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ORIGINAL PAPER

Determinants of child nutritional status in the eastern province of Zambia: the role of improved maize varieties

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Abstract Using household survey data from a sample of 810 households, this paper analyses the determinants of children's nutritional status and evaluates the impacts of improved maize varieties on child malnutrition in eastern Zambia. The paper uses an endogenous switching regression technique, combined with propensity score matching, to assess the determinants of child malnutrition and impacts of improved maize varieties on nutritional status. The study finds that child nutrition worsens with the age of the child and improves with education of household head and female household members, number of adult females in the household, and access to better sanitation. The study also finds a robust and significant impact of improved maize varieties on child malnutrition. The empirical results indicate that adoption of improved maize varieties reduces the probability of stunting by an average of about 26 %.

Keywords Children's nutritional status · Stunting · Endogenous switching probit · Zambia

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Introduction

Malnutrition remains pervasive in many countries despite significant reductions in income poverty in recent years (Horton et al. 2008). More than 30 % of the developing world's population suffers from micronutrient deficiencies and approximately one-third of the children in developing countries are either underweight or stunted (World Bank 2008). Malnutrition is the largest single factor contributing to the global problem of disease and accounts for about 30 % of infant deaths (Headey 2013). Malnutrition also has adverse effects on the child's physical development, mental capacity, school performance, and reduces adult labour productivity and wage earnings, as well as overall economic growth (Apodaca 2008; Horton et al. 2008).

Malnutrition is widespread among children in Zambia and it is one of the leading contributors to the high burden of disease in the country (Masiye et al. 2010). According to the UNDP (2011), about 50 % of children under the age of five are stunted or too short for their age indicating chronic malnutrition, while about 19 % of Zambian children are underweight or too thin for their age.

Malnutrition principally results from the independent or combined effects of three elements: inadequate food availability, poor access to food by the hungry and poor food utilization (Staatz 2000). Food availability refers to the supply of food through adequate production (commercial and home produced), food aid, or food imports (Apodaca 2008). Food access on the other hand refers to whether a person has a socially recognized claim on the available supply of food. It follows therefore that owning productive assets for producing food and income both play a role in enabling people to have access to food. Food utilization depends on having adequate knowledge about how to prepare food in a way that preserves its nutritional value and to get it to those in the household who need it most.

The above implies that adoption of improved agricultural technologies can play an important role in reducing malnutrition. Adoption of modern agricultural technologies such as improved maize varieties has a positive and significant impact on crop yields as well as household welfare (Alene et al. 2009; Becerril and Abdulai 2010). Increased agricultural production through adoption of improved maize varieties increases the income earning opportunities for most poor households in rural areas, thereby improving access to food. According to Headey (2013), higher incomes raise expenditure levels on food, thereby increasing the quality and quantity of diets. Furthermore, income raises expenditure on nutrition-relevant non-food expenditures, such as health, sanitation, electricity, water, and housing quality.

The purpose of this paper is to analyse the determinants of chronic malnutrition (stunting) and to evaluate the impacts of improved maize varieties on stunting in eastern Zambia. The paper uses household survey data from a sample of 810 households and applies the endogenous switching probit (ESP) model to identify the determinants of child nutritional status and impact of improved maize varieties. We complement our results by also estimating the impacts of improved maize using semi-parametric propensity score matching (PSM).

The paper adds to existing literature on child nutrition and the nutritional impacts of improved agricultural technologies on malnutrition. A number of studies have looked at the determinants of child malnutrition in Africa (e.g. Christiaensen and Alderman 2004; Kabubo-Mariara et al. 2008; Masiye et al. 2010; Ssewanyana 2003; Asenso-Okyere et al. 1997). However, to our knowledge, none of the studies have tried to establish a causal link between improved agricultural technologies such as improved maize varieties and child malnutrition using rigorous impact evaluation methods except Zeng et al. (2014). They used Instrumental Variable (IV) methods to show that adoption of improved maize varieties improves the nutritional status of children in Ethiopia. One of the drawbacks of most IV methods is that they only assume an intercept effect which may under- or over-estimate the impacts of adoption. Zeng et al. (2014) also assumed that the characteristics and resources of adopters and non-adopters have the same impact on outcome variables (i.e., homogenous returns to their characteristics and resources). In this study, we control for selection and endogeneity biases that may potentially arise due to correlation between unobserved household characteristics and observed health outcomes using the ESP approach. The ESP model estimates two separate equations for adopters and non-adopters, thus allowing us to explore the differential effects of the two groups.

The remainder of the paper is organized as follows. The next section discusses child malnutrition in Zambia. The third section outlines the conceptual and empirical frameworks followed by a section presenting the data and descriptive statistics. The penultimate section presents the empirical results and the last section draws conclusions.

Child malnutrition and adoption of improved maize varieties in Zambia

Child malnutrition in Zambia

Child malnutrition rates in Zambia have long been high, but there has been a noticeable increase in the past decade. Although the burden of other infectious and preventable diseases is high and contributes significantly to child morbidity and mortality, nearly 52 % of all under 5 deaths in Zambia are attributed to malnutrition (UNICEF 2008). There are several factors that have been identified as causes of child malnutrition in Zambia, including household food insecurity, lack of access to health and other social services, especially among the poor and rural population, poor nutrition of mothers and frequent infections (Masiye et al. 2010; Sitko et al. 2011). Poverty coupled with current rising food and fuel prices, scarcity of food due to extensive crop loss owing to climate change effects such as flooding, and in some cases lack of knowledge on proper infant feeding practices further exacerbates the underlying chronic nutrition problems (UNICEF 2008).

