Examining Child Health and Nutrition Inequalities in Tanzania

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DECLARATION

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Conceptualisation, cleaning and organising data, formal analysis and writing	70 %

The following co-authors have contributed to Chapters 2, 3 and 4:

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The undersigned hereby confirm that:

1. The declaration above accurately reflects the nature and extent of the contributions by the candidate and the co-authors to Chapters 2, 3 and 4.
2. No other authors contributed to Chapters 2, 3 and 4 besides those specified above.
3. Potential conflicts of interest have been revealed to all interested parties and the necessary arrangements have been made to use the material in Chapters 2, 3 and 4 of this dissertation.

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ABSTRACT

More than one-third of stunted children under the age of five reside in sub-Saharan Africa. Due to the multifaceted underlying causes of malnutrition, this has become a challenging situation to address. Tanzania is among the top five countries in Eastern and Southern Africa with unacceptably high prevalence and spatial inequality in malnutrition, making it an interesting case study for generating evidence to inform policies in sub-Saharan Africa. Over three chapters, this thesis attempted to explain the persistent malnutrition and inequality in malnutrition and highlight potential pathways to tackle it using data from Tanzania. Chapter 2 examines the impact of the maize price fluctuation on the growth of the children from households that produce foods and those which do not. Chapter 3 explored the impact of meat and milk consumption on child growth and how the effects are mediated by keeping homestead livestock. Chapter 4 estimates the inequality of opportunity in malnutrition and considers the contribution made by access to water and sanitation.

Three major findings emerged from this thesis. The first relates to the heterogeneity impact of high maize prices on the growth of children from food-producing and food non-producing households. While a large body of research advocates for low food prices to protect children's nutrition, this thesis found that children from households that produce food could benefit from high prices. The negative impact of high maize price on growth is significantly more stronger on children from households that do not produce food than from food producing households. The results also show that girls from food non-producing households suffered more than boys from high maize prices. Across children of different ages, the study found that children aged 24-35 months who were no longer breastfeeding and began to eat from the same plate as older household members are more vulnerable to shock than other age groups. The mechanism through which the maize price affects child growth is by reducing micronutrient and diet diversity in food non-producing households and increasing consumption in the food producers.

Second, the results show that the effects of milk are revealed after transitioning from breastfeeding, while the effects of meat is insignificant in all age groups. Specifically, milk significantly led to higher growth in children aged 24-35 months and 36-60 months living in households which own mixed but. Third, the findings reveal that 20 per cent of inequality of opportunity in Tanzania needs to be compensated in order for equality of opportunity to prevail. Strikingly, the results show that the circumstances affecting children in urban and rural areas are different. Water and sanitation contribute 42 per cent of the inequality of opportunity in rural areas. Intergenerational aspects, early life feeding practices and market volatility were found to be more important in urban areas than rural areas.

Overall, the results suggest that for the effective reduction of malnutrition, public health interventions should consider the different underlying levels and causes of child malnutrition between subgroups and the impact that a range of interventions could have on children from rural and urban areas. Policies that address the needs of specific groups could effectively reduce malnutrition in Tanzania. A combination of nutrition and water and sanitation interventions has the potential to reduce both the prevalence of malnutrition and inequality of opportunity in Tanzania.

Key words:

Maize price fluctuation , child nutrition status, agriculture, food production, milk ruminants, meat ruminants, inequality of opportunity, Tanzania

OPSOMMING

Meer as 'n derde van kinders jonger as vyf jaar oud met belemmerde groei woon in Afrika suid van die Sahara. Weens die veelvuldige onderliggende oorsake van wanvoeding is dit 'n baie uitdagende situasie om aan te pak. Tanzanië is een van die voorste vyf lande in Oos- en Suidelike Afrika met 'n onaanvaarbaar hoë voorkomssyfer en fisiese ongelykheid van wanvoeding, en kan dus as 'n interessante gevallestudie dien om inligting vir beleid in sub-Sahara-Afrika in te samel. In die drie hoofstukke van hierdie tesis word gepoog om hierdie voortdurende wanvoeding en ongelykheid in wanvoeding te verklaar en die potensiële maniere waarop die aangepak kan word, toe te lig, deur data van Tanzanië te gebruik. Hoofstuk 2 ondersoek die impak van die mielieprysskok op die groei van die kinders in huishoudings wat voedsel produseer teenoor dié wat nie produseer nie. Hoofstuk 3 ondersoek die impak van vleis- en melkverbruik op kinders se groei en hoe die aanhou van vee die effek bemiddel. Hoofstuk 4 beraam die ongelykheid van geleenthede in wanvoeding en oorweeg die bydrae van toegang tot water en sanitasie.

Drie hoofbevindings het in hierdie tesis na vore gekom. Die eerste hou verband met die heterogene impak van hoë mieliepryse op die groei van kinders in voedselproduserende huishoudings en huishoudings wat nie voedsel produseer nie. Alhoewel 'n groot deel van navorsingsinligting lae voedselpryse voorstaan om kinders se voeding te beskerm, is met hierdie tesis gevind dat kinders in huishoudings wat voedsel produseer by hoë pryse kan baat. Hoë mieliepryse het slegs 'n negatiewe effek op kinders in huishoudings wat nie voedsel produseer nie. Die resultate toon ook dat meisies in huishoudings wat nie produseer nie, meer as seuns weens die hoë mieliepryse gely het. By kinders van verskillende ouderdomme is bevind dat kinders tussen 24 en 35 maande wat nie meer geborsvoed word nie en dieselfde kos as ouer gesinslede begin eet het, meer kwesbaar was vir skok as ander ouderdomsgroepe. Die meganisme waardeur die mielieprys kinderontwikkeling affekteer is die vermindering van mikronutriënte en verskeidenheid in die dieet van huishoudings wat nie produseer nie, en die verhoging van verbruik daarvan by voedselprodusente.

Tweedens het die resultate getoon dat die effek van melk na vore kom nadat borsvoeding gestaak is, terwyl die effek van vleis eers op 'n later stadium van kinders se groei na vore kom. Melk spesifiek het tot beduidende hoër groei gelei in kinders van 24 tot 35 maande en 36 tot 60 maande in huishoudings wat gemengde maar nie melkdiere besit het nie. Vir vleis was die effek beduidend in die ouderdomsgroep van 36 tot 60 maande van eienaars van vleisdiere. Derdens is bevind dat 20 persent van die ongelyke geleenthede in Tanzanië gekompenseer moet word om gelyke geleenthede te kan voorsien. Dit is opvallend dat die resultate getoon het dat die omstandighede wat kinders in stedelike en landelike gebied beïnvloed, verskillend is. Water en sanitasie dra 42 persent by tot ongelyke geleenthede in landelike gebiede. Die tussengenerasie-aspekte, vroeë voedingspraktyke en markvolatiliteit was belangriker in stedelike gebiede as in landelike gebiede.

In die geheel gesien dui die resultate dat om wanvoeding effektief te verminder, openbare gesondheidsintervensies oorweging moet skenk aan onderliggende vlakke en oorsake van kinderwanvoeding tussen subgroepe en die impak wat 'n verskeidenheid van intervensies op kinders in landelike en stedelike gebiede kan hê. Beleid wat op die behoeftes van spesifieke groepe gemik is, kan wanvoeding in Tanzanië effektief verminder. 'n Kombinasie van intervensies vir voeding en water en sanitasie het die potensiaal om sowel die voorkoms van wanvoeding en ongelyke geleenthede in Tanzanië te verminder.

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LIST OF ABBREVIATIONS AND/OR ACRONYMS

AARR	Average Annual Reduction Rate
ASF	Animal Source Food
D-index	Dissimilarity index
EED	Environmental Enteric Disorder
FFC	Food Frequency Consumption
HAD	Height-for - Age -Differences
HDDS	Household Diet Diversity Score
HAZ	Height-for-Age Z-scores
HOI	Human Opportunity Index
IGF	Insulin-like Growth Factor
ILSM	Integrated Living Standard Measurement Survey
IoP	Inequality of Opportunity
IV	Instrumental Variables
LSMS	Living Measurement standard Study
LMICs	Low and Middle Income Countries
MDGs	Millenium Development Goals
NFRA	National Food Reserve Agency
NDVI	Normalized Difference Vegetation Index
PCA	Principal Component Analysis
RCT	Randomised Controlled Trial
RESEP	Research on Socioeconomic Policy
RIF	Recentered Influence Function
SDGs	Sustainable Development Goals

SES	Socioeconomic Status
TLU	Total Livestock Unit
TNPS	Tanzania National Panel Surveys
UN	United Nations
USA	United States of America
VLUP	Village Land Use and Planning
WASH	Water, Sanitation and Hygiene
WAZ	Weight-for-Age Z-scores
WHO	World Health Organization
WHZ	Weight-for-Height Z-scores

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The child mortality rate is highest in sub-Saharan Africa, representing more than half of the total deaths of under-five children globally (Thomas, 2020). Malnutrition accounts for the largest number of these preventable deaths: about 45 percent of child deaths in 2015 were linked to malnutrition (Fanzo *et al.*, 2018)[1]. The latest data show, Africa as a whole recorded a decline in stunting of only 8 percentage points from 38.3 percent to 30.3 percent and increase in absolute numbers from 50.4 million to 58.5 million between 2000 and 2016 (UNICEF *et al.*, 2018; Fanzo *et al.*, 2018). In Tanzania, stunting declined from 42 percent to 34.7 percent between 2000 and 2014 (TFNC, 2015). However, this level is higher than the average of 25 percent observed in Africa (URT, 2016). Tanzania has recorded an average annual reduction rate (AARR) in stunting of 0.08 percent over the last 25 years (50–34 percent from 1990/91 to 2015/16), which is less than the targeted AARR of 4 percent that was set to meet the SDGs. The recent Tanzania National nutrition survey indicates that as of 2018, the stunting rate was 31.8 percent, an overall decline of 2.9 percent from 2014, where a consistently higher prevalence was observed in rural areas (TFNC, 2019). This trend has implications on the future population health and economic growth.

This thesis focuses on stunting and inequality thereof among children under five in Tanzania, exploring the effects of prices and feeding practices in the home. The focus on stunting and nutrition is motivated by social concern about high levels of child mortality attributable to poor nutrition in African countries. Stunting also has impact child's mental and physical development, leading to poor human capital formation and poverty in adulthood.

[1]Malnutrition occurs in different forms such as stunting, underweight, wasting, and overweight. The WHO recommends the standard measures for height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ) and weight-for height z-scores (WHZ) to assess child growth. According to WHO (2006) guidelines, scores below 0 are considered ill-health, where scores between -2 and -3 and below -3 are of more concern, indicating moderate to severe conditions. Stunting is a condition that describes a child who is too short for his or her age; in other words, a child with z-scores below -2SD from the median values of a well-nourished child of the same age and gender. It is also referred to as chronic malnutrition, reflecting the long-run investment in child health. A wasted child has WHZ scores below -2SD, indicating severe weight loss from recent episodes of infectious diseases and lack of sufficient food to eat. Underweight describes a child with low WAZ below -2SD. Overweight is another form of malnutrition which is rising at a rapid rate in sub-Saharan Africa, indicating a child with excess weight for his height based on body mass index classification. It has been shown that a child can have more than one form of malnutrition (Keino *et al.*, 2014; Khara *et al.*, 2018). For example, an underweight child can also be stunted and wasted and similarly for an overweight child who is also stunted.

The sustainable development goal SDG-2 acknowledges the need to end malnutrition in all its forms by 2030 to increase child survival chances and the associated long-term benefits (United Nations, 2016).It also recognises that efforts to end malnutrition should go beyond SDG-2 to include ending all forms of poverty (SDG-1), attain universal access to health care (SDG-3), improved water and sanitation (SDG-6) among others, due to the strong interlinkage between goals. The explicit inclusion of stunting as an indicator in the current development goals demonstrates the increasing commitment to poverty reduction and economic development. Stunting is strongly linked to poverty cycles and development. Besides death, stunting has devastating consequences on cognitive ability (Kar *et al.*, 2008; Nyaradi *et al.*, 2013) which in turn affects schooling (Alderman *et al.*, 2009; Nandi *et al.*, 2015; Behrman, 1996), economic opportunities and earning (Galler *et al.*, 2012). Studies in developing countries show that stunting is associated with a one-year reduction in schooling (Martorell *et al.*, 2010), whereby the expected return of an additional year of schooling ranges between 8.3 and 7.5 percent in urban and rural areas, respectively (Orazem *et al.*, 2009). Stunted children earn 20–26 percent less adult income than non-stunted children (Grantham-McGregor *et al.*, 2007; Richter *et al.*, 2017) and are less likely to be employed in higher-paid skilled labour (Hoddinott *et al.*, 2011). Based on 2010 statistics, 43 percent of stunted children below the age of five in low and middle-income countries (LMICs) were at elevated risk of living in poverty and likely to lose more than a quarter of the average adult income per year (Richter *et al.*, 2017). The likelihood that non-stunted children escape poverty as adults is 33 percent higher than their stunted counterparts (Horton and Steckel, 2013). At the national level, Galasso and Wagstaff (2019) estimated that a country loses about 5-7 percent of its per capita income as a result of some of its workforce being stunted in childhood. Studies in Tanzania show that it could increase its national income by 16 percent if stunting were eradicated (Hoddinott *et al.*, 2013).

Reducing stunting also has long-term benefits on the health of the future population. Stunting in childhood is associated with poor health in adulthood, which intensifies poverty and undermines efforts in economic development. Studies in Guatemala (Schroeder *et al.*, 1999), Portugal (Henriques *et al.*, 2018) and Brazil (De Lucia Rolfe *et al.*, 2018) document the association between chronic childhood undernutrition and development of obesity. Increased obesity has a negative impact on economic growth and development, given the strong link between adult body size and composition and the ability to work and/or productivity (Li *et al.*, 2003). Chronic undernutrition is also postulated to increase the risk of hypertension in life by activating the renin–angiotensin system

(Kingdom *et al.*, 1993), increasing sympathetic nervous activity and insulin sensitivity (Leon-Quinto *et al.*, 1998; Somova and Moodley, 2000), and changing vascular structure, function and compliance (Yoshida *et al.*, 1995). Several empirical studies found evidence of the association between childhood stunting and increased blood pressure in adolescence and adulthood (Eriksson *et al.*, 2001; Sesso *et al.*, 2004; Sawaya *et al.*, 2005; De Lucia Rolfe *et al.*, 2018).

Reducing income inequality has only recently been made explicit in the current development goals (SGD-10) despite being widely debated in the last decades. The literature is replete with studies describing the exogenous and endogenous drivers for income inequality and potential pathways to achieve equality (Dabla-Norris *et al.*, 2015; Su and Heshmati, 2013). Advocates for equal society argue for distributive policies for faster poverty reduction and economic growth (Luebker *et al.*, 2012; Bergstrom, 2020). Stunting during childhood features prominently in this debate given its potential to increase income inequality both within and between countries.

While not all inequalities are unacceptable, inequality caused by circumstances is unjust. The fairness of outcomes is a foundation of the emerging literature on the inequality of opportunity, which was widely debated by social scientists and philosophers in the 1970s to 1980s (Rawls, 1971; Nozick and Williams, 1975; Dworkin, 1981; Arneson, 1989, 1990; Cohen, 1989; Sen, 1979, 1985), and formalized by Roemer (1993, 1998, 2002). According to Roemer, circumstances are factors(social, genetic, biological) that affects the achievement of an outcome over which an individual has no control and refers to inequality caused by circumstances as inequality of opportunity or illegitimate inequality. In his works, Roemer stresses that inequality in outcomes should only depend on effort and that policies should work to equalize opportunities independent of circumstances. Efforts refer to the behaviours and decisions that individuals can be held accountable for. The inequality of opportunity principles, therefore, requires equal opportunity across the same levels of efforts and across different circumstances groups or type[2].

Research has shown that stunting affects children unequally based on circumstances such as parental characteristics, geographical location and access to public services (Amara *et al.*, 2017; Sanoussi, 2017; Aizawa, 2019). The literature has generally shown persistent and large spatial disparities in inequality of opportunity between regions. In sub-Saharan Africa, children in rural areas are disproportionately more stunted than those in urban areas (Fotso, 2006). Despite the evidence of

[2]Type or circumstance groups refers to the set of individuals with the same circumstances.

urban areas doing better than rural areas in terms of average health (Smith *et al.*, 2005; Paciorek *et al.*, 2013), socioeconomic inequalities in stunting and mortality have been found to be higher in urban than rural areas (Menon *et al.*, 2000; Fotso, 2007; Van de Poel *et al.*, 2007*b*).The inequality in malnutrition within urban areas is larger than the overall rural–urban gap in malnutrition (Fotso, 2006). Fotso (2007) shows that the widening socioeconomic inequality recorded in many sub-Saharan African countries is due to the increase in malnutrition in urban areas relative to rural areas. In Kenya an increase in the child mortality rate in urban areas was reported to narrow the rural–urban child health inequality (Gould, 1998). Similarly, children from lower income quintiles are more likely to be malnourished than their counterparts in higher income quintiles. It is well documented that circumstances that affect the current generation's opportunities shape those that future generations will face. Palloni *et al.* (2009) examined the effects and contribution of early childhood health and socioeconomic status conditions on adults' socioeconomic position and health inequality among a 1958 British cohort and found that early childhood health influences skills acquisition which in turn affects socioeconomic position in adulthood.

