with respect to child malnutrition since the latter could be also considered a determinant of lower welfare status. The argument runs as follows: malnourished children need more care from their parents, who in devoting a greater share of their time to childcare may earn less and hence dispose of lower monetary resources for expenditure.

[8] Our regressions control for market access including a variable for travel time to the nearest town with at least 20 thousand people. In the random effects model, it has differential impact according to the livestock type, being negative for beef consumption (given the relative scarcity of this food item in rural areas), while positive for chicken consumption, reflecting the relative abundance of chickens in rural setting. The variable is time invariant and is therefore not included in the fixed effect estimates.

References

Asiimwe, B. & Mpuga, P. (2007). Implications of Rainfall Shocks for Household Income and Consumption in Uganda. *AERC Paper* 168. Nairobi, African Economic Research Consortium.

Alexandratos, N. & J. Bruinsma. (2012). World agriculture towards 2030/2050: the 2012 revision. *ESA Working paper* No. 12-03. Rome, FAO.

Allen, L. (2003). Interventions for Micronutrient Deficiency Control in Developing Countries: Past, Present, and Future. *The Journal of Nutrition*, 133, 3875S-3878S.

Ayele, Z., & Peacock, C. (2003). Improving Access to and Consumption of Animal Source Foods in Rural Households: The Experiences of a Woman-Focused Goat Development Program in the Highlands of Ethiopia. *The Journal of Nutrition*, 133, 3981S-3986S.

Bandiera.O, Burgess, R., Das, N., Gulesci, S., Rasul, I., & Sulaiman, M. (2013). Can Basic Entrepreneurship Transform the Economic Lives of the Poor?, *STICERD - Economic Organisation and Public Policy Discussion Papers Series* 43, London School of Economics.

Banerjee,A., Duflo, E., Chattopadhyay, R. & Shapiro, J. (2011). Targeting the Hardcore Poor: An Impact Assessment, *CGAP and Abdul Latif Jameel Poverty Action Lab (J-PAL) Working Paper*.

Bardhan, P. & Udry, C. (1999). *Development Economics*. New York: Oxford University Press.

Biesalski, H. (2005). Meat as a Component of a Healthy Diet – Are there any Risks or Benefits if Meat is avoided in the Diet? *Meat Science*, 70, 509–524.

Black, M. (2003). Micronutrient Deficiencies and Cognitive Functioning. *The Journal of Nutrition*, *133*, 3927S-3931S.

Brown, D. (2003). Solutions Exist for Constraints to Household Production and Retention of Animal Food Products. *The Journal of Nutrition*, 133, 4042S-4047S.

Bwibo, N. & Neumann, C. (2003). The Need for Animal Source Foods by Kenyan Children. *The Journal of Nutrition*, 133, 3936S-3940S.

Deaton, A. & Grosh, M. (2000). 'Consumption', in Grosh, M. & Glewwe, P (eds.) *Designing Household Survey Questionnaires for Developing Countries: Lessons from 15 Years of the Living Standards Measurement Survey*, Volume III. Chapter 5, Washington, DC, World Bank.

Demment, M., Young, M., & Sensenig, R. (2003). Providing Micronutrients through Food-Based Solutions: A Key to Human and National Development. *The Journal of Nutrition, 133*, 3879S-3885S.

DHS. (2011). Uganda Demographic and Health Surveys, 2011. Retrieved 17 September, 2013, from http://www.statcompiler.com.

Dror, D. & Allen, L. (2011). The Importance of Milk and Other Animal-source Foods for Children in Low-income Countries. *Food and Nutrition Bulletin*, 32(3), 227-243.

Dore, A., Adair, L., & Popkin, B. (2003). Low Income Russian Families Adopt Effect Behavioral Strategies to Maintain Dietary Stability in Times of Economic Crisis. *The Journal of Nutrition*, 133, 3469-3475.

FAO. (2011). *The State of Food and Agriculture 2010–2011. Women in Agriculture: Closing the Gender Gap for Development*. Rome: FAO.

FAO-WHO. (2004). *Human Energy Requirements*, Report of a Joint FAO/WHO/UNU Expert Consultation, Food and Nutrition Technical Report Series, FAO, Rome

Fewtrell, L. & Colford J. (2004). Water, Sanitation and Hygiene: Interventions and Diarrhoea: A Systematic Review and Meta-analysis, *HNP Discussion Paper*, World Bank, Washington, DC.

Fischer, T. (2003). The Livestock Revolution: A Pathway from Poverty? In Brown, A. (eds.). *The Livestock Revolution: A Pathway from Poverty*, Proceedings of a Conference Held at the ATSE Crawford Fund, Parliament House, Canberra. ATSE Crawford Fund.