Table 1 presents trends in the nutritional status of children in Zambia using anthropometric data from the Zambia Demographic Health Surveys (ZDHS) undertaken from 1992 to 2007 and the 2011 Zambia Human Development Report (ZHDR). Inspection of Table 1 shows that there was no consistent trend in the nutritional indices for children under the age of five over the past four ZHDS surveys (1992, 1996, 2002, and 2007). Wasting remained at roughly the same levels throughout. During the period between 1992 and 2002, Zambia experienced an increasing trend in the malnutrition levels as measured by stunting and underweight, coinciding with the time that the country experienced some droughts and unfavourable weather. However, the results of the 2007 ZDHS show a notable improvement in the nutritional status of children as measured by both the height-for-age and weight-for-age indices from the 2002 and 2007 ZDHS surveys. Although there was a significant reduction in stunting (45 %) and underweight (15 %) levels from 2002 to 2007, the stunting rates were still high relative to the average prevalence of child stunting of 39 % for 19 sub-Saharan African countries in the mid-nineties (Morrisson et al. 2002). The 2007 ZDHS further reveals that there were slightly more boys (48 %) than girls (42 %) who were stunted. Results from all the demographic health surveys show that the rural areas have more children who are suffering from malnutrition than those in urban areas. Among the nine provinces, eastern province has one of the highest rates of malnutrition in Zambia at 50 %, third only to central and Luapula provinces at 53 % and 59 %, respectively. Table 1 further show that the 2009 average stunting and underweight rates have started rising again, with stunting going up from 45 % to 50 % and underweight going up from 15 % to 19 %.

Table 1 Trends in the malnutrition levels of under-five children in Zambia, 1992–2009 (%)

Indicator	1992 (ZDHS)	1996 (ZDHS)	2002 (ZDHS)	2007 (ZDHS)	2009 (ZHDR)
Stunting	46	49	53	45	50
Wasting	6	5	6	5	-
Underweight	21	19	23	15	19

Note: ZDHS = Zambia Demographic Health Survey; ZHDR = Zambia Human Development Report

Source: UNZA, CSO and MII (1993, 2009), CSO, CBoH and ORC Macro (2003), UNDP (2011)

Adoption of improved maize varieties in Zambia

Improved maize varieties were introduced to smallholder farmers in Zambia in the 1970s and almost 60 % of the farmers have adopted these varieties to date (Kumar 1994; Tembo and Sitko 2013). Improved maize varieties consist of both hybrids and open pollinated varieties (OPVs). In simple terms, hybrid maize results from the fertilization of one maize plant by another genetically un-related plant (MacRobert et al. 2014) while OPVs are populations that breeders have selected for a very specific set of traits and generally they can be replanted up to three years without a decline in yields (Becerril and Abdulai 2010). Over the past three decades, more than 50 improved maize varieties have been developed by the Zambia Agricultural Research Institute (ZARI) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) (Kalinda et al. 2014). The eastern province of Zambia is one of the largest producers of maize in the country. For instance in the 2011–2012 season, the province accounted for 21 % of the total maize produced by small and medium scale farmers in Zambia (Tembo and Sitko 2013), second only to the Southern Province which contributed about 22 %.

Improved maize varieties have several advantages over local varieties which include, but are not limited to: higher yields; early maturation; uniform grain color and resistance to diseases. Most of the improved varieties in Zambia have an estimated yield advantage of 20–60 % over locals (Howard and Mungoma 1996). For instance one of the most popular varieties in the eastern province of Zambia is MRI 634, which was released in 2000 through the Zambia Agricultural Research Institute (ZARI). This is a medium maturing hybrid variety, with dent white grains and a potential yield of 10 tons per ha. Increased maize yields certainly play an important role in increasing incomes and reducing poverty through the sale of surplus maize. For example, recent studies in Zambia show that improved maize varieties have significantly increased income for adopters (Khonje et al. 2015; Smale and Mason 2014). Although there is enough evidence on the productivity and income effects of improved maize varieties, there is limited evidence on the nutritional impacts on children under the age of five.

Theoretical and empirical approaches

Theoretical framework

Figure 1 shows the pathway through which agriculture is expected to affect child nutritional status. The figure shows that there are two pathways through which adoption of improved maize varieties could affect child nutritional status. It is expected that improved maize adoption will lead to an increase in yields and consequently availability of more food for the household. On the other hand, improved maize adoption is expected to increase household income through the sale of surplus maize, which in turn translates into increased food expenditure on high calorie and protein foods, finally leading to improvement in child nutritional status (solid arrows in Fig. 1).

The other pathway involves the adoption of nutrition enhancing technologies, e.g. adoption of crops that are high in protein content. Consumption of such crops is expected to increase the intake of proteins which will translate into improved child nutritional status. In this study, we envisage that adoption of improved maize varieties will affect child nutritional status through both the household income pathway and the diet composition pathway. According to Dorosh et al. (2009), maize accounts for about 60 % of the national calorie consumption and serves as the dietary mainstay in central, southern, and eastern Zambia, hence in addition to income, we believe that adoption of improved maize varieties also serves as a proxy for food availability, providing the much needed calories and energy for children. The supply of child nutrition is a complex process, and it may involve multiple relationships, hence we cannot entirely rule out the nutrition effects through the diet composition pathway.

The challenge in this study is to estimate the causal effect of improved maize adoption on child nutrition (Fig. 1). One way is to compare the stunting levels for children from improved maize adopting and non-adopting households. However, just comparing stunting levels between adopters and non-adopters may be misleading, because there may also be differences in e.g. access to resources, sanitation and health services. Without controlling for these other factors the conclusions obtained from this type of analysis may be false. One way to control for other factors would be to regress the adoption variable on the outcome variable (stunting) with variables such as access to sanitation added as controls. However, because farmers often

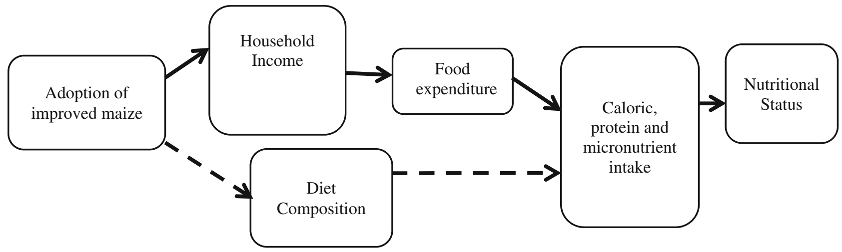

Fig. 1 Pathways of impact of agricultural interventions on child nutritional status (adapted from Masset et al. (2011))

self-select into the adopter category or some technologies are targeted to a given group of farmers, endogeneity problems may arise which may lead to biased estimates (Alene and Manyong 2007; Rao and Qaim 2011). Other methods such as instrumental variable (IV) regression can be used to account for endogeneity; however this method assumes technology adoption has an average impact on child nutrition over the entire sample of children, by way of an intercept shift in the child nutrition production function. Other factors such as education can also lead to an improvement in child nutrition by way of slope shifts in the nutrition production function but are not captured by IV type of regressions. To fully assess the differential effects of the above aspects, two separate equations for adopters and non-adopters have to be specified (Alene and Manyong 2007). Interactions between improved maize adoption and a set of explanatory variables at the same time accounting for endogeneity can only be effectively examined through the simultaneous endogenous switching regression model.