While other forms of malnutrition are equally important to address in order to achieve SDGs, stunting is the major public health challenge in developing countries. Unlike wasting that can easily be reversed with timely treatment such as by providing a child with a sufficient and quality diet, the effects of stunting can be permanent (Andersen *et al.*, 2017).[3] Stunting continues to be the most prevalent form of malnutrition in developing countries and, according to the global nutrition report (Renata, 2020), only five countries are on course to meet the global nutrition targets for stunting compared to 17 countries, including Tanzania, for the case of wasting. Moreover, what makes stunting even more concerning is its early development in *utero*, and in developing countries it has been shown to accumulate until after the first 1 000 days (Leroy *et al.*, 2014). Researchers widely agree that stunting two years after birth is irreversible: the first 1 000 days is regarded as a critical window for nutritional intervention to recover some linear growth. Mani (2012) recommends that efforts to improve child nutrition must be made at all ages with an emphasis on younger children. While there is evidence of catch-up growth, (Crookston *et al.*, 2010; Outes and Porter, 2013; Prentice *et al.*, 2013), public health interventions that improve the environments and nutrition of at-risk children is paramount.

[3]Wasting can also be addressed by the same inventions that target stunting since the factors which cause stunting and wasting are the same (WHO, 2014*a*).

Leroy *et al.* (2015) found that catch-up-growth is infrequent in developing countries and rare among children who continue to live in the same environment that caused the retarded growth in the first place. Leroy *et al.* findings support those of Martorell *et al.* (1994) which show that children with continued exposure to the same factors that contributed to faltering growth in childhood are short as adults. Stunted children adopted by wealthy families with access to adequate food, sanitation, clean water, and electricity demonstrated higher catch-up growth than those who were not adopted who had no access to basic services (Martorell *et al.*, 1994; Mani, 2012; Outes and Porter, 2013). These findings from past studies suggest that sub-Saharan Africa could gain much from broadening the understanding of context-specific conditions that need to be improved to meet SDG targets.

1.2 Determinants of undernutrition

Undernutrition is the outcome of a complex interaction of immediate and underlying factors whose relevance tends to differ across countries and population subgroups. Broadly, the determinants of undernutrition can be grouped into contextual and proximal factors. Contextual factors related to factors that act at a community or societal level: agriculture production, food prices, climate, healthcare system, water sanitation and the environment. Proximal determinants include factors such as household characteristics, feeding practices and infections. This thesis explored both the proximal and contextual determinants of undernutrition. Specifically, this thesis examined the heterogeneous impact of short-lived maize price fluctuation s on stunting in Tanzania. Similarly, we used quasi-experimental methods to establish whether feeding children meat and milk leads to improved growth in Tanzanian children. In addition, we examined whether livestock keeping moderates the effect of meat and milk on child growth was examined. Finally, the study quantified the inequality of opportunity in malnutrition in Tanzania and decomposed it to examine how access to water and sanitation contribute to inequality.

1.2.1 Proximal determinants of undernutrition

One of the major immediate causes of undernutrition is diet, which is determined partly by feeding practices. The WHO (2002) recommended that a child is introduced to breastmilk within the first hour after birth and exclusively breastfed for six months. Breastfeeding should continue until age two with a gradual introduction of solid complementary foods. The level of adherence to the feeding recommendations in sub-Saharan Africa is not satisfactory, including Tanzania. Based on the 2015–16 DHS survey, only 59 percent of children under six months in Tanzania are exclusively breastfed (Dede and Bras, 2020).While nine in ten children aged 6–8 months are introduced to complementary foods as per the recommendations, the nutritional quality of their diets is low (Victor *et al.*, 2014; Kulwa *et al.*, 2015; De Bruyn *et al.*, 2018). Appropriate feeding practices are a strong predictor of proper child growth (Saha *et al.*, 2008; Zongrone *et al.*, 2012; Heidkamp *et al.*, 2015; Som *et al.*, 2021).

Most of the nutrition deterioration leading to faltering growth increases with the age of the child and often occurs during complementary feeding (Dewey and Huffman, 2009; Victora *et al.*, 2010). For a smooth transition from breastfeeding, children need a quality diet with sufficient micronutrients. The starch-based diet predominant in developing countries lacks the necessary micronutrients to support growth. Research shows that humans do not synthesise all the required amino acids and therefore supplements, particularly protein-rich foods, are necessary. Lysine, which is not synthesised by humans, is an essential amino acid found in protein which has a greater biological role on the brain, synthesis of enzymes, muscle protein synthesis, antibodies, opsins and calcium absorption (Moya, 2016).

Deficiency of lysine in children may result in retarded growth. Decades of research has shown that animal source food contains a large quantity and quality protein compared to plants. Most plants contain low lysine amino acid, and grains such as beans and peas, which are rich in lysine, lack essential sulphur-containing amino acids (Leinonen *et al.*, 2020). Some researchers argue for the consumption of multiple plants to obtain as much amino acid as one would from animal source food (Weindl *et al.*, 2020). Nevertheless, the nutritional value of animal protein rests on the digestibility and bioavailability of its amino acids and less metabolic activities which are required to absorb a sufficient level for growth stimulation and body protein turnover (FAO, 2013*a*). Animal Source Food (ASF) contains higher bioavailable micronutrients such as folic acid, essential fatty acids, vitamin A, vitamin D3, iodine, zinc, calcium and iron than plants (Neumann *et al.*, 2002; Adesogan *et al.*, 2020). Additionally, vitamin B12, whose deficiency is associated with cognitive anomalies, is only available in its natural form in meat (Adesogan *et al.*, 2020). Very rarely, plants such as algae produce vitamin B12 when they are exposed to bacteria that can produce the vitamin (Neumann *et al.*, 2002).

Infants and children older than five months are widely shown to benefit from consuming high quality animal source protein (Murphy and Allen, 2003; de Beer, 2012; Grace *et al.*, 2018). For example, a large-scale cross-country study that used data from 46 LMICs for children aged 6–24 months found a strong association between the combination of ASF and stunting and the consumption of individual food types: dairy, meat/fish, eggs and stunting (Headey *et al.*, 2018). In Ecuador, stunting and underweight reduced by 47 and 74 percent, respectively, following an intervention providing malnourished children with an egg a day for a year (Iannotti *et al.*, 2017). These findings from Ecuador highlight an important policy issue also observed in a study conducted in low-income settings (Krebs *et al.*, 2011) that even the consumption of a small amount of ASF improves child growth. Research indicates that interventions that include ASF are more likely to produce the intended outcomes than plant-based foods. Children in the meat group were taller than in the cereal-based diet group in RCT studies conducted on infants in USA (Tang and Krebs, 2014; Tang *et al.*, 2018). Only a handful of research fails to establish an association between ASF and child growth (Muslimatun and Wiradnyani, 2016), suggesting a greater biological role of livestock-derived food.

Given the large amount of evidence supporting a stronger link between ASF and growth, increasing its consumption could help to reduce the high rate of undernutrition in sub-Saharan Africa. The current levels of consumption of ASF in Africa are low and are thought to be the main reason for the higher prevalence rate of nutrition-related complications (Semba, 2016). Adesogan *et al.* (2020) show that countries with higher consumption of meat have a lower stunting rate than countries which consume less. The relatively higher price in developing countries than developed countries largely explains the under-consumption of ASF. For example, the per calories price for eggs and meat is 9–10 and 5–6 times higher, respectively, than per calorie prices of cereals in Africa (Headey *et al.*, 2018). Nevertheless higher prices, fasting habits and taboos (Gordon *et al.*, 2007) and only a small fraction of the population with sufficient knowledge of the nutritional benefits of ASF (Kim *et al.*, 2016; Warren and Frongillo, 2017) are also hindrance factors in Africa. Grace *et al.* (2018) estimated that only 20 percent of the protein consumed in sub-Saharan Africa and Asia is sourced from animal products.

Notably, diet and complementary feeding may be influenced by household practices such as child-care and food production (Fenske *et al.*, 2013). The strong link between parental education and feeding practices explains much of the variation in nutrition observed among children from well-educated compared to poorly educated parents (Webb *et al.*, 2003; Semba *et al.*, 2008; Svensson *et al.*, 2014; Alderman and Headey, 2017). Other household characteristics, such as the number of dependants, birth order and household size, influence investment in a child through intra-household food distribution and the quality of diet a child receives in households that face a quality–quantity trade-off. These factors have been widely shown to limit children from achieving their full growth potential (Jayachandran and Pande, 2017; Rizal and van Doorslaer, 2019). The influence of agriculture and livestock production on children's diet has also been widely debated in the literature, given the size and importance attached to these sectors for livelihood, particularly in rural areas.

1.2.2 Contextual determinants of undernutrition

1.2.2.1 Agriculture production, livestock keeping and nutrition

The role of agriculture on nutrition has been a topic for policy discussion for decades. It is considered a key sector for addressing undernutrition in developing countries, given the high proportion of malnourished children residing in farming households. Despite the fact that undernutrition is a product of the complex interaction of several underlying factors, agriculture growth has great potential to reduce the risk of stunting. Past initiatives that built on UNICEF's conceptual framework identified six pathways through which agriculture may improve child nutrition (Gillespie *et al.*, 2019; Headey *et al.*, 2012). The first three of these are closely linked to what this thesis explores in Chapters 2 and 3.

The first pathway relates to food availability when households consume what they produce. Increased agriculture production is associated with improved food availability in the household (Baldos and Hertel, 2014; Bandara and Cai, 2014). In the recent past, there has been increased promotion of nutritional-sensitive agriculture to ensure that the agricultural sector delivers maximum nutrition to the benefit of children and farming households (FAO, 2013*b*; Pinstrup-Andersen, 2013; Alderman *et al.*, 2013). The focus has been on farm-level crop diversification to increase food availability with diverse macro and micronutrients in the household. Several empirical studies in sub-Saharan Africa found a stronger link between farm-level crop diversity, diet diversity and child growth (Lovo and Veronesi, 2019; Sibhatu *et al.*, 2015; Chegere and Stage, 2020; Kansanga *et al.*, 2020; Sariyev *et al.*, 2021). This pathway, however, is mediated by many other factors such as feeding practices, intra-household distribution of food and supply of adequate nutrition (Headey *et al.*, 2012; Ruel *et al.*, 2013; Hoddinott *et al.*, 2012).

The second pathway links nutrition with income generated from agriculture production either directly through agriculture sale or by supplying labour. The income earned from agriculture may enable households to purchase a more diversified diet. The increased income from agricultural growth may also lead to further investment in a child as poverty declines, an important correlate of nutrition. The contribution of agriculture to poverty reduction and child nutrition has been reported in different settings, except for India, where a large disconnect between agriculture and nutrition was observed (De Janvry and Sadoulet, 2010; Christiaensen *et al.*, 2011; Headey *et al.*, 2012).

The third pathway links agriculture policy, food prices and food consumption. The demand and supply for agriculture products determine the price for food and income from agriculture sales, which affect the purchasing power of farmer and non-farmer households. While farmers who sell cash crops are expected to benefit from high food prices, most of the farmers in sub-Saharan Africa are net buyers because of their inability to increase production beyond subsistence level (Akter and Basher, 2014). Although the literature indicates that high food prices tend to reduce household welfare in the short term, in the medium to long-term high prices may benefit farmers as the labour market adjusts and farmers respond to high prices by increasing supply (Jacoby, 2013; Akter and Basher, 2014; Headey, 2016). Children are more vulnerable to high prices due to the reduction in the quality and quantity of food households can afford. Several empirical studies provide evidence of the decline in HAZ when food prices spike (De Brauw, 2011; Arndt *et al.*, 2016; Woldemichael *et al.*, 2017; Cornia *et al.*, 2008; Brenton and Nyawo, 2021).

The fourth mechanism links the socioeconomic status (SES) of women in agriculture and child nutrition as they influence the intra-household decision-making and food distribution. The emerging literature on women empowerment in agriculture shows that children from households with empowered women have higher HAZ than those who are less empowered (Malapit *et al.*, 2015; Heckert *et al.*, 2019). The fifth pathway is through maternal labour supply in agriculture, which influences childcare and feeding practices. Time poverty among women in agriculture is one of the hindrance factors for proper child growth (Jones *et al.*, 2012; Seymour *et al.*, 2019). Finally, heavy workload, particularly when energy use exceeds energy intake, and hazardous activities due to agricultural chemical use, may compromise maternal nutrition and health, which in turn affect children's health.

Although agriculture production provides households with the basic micronutrients necessary for child growth, supplementing plant-based foods with micronutrient-rich foods is always recommended (Bouis, 2000). Therefore, the role of livestock keeping to ensure protein security is indispensable. The sector has gained much attention in recent years following the global increase in demand for quality protein, leading to a shift of focus from agriculture to sustainable livestock keeping to meet the nutritional requirements of the growing population. Beyond the direct livestock-nutrition pathway stemming from increasing availability via own consumption, the contribution of livestock keeping to household income may lead to a higher diversified diet. Increased production at a country and regional level may also be helpful to suppress the present higher prices of livestock products by taking advantage of international trade.

Several livestock-keeping interventions have been undertaken to increase the uptake of ASF. For example, Heifer International launched a dairy cow and meat goat donation intervention programme in Rwanda which, upon evaluation, Rawlins *et al.* (2014) found an increase in the consumption of dairy and meat, resulting in a reduction in stunting in the dairy cow recipient group but not the goat meat group. Similar livestock transfer interventions: 'One Cow per Poor Family' in Rwanda (Argent *et al.*, 2014), RCTs in India (Banerjee *et al.*, 2011) and Bangladesh (Bandiera *et al.*, 2013) found the programmes yielded the greatest impact if accompanied with training. Many other observational studies established an association between livestock keeping and consumption of ASF (e.g. Azzarri *et al.*, 2015; Kabunga *et al.*, 2017; Choudhury and Headey, 2018; Broaddus-Shea *et al.*, 2019; Pasqualino *et al.*, 2020; Bundala *et al.*, 2020). Studies linking animal ownership and child growth pathways, however, produce mixed findings. These findings are documented in studies such as Hoddinott *et al.* (2015); Mosites *et al.* (2015) while Jin and Iannotti (2014); Mosites *et al.* (2016); Dumas *et al.* (2018) fail to establish context for such evidence. This inconsistency in the literature indicates the need for a context-specific exploration of the nature of the association in Tanzania.[4]

However, as discussed in Nicholson *et al.* (2003) and Randolph *et al.* (2007), sometimes livestock production can have a negative effect on child nutrition in multiple ways. First, livestock keeping may reduce crop production and crop sales as the household allocates more land and labour to livestock production. Second, livestock keeping may increase labour demand, particularly among women, which reduces the available time for caring and quality feeding of children. Third, livestock

[4]Tanzania is ranked third, next to Ethiopia and Sudan, with a large number of livestock but also a stunting rate above average level for Africa (URT, 2015, 2016).

keeping may affect child nutrition directly by transmitting zoonotic and other food-borne diseases, and indirectly through water contamination from animal faeces. The last channel has received much interest recently in the literature given the strong link between water, sanitation and hygiene (WASH) and nutrition, also discussed in Section 1.2.2.2 of the thesis.

1.2.2.2 Water, Sanitation and Hygiene (WASH) and child nutrition

Diarrhoea and environmental enteric disorder (EED) are important pathways linking WASH and child growth. Acute diarrhoea and EED severely damage the gut and lead to the development of malabsorption, a condition characterised by the failure of the small intestine to absorb enough food nutrients during digestion (Guerrant *et al.*, 2013). Even a brief episode of diarrhoea among malnourished children may lead to further nutritional deterioration, and when repeated, might slow down catch-up growth (Checkley *et al.*, 2008; Guerrant *et al.*, 2013). The infectious pathogens causing diarrhoea and EED are transmitted primarily through oral consumption (Feachem *et al.*, 1983), explaining the relevance of improving sanitation particularly the safe disposal of human faeces. Human faeces excrete a wide range of infectious pathogens in a larger quantity than any other source of human excreta (Mara *et al.*, 2010). Several studies have found that children with access to a toilet have a lower likelihood of being stunted than children living in areas where open defecation takes place (Cumming and Cairncross, 2016).

Evidence on the impact of WASH on diarrhoea and stunting is mixed. Cluster-randomised and case-control studies consistently show that WASH reduces diarrhoea (Fewtrell *et al.*, 2005; Wolf *et al.*, 2014; Freeman *et al.*, 2017), however, Dangour *et al.* (2013) found a limited benefit of WASH on stunting. An observation study from 70 LMICs, which used 171 DHS surveys, found that improved sanitation reduced the risk of diarrhoea and stunting (Fink *et al.*, 2011). Using DHS data for 59 countries and difference-in-difference regressions, Headey and Palloni (2019)found that access to piped water reduced stunting but not improved access to water from other sources. They also found that improved sanitation predicted a large reduction in diarrhoea prevalence but not in stunting or wasting. The recent large-scale high quality WASH intervention studies in Kenya, Bangladesh and Zimbabwe produced disappointing results sparking questions on the value of investing in WASH. The findings of these studies showed no effect of WASH on child growth and diarrhoea (Luby *et al.*, 2018; Null *et al.*, 2018; Humphrey *et al.*, 2019). Researchers argued that a reason for the unexpected results was the narrow focus of the current WASH programmes on constructing toilets, water and hygiene with little emphasis on eliminating pathogens originating from animal faeces (Headey and Hirvonen, 2016; Cumming and Curtis, 2018).