Garrett, J. & Ruel, M. (1999). Are Determinants of Rural and Urban Food Security and Nutritional Status Different? Some Insights from Mozambique, *World Development*, 27(11), 1955-1975.

Gebhard, S. & Thomas, R. (2002). Nutritive Value of Foods, *Home and Garden Bulletin*, Number 72, U.S. Department of Agriculture, Agricultural Research Service, Washington, D.C., Government Printing Office.

Gerosa, S. & Skoet, J. (2013). 'Milk Availability: Current Production and Demand and Medium-term Outlook', in Muehlhoff, E., Bennett, A., & McMahon, D. (eds.) *Milk and Dairy Products in Human Nutrition*. Chapter 2. FAO, Rome.

Griffin, I. & Abrams, S. (2001). Iron and Breastfeeding. *Pediatric Clinic of North America*, 48, 401- 414.

Grosse, S. (1998a). *Farm Animals and Children's Nutritional Status in Rural Rwanda*, Paper Presented at the Symposium on Human Nutrition and Livestock, October 14. Heifer Project International, Little Rock, Arkansas, USA.

Grosse, S. (1998b). *Farm Animals, Consumption of Animal Products, and Children's Nutritional Status in Developing Countries*, Paper Presented at the Symposium on Human Nutrition and Livestock. October 14. Heifer Project International, Little Rock, Arkansas, USA.

Herbert, V. (1994). Staging Vitamin B12 (cobalamin) Status in Vegetarians. *The American Journal of Clinical Nutrition*, 59 (5 Suppl.), 1213S–1222S.

Honore, B. 1992. Trimmed Lad and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects, *Econometrica*, 60(3), 533-565.
Hop, L. (2003). Programs to Improve Production and Consumption of Animal Source Foods and Underweight in Vietnam. *The Journal of Nutrition, 133*, 4006S-4009S.
Hoppe, C., Andersen, G., Jacobsen, S., Molgaard, C., Friis, H., Sangild, P., & Michaelsen, K. (2008). The Use of Whey or Skimmed Milk Powder in Fortified Blended Foods for Vulnerable Groups. *The Journal of Nutrition*, 138(1), 145S-161S.
Iannotti, L. (2012). 'Milk and Dairy Programmes Affecting Nutrition', in Muehlhoff, E., Bennett, A. & McMahon, D. (eds.), *Milk and Dairy Products in Human Nutrition*, Chapter 7, FAO, Rome.
Jin, M. & Iannotti, L. (2014). Livestock Production, Animal Source Food Intake, and Young Child Growth: The Role of Gender for Ensuring Nutrition Impacts. *Social Science & Medicine*, 105:16-21.
Kabubo-Mariara, J., Ndenge, G. & Mwabu, D. (2009). Determinants of Children's Nutritional Status in Kenya: Evidence from Demographic and Health Surveys. *Journal of African Economies*, 18(3), 363-387.
Kariuki, J., Njuki, J., Mburu, S., & Waithanji, E. (2013). Women, Livestock Ownership and Food Security Women, in Njuki, J. & Sanginga, P. (eds.), *Livestock Ownership and Markets: Bridging the Gender Gap in Eastern and Southern Africa,* Chapter 7, International Livestock Research Institute and the International Development Research Centre.
Kennedy, G., Nantel, G., & Shetty, P. (2003). *The Scourge of "Hidden Hunger": Global Dimensions of Micronutrient Deficiencies*, FAO, Rome.
Key, N., Sadoulet, E., & de Janvry, A. (2000). Transaction Costs and Agricultural Household Supply Response. *American Journal of Agricultural Economics*, 82(2), 245-259.
Miller, J. & Rodgers, Y. (2009). Mother's Education and Children's Nutritional Status: New Evidence from Cambodia. *Asian Development Review*, 26(1), 131-165.
Muehlhoff, E., Bennett, A., & McMahon, D. (2013). *Milk and Dairy Products in Human Nutrition*. FAO, Rome.
Murphy, S. & Allen, L. (2003). Nutritional Importance of Animal Source Foods. *The Journal of Nutrition*, 133, 3932S-3935S.
NASA (2011). *Land Processes Distributed Active Archive Center (LP DAAC): MODIS Vegetation Indices version 5*. USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota.
Neumann, C., Harris, D., & Rogers, L. (2002). Contribution of Animal Source Foods in Improving Diet Quality and Function in Children in the Developing World. *Nutrition Research*, 22(1-2), 193–220.
Pandya, A. & Ghodke, K. (2007). Goat and Sheep Milk Products other than Cheeses and Yoghurt. *Small Ruminant Research*, 68, 193–206.
Pickering, H., Hayes, R., Ng'andu, N., & Smith, P. (1986). Social and Environmental Factors Associated with the Risk of Child Mortality in a Peri-urban Community in The Gambia. *Transaction of the Royal Society of Tropical Medicine and Hygiene*, 80 (2), 311-316.
Pimkina, S., Rawlins, R., Barrett, C., Pedersen, S. & Wydick, B. (2013). Got Milk? The Impact of Heifer International's Livestock Donation Programs in Rwanda, *Food Policy,* 44: 202-213