The endogenous switching probit model

The modelling of the impact of adopting improved maize varieties on child nutritional status using the ESP model proceeds in two stages. The first stage is the decision to adopt improved maize varieties and it is estimated using a probit model. In the second stage, a probit regression with selectivity correction is used to examine the relationship between the outcome variable (stunting) and a set of explanatory variables conditional on the adoption decision.

The observed outcome of the improved maize varieties adoption decision can be modelled in a random utility framework. Following Aakvik et al. (2000), Heckman et al. (2001) and Alene and Manyong (2007) let the adoption of the improved maize varieties be a binary choice, where a farmer decides to adopt improved maize varieties if the difference between the utility of adopting and not adopting improved maize varieties is positive. Let this difference be denoted as $I^* = U_1 - U_0$, where U_1 is the utility obtained from adopting improved maize varieties and U_0 the utility from not adopting improved maize varieties. The farmer will adopt improved maize varieties if $I^* > 0$. However, I^* is not observed, what is observed is I, a binary indicator that equals one if a farmer adopts improved and zero otherwise. More formally, the relationship can be expressed as;

$$\begin{aligned} I_i^* &= Z' \alpha + \varepsilon_i \\ I_i &= 1 \text{ if } I_i^* > 0, \\ I_i &= 0 \text{ if } I_i^* \leq 0. \end{aligned} \tag{1}$$

where Z is a vector of observed household and farm characteristics determining adoption; α is the vector of unknown parameters to be estimated; and ε_i the vector of random disturbances related with the adoption of improved maize varieties with mean zero and variance σ_i^2.

Following Lokshin and Sajaia (2011), the two outcome regressions equations, conditional on adoption can be expressed as;

$$\begin{aligned} &\text{Regime 1 (Adopters)}: && y_{1i} = \beta_1 X_{1i} + u_{1i} \text{ if } I_i = 1 \\ &\text{Regime 2 (Non-adopters)}: && y_{2i} = \beta_2 X_{2i} + u_{2i} \text{ if } I_i = 0 \end{aligned} \tag{2}$$

where y_{1i} and y_{2i} is our outcome variable, viz. stunting; X_{1i} and X_{2i} are vectors of weakly exogenous covariates; β_1 and β_2 are vectors of parameters; and u_{1i} and u_{2i} are random disturbance terms.

For the ESP model to be identified, it is important for the Z variables in the adoption model (eq. 1) to contain a selection instrument. We use distance to extension agent's office (minutes) and sources of variety information (government extension (1 = yes) and non-governmental organization extension (1 = yes)) as instrumental variables for the identification of the impact of adoption on child nutrition. We envisage that farmers are less likely to adopt improved maize varieties if they live far from the office of the extension agents because the further away, the more costs are incurred if the farmers are to access extension. Similarly, information variables affect the decisions to adopt improved agricultural technologies in Africa (Di Falco and Veronesi 2013; Di Falco et al. 2011). We envisage that these variables are correlated with the adoption of improved maize varieties, but are unlikely to directly affect the nutritional status of children. We follow Di Falco et al. (2011) in establishing the admissibility of these instruments; if a variable is a valid instrument, it will affect the decision to adopt, but it will not affect the stunting levels of children among households that did not adopt. The results[1] show that three variables can be considered as valid

[1] Since the treatment and outcome variables are both binary, we used a probit regression model to test validity of the instrumental variables. The results from these tests are not discussed because of limited space but are available on request

instruments because they are jointly statistically significant in explaining the adoption decision [$\chi 2 = 13.17$ ($p = 0.004$)] but are not statistically significant in explaining the outcome equation [$\chi 2 = 5.61$ ($p = 0.133$)].

The estimation of β_1 and β_2 above using a probit regression may lead to biased estimates because of self-selection into the adopter or non-adopter categories resulting from the non-zero covariance between the error terms of the adoption decision equation and the outcome equation (Abdulai and Huffman 2014). The error terms (u_1, u_2, ε) are assumed to have a joint normal distribution with mean vector zero and correlation matrix;

$$\Omega = \begin{bmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{bmatrix} \tag{3}$$

where ρ_0 and ρ_1 are the correlations between the error terms u_1, ε_i and u_2,ε_i and ρ_{10} is the correlation between of u_1 and u_i. We assume that ρ_{10}=1, since α is estimable only up to a scalar factor.

Estimation of average treatment effects

The endogenous switching probit model can be used to estimate the average treatment effects on the treated (ATT) and the average treatment effect of the untreated (ATU) by comparing the expected values of the outcomes of adopters and non-adopters in actual and counterfactual scenarios. Following Aakvik et al. (2000), and Lokshin and Sajaia (2011), we calculated the ATT and ATU based on the expected outcomes, conditional on adoption:

Adopters with adoption (actual expectations observed in the sample)

$$E(y_{1i}|I=1;X) \tag{4a}$$

Non-adopters without adoption (actual expectations observed in the sample)

$$E(y_{2i}|I=0;X) \tag{4b}$$

Adopters had they decided not to adopt (counterfactual expected outcome)

$$E(y_{2i}|I=1;X) \tag{4c}$$

Non-adopters had they decided to adopt (counterfactual expected outcome)

$$E(y_{1i}|I=0;X) \tag{4d}$$

The average treatment effect on the treated (ATT) is computed as the difference between (4a) and (4c);

$$ATT = E(y_{1i}|I=1;X) - E(y_{2i}|I=1;X) \tag{5}$$

The average treatment effect on the untreated (ATU) is given by the difference between (4d) and (4b)

$$ATU = E(y_{1i}|I=0;X) - E(y_{2i}|I=0;X) \tag{6}$$

Previous studies that have used the ESP model include; (Ayuya et al. 2015; Gregory and Coleman-Jensen 2013; Lokshin and Glinskaya 2009).