While human faeces is seen as a major reservoir for pathogenic bacteria, animal waste is also found to contain pathogenic and non-pathogenic bacteria, whose accumulation in the small intestine can also lead to EDD and stunting. Marquis *et al.* (1990); Ngure *et al.* (2013); George *et al.* (2015) found that animal faeces and faecal-contaminated soil in Bangladesh, Zimbabwe and Peru contains a greater concentration of pathogenic bacteria. Children in these areas were found ingesting a high proportion of poultry faecal or faecal-contaminated soil for the duration they were studied. Animal faeces was observed in 38–42 percent of households in Ethiopia, Bangladesh and Vietnam which is positively associated with livestock ownership and negatively associated with child linear growth (Headey *et al.*, 2017). In a study of children in rural Ethiopia, Headey and Hirvonen (2016) found that the practice of keeping poultry within the household overnight was negatively associated with HAZ while, in general, livestock keeping positively correlated with HAZ.

Notably, the impact of WASH interventions tended to be stronger when both water and sanitation were improved (Esrey, 1996; Gundry *et al.*, 2004; Eisenberg *et al.*, 2007; Fuller *et al.*, 2015). VanDerslice and Briscoe (1995) show that the positive impact of water on diarrhoea is stronger only if a child lives in a community with improved sanitation. The effect disappears when sanitation is measured at the household level. Other studies provide evidence that improved sanitation may have a relatively greater effect on reducing diarrhoea than improving water infrastructure (Esrey, 1996; Fink *et al.*, 2011; Fuller *et al.*, 2015). Taken together, the findings from these studies suggest that a more comprehensive WASH programme is required for the maximum benefit of the intervention to be realised.

The subsequent section discusses the analytical framework guiding the analysis in this thesis. The framework describes the interlinkage between the different proximal and contextual factors highlighted above and child growth. In the analytical framework section, we discuss how different factors may affect child growth before and after birth, thus providing the theoretically expected sign of the reduced form and structural coefficients estimated in Chapters 2, 3 and 4.

1.3 Analytical Framework

Health is a production process (technology) that converts inputs into output (Grossman, 1972). Individuals make decisions about their health by choosing which goods, and in what quantity, to consume to produce health. According to Grossman's model, an individual inherits an initial stock of health that depreciates with age and more investment in health inputs such as nutritious diet can increase this stock. The question of where this health originates is what Rosenzweig and Schultz (1983) extension model tries to explain. The assumption underlying this model is that an infant inherits a certain level of health stock from their mother. Thus a mother's investment in her health during pregnancy determines the health of her infant child at birth. Similarly, even after birth, mother's choices of what to feed her child can have a short- and long-term impact on child health. Rosenzweig and Schultz (1983) model with slight modification can also be used to explain child health after birth, where the decision of what to consume is made by the parent(s) or collectively at the household level.

This study, therefore, follows Rosenzweig and Schultz (1983) Hybrid Household Production theoretical model which has been slightly modified in a way that fits the analysis of under-five children's health. According to Rosenzweig and Schultz (1983) and Mwabu (2007), a household is assumed to derive utility from child health (H), and consumption of (n) X-goods, and (m-n) Y-goods, where consumption of good X increases the household utility but does not directly affect the health of a child, for example, clothes. The household utility function is therefore given as:

$$U = U(H, X_i, Y_j), \quad i = 1, ..., n; \quad j = n+1, ..., m; \quad U_H, U_X, U_Y > 0 \tag{1.1}$$

Since children cannot make decisions regarding what to consume the assumption is that their health depends on the household's consumption choices. The household produces child health (H) by consuming (r-m) Z_k goods such as child immunisation and medical care that directly affects H and indirectly affects U. The household's consumption of good Y_j such as diet, directly affects both H and U. The household production function is thus given as:

$$H = h(Y_j, Z_k, \mu), \quad k = m+1, ..., r \tag{1.2}$$

where a parameter μ is the stochastic error term that captures the unobserved individual, household or community-specific characteristics that affect child health and over which a household has no control, for example, genetic differences and weather conditions.

The household's demand for inputs is constrained by the limited pooled income as represented by the budget constraint,

$$I = \sum_t Q_t P_t, \quad t = 1, ...r \tag{1.3}$$

where I is pooled household income, which is exogenous in this setup, Q_t is a vector of all market purchased health inputs X,Y and Z, and P_t is a vector of prices of r goods.

The household, therefore, maximises utility Eqn 1.1 subject to the child production function Eqn 1.2 and budget constraint Eqn 1.3. The solution for this household maximisation problem yields a reduced demand function for r goods and r-n health inputs and reduced demand for the health outcome represented by Eqns 1.4 and 1.5 respectively;

$$S_t = G_t(p, I, \mu), \quad t = 1, ...r \tag{1.4}$$

$$H = \theta(p, I, \mu) \tag{1.5}$$

The demand function Eqn 1.4 satisfies all the properties of normal demand function such as negative own compensated price effects and symmetric cross compensated price. However, the health demand function Eqn 1.5 does not have any predictive properties effects (Pitt and Rosenzweig, 1986). The effect of change in input price such as maize price cannot be a priori. Mathematically, this can be demonstrated by taking the total derivative of Eqn 1.2:

$$dH = h_y dY + h_x dX + h_\mu d\mu \tag{1.6}$$

For each health input; X, Y and Z the effect of change in own price and price of the related input is given as;

$$dH/d_x = h_y dY/d_x + h_x dX/d_x + h_\mu \tag{6a}$$

$$dH/d_y = h_y dY/d_y + h_x dX/d_y + h_\mu d\mu/d_y \tag{6b}$$

$$dH/d_z = h_y dY/d_z + h_x dX/d_z + h_\mu d\mu/d_z \tag{6c}$$

where, h_y, h_x and h represent the marginal products of the health inputs. The last term in Eqn

6a - 6c is zero since the price of inputs are uncorrelated with the stochastic error term μ (Mwabu, 2008). The derivative expressions above indicate that even with positive marginal products for all inputs, a change in the price of one good say X can positively or negatively affect health. That is, if X and Y are substitutes a change in price in X might increase the consumption of Y and therefore, improves health. The net effect of a price change depends on the sign and size of the cross and own price effects of the inputs and the relative size of the marginal products (Pitt and Rosenzweig, 1986; Mwabu, 2008).

Notably, Eqns 1.4 and 1.5 are not suitable for the estimation of the causal effects since there is no direct connection between the two. In an attempt to address this limitation Rosenzweig and Schultz (1983) proposed a hybrid production function:

$$H = \psi(Y_m, p_l, I, \mu), \quad l = 1, ...m-1, m+1, ...r \tag{1.7}$$

where Y_m is the health inputs of type m that combine all types of inputs, p_l is the vector of input prices of type m, in this case food prices, and excludes prices of $r-m$ inputs such as healthy neutral inputs.

Household behaviour influences the choices of the health inputs which are thus, are endogenous in the model. Consistent and unbiased estimates of Eqn 1.7, can be obtained by instrumenting the health inputs (Mwabu, 2008). In practice, the reduced demand models are favoured due to the difficulty in obtaining appropriate instruments that address the simultaneity between the health inputs and the production process (Sahn and Alderman, 1997). The reduced models have shown to be more suitable if the interest is to establish the impact of a variable or intervention on health. However, unlike the production function, the reduced models are limited to explore existing conditions and not easy amendable. The production function provides more stable coefficients particularly when there is a change in economic conditions over time (Rosenzweig and Schultz, 1988). Food prices can be used as instruments for the health inputs in 2SLS to obtain consistent estimates in the absence of panel data (Rosenzweig and Schultz, 1983; Sahn and Alderman, 1997; Mwabu, 2008). Alternatively, with panel data, one can directly control unobservable heterogeneous child health endowment (Schultz, 1984). In Section 1.4, we discuss the potential bias that may arise from selective mortality in the estimation as well as the research questions that the described analytical framework seeks to answer and in Section 1.5 the contribution of the findings to fill the existing gap of knowledge.

1.4 Selection Mortality: Potential Bias and Suggested Solution

Due to the strong link between stunting and child mortality, taller and healthier children may be more likely to survive, complicating the relationship between HAZ and economic variables. Through this mechanism, regions with a high mortality rate can thus record lower stunting rates than what would have been given the local conditions, but not necessarily low. The 'selective mortality' may potentially introduce bias to the regression results shown in Chapter 2 and 3 and regional inequality analysis in Chapter 4. For example, with selective mortality, the effects of maize prices on growth might mistakenly be interpreted as positive by capturing the effect on taller children. Research has associated selective mortality with the greater height stature observed among the African population despite the high stunting rate in childhood (Moradi *et al.*, 2010; Alderman *et al.*, 2011; Gørgens *et al.*, 2012). Several methods have been suggested in the literature to address this problem, including inputting the anthropometric data of deceased children using marginal structural models and matching methods (Alderman *et al.*, 2011; Tan *et al.*, 2018). A more practical solution to address the selection bias in this thesis would be to control for infant mortality rates by region in the various birth years. However, information on mortality is not available in the data, so instead to minimise the bias, we controlled for community fixed effects, assuming that infant mortality is stable over time. With fixed effects, we expect less biased results. It is encouraging that evidence from sub-Saharan Africa shows that mortality only marginally influences anthropometric measures (Boerma *et al.*, 1992; Pitt, 1997; Harttgen *et al.*, 2017).

1.5 Research Aims and Study Contributions

Childhood undernutrition threatens the health of future generations and the economic prosperity of many developing countries. The literature sheds light on the likely consequences of a large proportion of a country's population being malnourished during childhood. Persistent poverty, large income inequalities and increased costs of accessing and financing health care are among the few documented effects of childhood malnutrition. Other research has studied the determinants of child malnutrition in different countries and across regions. High food prices emerged as among the core variables explaining the growth of children in developing countries. A particular focus has been on the 2007/08 food price crisis, which led to a huge spike in prices in many countries. Most of the evidence on the impact of food prices on child growth was, however, generated from simulation studies rather than empirically. A few existing empirical studies have broadly assumed that the impact of food prices on growth is homogeneous across all children irrespective of their food production status (Kidane and Woldemichael, 2020; Ilman and Wibisono, 2019; Block *et al.*, 2004).

Similarly, another strand of literature advocates for ASF consumption to make up for the micronutrient insufficiency in children's diets in developing countries. These arguments are largely grounded in evidence of the association between ASF consumption and growth. Some evidence on the causal relationship, particularly meat consumption, from RCT studies in developed countries, has been established, pointing to the positive impact of ASF on growth. However, these results leave a large gap of knowledge for developing countries for two main reasons. First, these RCT studies were carried out in a context with low malnutrition prevalence. Thus, it is not certain that meat consumption could have the same effects in developing countries where many children are stunted. Second, these RCT studies are limited to only children under two years, and it is not clear whether meat consumption would have the same effect on children beyond two years where considerable catch-up growth is happening. Moreover, in sub-Saharan Africa, many households, particularly in rural areas, either grow crops, keep livestock or practise both. Some studies have demonstrated that livestock keeping is associated with child growth. However, little is known in the Tanzania context and, likewise, evidence for a causal relationship is lacking. The literature is also silent on whether ownership of milk, meat or both ruminants yields the same effects on consumption of ASF and child growth.

Furthermore, many other studies have estimated and decomposed the inequality in malnutrition to provide insight for policy intervention. Most of these focused on the socioeconomic inequality in malnutrition – a subset of the emerging literature of inequality of opportunity. Most studies also show the existence of high socioeconomic inequality in child nutrition with children from low socioeconomic profiles being more malnourished than children with higher socioeconomic status. Unlike socioeconomic inequality, inequality of opportunity separates unfair inequality from total inequality, which is more insightful. The literature on the inequality of opportunity builds on Roemer (1998, 2002) theoretical framework, which explains inequality of opportunity as being due to factors beyond an individual's control. A growing number of studies have estimated inequality of opportunity in different countries (Paes de Barros *et al.*, 2009; Barros *et al.*, 2008) and decomposed the inequality into contributing factors (Contreras *et al.*, 2012). However, studies that decomposed the inequality of opportunity pay little attention to the contribution of factors such as access to water and sanitation on the inequality despite their relevance to average health.

This thesis responds to the highlighted knowledge gap. Using Tanzania National Panel Survey (TNPS), this thesis contributes to the literature by exploring the following: (i) The potential heterogeneity impact of maize price fluctuation on the growth of children from food-producing households and food non-producers. (ii) The effects of animal source foods (meat and milk) on child growth and whether livestock keeping mediates these effects. (iii) The role of water and sanitation in explaining inequality of opportunity in stunting in rural and urban Tanzania. The TNPS is part of the living standard measurement survey (LSMS) by the world bank.

Chapter 2 specifically made the following contributions to the literature. First, we provided evidence for the differential effect of maize price fluctuation on the growth of children from food producing households and food non-producing households. As mentioned before, although previous works examined the consequences of high food prices on children nutrition outcomes they could not study the potential heterogeneous effect on children from households that produced food and those that did not. The only exception is the study by Yamauchi and Larson (2019) which examined the impact of the 2007/08 crisis on child growth in Indonesia. They found a negative effect of food price spikes on the growth of children in households which did not produce food and no significant impact on children in those who did. More evidence on the differential impact of high food prices on child growth will add to existing knowledge, which remains scarce, particularly in the sub-Saharan Africa context. As in Yamauchi and Larson (2019), this study finds that a high maize price has heterogeneous effects on the growth of children from food-producing and food non-producing households – the effect is less negative among food producing households than children from food non-producing households.

Second, this study adds to Yamauchi and Larson (2019) contribution by examining the potential channels through which maize price can affect child growth. Specifically, we tested whether a different price effect across producers and non-producers works through the differential effects on the consumption of household micronutrients. Chapter 2 shows that the mechanism is through a reduction in diet diversity and micronutrients intake in food non-producers' households, and an increase in diet diversity and micronutrient consumption in food-producing households.

Third, children in different age groups have different dietary and energy requirements. An adequate supply of energy-rich and micronutrient food is crucial in the first 1 000 days of life. Chapter 2 provides an age and gender-specific analysis of the impact of soaring prices on the growth of children from households who produced food and those who did not. In their study, Yamauchi and Larson (2019) did not show whether the effect of a high food price on child growth differs by age and gender of a child. The findings by age groups from this chapter coincide with that in Chapter 3. This chapter highlights the relative importance of ownership of different types of livestock – meat ruminants and mixed ownership (both milk and meat ruminants) on child growth. Previous studies did not distinguish between types of animals. The quasi-experimental methods applied in the analysis enable causal inferences, which is lacking in the literature. The findings in Chapter 2 show that the negative effects of food prices on child growth is more pronounced for age brackets 24–35 months. However, in Chapter 3, we find a counteractive effect on the growth of ownership of mixed ruminants for this age group. Milk leads to positive growth only in children older than 23 months, and the effect is significant when a child comes from a household that owns mixed ruminants. The age group 24–35 months corresponds to the transition from the breastfeeding stage in Tanzania. Therefore, the results suggest that increased consumption of micronutrients, particularly milk consumption, around the transition stage from breastfeeding could be useful to reduce growth deterioration. Children from households that keep mixed ruminants are likely to be more protected than children from non-ruminant owner households.

The findings in Chapter 2 also contribute to two strands of literature on food prices and food security and the association between diet diversity and child nutrition outcomes in Tanzania. Studies by Rudolf (2019) and Romano and Carraro (2015) analysed the impact of maize price on food security in Tanzania. They present evidence that calories and micronutrient intakes such as calcium, vitamin A and fats declined in various degrees in response to high maize prices. Rudolf (2019) further showed that net maize buyers are more vulnerable to price than net maize sellers when the share of calories of maize is used as a dependent variable, and no effect was observed when HDDS was used. Chegere and Stage (2020) present evidence of a positive impact of HDDS on stunting among children.

The analysis presented in Chapter 2 differs from these studies in two ways. First, while the focus in this chapter is on the link between HDDS and the growth of children, their studies focus on food security. Except for Chegere and Stage (2020) who focus on children from food producing households, we simultaneously focus on children of both food producers and non-producers. Second, our household classification into producers and non-producers is based on household food consumption in the last seven days rather than plot-level information of crops cultivated, as used in Rudolf (2019). This classification allows capturing production shocks that often destroy food crops, which is difficult to capture when plot-based information on whether a household cultivated any plot is used.