Randolph, T., Schelling, E., Grace, D., Nicholson, C., Leroy, J., Cole, D., Demment, M., Omore, A., Zinsstag, J., & Ruel, M. (2007). Role of Livestock in Human Nutrition and Health for Poverty Reduction in Developing Countries. *Journal of Animal Science*, 85: 2788-2800.

Robinson, T., Franceschini G., & Wint, W. (2007). *Gridded Livestock of the World*, FAO, Rome.

Sadler, K. & Catley, A. (2009). *Milk Matters: The Role and Value of Milk in the Diets of Somali Pastoralist Children in Liben and Shinile, Ethiopia*. Feinstein International Center, Tufts University and Save the Children, Addis Ababa.

Sahn, D. & Alderman, H. (1997). On the Determinants of Nutrition in Mozambique: The Importance of Age-specific Effects. *World Development*, 25 (4), 577-588.

Senauer, B. (1990). Household Behavior and Nutrition in Developing Countries. *Food Policy*, 15(5), 408-417.

Siekmann, J., Allen, L., Bwibo, N., Demment, M., Murphy, S., & Neumann, C. (2003). Kenyan school Children Have Multiple Micronutrient Deficiencies, but Increased Plasma Vitamin B-12 is the only Detectable Micronutrient Response to Meat or Milk Supplementation. *The Journal of Nutrition*, 133, 3972S‐3980S.

Singh, I., Squire, L. & Straus, J. (1986). *Agricultural Household Models*. Baltimore, MD: The Johns Hopkins University Press.

Sigman, M., McDonald, M., Newmann, C., & Bwibo, N. (1991). Prediction of Cognitive Competence in Kenya Children from Toddler Nutrition, Family Characteristics and Abilities. *Journal of Child Psychology and Psychiatry*, 32(2), 307-320.

Smith, J. Sones, K., Grace, D., MacMillan, S., Tarawali, S., & Herrero, M. (2013). *Beyond Milk, Meat, and Eggs: Role of Livestock in Food and Nutrition Security*. International Livestock Research Institute, Nairobi, Kenya.

Strauss, J. & Thomas, D. (1995). 'Human Resources: Empirical Modeling of Household and Family Decisions', in Behrman, J. & Srinivasan, T. (eds.), *Handbook of Development Economics*, Vol. 3., North-Holland, Amsterdam.

Taylor, J. & Adelman, I. (2003). Agricultural Household Models: Genesis, Evolution, and Extensions. *Review of Economics of the Household*, 1, 33-58.

UN ACC/SCN (United Nations, Administrative Committee on Coordination/Subcommittee on Nutrition). (1997). Third Report on the World Nutrition Situation. WHO, Geneva.

Vella, V., Nviku, A. & Marshall, T. (1995). Determinants of Nutritional Status in Southwest Uganda. *Journal of Tropical Pediatrics*, 41, 89-98.

Vella, V., Tomkins, A., Borghesi, A., Migliori, G.B., Adriko, B.C. & Crevatin E. (1992) Determinants of Child Nutrition and Mortality in Northwest Uganda. *Bulletin of the World Health Organization*, 70 (5), 637-643.

Villa, K., Barrett, C., & Just, D. (2010). Differential Nutritional Responses across Various Income Sources Among East African Pastoralists: Intrahousehold Effects, Missing Markets and Mental Accounting. *Journal of African Economies*, 20(2), 341-375.

WHO. (2010). *Nutrition Landscape Information System (NLIS) Country profile Indicators: Interpretation Guide.* Geneva, Switzerland.

Wijesinha-Bettoni, R., & Burlingame, B. (2013). 'Milk and Dairy Product Composition' in Muehlhoff, E., Bennett, A., & McMahon, D. (eds.) *Milk and Dairy Products in Human Nutrition*. Chapter 3, FAO, Rome.

Wiley, A. (2009). Consumption of Milk, but Not Other Dairy Products, Is Associated with Height among US Preschool Children in Nhanes 1999–2002. *Annals of Human Biology* 36(2), 125-138.

Wooldridge, J. (2010). *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, MA.

Ziegler, E. (2011). Consumption of Cow's Milk as a Cause of Iron Deficiency in Infants and Toddlers. *Nutrition Review*, 69 (Suppl. 1), S37-S42.