The propensity score model

The ESP model can sometimes be sensitive to exclusion restriction assumptions, hence, to check the robustness of the ESP results, we also estimated the ATTs using the propensity score matching approach.

Following Becerril and Abdulai (2010) and Caliendo and Kopeinig (2008), let Y_{iA} and Y_{iN} denote child stunting in household i that adopts an improved variety and the household that does not adopt an improved variety, respectively. In reality, only Y_{iA} or Y_{iN} are observed at one particular time and not both. Let T represent a binary treatment variable that equals one if a farmer adopts an improved variety and zero otherwise. The observed stunting can be expressed as;

$$Y_i = T_i Y_{iA} + (1-T_i) Y_{iN} \ \mathrm{T} = (0,1) \tag{7}$$

Furthermore, let P be the probability of observing a household with $T = 1$. The Average Treatment Effect (ATE) can be expressed as follows;

$$\begin{aligned} ATE = P.[E(Y_A|T=1) - E(Y_N|T=1)] \\ + (1-P).[E(Y_N|T=0) - E(Y_N|T=0)] \end{aligned} \tag{8}$$

The ATE is the weighted average effect of adoption on the population, which is simply the difference of the expected outcomes after adoption and non-adoption (Caliendo and Kopeinig 2008). However since the counterfactual mean $E(Y_N| T = 1)$ is not observed, one has to choose a proper substitute for it in order to estimate ATT (Caliendo and Kopeinig 2008). According to Caliendo and Kopeinig (2008), using the mean outcome of untreated individuals $E(Y_N| T = 0)$ in non-experimental studies is usually not a good idea because it is most likely that components which determine the treatment decision also determine the outcome variable of interest. To address this problem, the Propensity Score Matching (PSM) approach is used. The propensity score is defined as the conditional probability that a farmer adopts the new technology, given pre-adoption characteristics (Rosenbaum and Rubin, 1983). The PSM employs the unconfoundedness assumption also known as conditional independence assumption (CIA) or selection on observables assumption. This assumption implies that systematic differences in outcomes between adopters and comparison individuals with same values for covariates are attributable to adoption thereby making adoption random and uncorrelated with the outcome variables (Ali and Abdulai 2010; Caliendo and Kopeinig 2008). The propensity score can be expressed as;

$$p(X) = \Pr(T = 1|X) = E(T|X); \mathrm{p}(X) = F\{h(X_i)\}, \quad (11)$$

where X is the multidimensional vector of pre-treatment characteristics (same as Z in eq. 1 above); and F {.} is the cumulative distribution function. If the $p(X)$ is known, then the ATT can be estimated as follows:

$$\begin{aligned} ATT &= E\{Y_{iA} - Y_{iN}|T = 1\} \\ &= E[E\{Y_{iA} - Y_{iN}|T = 1, p(X)\}] \\ &= E[E\{Y_{iA}|T = 1, p(X)\} - E\{Y_{iN}|T = 0, p(X)\}|T = 1] \end{aligned} \quad (12)$$

where the outer expectation is over the distribution of ($p(X)$ $|T=1$) and Y_{iA} and Y_{iN} are the potential outcomes in the two counterfactual situations of adoption and no adoption respectively.

Data, variable specification and descriptive statistics

Survey design and data collection

The data used in this paper come from a survey of 810 sample households conducted in January and February 2012 in the eastern province of Zambia. This was a baseline[2] survey conducted by the International Institute of Tropical Agriculture (IITA) and the International Maize and Wheat Improvement Centre (CIMMYT) in collaboration with the Zambia Agricultural Research Institute (ZARI) for the project entitled Sustainable Intensification of Maize-Legume Systems for the eastern province of Zambia (SIMLEZA). A survey questionnaire was prepared and administered by trained enumerators who collected data from households through personal interviews. The survey was conducted in the same SIMLEZA project districts in eastern Zambia — Chipata, Katete, and Lundazi — which were targeted by the project as the major maize and legume growing areas. In the first stage, each district was stratified into agricultural blocks[3] (8 in Chipata, 5 in Katete and 5 in Lundazi) as primary sampling units. In the second stage, 41 agricultural camps were randomly selected, with the camps allocated proportionally to the selected blocks and the camps selected with probability of selection proportional to size. Overall, 17 camps were selected in Chipata, 9 in Katete and 15 in Lundazi. A total sample of 810 households

Table 2 Distribution of sample households by district and gender

District	Number of blocks	Number of camps	Female-headed	Male-headed	All
Chipata	8	17	129	205	334
Katete	5	9	63	117	180
Lundazi	5	14	98	198	296
All	18	40	290	520	810

was selected randomly from the three districts with the number of households from each selected camp being proportional to the size of the camp (Table 2).

The selected sample of 810 households was surveyed using a semi-structured questionnaire. Of the 810 households, 444 households provided anthropometric data on 752 children of ages 3–60 months. The weight of the children was measured using a standard scale. The standing height as opposed to recumbent length was measured using a measuring ruler, preferred mainly for ease of use. Table 3 shows the total number of 670 children who were considered in the analysis since extreme or biologically implausible z-scores were removed as recommended by Masiye et al. (2010)). The extreme values for height-for-age z-scores (HAZ) were those which were below −6 or above 6.

Variable specifications in the outcome and selection equations

The dependent variable in our nutritional status model is stunting representing children who have low height-for-age z-score index, i.e. a z-score below −2. Stunting is preferred to the weight-for-height z-scores (WHZ) and weight-for-age z-scores (WAZ) indices because it represents the prevalence of long-term growth failure. The WHZ is a condition that usually reflects severely inadequate food intake and infection happening at present and, as such, it is recommended that WHZ should be regressed on flow and not stock variables (Christiaensen and Alderman 2004). Weight-for-age on the other hand is a compound measure of height-for-age and weight-for-height which reflects body mass relative to age and thus making interpretation difficult (O'Donnell et al. 2008).

Table 3 Distribution of sample children by district and gender

	Gender of Child		
District	Female	Male	All
Chipata	140	137	277
Katete	51	64	115
Lundazi	161	117	278
All	352	318	670

[2] A follow up survey will be conducted in 2015 where the same household who were interviewed at baseline will be interviewed.