In addition to the estimation of the inequality of opportunity in malnutrition, Chapter 4 provides a spatial disaggregated analysis of the contribution of different circumstances on the inequality of opportunity. Unlike previous studies that broadly treated access to water and sanitation as opportunities, Chapter 4 shows that they are both circumstances hindering child growth and opportunities that need to be equalised. The findings show that access to clean water and sanitation are the leading contributors to inequality of opportunity in malnutrition in Tanzania. These findings also relate to those in Chapter 3 given the link between overall sanitation and child growth. Animal ownership might lead to poor sanitation, especially when there is mismanagement of faeces, which could reduce the growth benefits of milk consumption. Chapter 4 also makes a unique contribution to the literature by including the market fluctuations circumstance variables in the decomposition of inequality of opportunity. The decomposition results show market fluctuations contributes to a large share of inequality of opportunity in urban rather than rural areas. These findings are consistent with those in Chapter 2 where higher prices affected only food non-producing households, of which most are urban dwellers.

1.6 Summary

This thesis finds that a household's choice of different livelihood strategies affects children's growth differently. Food production offers protection to children from the adverse effects of market fluctuations on growth, while animal ownership, particularly mixed ruminants and meat ruminant ownership, lead to higher growth due to stable milk and/or meat consumption. In both cases, children transiting from breastfeeding appear to benefit more than younger children. Likewise, access to water and sanitation explains much of the inequality of opportunity in nutrition in rural areas but not in urban areas. Overall, this heterogeneity suggests that malnutrition in Tanzania would be best addressed by different policy interventions for different groups.

CHAPTER 2

MAIZE PRICE FLUCTUATION , AGRICULTURE PRODUCTION AND CHILDREN NUTRITION OUTCOMES IN TANZANIA

2.1 Introduction

Food price fluctuation s have become an important feature in current policy debates due to potential implications on children and the poor. Prior to the 2008–09 food crisis, low food prices were considered unacceptable (Swinnen and Squicciarini, 2012) because it hurt poorer rural farmer households who depended on agriculture as their primary source of income. The declining food prices trend observed from 1974 to the mid-2000s raised concerns about the lower returns of agriculture and the likelihood for farmer households to escape poverty. However, the 2008 food crisis accompanied by high food prices forced policymakers to change their perspective regarding high prices. The welfare and nutrition indicators that deteriorated because of the crisis (Alexander, 2010; Tiwari and Zaman, 2010; Akter *et al.*, 2013; Attanasio *et al.*, 2013; Rajmil *et al.*, 2014), made multilateral organisations revisit policy recommendations, in particular for developing countries.

Additionally, the correlation between domestic prices and weather shocks in developing countries is stronger than with external shocks (Brown and Kshirsagar, 2015; Baffes *et al.*, 2017). The increasingly frequent occurrence of extreme and unpredictable weather has called for the need to incorporate climate change into food security and welfare policies. Dry spells, drought and floods have been increasing for the past few decades, and they are expected to happen more frequently in the next 25 years (Bailey *et al.*, 2015). Natural hazards accounted for 2–15 percent damage to total GDP between 1990 and 2000 and can be linked to the volatile food prices recently observed in developing countries (UNESCO, 2013). Domestic food prices appear to be more volatile even when world prices are stable (Cornia *et al.*, 2016), indicating a low transmission of international prices to local prices and likely high dependence on local crops in the short run (Ellis and White, 2000).

Globally, high food prices have resulted in a food price dilemma due to mixed effects on different population subgroups (Lustig, 2012). World Bank (2008) and Bibi *et al.* (2010) show that children are at higher risk of being affected by high food prices over the short and long terms. The extent to which children are affected by high food prices is still unclear (Arndt *et al.*, 2016) and is likely to be context specific. The literature documents several potential channels through which food prices can affect children health. The most direct impact is the first-order effect operating via the quantity and quality of food consumed.

The evidence of the impact on the poor and on smallholder farmers is scant despite the size and importance of this stakeholder group (Ivanic and Martin, 2008). Insufficient data limits a rigorous investigation of the nutritional consequences of higher food prices (Torlesse *et al.*, 2003; Zaki *et al.*, 2014). As a result, many existing studies in Africa have underestimated the impact of food price on nutrition and poverty (Compton *et al.*, 2010). The current understanding is that the effect differs depending on the household net buyer(seller) market position (Ivanic and Martin, 2008). Higher prices are expected to improve the welfare and nutrition of smallholding farmers who can produce enough for their families and have surplus to sell. Income earned from such sales can be used to buy a more diversified diet even in high food shortage seasons. On the other hand, those who suffer are rural net buyers with no other source of income than agriculture, and the urban poor who spend more than half of their income on food they buy from the market to meet their daily caloric intake requirement. High prices, therefore, erode the purchasing power of poor households and force them to adjust their basket of food to include more affordable items, which often comes at the cost of micronutrients (Zaki *et al.*, 2014). Due to a combination of low meal frequency and insufficient micronutrients, children can become malnourished and suffer from a weak immune system, increasing their vulnerability to infectious diseases.

The widely held view that rural and smallholding farmer households are less vulnerable due to their participation in agriculture has been challenged and is, therefore, no longer entirely valid. Higher prices create opportunities only for the net sellers, with net buyers losing out. The research, however, shows that in developing countries, smallholding farmers are net buyers because they cannot increase their production beyond the subsistence level (Aksoy and Isik-Dikmelik, 2008; Arndt *et al.*, 2008; Martin and Ivanic, 2010; Karfakis *et al.*, 2011). The estimates also show that not more than 20 percent of smallholding farmers in developing countries can produce surplus (Brinkman *et al.*, 2009).

Noteworthy, is that even self-sufficient households are adversely hurt by high food prices due to dependence on the market, particularly during the lean season. This is because most households sell their crops at low prices for cash income to finance the household's expenses and then buy the food later during the lean season when prices have increased (Tefera *et al.*, 2011; Tibaingana *et al.*, 2018; Musara *et al.*, 2019). Additionally, considering Tanzania as a case, poor transport enslaves farmers to the middlemen at local markets who offer them low prices (Misaki *et al.*, 2016). Instead of farmers, the middlemen reap the benefit of high food prices since they are well informed about prices in the regional and national wholesale markets. Farmers are, therefore, forced to be price takers and thus ready to accept any price offered by the middlemen once they are at market after transporting their crops by head from miles away (Compton *et al.*, 2010).[1]

In addition to the net buyer(seller) market position, other factors also play a role. The source of the rural population's income, type of food which is assessed, magnitude of the price increase, and size and adjustment speed of the commodity and labour markets, in both farm and non-farm subsectors, are also very important (Gelaw and Sileshi, 2013; Jacoby, 2013; Akter and Basher, 2014; Headey, 2016). Looking at these factors is important, particularly if the interest is in the medium and long-run effects. There is evidence that high prices may have severe effects in the short run, but adjustment in the labour and commodity markets can neutralise the severity of the effects in the medium to long run period of two to three years (Akter and Basher, 2014). The negative effect of food prices can be offset if farmers manage to increase supply through production and non-farmers' engagement in agriculture (Headey, 2016).

The current study aims to examine the impact of maize price fluctuation on the growth of children from food-producing and food non-producing households. We hypothesise that high maize prices do not negatively impact children from food non-producing households more than children from food-producing households. This hypothesis is guided by the evidence that food producers can benefit from agriculture through income earned by selling the food and a diversified diet from consuming what they produce (Ruel *et al.*, 2013). However, the open question is whether the current level of subsistence production provides children from food-producing households with a buffer against the adverse effects of maize price hikes.

In particular, our interest is in the reduced form as well as the structural coefficients to establish a causal association. The analysis was performed in steps where the reduced form equation was

[1]Similar trade patterns are also reported in Near East regions: Egypt, Jordan, Morocco, Sudan, Syria and Yemen where only a small percentage of farmers were found selling their harvest direct to consumers, rather a large number of them selling to traders in the open rural markets. Consistently in all six countries, a higher percentage of farmers sold their harvest below market price when prices peaked or market activities were matured (Eldukhery *et al.*, 2010).

estimated using OLS for a pooled sample in the first step and control function for the endogenous switching regression by Murtazashvili and Wooldridge (2016) in the second step. The control function accounts for the endogeneity in food production decision which is not random across households. First, we estimated the structural equation that links HAZ and maize price, followed by the second equation that links HAZ and measures for diet diversity and share of calories of maize consumed. In the Tanzanian context, we use the share of calories of maize as a proxy for low diet diversity. When prices are high, households are likely to increase consumption of energy-rich foods, and in the most basic case, maize, to assuage their hunger, because maize remains relatively cheap when the price of other staples rises. Given that maize is the cheapest staple, there is no substitution option, thus the impact of price hikes hit harder.

Similar to Yamauchi and Larson (2019) this study finds that an increase in maize price reduces the growth of children from food non-producing households more significantly than children from food-producing households. However, this study makes multiple additional contributions to the literature. First, unlike Yamauchi and Larson (2019), we provide an age and gender-specific analysis of the impact of soaring prices on the growth of children in households which produced food and those who did not. We find less negative effects on boys than girls in food non-producers households, thus supporting Becker (1981) assertion that households treat children differently conditional on gender depending on the economic conditions. While no research has explicitly assessed how the gender of a child influences feeding practices in Tanzanian households, the evidence that sons are preferred has been documented in many parts of the country (Msuya, 2019; Mwageni *et al.*, 2001; Mulema, 2014). The cultural norms which view a son as an asset and a daughter as a liability have, over overtime, influenced household investment in children in favour of boys, with a detrimental impact on girls' mental and physical health (Msuya, 2019).

Exploring the age-specific effect of maize price, we find that the negative impact of maize price on growth is significant among children aged 24–35 months from food non-producing households. In Tanzania, most children stop breastfeeding at this growth stage and begin to eat from the same plate as other adults in the household. One possible reason for this age-specific effect is that the diet children consume when prices are high lacks the essential micronutrients available in breast milk to continue support growth beyond two years. Another reason could be related to cultural norms. In rural Tanzania, household members eat from the same plate, which may negatively affect the nutritional intake of younger children who often eat slowly (FAO, 2008). Thus, with increased food prices and reduced food availability, children who are in the process of being weaned become vulnerable because they cannot keep pace with older children and adults in the household.

Third, we examine the mechanism of the growth effect of maize price fluctuation . Specifically, we tested whether a different price effect across producers and non-producers works through the differential effects on household micronutrient consumption.[2] We established that the mechanism is through changes in micronutrients and diet diversity. The food producers consumed less energy-rich foods and increased consumption of micronutrients when prices were high. In contrast, food non-producers increased consumption of energy-rich food (proxied by share of maize consumption) and cut back their consumption of micronutrient-rich food.

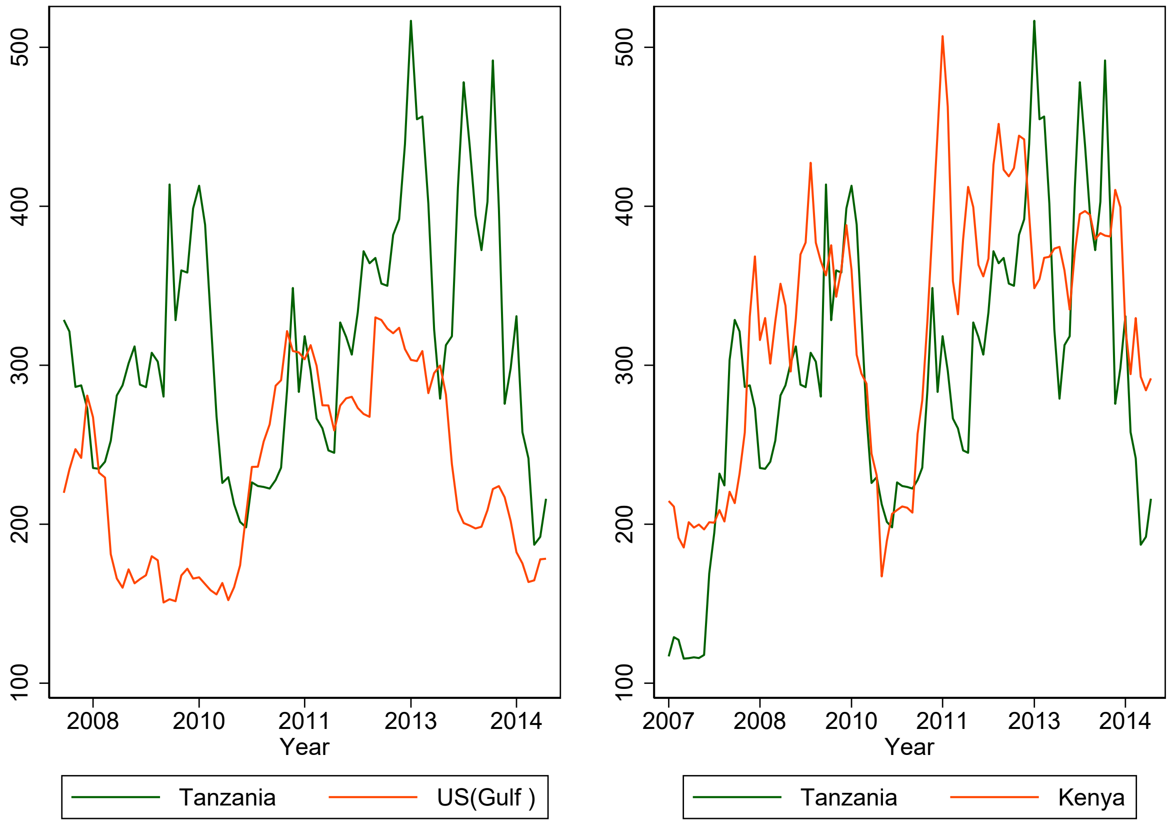
In the next sections, we present the background of the maize production and price trends in Tanzania, describe the data and specify the model. The last two sections provide the results and discussion and finally the conclusions of the study.

2.2 Country Context

Maize is the main staple in Tanzania with a per capita consumption of 80–135 kg/person and contributes 80 percent to total caloric intake (USDA, 2018; FEWS NET, 2018). Maize production accounts for approximately 41 percent of total cultivated land during the long rain season and 47 percent during the short rain season (MAFAP, 2013). A large proportion, 80 percent, of maize is produced by smallholding farmers, where 65–80 percent serves for family consumption and 25–40 percent is traded (Wilson and Lewis, 2015; USDA, 2018).

[2]Many studies on food prices focus on household expenditure or poverty and their analysis is dominated by the household's net food consumption position assessment (Deaton, 1989). While income can mediate the association between food prices and child nutrition, a rigorous analysis of the impact of price fluctuations on diet diversity across net-buyer(seller) households could be useful (Headey and Masters, 2019). However, we do not follow the net buyer(seller) classification approach because it limits our broader understanding of the role of own production; being a food producer can have an impact on its own. Moreover, a household may not necessarily be a net buyer(seller) of food. Still, consumption of own production can reduce the risk of food insecurity and malnutrition, particularly when food prices are high. Moreover, household net food consumption is hardly accurately measured in household surveys which impose systematic errors (Deaton, 1989). While income can mediate the association between food prices and child nutrition, a rigorous analysis of the impact of price fluctuations on diet diversity across net-buyer(sellers) households could be useful (Headey and Masters, 2019). However, we do not follow the net-buyer(sellers) classification approach because it limits our broader understanding of the role of own production; being a food producer can have an impact on its own. Moreover, a household may not necessarily be a net-buyer (seller) of food. Still, consumption of own production can reduce the risk of food insecurity and malnutrition, particularly when food prices are high. Moreover, the household net food consumption is hardly accurately measured in household surveys which impose systematic errors (Headey and Fan, 2010).

Unlike many countries that experienced immediate price increases on the main food staples during the 2008 and 2011 food crises, the transmission to Tanzania was comparatively small and slow to feed through the system. Domestic prices increased but at a slower rate, while international prices rose from mid-2007 to March 2008 and continued to increase when international prices were decreasing (Macharia *et al.*, 2009). The data for Tanzania also indicates that the maize price fluctuated and deviated from international prices in the analysed period 2008–13 (Figure 2.1). However, of much interest in this study is a maize price fluctuation marked by a huge spike in the last quarter of 2012 to the second quarter of 2013 (see Figure 2.1). While regional trade movements are often linked to large domestic price swings, factors such as seasonality, unpredictable trade policies and intervention through the National Food Reserve Agency (NFRA) have an impact (Rashid *et al.*, 2010; Baffes *et al.*, 2017). Seasonality on its own causes about two-thirds of domestic price fluctuations (Baffes *et al.*, 2017).



Source: Author. Data sources: FAOSTAT

Figure 2.1: Monthy Maize Price Trend, Tanzania, Kenya and US (Gulf)

Maize trade is mostly used as an intervention tool through export bans to stabilise prices in the major consumption market in Tanzania (World Bank, 2004). For example, for the period between 2006 and 2012, the ban was imposed and lifted at least ten times (Stryker and Amin, 2013). Export bans are, however, reported to be less effective at lowering prices, but rather are disruptive (Diao and Kennedy, 2016). An analysis of the export bans imposed during 2005–10 shows that the objective of the ban was only partly achieved. During the ban period, the maize could not be moved from surplus to deficit markets where the price was high and instead distorted farmers' profit in the surplus zones (MAFAP, 2013). Baffes *et al.* (2017) also show that prices decrease only temporarily when the ban is imposed and return to an even higher level when the ban is lifted.

2.3 Related Literature

A large body of existing literature on the food price and welfare nexus focuses on the 2007–08 food crisis that resulted in large swings in food prices in many countries (see, De Hoyos and Medvedev (2009); Hadley *et al.* (2011, 2012); Alem and Söderbom (2012); Ivanic and Martin (2014)). However, as argued by Ivanic *et al.* (2012), even short-lived price fluctuation s exert significant impacts on the poor and smallholding producers by affecting their caloric and nutrition intake (Skoufias *et al.*, 2011). Children under age 24 months are reportedly more vulnerable to price variations due to their dietary and caloric requirements in their first 1 000 days of life. A period of only six months of insufficient food consumption is enough to cause permanent physical and mental harm to infants (Victora *et al.*, 2008; Lustig, 2012).

In Ethiopia, Woldemichael *et al.* (2017) used DHS and monthly retail price data to show that children aged 5–6 months who were exposed to high cereal prices were shorter and lighter than normal. Specifically, children who were exposed to a 10 percent food inflation on average lost about 0.08 cm of height and 5 g of weight. Conversely, Brenton and Nyawo (2021) found improvement in height-for-age z-scores (HAZ) with no clear effect on weight-for-age z-scores (WAZ) in response to market prices.

Using household survey data for Mozambique Arndt *et al.* (2016) studied the impact of food price variations in different quarters of the year 2008–09 on child malnutrition measured by weight-for-height (WHZ) and WAZ. Their findings show that children's nutrition indicators improve in the quarters when food prices were low and worsen when food prices are high. They also found WAZ to be more sensitive to price movement as the proportion of underweight children declined by 40 percent in a quarter with low food prices. In El Salvador De Brauw (2011) show that the proportion of stunted children aged under three years increased due to the 2007–08 food price crisis shock, with a more pronounced effect among children without access to remittances. Cornia *et al.* (2008) demonstrate that the number of malnourished children in Niger intensified when drought hit the country and lead to a sharp increase in millet prices in 2005.

Notably, as one of the main pathways through which food prices affect children, food security has featured very well in the welfare debate (see, Karfakis *et al.* (2011); FAO (2010); Maltsoglou *et al.* (2010); Cohen and Garrett (2010); Woertz *et al.* (2014)) due to its implications on the overall quality of children's diet. The literature broadly established a positive association between higher diet diversity and child nutrition outcome. An increase in diet diversity by one food group was found to improve HAZ and WAZ respectively, by 0.09 and 0.06 sd in India (Menon *et al.*, 2015), 0.08 and 0.04 sd in Bangladesh (Zongrone *et al.*, 2012), and 0.11 and 0.117 sd in rural Ethiopia (Amugsi *et al.*, 2014). Frempong and Annim (2017) found a higher rate of stunting among children who did not meet the minimum diet diversity(MDDS) in Ghana and according to Zongrone *et al.* (2012) children in Bangladesh who do not meet (MDDS) are 0.02 sd shorter than those who meet the requirement. (Perkins *et al.*, 2018) found a positive association between diet diversity and HAZ among children aged 24–54 months and no association in the age group 12–24 months in Sri Lanka but did not find any significant relationship with anthropometric failures; obesity, stunting, wasting. A study by Amugsi *et al.* (2017) that covered five sub-Saharan African countries; Kenya, Ghana, Nigeria, Mozambique and Democratic Republic of Congo (DRC) found a positive association between diet diversity and HAZ across the conditional distribution of HAZ. They observed a significant influence of diet diversity on HAZ only in the $5^{th}, 10^{th}, 25^{th}, 50^{th}$ quintiles in all countries (except DRC) but also at the 90^{th} quintile in Nigeria. A stronger impact of diet diversity was evidenced on the lower 5^{th} and upper 90^{th} quintiles except for DRC where the effect is at 5^{th} quintile only.

The evidence of the link between food prices and food security is largely inconclusive due to mixed findings. For example, Harttgen *et al.* (2012) using household survey data from Malawi and Uganda show that staple price fluctuation had a significant negative impact of food prices on food security in both countries. Similarly, Akter *et al.* (2013) found an increase in food insecurity among households in rural Bangladesh, while Hasan (2019) found no effect on caloric consumption and diet diversity in the same settings. In a study involving 69 low and middle-income countries, Headey (2013) found a substantial impact of high food prices on food security in most countries surveyed. In China, Jensen *et al.* (2008) also found a modest decline in caloric consumption among households.

These findings are by and large consistent with empirical welfare studies (Ivanic and Martin, 2008; Ivanic *et al.*, 2012; Balagtas *et al.*, 2014; Iqbal, 2018) that show an increase in absolute and depth of poverty. In Uganda, the incidence and depth of poverty increased by 2.6 and 2.2 percent, respectively, when prices increased during the 2007/08 food crisis where only modest decline in welfare was reported in Benson *et al.* (2008). The incidence of poverty in Ethiopia increased from 37 percent in 2004 to 54 percent in 2009 when average grain inflation between the two periods rose by 308.09 percent (Gelaw and Sileshi, 2013). The benefit of high food prices to the farmers was also found to be small compared to the adverse effects experienced by the poor (Wodon and Zaman, 2008).

2.4 Data and Methods

This study uses the three waves of the Tanzania National Panel Survey (TNPS); 2008–09, 2010–11 and 2012–13 which collects various information on living standards. The data is part of the Living Measurement Standard Study (LSMS) by the World Bank, which follows a stratified, multistage cluster sampling design. The sample size for waves I, II and III were 3 265, 3 924 and 5 010 households, respectively. Attrition across surveys was low, with 96 percent of original households successfully maintained. The focus of this study is children under the age of five, and thus all other household members that did not meet our criteria were excluded from the analysis. Furthermore, we dropped observations with missing information on child height and age, leaving a working sample of 2017, 2205 and 2704 children in 2008, 2010 and 2012 surveys. (Table 2.1). We classified a child as belonging to a food-producing household based on the self-reported food consumption information.[3]

The outcome variable used in this study is the child height-for-age z-score (HAZ) as per 2006 WHO growth standards. The z-scores calculated are age and sex-specific. Children with biologically implausible scores below -6 and above $+6$ standard deviation were excluded. A z-score below zero indicates poor growth; scores between 0 and -2, -2 and -3 and below -3 refer respectively to mild, moderate and severe stunting conditions. Similarly, we define a child as stunted if the z-score lies

[3] The authors acknowledges the possible error that might arise due to misclassification of producers into non-producers if a particular household had nothing in stock during the time of survey.

below −2SD of the WHO standard median.

The maize prices were computed directly from the households' food expenditure section that reports the quantity of food purchased and its monetary value. The prices were obtained by dividing the total value of the maize purchased and its quantity purchased by a household. The prices were then aggregated at the district level, the lowest possible administrative division, and median, instead of unit values, were used in the analysis. The surveys also collect price data at a community level from community centres, shops and markets reported in the community section. However, these data could not be used due to many missing values. To ensure that we use the correct prices, a correlation analysis between the constructed prices and community level prices for the districts with price information was conducted, which showed no substantial difference between the two prices **??** in the appendix.

The households are defined as food producers if, in last seven days, they consumed either of the main staples (maize, cassava, rice and sorghum) from the stock of their last seasons own production. Cassava, rice and sorghum are the second, third, and fourth predominant food staples after maize in Tanzania, each contributing about 13 percent, 8 percent and 4 percent of the total calories intake (Minot, 2010). Households are defined as food non producers if the food they consumed in the last seven days was purchased from the market. This classification has advantages over classification that is based on whether a household cultivated any plot in the last season or not as used by Rudolf (2019). The probability that a farmer cultivates a plot and harvest nothing is very high due to shocks such as climate shocks, pest and diseases which are more pronounced recently. However, we also acknowledge that our definition may also have some limitations when producers are erroneously misclassified into nonproducers if a household has nothing in stock during the survey. Under such circumstances, the results are likely to be downward biased as they don't capture the true effect of food production.

Table 2.1 reports the characteristics of the sample and descriptive statistics of the variables used in the study. The first column presents the statistics for the pooled sample, and columns (2)–(4) present wave-specific statistics. On average, children's HAZ improved over six years while the mean price for maize did not increase substantially over the same period.[4] While the mean number of

[4]It is possible that the changes we observe are driven by changes in the sample across waves of the panel. Comparing the same children across waves is difficult because doing so crosses the five-year cut-off. The increase in the average values of other variables such as a household's ownership of assets and mothers' years of schooling is an indication that the sample has changed over time.

Table 2.1: Sample Characteristics

	Pooled Sample		2008		2010		2012	
producer	mean	sd	mean	sd	mean	sd	mean	sd
HAZ	-1.59	(1.54)	-1.79	(1.50)	-1.48	(1.53)	-1.53	(1.56)
Maize Price	7.16	(0.24)	7.02	(0.15)	7.07	(0.16)	7.34	(0.25)
Consumption(log)	14.70	(0.73)	14.44	(0.65)	14.64	(0.67)	14.95	(0.74)
Household Size	7.89	(5.38)	7.32	(4.57)	8.06	(5.92)	8.19	(5.47)
Mother's Education	5.39	(3.32)	5.16	(3.24)	5.32	(3.36)	5.62	(3.34)
Male Headed	0.84	(0.37)	0.83	(0.37)	0.84	(0.37)	0.84	(0.37)
Head Age	44.35	(14.26)	43.34	(13.77)	44.75	(14.37)	44.83	(14.51)
Distance to Market	56.18	(41.03)	53.52	(39.77)	56.31	(41.43)	58.02	(41.54)
Rural	0.90	(0.30)	0.91	(0.29)	0.90	(0.30)	0.89	(0.31)
Child=Male	1.50	(0.50)	1.52	(0.50)	1.50	(0.50)	1.50	(0.50)
Child Age	2.13	(1.61)	2.02	(1.36)	2.10	(1.59)	2.23	(1.80)
0-5mo	0.08	(0.27)	0.05	(0.22)	0.09	(0.28)	0.09	(0.28)
6-23mo	0.31	(0.46)	0.31	(0.46)	0.32	(0.47)	0.29	(0.46)
24-35mo	0.21	(0.41)	0.21	(0.41)	0.20	(0.40)	0.22	(0.42)
36-60mo	0.40	(0.49)	0.43	(0.50)	0.39	(0.49)	0.40	(0.49)
HDDS	7.49	(2.38)	7.33	(2.31)	7.66	(2.34)	7.49	(2.46)
Share Calories(meat+fish	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)
Share Calories (nuts+seeds)	0.01	(0.03)	0.01	(0.04)	0.01	(0.02)	0.01	(0.03)
Share Calories (vegetables)	0.00	(0.01)	0.00	(0.01)	0.00	(0.00)	0.00	(0.00)
Share Calories(fruits)	0.01	(0.02)	0.01	(0.03)	0.01	(0.03)	0.01	(0.02)
Observations	5428		1556		1714		2158	
non-producer	mean	sd	mean	sd	mean	sd	mean	sd
HAZ	-1.20	(1.53)	-1.31	(1.48)	-1.04	(1.52)	-1.24	(1.56)
Maize Price	7.18	(0.22)	7.02	(0.11)	7.12	(0.12)	7.38	(0.23)
Consumption(log)	15.13	(0.74)	14.99	(0.74)	15.13	(0.71)	15.25	(0.73)
Household Size	5.87	(2.91)	5.74	(2.68)	6.25	(3.21)	5.63	(2.76)
Mother's Education	7.52	(3.40)	7.41	(3.01)	7.52	(3.57)	7.61	(3.55)
Male Headed	0.78	(0.41)	0.81	(0.40)	0.76	(0.43)	0.78	(0.42)
Head Age	39.66	(12.71)	40.25	(13.00)	40.14	(12.29)	38.72	(12.80)
Distance to Market	17.80	(29.33)	11.82	(20.88)	17.43	(29.88)	22.60	(33.17)
Rural	0.29	(0.45)	0.15	(0.36)	0.35	(0.48)	0.34	(0.47)
Child=Male	1.51	(0.50)	1.51	(0.50)	1.51	(0.50)	1.50	(0.50)
Child Age	1.56	(0.75)	1.54	(0.70)	1.60	(0.83)	1.54	(0.72)
0-5mo	0.07	(0.26)	0.03	(0.17)	0.10	(0.30)	0.09	(0.28)
6-23mo	0.34	(0.47)	0.32	(0.47)	0.33	(0.47)	0.36	(0.48)
24-35mo	0.20	(0.40)	0.22	(0.42)	0.18	(0.39)	0.21	(0.41)
36-60mo	0.39	(0.49)	0.43	(0.50)	0.39	(0.49)	0.35	(0.48)
HDDS	9.14	(2.36)	9.36	(2.22)	9.18	(2.34)	8.91	(2.47)
Share Calories(meat+fish	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)
Share Calories (nuts+seeds)	0.02	(0.03)	0.02	(0.03)	0.02	(0.02)	0.02	(0.03)
Share Calories (vegetables)	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)
Share Calories(fruits)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)	0.01	(0.02)
Observations	1500		461		491		548	

All controls variables are defined separately in each wave.

households accessing health care increased by 35 percent between the first and third wave, the mean number of households with access to clean and safe water reduced by 22 percent. On average, the number of children born to mothers under the recommended childbearing age of 18 years increased from 53 to 70 percent between 2008 and 2012. Early childbearing is associated with the risk of a child born being underweight, often resulting in serious health and development problems.

2.5 Model Specification and Estimation

The empirical specification draws on the influential Grossman (1972) health production theoretical model and the extended hybrid household health production model for children under five years (Rosenzweig and Schultz, 1983; Mwabu, 2007). We estimated the reduced form child health input demand function using OLS and control function for the endogenous switching regression model in the second step.

(a) *Reduced Form Equation*

The empirical reduced form equation is specified as follows:

$$HAZ_{it} = \alpha + \beta_1 MaizePrice_{it} + \beta_2 MaizePrice_{it} \times Producer_{it} + \beta_3 Producer_{it} + \gamma X_{it} + \delta D + \mu_{it} \quad (2.1)$$

where HAZ_{it} is the height for age child z-score, and $\beta' s$ are the coefficients of primary interest which capture the effects of a maize price fluctuation on the HAZ scores. γ represents a vector of coefficients that captures the effects of non-price variables that are likely to affect child HAZ. D is a vector of community fixed effects and survey specific dummies, and the last term μ_{it} is a well behaved stochastic error term.[5]

Estimating Eqn. 2.1 using OLS allows us to establish for a correlation between the variables of interest and the outcome variable. The model was estimated by child gender, age categories, and harvesting seasons subsamples. In both approaches, we interacted with the maize price, a dummy for food producers, to examine whether the effects differ between the two groups. The assumption is that the sensitivity of HAZ to maize price depends on which group a child belongs to. Food

[5] We did not add child or household Fixed Effects (FE) because children are difficult to follow across waves within this very narrow age group of 0-5 years.

producers might be less sensitive since they can consume what they produce and purchase only a small share if necessary, while the food nonproducing households have to purchase everything (Grace *et al.*, 2014).

(b) *Control Function for Endogenous Regression Switching Model*

In any given year, a household decision to produce food crops depends on the expected benefit of producing food crops over other crops. The decision to produce food is not random and may be subjected to selection bias and influenced by unobserved heterogeneity between households and farm specific characteristics. The unobserved heterogeneity is likely to affect both the decision to produce food and the outcome variable and, therefore, lead to biased estimates, particularly when OLS is used. To establish a causal association, we combine the control function and Instrumental Variable (IV) to estimate the endogenous switching regression model. We specifically follow a constant coefficient switching regression model for panel data presented in section 3.1 in Murtazashvili and Wooldridge (2016). We treated the decision to produce food as an endogenous switching variable and specified the two regimes as follows:

$$h_{it1}^{(q)} = X_{it1}\beta_q + c_{i1q} + \mu_{it1q}, \quad i = 1, ..., N; \quad and \quad t = 1, ...T \tag{2.2}$$

where $h_{it1}^{(q)}$ is an outcome variable (HAZ), c_{i1q} is the time constant individual-specific unobserved effects, and μ_{it1q} is an idiosyncratic error term in the two regimes represented by q, such that q =1 if a household produces food and 0 if not. X is a vector of endogenous and exogenous explanatory variables such as HDDS, share of calories of maize, household expenditure, maize price, household size, maize producers, and distance to the market. β_q is a vector of coefficients in the q regimes. β_1 and β_0 are the coefficients of interest where for simplicity we write $\gamma = \beta_1$ - β_0 in a full model specification as in the Eqn 2.3 below.

$$h_{it1} = X_{it}\beta + h_{it3}X_{it}\gamma + \bar{z}_i\rho_0 + h_{it3}\bar{z}_i\rho_1 + \delta_0\hat{gr}_{it3} + \delta_1 h_{it3}\hat{gr}_{it3} + \mu_{it} \tag{2.3}$$

where $\bar{z}_i = \sum_{t=1}^{T} z_{it}$, are the mean values of the Mundlak devices (z_{it}) which consists of strictly exogenous variables such as (head gender, head age and mother's education), h_{it3} is an endogenous switching variable, $\hat{gr}_{it3}$ is a generalised residual from the first stage regression, $h_{it3}\hat{gr}_{it3}$ is an interaction between a switching variable and generalized residual, and μ_{it} is an error term. The estimation procedure involves running a probit model of h_{it3} on z_{it} and $\bar{z_i}$ for all N x T observations in the first stage to generate generalized residual $\hat{gr}_{it3}$. In the second step, Eqn 2.3 is estimated by 2SLS using $(\bar{z_i}, h_{it3}\bar{z_i}, \hat{gr}_{it3}, h_{it3}\hat{gr}_{it3})$ as instruments if there is an endogenous explanatory variable in the model, otherwise the second step involves estimation of the standard OLS.