[3] A camp is a catchment area made up of 8 different zones consisting of villages and is headed by an agricultural camp officer. A block is made up of camps and is managed by an agricultural block officer.

Child characteristics

The explanatory variables relate to child, household, community and agricultural characteristics. Child level covariates include gender, age and whether or not the child had suffered from diarrhea in the past year. Some evidence from previous studies in Sub-Saharan Africa shows that boys are more likely to be stunted than girls (Ojiako et al. 2009; Sanginga et al. 1999; Svedberg 1990). However, some studies in Asia (e.g. Kumar et al. 2006) show that girls are more stunted than boys; hence the impact of gender on stunting is indeterminate. Age of the child is an important determinant of the physiological characteristics which convert consumption into nutrition and nutrition into higher productivity and, therefore, higher earning potential (Sarmistha 1999). Younger children are expected to have better nutritional status than the older children following commonly observed patterns in developing countries, explained by better child care and better feeding practices for younger children and exposure of older children to relatively harsh environments (Sanginga et al. 1999). Illness of a child is hypothesised to negatively affect child nutrition. Diarrhea (proxy for illness) is expected to be inversely related to child nutritional status because it causes nutrients to flush through the intestinal tract too quickly to be absorbed (Apodaca 2008). A repeatedly sick child may not consume adequate levels of food, which can result in growth retardation.

Household characteristics

Household characteristics include: age of the household head; gender of the household head; marital status of the household head; household size; education of the household head; highest grade attained by the most educated female of the household; number of household members above 65 years; number of household members below 15 years; number of adult females in the household (16–65 years old); household assets; cooperative membership (group membership); kinship and political connections. The gender of the household head is measured by a dummy variable equal to one for male headed households and zero for female headed households. Men are generally believed to be less involved than women in taking care of children and providing for their families' food needs (Onyango et al. 1994). However, past studies have also shown that female headed households are usually poor relative to their male counterparts and therefore expenditure on child related nutrition is expected to be less than in male headed households. We therefore expect the sign on the gender of the household head to be either negative or positive. Similarly we expect the marital status of the household to have a positive effect on the nutritional status of children because children will have good care as both parents can take turns in looking after the child. Parental education is assumed to have a direct positive link to child nutrition through better childcare practices and resource allocation in the household. Education affects care giving practices through the ability to acquire skills and the ability to model behaviour (Chirwa and Ngalawa 2008). In addition, to account for potential intra-household externalities from education, which are especially important in households at low education levels (Christiaensen and Alderman 2004), we posit that the presence of educated female household members will have a positive effect on child nutritional status. It is assumed that household members who at least completed primary school are in a better position to comprehend and apply information related to children's health.

Information gleaned from the literature shows that large family sizes impact negatively on nutritional status and household welfare in that the percentage of children under five, relative to total household size, reflects the burden of care in terms of nutrition finance, and parental time, and thus affects nutrition outcomes (Ajieroh 2009). Household assets are often used as a proxy for household wellbeing or resources and some studies have shown that it is a positive determinant of child nutritional outcomes (Kabubo-Mariara et al. 2008). Greater assets at household level allow people to spend more on important aspects of child nutrition such as health care, hygiene, food and clean water (Alderman et al. 2005). We also expect the nutritional status to reduce with an increase in the number of household members below 15 years and above 65 (dependants) because with an increase in the number of dependants, we expect a greater burden on household resources for food consumption.

Group membership, kinship (number of relatives) and the number of relatives or friends in leadership positions (political connections) represent the household social networks. Previous studies have shown that cooperative group membership indicates the intensity of contacts with other farmers (Adegbola and Gardebroek 2007) hence we expect farmers who are members of a group to have more information on improved maize varieties. Membership is therefore hypothesized to be positively associated with better child nutrition. Households with more relatives are more likely to have children who are better nourished as the household may have relatives they can rely on for critical support. However, an increase in the number of relatives may also come at the expense of income growth, which may negatively affect the the nutritional status of children. Therefore the sign on kinship is indeterminate. Similarly we expect households with political connections to have children who are well nourished as they can obtain support from their influential relatives/friends in times of problems.

Agricultural characteristics

To capture farm characteristics, we included adoption[4] of improved maize varieties, total land cultivated and distance to the nearest market. Adoption of improved maize varieties is expected to improve the nutritional status of children by

[4] An adopter in this study is defined as any farmer who planted or allocated land to at least one improved maize variety consistently for the past three years prior to the survey

promoting a link between food security and nutrition security (World Bank 2008). Adoption of improved maize varieties leads to higher yields which in turn improves the food security status of farmers as well as increased income through sale of surplus food. The demand for productive agricultural land has been growing, partly due to the growing population in many developing countries. The more arable land under permanent crops or pastures, the more food there is and this in turn allows greater access to nutrition by increasing the availability of food (Apodaca 2008). Distance to the nearest market reflects the transaction costs that the household incurs, such that the greater the distance, the higher the costs. We therefore expect distance to the nearest market to be negatively related with the nutritional status of the child.

Community characteristics

Sanitary conditions in the community are usually reflected in the percentage of households using toilets and the percentage of households who have access to safe drinking water from taps and deep, well protected wells. Access to good toilet and safe drinking water facilities is expected to affect nutrition in a positive way as some studies have shown (Glewwe et al. 2002; Christiaensen and Alderman 2004; Chirwa and Ngalawa 2008). Access to good sanitation may prevent the occurrence of infectious diseases such as diarrhea, dysentery and cholera which can adversely affect child nutrition.

The distance to the health centre approximates the availability and costs of health services; therefore we expect the distance to the nearest health centre to be inversely related to the child nutritional status.

Factors that are hypothesised to affect adoption of improved maize varieties include household and social network characteristics mentioned above. For a detailed description of the hypothesized relationships between adoption and the variables used in the selection equation see Feder et al. (1985) and Kassie et al. (2013).