This approach has several advantages over applying IV or endogenous switching regression model on its own as has been used in previous related studies (Salazar *et al.*, 2015; Cawley *et al.*, 2018; Di Falco *et al.*, 2011; Asfaw *et al.*, 2012; Kassie *et al.*, 2018; Ali and Awade, 2019). Applying IV methods or regressing the fitted values $\hat{y}$ obtained in the first stage on y (Adams *et al.*, 2009; Zereyesus *et al.*, 2017) yields inconsistent results, particularly when there is more than one source of unobserved heterogeneity (Murtazashvili and Wooldridge, 2016). A control function combined with IV accounts for the correlation between endogenous and exogenous explanatory variables. The inclusion of Mundlak (1978) and Chamberlain (1980) devices which are simply the means of time varying strictly exogenous covariates in the food producer and outcome equations adjust for the time-constant unobserved heterogeneity. Furthermore, the approach is flexible to allow either the switching variable alone or both switching and other explanatory variables to be endogenous in the model.

2.5.1 Instrumental Variable (IV)

Similar to Zanello *et al.* (2019) and Dubbert (2019), we instrument decision to produce food by the share of maize farmers within a cluster. The instrument meets the identification and exclusion criteria by having a low correlation with the outcome variable and strong correlating with the decision to produce food (First stage regression is reported in Table 2.8)[6]. The share of maize farmers within a cluster can represent the suitability of soil for growing food crops, which in turn affects the decision to produce food. The effect of the instrument on HAZ is only indirectly through food production. Additionally, the effect can be through information externalities where farmers are expected to learn from their fellow farmers nearby (Holloway *et al.*, 2002; Michelson, 2017; Li and Zhao, 2018). It could be possible that the share of maize farmers captures the socioeconomic status in the cluster, which may directly affect HAZ. Children living in communities with many

[6]We asses the quality of the IV based on the rule of thumb $F > 10$ by taking a square of the z-statistic $((0.013/0.003)^2 = 18.775)$ which is greater than the cutoff value.

food producers are likely to have higher HAZ than those with fewer producers due to high food availability. To eliminate this possibility, we include community fixed effects in the regression.

The explanatory variables: household diet diversity Score (HDDS) and share of calories of maize consumption in the HAZ regression cannot be exogenous. Feeding practices are heterogeneous across households and can be influenced by both observed and unobserved factors which also affect HAZ. The relationship between HAZ and diet measures runs in both directions and thus, OLS estimators of Eqn 2.3 are inconsistent. For example, when a household changes the composition of diet after observing the deterioration in child nutrition, the direction of causality will run from HAZ to HDDS (Frempong and Annim, 2017). We instrument the HDDS and share of calories of maize with the maize price. The effect of maize prices on child nutrition is indirect and works via a change in diet composition and, thus, serves as a valid instrument. The maize price averaged at district level was also used to instrument crop diversity in a study by Lovo and Veronesi (2019) in Tanzania.

2.5.2 Construction of Diet Diversity (HDDS) and Calculation of Calories

To assess the access and quality of food consumed by children in the household, we constructed a household diet diversity score (HDDS) – a validated indicator of the ability to access food in the household – based on a simple count of food groups consumed by the household. HDDS strongly correlates with caloric and protein intake adequacy and household income (Swindale and Bilinsky, 2006), making it relevant for the assessment of the overall food security in the household, particularly when prices increase. The construction of HDDS was based on FAO guidelines, which recommend a seven day recall period of all food consumption (Kennedy *et al.*, 2011) and previous works (Kumar *et al.*, 2015; Chegere and Stage, 2020). We particularly sum the number of food groups out of 12 food groups: Cereals; Nuts and seeds; White tubers and roots; Vegetables; Fruits; Legumes; Meat; Eggs; Fish and other seafood; Milk and milk products; Sweets; Spices, condiments; Beverages and Oils and fats that a particular household consumed in the last seven days. We also calculated the food-specific and food group kilocalories using conversion units in calories per kg for each 59 food items provided in the National Panel Survey reports (NBS, 2012, 2014).

2.6 Results and Discussion

2.6.1 Descriptive Results

Figure 2.2 presents the distribution of children's HAZ scores over the three surveys. In all the surveys, the scores are skewed to the left, indicating that a higher number of children are malnourished. Only a small number of the children fall under the mild category, while the majority are either moderate or severely malnourished as their HAZ scores are below minus two standard deviations (-2SD). There is a noticeable shift in the HAZ scores distribution curves to the right after the first survey, indicating a decline in malnutrition, but no clear difference can be observed between the second and third surveys.

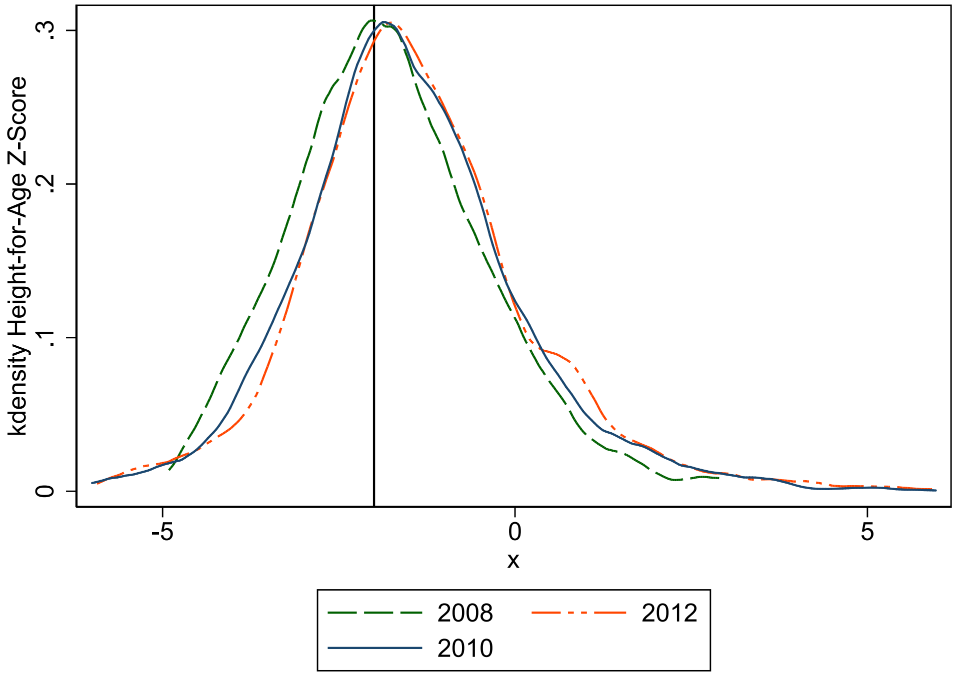


Figure 2.2: Distribution of Height-for- Age Z- Score 2008-2012

Stunting levels are higher in rural areas than urban areas as seen in Figure 2.4, where nearly 47 percent of the children in rural areas compared to 33.2 percent of those in urban areas were stunted in 2008. In 2010 stunting levels decreased by 9.5 percent and 8.2 percent in rural and urban areas, respectively. Despite the higher prevalence of stunting in rural areas, stunting increased by a higher proportion in urban areas in 2012. Stunting increased by about 5.7 percent in urban areas compared

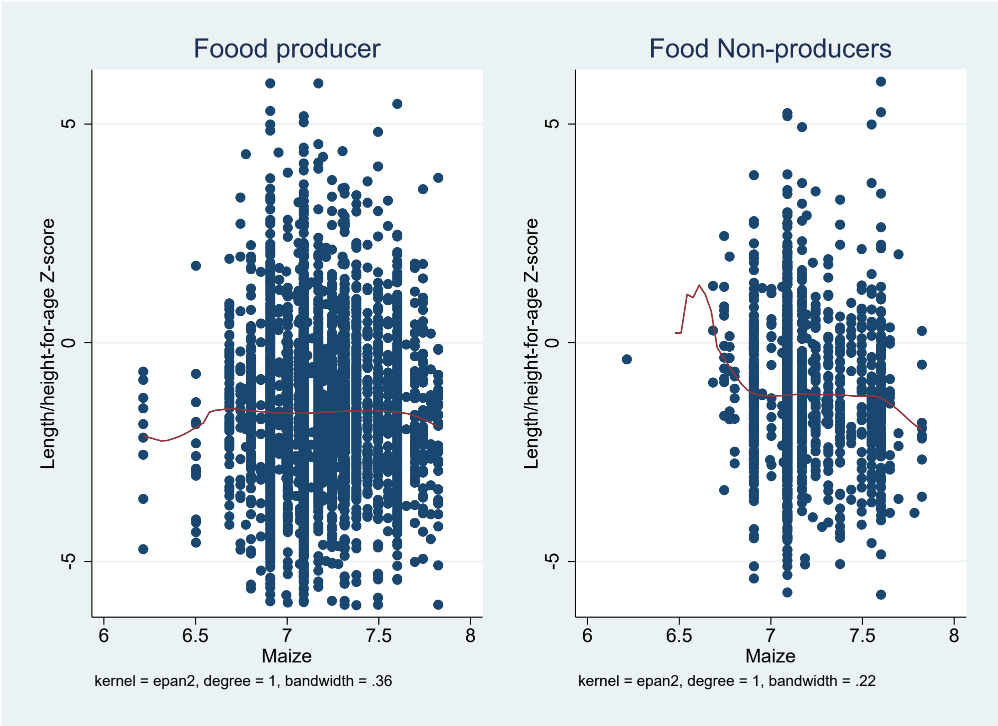


Figure 2.3: Relationship between Maize Price and Height-for- Age Z- Score 2008-2012

to 1.7 percent in rural areas. These patterns are consistent with a maize price fluctuation that hit the economy between 2012 and 2013, as is shown in Figure 2.1. The levels of stunting were 39.6 percent in rural areas and 30.7 percent in urban areas in the year 2012. Compared to other waves, the baseline stunting levels are also very high, plausibly attributable to the 2007/08 food crisis, which is reported to have doubled the maize price, particularly in urban Tanzania (Rudolf, 2019).

Figure 2.5 shows a higher stunting prevalence among food producers than food non-producers in all the surveys. This distribution represents an important aspect of endogeneity in food production; poor households often have children who are short for their age and use food production as a coping strategy. The stunting prevalence substantially declined in 2010 among both food producers and non-producers but increased by a larger proportion among children from food non-producing households than food-producing households in 2012. Nearly 7 percent of the children from the non-producing households became stunted in 2012. This trend indicates that food production increased the relative resilience to price fluctuation for food-producing households. Figure 2.3 provide some hints of what could be the reason behind the observed trend. The HAZ is plotted against maize price showing the relationship is negative for food non-producing households but the relationship is linear, but fairly flat in food producing households [7].

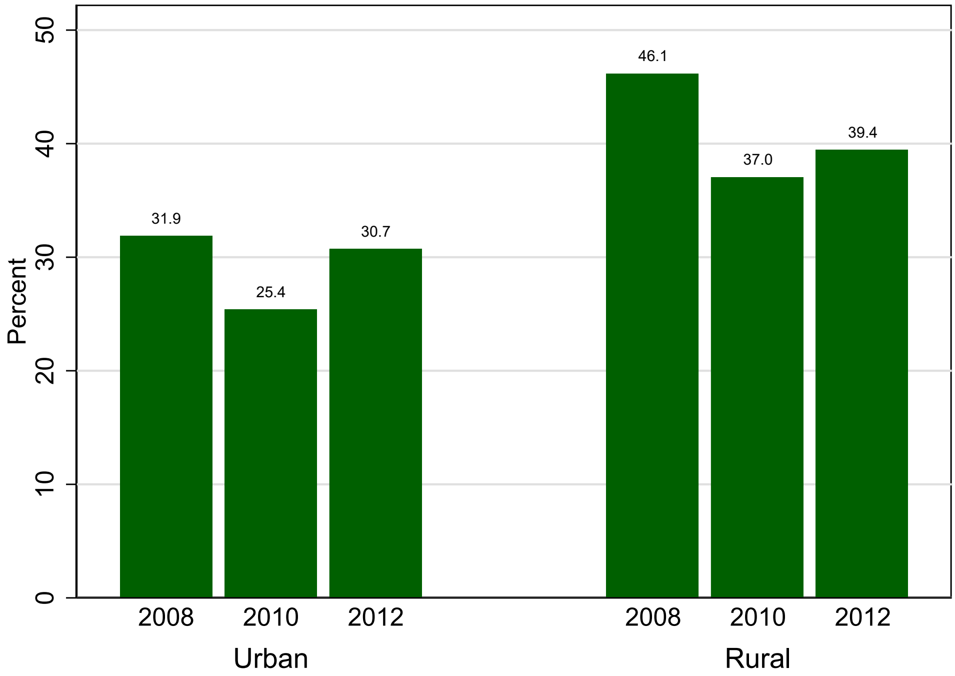


Figure 2.4: Proportion of Stunted Under-Five Children by Area of Residence

Table 2.2 shows that during the maize price surge in 2012, the average per capita maize consumption declined by 22 and 3 percentage points among food producers and food non-producers, respectively. This differential drop in maize consumption has two implications. First, non-producers are at greater risk of experiencing a reduction in consumption below the critical level given that consumption was already low before the maize price fluctuation . The second is the substitution from maize consumption to other food bought in the market among food producers. It is likely that food producers reduced their share of maize consumption and sold some when prices increased.

Nevertheless, despite the higher stunting rate that we observe, children appear to catch up on growth as they age, particularly in rural areas (Table A.1 in the appendix). The transition matrix in Table 2.3 and Table 2.4 also confirms catch-up growth among both male and female children, where quite considerable movements ranging 45 percent to 51 percent between 2008 and 2010 and 43 percent between 2010 and 2012 can be observed. However, with transition matrices alone, it is

[7]While I do not account for the non-linearity for non-producers in my models, these non-parametric results are consistent with the linear modelling strategy: price has a negative relationship with HAZ that is mitigated by being a producer.

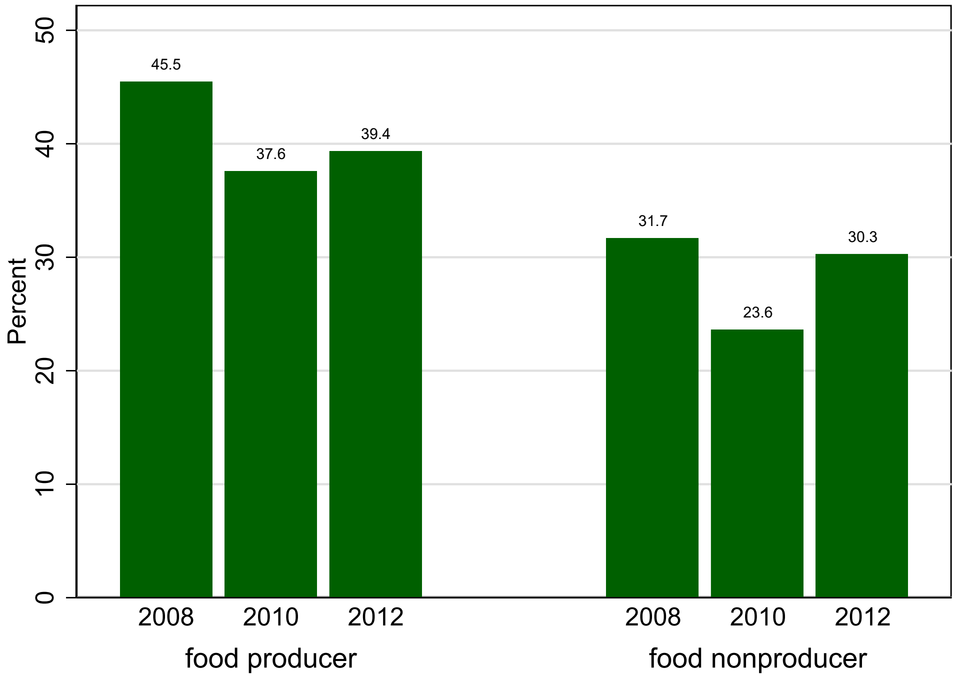


Figure 2.5: Proportion of Stunted Under-Five Children by Food producers and Non Food producers

Table 2.2: Average Consumption per Capital of Food in Kg

	Producers			Non- Producers		
	2008	2010	2012	2008	2010	2012
Maize	0.846	0.926	0.704	0.252	0.210	0.172
Observations	2737	2238	2176	455	598	541

difficult to tell whether the improvement is from moderate to mild or a completely healthy state.

The analysis by age group in Table A.1 shows that the movement is only at the margins as a higher proportion of children move from worst to the second-worst category, and that younger children are more likely to be stunted than older ones. Table 2.5 and Table 2.6 also shows that catch-up growth among children is more likely to happen in urban than rural areas – 71 percent vs 43 percent (2008-2010) and 47 percent vs 43 percent (2010-2012).

Table 2.3: Transition Matrix for the Stunted Children by Sex (%) - 2008 to 2010

	Male		Female		
	non stunted	stunted	non stunted	stunted	Total
non stunted	86.89	13.11	83.88	16.12	100
stunted	50.95	49.05	45.41	54.59	100
Total	68.75	31.25	67.21	32.79	100

Table 2.4: Transition Matrix for the Stunted Children by Sex (%) - 2010 to 2012

	Male		Female		
	non stunted	stunted	non stunted	stunted	Total
non stunted	73.84	26.16	76.19	23.81	100
stunted	43.6	56.4	44.1	55.9	100
Total	61.4	38.6	64.41	35.59	100

Table 2.5: Transition Matrix for Stunting in Rural and Urban Areas (%) - 2008 and 2010

	Rural		Urban		
	non stunted	stunted	non stunted	stunted	Total
non stunted	81.73	18.27	92.77	7.23	100
stunted	43.23	56.77	70.69	29.31	100
Total	62.88	37.12	83.69	16.31	100

Table 2.6: Transition Matrix for Stunting in Rural and Urban Areas (%) - 2010 and 2012

	Rural		Urban		
	non stunted	stunted	non stunted	stunted	Total
non stunted	74.49	25.51	79.69	20.31	100
stunted	43.36	56.64	46.77	53.23	100
Total	61.82	38.18	68.95	31.05	100

2.6.2 Regression Results

Table 2.7 presents the reduced form results based on the pooled sample. Column (1) shows that the maize price is negatively significantly associated with HAZ of the food non-producers' children and positively significantly associated with HAZ of the food producers' children. Previous literature has noted that the relationship between child nutrition and other potential covariates can be driven by seasonality, highlighting the need to account for seasonality in the estimation (Bevis *et al.*, 2019; Zanello *et al.*, 2019). Lack of storage also determines food access and availability between the harvest and lean seasons and thus the household's nutrition (Basu and Wong, 2015; Omotilewa *et al.*, 2018). Columns (8) and (9) provide estimates for the lean and post-harvest agricultural seasons. As seen in the table, the association between maize price and HAZ appears to persist in both lean and post-harvest agricultural seasons, implying that the observed relationship is not driven by seasonality.[8] The results suggest that households can smooth inter-seasonal food consumption by consuming from their stock and selling at a higher price in the lean season to buy other foods from the market.

In columns (2) and (3) we can see a significant negative association between maize price and HAZ only among female children from the food non-producers. The coefficient of maize price among male children from food non-producers is negative but not significant. Similarly, for children from food producers, we observe a positive association between maize price and HAZ only among female children. Columns (4)–(7) present the correlation between maize price and HAZ across different age categories. The significant negative association between maize price and HAZ is observed only among older children aged 24–35 months and 36–60 months from food non-producing households. The association is positive for children from food-producing households but only significant among the 24–35 months age group.

The negative and significant coefficient for the food production dummy signifies the endogeneity in food production, which was also revealed in the descriptive analysis, justifying our choice for the control function to establish causality in the next section. One explanation is that the dummy captures producers, of which the majority consists of rural households with a high proportion of stunted children compared to urban households. The negative correlation we observe could be the nutrition status of the severely malnourished group (producers) relative to the reference group, the

[8]The Chow test (Table C.1) confirms that the two equations are essentially equivalent.

food non-producers. Similarly, previous studies in Tanzania also suggest that regions with abundant food production have a higher prevalence of chronic malnutrition than regions with frequent food unavailability (TFNC, 2012).

Table 2.7: OLS Regression for Height-for-Age z-score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Child Gender		Age of a Child				Season	
	Pooled OLS	male	female	0-5mo	6-23mo	24-35mo	36-60	Lean	Post harvest
Maize Price	-0.483***	-0.409	-0.557**	-0.534	-0.386	-1.107***	-0.378	-0.730***	-0.815**
	(0.163)	(0.268)	(0.267)	(0.890)	(0.357)	(0.270)	(0.235)	(0.254)	(0.357)
Producer X Maize Price	0.316*	0.147	0.480	0.981	-0.090	0.743**	0.265	0.688	0.804**
	(0.185)	(0.277)	(0.296)	(0.987)	(0.398)	(0.311)	(0.252)	(0.275)	(0.392)
Consumption(log)	0.331***	0.310***	0.349***	0.283*	0.372***	0.345***	0.281***	0.334***	0.311***
	(0.033)	(0.044)	(0.046)	(0.159)	(0.072)	(0.054)	(0.043)	(0.043)	(0.057)
Household Size	-0.036***	-0.035***	-0.038***	-0.014	-0.007	-0.020**	-0.008	-0.050***	-0.022
	(0.007)	(0.012)	(0.010)	(0.021)	(0.010)	(0.008)	(0.005)	(0.009)	(0.015)
Mother's Education	0.008	0.004	0.012	-0.012	-0.022*	0.029**	0.027***	0.002	0.018**
	(0.006)	(0.008)	(0.009)	(0.023)	(0.012)	(0.011)	(0.007)	(0.007)	(0.008)
Male Headed	-0.065	-0.148*	0.010	-0.114	-0.152	0.060	-0.074	-0.121**	0.004
	(0.050)	(0.077)	(0.066)	(0.282)	(0.101)	(0.094)	(0.061)	(0.058)	(0.081)
Head Age	0.001	-0.001	0.003	-0.008	-0.001	0.004	0.002	0.004**	-0.003
	(0.001)	(0.003)	(0.002)	(0.008)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
Distance to Market	0.000	0.000	0.000	0.000	0.001	-0.001	-0.001	-0.000	0.001
	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Urban	-0.188***	-0.268***	-0.107	-0.421	-0.298***	-0.125	-0.061	-0.223***	-0.130
	(0.049)	(0.089)	(0.074)	(0.274)	(0.098)	(0.112)	(0.069)	(0.076)	(0.085)
Producer	-2.391*	-1.108	-3.644*	-6.912	0.538	-5.390**	-2.109	-1.543	-2.974
	(1.330)	(1.984)	(2.125)	(7.163)	(2.852)	(2.234)	(1.827)	(1.875)	(2.211)
Child Age	0.107***	0.131***	0.087***					0.164***	0.006
	(0.022)	(0.040)	(0.030)					(0.028)	(0.040)
Child=Male				0.197	0.224***	0.228***	0.089**	0.199***	0.113*
				(0.168)	(0.086)	(0.069)	(0.044)	(0.046)	(0.058)
Constant	-2.711**	-2.886	-2.464	0.179	-4.105*	0.578	-3.008*	-3.763**	-2.302
	(1.175)	(1.873)	(1.952)	(6.798)	(2.388)	(2.018)	(1.778)	(1.755)	(2.193)
Observations	6827	3387	3440	524	2151	1429	2723	4110	2717

Notes: The standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.01. All specifications includes time and community fixed effects.

To disentangle the differential causal effects of a maize price fluctuation on food producers and non-producers we estimated a control function by fitting a probit regression for the decision to produce food in the first stage and the subsequent second stages and 2SLS regressions. The results are presented in Table 2.8 and 2.11. Table 2.8 shows that all the variables, including our instrument in the probit regression in column (1), are statistically significant and have expected signs. Column (2) shows the control function where we allow the switching indicator to interact with the maize price. As suggested by Murtazashvili and Wooldridge (2016), we estimated Eqn 2.3 using OLS after obtaining the generalised residual from the first stage probit regression, since the maize price variable is exogenous in the model.

Table 2.8: Probit and Second Stage Control Function Regression Results

	(1) Probit	(2) HAZ	(3) HDDS	(4) Maize Calories
Maize Price		-0.541***	-1.651***	0.292***
		(0.164)	(0.207)	(0.027)
Producer X Maize Price		0.362*	0.715***	-0.143***
		(0.185)	(0.237)	(0.034)
Consumption(log)	-0.618***	0.291***	1.946***	0.053***
	(0.059)	(0.039)	(0.042)	(0.010)
Household Size	0.138***	-0.005	-0.108***	-0.008***
	(0.014)	(0.006)	(0.008)	(0.001)
Mother's Education	-0.038***	0.003	0.030***	-0.001
	(0.010)	(0.006)	(0.008)	(0.001)
Male Headed	0.531***	-0.056	0.209***	-0.041***
	(0.082)	(0.052)	(0.072)	(0.014)
Head Age	0.015***	0.002	-0.012***	-0.002***
	(0.003)	(0.002)	(0.002)	(0.000)
Child Age	0.002	-0.012***	-0.001	-0.000*
	(0.002)	(0.001)	(0.001)	(0.000)
Child=Male	-0.036	0.172***	0.057	0.001
	(0.063)	(0.033)	(0.049)	(0.009)
Distance to Market	0.012***	0.001	-0.003***	-0.001***
	(0.001)	(0.001)	(0.001)	(0.000)
Urban		-0.155***	0.170	-0.330***
		(0.048)	(0.149)	(0.030)
Producer		-2.917**	-6.051***	1.676***
		(1.350)	(1.705)	(0.239)
Resid		0.098	0.243*	-0.278***
		(0.095)	(0.147)	(0.026)
Resid X Producer		0.081	0.913***	-0.203***
		(0.111)	(0.159)	(0.023)
Maizeprod(IV)	0.013***			
	(0.003)			
Constant	7.493***	-1.545	-7.560***	-2.220***
	(0.837)	(1.262)	(1.507)	(0.215)
Observations	6827	6827	6827	6795
p-val: $\hat{\beta}_{Maize} + \hat{\beta}_{MaizeXProducer} = 0$		0.040	0.000	0.000

Notes: All specifications are controlled for time and community fixed effects.
The standard errors (in parentheses) * p<0.10, ** p<0.05, *** p<0.01

We find a negative statistically significant effect of maize price on HAZ among children from food non-producing households and a significant positive effect on HAZ among those from food-producing households. The results confirm the findings of previous works by Yamauchi and Larson (2019) in Indonesia and Cogneau and Jedwab (2012) in *Côte* d'Ivoire. Deducing from the main and interaction effect coefficients, we argue that the impact of high maize price is only less positive for food producers compared to the food non-producers (-0.179), and can, therefore, be interpreted as a protective effect.

Table 2.9: Second Stage Control Function Regression for HAZ

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Child Gender		Age of a Child				Seson	
	male	female	0-5mo	6-23mo	24-35mo	36-60	Lean	Post harvest
Maize Price	-0.418	-0.558**	-0.524	-0.353	-1.069***	-0.308	-0.735***	-0.770**
	(0.270)	(0.269)	(0.869)	(0.358)	(0.279)	(0.229)	(0.257)	(0.362)
Producer X Maize Price	0.159	0.475	1.007	-0.102	0.730**	0.199	0.684**	0.703*
	(0.278)	(0.299)	(0.971)	(0.396)	(0.326)	(0.249)	(0.261)	(0.398)
Consumption(log)	0.305***	0.371***	0.274	0.334***	0.298***	0.237***	0.318***	0.211***
	(0.052)	(0.052)	(0.173)	(0.076)	(0.061)	(0.045)	(0.047)	(0.078)
Household Size	-0.034***	-0.041***	-0.015	-0.002	-0.014	-0.001	-0.048***	-0.006
	(0.012)	(0.010)	(0.024)	(0.010)	(0.009)	(0.005)	(0.010)	(0.017)
Mother's Education	0.004	0.013	-0.012	-0.026**	0.023*	0.021***	0.001	0.011
	(0.008)	(0.009)	(0.026)	(0.012)	(0.013)	(0.007)	(0.007)	(0.009)
Male Headed	-0.146*	-0.005	-0.118	-0.117	0.112	-0.018	-0.105*	0.059
	(0.077)	(0.070)	(0.293)	(0.109)	(0.102)	(0.064)	(0.060)	(0.086)
Head Age	-0.001	0.002	-0.007	0.001	0.005*	0.003*	0.005***	-0.001
	(0.003)	(0.002)	(0.008)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
Distance to Market	0.000	0.000	0.000	0.001	-0.000	-0.000	0.000	0.002**
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Urban	-0.264***	-0.118	-0.429	-0.085	0.182	0.183	-0.214***	-0.103
	(0.088)	(0.076)	(0.513)	(0.217)	(0.233)	(0.135)	(0.079)	(0.086)
Producer	-1.237	-3.488	-7.227	0.231	-5.880**	-2.021	-1.526	-3.506
	(2.008)	(2.147)	(7.118)	(2.830)	(2.403)	(1.811)	(1.878)	(2.242)
Resid	0.038	-0.068	0.226	0.185	0.285	0.088	0.005	0.343**
	(0.105)	(0.117)	(0.479)	(0.179)	(0.215)	(0.162)	(0.109)	(0.157)
Resid X Producer	-0.036	-0.024	-0.496	0.142	0.187	0.406***	0.132	0.024
	(0.159)	(0.147)	(0.503)	(0.194)	(0.190)	(0.135)	(0.139)	(0.174)
Child Age	0.130***	0.089***					0.163***	-0.000
	(0.040)	(0.030)					(0.029)	(0.040)
Child=Male			0.187	0.226***	0.229***	0.091**	0.199***	0.110*
			(0.168)	(0.085)	(0.068)	(0.044)	(0.046)	(0.058)
Constant	-2.719	-2.815	0.447	-3.760	1.053	-2.954*	-3.642**	-0.906
	(1.957)	(2.006)	(6.744)	(2.372)	(2.126)	(1.774)	(1.759)	(2.360)
Observations	3387	3440	524	2151	1429	2723	4110	2717

Notes: All specifications are controlled for time and community fixed effects. The standard errors (in parentheses) * p<0.10, ** p<0.05, *** p<0.01

The results in Table 2.9 test for the gender heterogeneity effect of maize price on girls and boys. Overall, the control control function results do not substantially differ from OLS results. The effect of maize price on HAZ is significantly negative among girls from food non-producers and insignificant for boys. Moreover, maize price creates differential impact in boys and girls as can be seen in Table 2.9. The results suggest the effects of high price act the same direction on boys an girls but is stronger in girls. This may be due to the biological differences between male and female children, but also differential treatment of boys and girls due to the influence of gender preferences and cultural norms. These results are however different from what has been established for the case of weather shocks where boys were found more venerable than girls (Block *et al.*, 2021). Similarly, the insignificant coefficient on girls in food producers' households provide more reasons to think of boy child preference which may influence high investment on boys than girls when food becomes scarce in the households also documented in (Behrman, 1988).

A negative and positive statistically significant effect of maize price on HAZ is detected only for the age category 24–35 months. A possible explanation for this might be that most children are weaned at this age and eat from the same plate as adults in the households (Mosha *et al.*, 1998; Branson *et al.*, 1999). Evidence also shows that children in this age group have an increased physiological demand for nutrients and are more susceptible to diseases such as diarrhoea (Stoltzfus *et al.*, 1997; Nyaruhucha *et al.*, 2006) thus increasing the likelihood of being affected when prices increase.

In the next step, we explore the mechanisms through which food price can affect children's growth by paying particular attention to the quality and quantity of diet consumed in the household conduit. A household's response to high food prices is likely to be heterogeneous across food-producing and food non-producing households. Since food producers can eat from their basket, the food elasticities certainly differ between the two groups. Columns (3) and (4) of Table 2.8 provide evidence of the heterogeneous effect of maize price on the HDDS and share of calories of maize consumed in food-producing and food non-producing households. Maize price has a statistically significant negative effect on the HDDS of food non-producing households and a positive effect on that of food-producing households. These results suggest that a maize price fluctuation reduces the quality of diet intake among children from food non-producers and improves the quality of the diet of food producers' children. These findings are supported by the summary statistics, which show a slight decline in the average diet diversity for food non-producers from 9.3 in 2008 to 8.9 in 2012 and an increase from 7.3 to 7.5 in the same period for the food producers (Table B.2 in the appendix).

In column (4), we observe an increase in the share of calories from maize consumption among food non-producers and a decrease among food producers. The high share of calories of maize consumption reflects a low level of diet diversity in the household. These findings suggest that food non-producers could have been trapped in a situation preventing them from substituting maize with other staples, cereals or micronutrient-rich food since their prices also increased, unlike the food producers who could consume from their own production.