Socioeconomic characteristics of the sample households

Table 4 presents the characteristics of households in eastern Zambia. Considering all three districts, i.e. Chipata, Katete and Lundazi, on average 56 % of the children were stunted, with Katete having slightly more with 57 %. Table 4 further shows that about 23 % were severely stunted, with Lundazi having the largest percentage of 26 % of the severely stunted children. The average stunting rate (56 %) for the three districts was higher than the average for the eastern province of Zambia (50 %) partly because we only considered three districts out of the 9 districts available in the province. Table 4 further shows that in our sample, about 53 % of the children were girls with Lundazi having the highest number of almost 60 %. The results also show that the average age of the children in the sample was 33 months and at least 60 % of the children had diarrhea the year preceding the survey. Lundazi had the highest number of children who had diarrhea with 73 %, followed by Katete with 52 % and this could be one of the reasons as to why these districts had relatively higher percentages of stunted children compared to Chipata district.

The average household size was 7.3 persons and across districts it ranged from 8 persons in Lundazi to 6.6 persons in Katete with Chipata having 7.4 persons per household. At national level,

Table 4 Mean values of social economic characteristics of the sample households

District	Chipata	Katete	Lundazi	All
Child characteristics				
Normal stunting (> −2)	0.53	0.57	0.56	0.56
Moderate stunting (−3 to −2)	0.14	0.10	0.14	0.13
Severe stunting (< −3)	0.20	0.22	0.26	0.23
Child age (months)	31.98	33.38	33.98	33.11
Had diarrhea in the past one year (1 = yes)	0.52	0.54	0.73	0.60
Gender (1 = male)	0.49	0.56	0.42	0.49
Household characteristics				
Gender of household head (1 = male)	0.68	0.70	0.71	0.69
Marital status (1 = married)	0.85	0.87	0.92	0.89
Total household size (number)	7.38	6.56	7.99	7.31
Household completed primary school (1 = yes)	0.70	0.71	0.52	0.63
Asset per capita (000` ZMK)	1.06	1.34	1.30	1.23
Highest grade completed by most educated female (years)	6.68	6.30	7.47	6.94
Highest grade of most educated male (years)	7.55	6.83	8.66	7.67
Number of adult females in the household (16–65 years old) (number)	1.65	1.50	1.89	0.17
Number of household members above 65 years	0.21	0.14	0.22	0.20
Number of household members below 15 years	4	4	5	4
Kinship (number of relatives)	4	4	3	4
Household has political connections (1 = yes)	0.66	0.60	0.62	0.63
Group membership (cooperative) (1 = yes)	0.91	0.83	0.96	0.92
Agricultural characteristics				
Total cultivated land (ha)	3.22	3.37	5.38	4.14
Adoption of improved maize varieties (1 = adopted)	0.11	0.14	0.22	0.15
Distance to nearest market (minutes)	441	237	450	410
Community characteristics				
Distance to the nearest health center (minutes)	61.09	72.62	85.65	73.26
Access to toilets (sanitation) (1 = yes)	0.21	0.28	0.13	0.21
Access to safe water (1 = yes)	0.18	0.10	0.18	0.15

[a] ZMK = Zambian Kwacha

the average household size in Zambia in 2010 was 5.2 persons (CSO 2012), lower than the average in Table 4. Inspection of Table 4 reveals that most of the household heads completed primary school education with an average of 63 %. To control for household resources, we included total household assets per capita. On average, the value of assets for the households was about ZMK1.23 million (US$236),[5] with Katete having the highest with ZMK1.34 million (US$258). Households in Chipata on the other hand had the lowest assets per capita with a total asset value of ZMK1.06 million (US$204). Most of the farmers belonged to a cooperative group with an average of about 93 %, with Lundazi having the highest percentage of 96 %.

As stated earlier, agriculture is a major source of livelihood and a key determinant of food security in rural areas. On average about 14 % of the households adopted improved maize varieties, with Lundazi having the largest percentage of 20 %. The ownership of land by households is an indicator of the household's ability to withstand economic shocks and is also commonly used as a proxy for household income. Chipata had the lowest area of cultivated land per capita (3.22 ha) while Lundazi had the highest with 5.38 ha. One of the reasons why Chipata had the lowest cultivated land is that among the three districts, Chipata is the most densely populated district and hence there is more pressure on the land. According to CSO (2012), Chipata district contributed about 27 % to the population of the eastern province of Zambia, which was the largest amongst the three districts. Lundazi, on the other hand, is sparsely populated and therefore most farmers own relatively large pieces of land. However, owning large pieces of land may not necessarily translate into higher incomes as in the case of Lundazi, because it may also have to do with the quality and the capacity to work the land.

Table 4 also shows that, on average, 28 % of the households had access to toilet facilities in Katete and only 13 % in Lundazi. Similarly, Chipata and Lundazi had the highest proportion of farm households who had access to drinking water with 18 %. This is plausible because Chipata and Lundazi are relatively more urban than the Katete district.

The distribution of stunting by age and gender is presented in Table 5. WHO (1995) recommends that at least two age disaggregations be used, under 24 months and 24 months and over. The reason is that patterns of growth failure vary with age and the identification of determinants of malnutrition is facilitated. More girls (55 %) in the 0–23 age category were stunted than boys (36 %). Overall, the results show that the scourge of malnutrition affects older children (60 %) more than younger ones (47 %). This finding is consistent with other studies on the nutritional status of children in Africa (e.g. Ssewanyana 2003; Kabubo-Mariara et al. 2008).

Table 6 shows the relationship between adoption of improved maize varieties and child stunting. Non-adopting households had more children who were stunted (57 %) than those who adopted improved maize varieties (51 %). This may imply that improved maize adoption has an effect on child stunting, although we may not make a causal inference at this stage.

[5] Exchange rate at the time of the survey: 1US$ = ZMK5,1974

Table 5 Child stunting by age and gender in eastern Zambia

Age (months)	Male	Female	All
0–23	0.38	0.55	0.47
24–60	0.61	0.60	0.60

Empirical results

Determinants of child malnutrition

The estimated parameters for the endogenous switching probit (ESP) model, revealing the factors that affect child nutritional status, are presented in Table 7. Estimates for the first stage regression for the determinants of improved maize adoption are presented in the Appendix in Table 10 and to conserve space, the results will not be discussed here.

Child, household and community characteristics have differential impact among adopters and non-adopters (Table 7). Among the child characteristics, only age (for non-adopters) and diarrhea (for adopters) are important determinants of long-term child malnutrition. Similar to the descriptive results above, the results in Table 7 show that the probability of stunting increases with the age of the child among the non-adopters of improved maize varieties. As children grow older, weaning and less breast milk may make them more vulnerable to malnutrition (Kabubo-Mariara et al. 2008). It may also suggest that as children grow older, less attention is given to them by their parents in terms of health care, the food they eat, and the nutritional value of the food. Similarly, children who suffered from diarrhea the previous year before the survey were more stunted than those who did not and this is in line with our theoretical expectations. Food consumed by children suffering from diarrhea does not result in any meaningful nutrition for the child as nutrients flush through the intestinal tract too quickly to be absorbed.

In line with previous studies on child malnutrition (e.g. Kabubo-Mariara et al. 2008) parental education reduced the probability of stunting by as much 75 %. Similar to the results of Christiaensen and Alderman (2004) the presence of educated

Table 6 Child stunting by household adoption status and gender of child

	Gender of child		
Adoption status	Male	Female	All
Adopters	0.42	0.61	0.51
Non-adopters	0.58	0.56	0.57
All	0.55	0.56	0.56

female adults in a household also had a significant correlation with the probability of stunting amongst children from adopting households. The probability of being stunted reduces by 16 % with each additional year of schooling for the most educated female household member among adopters. This shows that educated females play an important role in sharing knowledge related to children's health such as good child care practices and the ability to recognize illness. Presence of adult females in the household has a negative effect on the probability of stunting amongst non-adopters, implying that there is knowledge transfer related to child care from elderly to young mothers which in turn benefits the nutrition of the children. Contrary to theoretical expectations, the results also show that marriage was not beneficial to the nutritional status of children among non-adopters. This may have to do with the age at which the mothers got married. Early marriages and age of the mother have been linked with reduced nutritional outcomes for children (Raj et al. 2010; Kabubo-Mariara et al. 2008). This is so because young mothers may have low educational attainment and may be physically immature, and socially and economically unstable (Bwalya et al. 2015), all of which are associated with child malnutrition. Consistent with our theoretical expectations, household heads who were members of a cooperative were associated with better child nutrition. Similarly, the probability of stunting increased by between 5 and 2 % among adopters and non-adopters, respectively, with kinship. This is so because the more relatives a household has, the more the pressure on household resources which may in turn result in poor nutrition especially among children.

Table 7 Determinants of child malnutrition in eastern Zambia

Variable	Adopters ($N = 106$) Coefficient	Non-Adopters ($N = 564$) Coefficient
Age in months	0.01 (0.89)	0.01 (3.51)***
Gender of child	−0.65 (0.82)	−0.04 (0.30)
Child had diarrhea	0.87 (2.17)**	−0.12 (0.98)
Ln distance to health center	−0.18 (0.59)	0.07 (1.17)
Age of household head	0.00 (0.15)	0.00 (0.79)
Number of elderly (>65 years)	0.25 (0.20)	−0.16 (0.99)
Number of children (<15 years)	−0.14 (0.31)	−0.05 (0.61)
Household completed primary school (1 = yes)	−0.75 (1.86)*	0.14 (1.05)
Gender of household head	−0.35 (0.91)	−0.07 (0.49)
Household size	0.04 (0.12)	0.08 (1.16)
Ln assets per capita	0.25 (0.72)	0.05 (0.79)
Highest grade completed by most educated female	−0.16 (1.67)*	−0.01 (0.51)
Number of adult females (16–65 years old)	0.44 (1.18)	0.23 (2.38)**
Married	−1.47 (1.42)	0.42 (2.09)**
Group membership	−2.29 (2.17)**	−0.09 (0.44)
Kinship	0.05 (2.04)**	0.02 (1.87)*
Political connections	0.28 (0.39)	−0.02 (0.11)
Total land cultivated	0.03 (0.47)	−0.01 (0.51)
Ln distance to nearest village market	−0.20 (0.90)	0.02 (0.48)
Access to sanitation	0.99 (1.59)	−0.70 (4.78)***
Access to safe water	0.09 (0.21)	0.04 (0.35)
Chipata district dummy	−0.23 (0.38)	−0.06 (0.38)
Lundazi district dummy	−0.13 (0.17)	0.05 (0.28)
Constant	1.40 (0.13)	−1.03 (1.19)
Diagnostic tests		
Wald test	$\chi^2(26) = 87.94; p > \chi^2 = 0.000$	

Note *, ** and *** denotes significance level at 10 %, 5 % and 1 % (*t*-ratio in parenthesis); Ln = Natural logarithm

Amongst the community variables, access to sanitation had a negative and significant effect on stunting among non-adopters. This can be partly attributed to the fact that with an improvement in sanitation, the elimination of parasites that cause infections such as diarrhea and dysentery is facilitated.

Impact of improved maize adoption on child malnutrition

The estimates for the average treatments effects (ATT), which show the impact of adoption on stunting after accounting for both observable and unobservable characteristics, are presented in Table 8. Both adopters and non-adopters benefit from adoption. Specifically, the probability of stunting for children from adopting households would be 26 % greater had the households not adopted improved maize varieties. This is the average treatment effect on the treated (ATT) which is statistically significant at the 1 % confidence level. Similarly, the probability of stunting for children from non-adopting households would be 33 % less had the household adopted improved maize varieties, implying that non-adopting households would have realized lower rates of stunting from switching to improved maize varieties under the given conditions. This is the average treatment effect on the untreated (ATU) which is also statistically significant and implies that children from non-adopting households would be better off if their parents were to adopt improved maize varieties (as opposed to local varieties).

The results from the ESP model above may be sensitive to the exclusion restriction assumption; hence we also used the PSM approach to check the robustness of the estimated effects

Table 8 Impact of improved maize varieties on child malnutrition (endogenous switching probit results)

Mean of outcome variable	Treatment effect	Average treatment effects (ATE)
Stunting	Farm households that adopted (ATT)	−0.26 (4.52)***
	Farm households that did not adopt (ATU)	−0.33 (17.10)***

Note *** denotes significance level at 1 % (*t*-ratio in parenthesis)

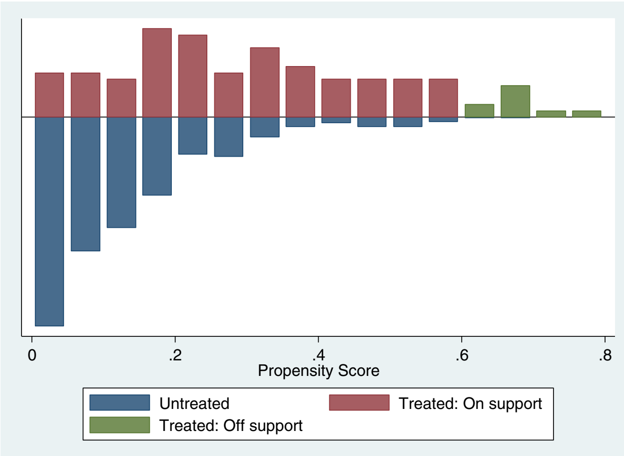

Fig. 2 Propensity score distribution and common support for propensity score estimation. Note**:** "Treated: on support" indicates the observations in the adoption group that have a suitable comparison. "Treated: off support" indicates the observations in the adoption group that do not have a suitable comparison

obtained from the ESP model. The same variables were used in the estimation of propensity scores as those reported in Table 10. We followed the rule of Augurzky and Schmidt (2001), and Brookhart et al. (2006), for quality implementation of propensity score estimation.

A visual inspection (Fig. 2) of the density distributions of the estimated propensity scores for the two groups indicates that the common support condition is satisfied: there was a substantial overlap in the distribution of the propensity scores of both adopter and non-adopter groups. The bottom half of the graph shows the distribution of propensity scores for the non-adopters and the upper half refers to the adopters.

Table 9 provides the ATT estimates from the PSM approach. The effect of improved maize varieties on stunting was estimated with the Nearest Neighbour (NNM) and the bias-adjusted NNM estimator developed by Abadie and Imbens (2011). Similar to the ESP results, adoption of improved maize varieties significantly reduces the probability of stunting. The causal effects from NNM approaches generally indicate that adoption of improved maize varieties exerts a negative and significant effect on stunting. Table 9 shows that on average, children from non-adopting households were relatively more stunted (62–63 %) than those from adopting households (51 %). Consistent with the ESP results reported in Table 8, the PSM results suggest that adoption of improved maize varieties significantly reduces the probability of stunting in the range of 11–12 %. Compared to the ESP results, the estimated effects from the PSM approach are relatively lower, probably because the latter does not take into account the selection on unobservables.

Conclusion and implications

This paper analyses the factors that affect the nutritional status of under-five children as well as the impact of improved maize varieties on child stunting in Zambia using household survey data from a sample of 810 households in the eastern province of Zambia. Given the non-experimental nature of the data used in the analysis, a combination of parametric and non-parametric econometric methods was used to mitigate biases resulting from both observed and unobserved characteristics.

Empirical results show that child malnutrition is a function of the child's age and gender, gender of the household head, education of female household members, number of adult females in the household, and access to sanitation. The results are largely consistent with findings from other malnutrition studies (e.g. Christiaensen and Alderman 2004; Kabubo-Mariara et al. 2008).

Average treatment effects from both the ESP and PSM analysis show that adoption of improved maize varieties significantly reduced the prevalence of stunting. The ESP results show that farm households that adopted benefited more from adoption. Probability of stunting for children from adopting households was reduced by as much as 26 %. The probability of stunting would have also reduced by about 33 % for children from non-adopting households, if the households had adopted improved maize varieties, suggesting that non-adopting households would have realized lower rates of stunting from switching from growing local to improved maize varieties. Results from the matching estimates show that the probability of stunting also reduced among children from adopting households.

The results stress the key role of adoption of improved maize varieties in improving the income earning opportunities for rural households in order to fight the scourge of malnutrition. However, realizing the full benefits of improved technologies such as improved maize varieties in terms of improved income earning opportunities and food security will require increased investment and policy support aimed at enhancing technology

Table 9 Impact of improved maize varieties on child malnutrition (matching results)

Matching Algorithm	Outcome variable	Means of outcome variables		ATT difference
		Adopters	Non Adopters	
Nearest Neighbor Matching	Stunting	0.51	0.63	−12 (1.74) *
Bias adjusted Nearest Neighbor Matching	Stunting	0.51	0.62	−11 (2.03)**

Note * and ** denotes significance level at 10 % and 5 % (*t*-ratio in parenthesis) adoption by farmers. Secondly, the significance of education in reducing child stunting suggests that the assimilation of nutritional messages may require more than basic education to be more effective. Promoting education among females is thus critical for nutrition-enhancing child care practices.

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Appendix

Table 10 Probit estimates of determinants of adoption of improved maize varieties in eastern Zambia

Variable	Coefficient
Age in months	0.01 (1.68)*
Gender of child	0.29 (2.10)**
Child had diarrhea	0.19 (1.30)
Ln distance to health center	−0.1 (153)
Age of household head	0.00 (0.45)
Number of elderly (>65 years)	−0.47 (2.77)**
Number of children (<15 years)	−0.23 (2.46)**
Household head completed primary school (1 = yes)	−0.12 (0.77)
Gender of household head	−0.06 (0.37)
Household size	0.17 (2.40)**
Ln assets per capita	0.19 (3.25)***
Highest grade completed by most educated female adult	0.02 (0.84)
Number of adult females in the household (16–65 years old)	−0.14 (1.30)
Married	0.01 (0.02)
Group membership	0.02 (0.08)
Kinship	0.01 (1.26)
Political connections	0.37 (2.39)**
Total land cultivated	0.04 (2.23)**
Ln distance to nearest village market	0.02 (0.35)
Access to sanitation	−0.07 (0.35)
Access to safe water	−0.05 (0.34)
Chipata district dummy	−0.08 (0.37)
Lundazi district dummy	0.11 (0.56)
Access to NGO extension	0.13 (0.96)
Access to government extension	0.22 (1.30)
Distance to extension office	0.00 (2.92)**
Constant	−4.60 (4.59)***

Note *,**, and *** denotes significance level at 10 %, 5 % and 1 %

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