Table 2.10: Second Stage Estimates: Effect of Maize Price on Consumption Shares of other Food(in calories)

	(1) Vitamin	(2) Meat and Fish	(3) Nuts and Seeds	(4) Vegetables	(5) Fruits
Maize Price	-0.028***	-0.008***	-0.024***	0.001**	-0.002*
	(0.005)	(0.001)	(0.003)	(0.001)	(0.001)
Producer X Maize Price	0.015***	0.005***	0.015***	-0.001	-0.003
	(0.005)	(0.001)	(0.003)	(0.001)	(0.002)
Consumption(log)	0.006***	0.001***	0.001*	-0.000**	0.001*
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Household Size	0.000**	0.000	-0.000***	-0.000**	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mother's Education	0.000*	0.000***	0.000	0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male Headed	-0.001	0.000	-0.000	0.000	0.001
	(0.002)	(0.000)	(0.001)	(0.000)	(0.001)
Head Age	0.000	-0.000	0.000***	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Child Age	-0.000	0.000	0.000**	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Child=Male	0.001	0.000	-0.000	-0.000*	0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Distance to Market	-0.000***	-0.000***	-0.000***	-0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urban	0.011***	0.002***	0.005***	-0.001***	0.003***
	(0.002)	(0.000)	(0.001)	(0.000)	(0.001)
Producer	-0.136***	-0.042***	-0.120***	-0.001	0.018
	(0.034)	(0.006)	(0.023)	(0.005)	(0.013)
$Resid_1$	0.010***	0.001***	0.001	0.003***	0.002***
	(0.002)	(0.000)	(0.001)	(0.000)	(0.001)
$Resid_1$ X Producer	0.005	0.002***	0.000	-0.001*	0.003*
	(0.003)	(0.001)	(0.002)	(0.000)	(0.001)
Constant	0.160***	0.050***	0.166***	0.006	0.008
	(0.033)	(0.006)	(0.022)	(0.005)	(0.011)
Observations	6795	6795	6795	6795	6795

Notes: All specifications are controlled for time and community fixed effects. The standard errors (in parentheses) * p<0.10, ** p<0.05, *** p<0.01

It is also likely that food producers reduced their share of maize consumption and sold part for cash income to buy other types of food. This possibility cannot be underrated, particularly in areas with good access to markets where increased income can significantly impact a household's quality of diet. A study from Tanzania (Rudolf, 2019) shows that doubling income, proxied by expenditure, increases diet diversity by 1.3 units. The descriptive analysis reveals that about 53 percent of the food producers reported selling food crops as their primary source of income and 11 percent as their second source of income. The average quantity of maize sold increased from 454 kg in 2008 to 781 kg in 2012, generating a more than 100 percent increase in the average real sale revenue (Table B.2). A similar observation was documented in Burkina Faso, where the increase in the price of the major staples improved the welfare of the farmers by a factor ranging from 2 and 6 percentage points in 2006 and 2011 due to agricultural price fluctuation (Nakelse *et al.*, 2018).

Changes in the price of the main staples can potentially affect the intake of micronutrients (Ecker and Qaim, 2011). The analysis of the cross-price effect of maize on the consumption of micronutrient-rich food presented in Table 2.10 shows an improvement in diet quality among food producers when the maize price increased. Specifically, this increase in maize price significantly boosted the consumption of vitamin A, meat and fish, nuts and seeds among food-producing households and decreased their consumption among food non-producers. The consumption of fruits significantly declined among food non-producers, while the effect was not significant among food producers. When examined together with the results in column (4) in Table 2.8, it can be argued that food non-producing households adjusted the composition of micronutrient in their consumption to maintain a higher calorie intake. The findings are in line with a study by Romano and Carraro (2015) in Tanzania, which found a decline in consumption of macro and micronutrients among vulnerable urban households, which constitutes most food non-producers in our sample. The signs of the coefficient for in column (4) possibly capture the substitution effect of what considered more superior foods (meat and fish) for vegetable, particularly in urban areas. In Tanzania vegetables are relatively cheaper compared to meat, fish and beans and thus, reduction in purchasing power due to high maize prices is likely to increase its consumption.

Turning to the causal effects of diet diversity, columns (1) and (2) in Table 2.11 present the final stage regression results for the impact of diet quality on child growth. As seen in the table, higher diet diversity has a statistically positive effect on children's HAZ. Increasing the share of maize in household food consumption is shown to affect child growth negatively. Higher maize consumption

Table 2.11: Final Stage Control Function Regression Results

	(1) HAZ	(2) HAZ
HDDS	0.221***	
	(0.074)	
Maize Calories		-1.494***
		(0.504)
Consumption(log)	-0.131	0.383***
	(0.138)	(0.048)
Household Size	0.019**	-0.018**
	(0.009)	(0.007)
Mother's Education	-0.004	0.001
	(0.006)	(0.007)
Male Headed	-0.087	-0.109*
	(0.060)	(0.062)
Head Age	0.005**	-0.001
	(0.002)	(0.002)
Child Age	-0.011***	-0.012***
	(0.001)	(0.002)
Child=Male	0.160***	0.174***
	(0.034)	(0.041)
Distance to Market	0.002**	-0.000
	(0.001)	(0.001)
Producer	-0.261	0.586
	(0.211)	(0.409)
Urban	-0.022	-0.529**
	(0.100)	(0.222)
$Resid_1$	0.081	-0.316*
	(0.116)	(0.185)
$Resid_1$ X Producer	-0.006	-0.120
	(0.127)	(0.178)
$Resid_2$	-0.171**	1.446***
	(0.076)	(0.530)
$Resid_2$ X Producer	-0.053**	0.134
	(0.021)	(0.165)
Constant	-1.312	-5.852***
	(1.380)	(0.526)
Observations	6827	6795

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

share implies that children eat a less diversified diet which leads to faltering growth. The traditional variety of maize consumed by a large number of households has broadly shown to contain insufficient protein (Nuss and Tanumihardjo, 2010) which is essential for child growth and development (Henley *et al.*, 2010; Akalu *et al.*, 2010). Increasing consumption of quality protein maize can significantly improve the growth of children (Gunaratna *et al.*, 2010).

2.7 Conclusion and Policy Recommendations

While a growing literature suggests that children are more vulnerable to high food prices, there is a paucity of evidence of whether the impact is heterogeneous across households that produce food and those who do not. Yamauchi and Larson (2019) appears to be the only study that provides evidence of the differential impact of food price on the growth of children from food producers and food non-producing households. This study adds to the literature by estimating a control function for endogenous switching regression using National Panel Survey data from 2008, 2010 and 2012. We empirically test the potential heterogeneous effect of high maize prices on children's HAZ for food producers and food non-producing households in Tanzania.

The findings of this study show that food non-producers' children experience a higher reduction in linear growth due to a maize price fluctuation compared to their counterparts from food-producing households. The relatively less severe impact of maize prices on the growth in food producing households is considered as a protective effect due to a slight significance and size of the interaction coefficient and also the proportion of children that fell into a stunted condition in the year 2012 when the maize price peaked.

We find reduction in growth due price fluctuations is statistically significant among girls than boys. While it is common for boys suffer more than girls from weather variation (Belesova *et al.*, 2017; Block *et al.*, 2021) , we find the opposite for the case of price fluctuation. We also find that significant negative effects of price fluctuations on children who stop breastfeeding and begin to eat the same food as other household members, indicating sensitivity of HAZ for this age group.

Moreover, high maize prices generated opposite effects on households' diet diversity score and share of calories of maize consumption. Food non-producers reduced the diversity of their diet and increased the share of calories intake of maize suggesting a reduction in the quality of food intake for the children. Conversely, food producers increased their diet diversity and reduced consumption of maize in their share of food consumed in the same period. We find the same pattern in the consumption of micronutrient-rich food where a negative cutback was observed among food non-producers while the effect was positive among food producers' households. These findings provide evidence which suggests that food production can offer protection against food price fluctuation s except if the shocks are caused by climate change, which will immediately reduce this protection. Furthermore, children's growth appears to improve when a household consumes a more diversified diet than increasing the consumption share of maize. This evidence has important policy implications on food aid and transfer programmes; the aim should be to enhance the diversity of a household's diet rather than focus on quantity alone.

The findings of this study enabled us to identify the group of children who are vulnerable to price fluctuation s and highlight a potential entry point for social protection programmes. Food safety net and cash transfer intervention programmes that have proved effective elsewhere in sub-Saharan Africa (Bhalla *et al.*, 2018; Dietrich and Schmerzeck, 2019) can be targeted to vulnerable children. Given that producers are less affected by price fluctuations indicates the need for efficient government interventions to reduce frictions in the market. The government may evaluate the price stabilization regulations such as export bans that are often used to prevent farmers from exploiting the gains of the free market due to the distortions created in the economy. Notably, if not handled with great care, price regulation can sometimes bring unintended outcomes (Ecker and Qaim, 2011). Intervention through the NFRA should target the areas with relatively higher prices due to possibility that subsidisation may crowd out consumption of other micronutrients when the price is too low. Evidence from Malawi shows that the government maize subsidisation programme crowded out the consumption of foods containing vitamins A and D (Ecker and Qaim, 2011).

CHAPTER 3

DOES FEEDING CHILDREN MEAT OR MILK IMPROVE LINEAR GROWTH IN TANZANIA? THE MEDIATION ROLE OF LIVESTOCK KEEPING

3.1 Introduction

The UN sustainable development goals (SDGs) aim to end malnutrition among under age five children by 2025. Despite the global reduction of malnutrition observed in the last decades, the rate remains too high in many developing countries. The high malnutrition rate is sometimes linked to inadequate protein consumption (Semba, 2016), suggesting that promoting the consumption of protein can help address malnutrition among under-five children in these countries. It is known that humans do not synthesise all the required amino acids and thus supplementation by particularly protein-rich foods is necessary. Lysine is an essential amino acid in protein not synthesised by humans which has a greater biological role on the brain, synthesis of enzymes, muscle protein synthesis, antibodies, opsins, and calcium absorption (Moya, 2016). Deficiency of lysine in children may result in retarded growth.

Protein consumption in early childhood promotes growth and adequate weight gain (Ong *et al.*, 2009; Hörnell *et al.*, 2013; Braun *et al.*, 2016). Protein intake beyond the recommended level during infancy can also lead to excessive weight gain and adiposity in childhood (Rolland-Cachera *et al.*, 1995; Hörnell *et al.*, 2013; Weber *et al.*, 2014; Braun *et al.*, 2016; Pimpin *et al.*, 2016). However, Switkowski *et al.* (2019) recently found a positive growth effect of protein intake among boys but not adiposity development in their puberty stage despite the children under study consuming above average protein during early childhood. They attributed these findings to the time window for programming adiposity and the potential effect of protein intake in different age groups. In their study Switkowski *et al.* (2019), find that early childhood protein intake occurred at age range 2.8–6.3 years after the first 1 000 days, a period considered sensitive for programming adiposity (Hörnell *et al.*, 2013; Braun *et al.*, 2016). In support of these findings, Rolland-Cachera and Michaelsen (2019) argue that increased adiposity established in previous studies could be explained mainly by the imbalance of protein and fat intake during the first two years as has been observed in many countries in the past.

The quality of protein differs depending on its source. Animal source food (ASF) is regarded as the best source of protein, energy, vitamins and minerals to children compared to plants. The amino acids available in the protein derived from animals can more easily be digested than that derived from plants, which is an essential stimulant for growth of children particularly in the first 1 000 days of life (Dror and Allen, 2011; Varijakshapanicker *et al.*, 2019). Meat for instance, is rich in multiple bioavailable micronutrients such as iron, zinc and vitamins B12 and B6, which spur child growth. Several studies have established a positive association between ASF with several child development outcomes such as cognition (Black, 2003; Miller *et al.*, 2016; Lee *et al.*, 2018) and better motor, speech and language development (Louwman *et al.*, 2000). However, evidence on its effect on child growth is limited (Eaton *et al.*, 2019) due to the small number of randomised and observational studies that focus on growth measures as an outcome (Headey *et al.*, 2018; Varijakshapanicker *et al.*, 2019).

While the benefits of ASF on improving diet and child development have been established (Iannotti *et al.*, 2017; Headey *et al.*, 2018; Baltenweck *et al.*, 2020), studies in Tanzania show that the level of ASF consumption in under-five children is low (De Bruyn *et al.*, 2018; Bundala *et al.*, 2020), consistent with other developing countries (Choudhury and Headey, 2018; Haileselassie *et al.*, 2020).[1] High meat prices are frequently cited as a barrier to consuming ASF in low-income households where high stunting rates are prevalent (Headey and Alderman, 2019; Dasi *et al.*, 2019). In the recent past livestock keeping has emerged as an important livelihood strategy to promote ASF consumption and child growth. The literature suggests a strong association between livestock keeping and ASF consumption (Hoddinott *et al.*, 2015; Hetherington *et al.*, 2017; Broaddus-Shea *et al.*, 2019; Kim *et al.*, 2019; Bundala *et al.*, 2020), however, evidence to support its impact on HAZ is mixed and largely dominated by non-causal association studies.

In this study, we examine the effect of meat and milk consumption on child growth. In particular, we assess the mediation effects of animal ownership on the link between meat and milk consumption and child growth by comparing children from households who own only one type of large ruminant animals (meat ruminants) and those who own both milk and meat ruminants (mixed ruminants) [2]. We derive the reduced form coefficients of a child health production function by estimating the

[1] The national estimates based on DHS data indicate that 36 percent of infants 6–23 months consume meat and fish, 22 percent consume milk and dairy products, and 7 percent consume eggs (Khamis *et al.*, 2019)

[2] Very few households own milk ruminants only to consider it as a separate

standard OLS and use the control function to establish a causal association. Moreover, consistent with the literature which shows that the impact of different investments on a child differs depending on the stage of the child's development (Headey *et al.*, 2018; Alderman and Headey, 2018), we disaggregate the analysis into five age brackets: 0–5 months, 6–11 months, 12–23 months, 24–35 months and 36–60 months. This classification allows us to examine whether the effect is heterogeneous across different age groups. We expect that a children's growth trajectories differ depending on the household type, child's age and sustainability of supply for such foods.

We find that mixed ruminant ownership complement milk consumption in the household, leading to significant increase in growth. The complimentarity effects of mixed ruminants ownership are noticeable after transitioning to complementary food consumption. Specifically, milk significantly led to higher growth of children aged 24–35 months and 36–60 months living in households owning mixed ruminants. The complimentarity effects of mixed ruminants ownership on meat consumption is insignificant. In regard to meat ruminants ownership, we did not find significant effects in all age brackets. The significant effect of mixed ruminant ownership on child growth may be explained by a stable supply of milk from own production but also income generated from livestock activities. Owning both milk and meat animals may provide households with diversified income sources to purchase ASF, particularly milk from the market. For example, oxen are often rented out for animal traction, generating income for households to spend on milk during seasons when the household's milk animals are not producing milk. Adesina (1992) showed that households who own draft oxen have a higher income than non-owners in West Africa. Other studies also show that oxen generate up to 75 percent of livestock-derived income compared to milk cattle (Randela, 2003). Keeping only milk animals may imply that supply and consumption of milk stops during a cow's gestation period and when their milk has dried up.

This study extends the existing literature by providing evidence for a causal association between meat and milk consumption and child growth. Emerging RCT studies focusing specifically on meat demonstrate the positive effects of meat on infant and child growth (Tang and Krebs, 2014; Tang *et al.*, 2014, 2018). This evidence is often limited and far from conclusive in developing countries. For example, in an observational study in DRC, Zambia, Guatemala and Pakistan, Krebs *et al.* (2011) found a low likelihood of stunting among infants and toddlers who consumed meat, suggesting a strong protective effect of high protein from meat. However, this protective effect was not observed in a randomised trial study conducted in the same settings (Krebs *et al.*, 2012). Understanding context is essential. The diet of children in developing countries primarily consists of starch-based foods and the inclusion of meat in their diet might compensate for the missing micronutrients relevant for growth. Moreover, many children in developing countries are stunted. It is not clear whether meat could deliver a similar growth effect beyond the age of 12 months and promote catch-up growth as in developed countries. The existing RCT studies from developed countries are limited to children below one year of age and in a setup with a low malnutrition prevalence. We therefore use observational data and control functions to approach a causal effect for younger and older children.

This study also provides causal estimates of the impact of livestock keeping on child growth. To date few studies (Rawlins *et al.*, 2014; Azzarri *et al.*, 2015; Jodlowski *et al.*, 2016; Kabunga *et al.*, 2017; Choudhury and Headey, 2018) have attempted to estimate the causal association between animal keeping and child growth. This study adds to the literature by providing more evidence, which is highly relevant in sub-Saharan Africa where stunting rates of higher than 30 percent are still prevalent. Unlike the previous studies we isolate the effects of ownership of meat only and mixed large ruminants on child nutrition.

3.2 Data and Methods

3.2.1 Data

This study uses the second and third rounds of the Living Standards Measurement Study (LSMS) data for Tanzania administered by Tanzania Bureau of Statistics under the World Bank's support. The data was obtained through multistage clustered sample design and covered 2008–09, 2010–11 and 2012–13. This set of surveys gathers diverse information using four sets of questionnaires: household, agriculture, community, livestock and fisheries. More specifically, the surveys collect anthropometric data for children under age five and the frequency that a child consumes different food types and groups, making it appropriate for assessing the relative importance of different inputs on a child's health production function over time.

3.2.2 Dependent Variable

The outcome variable for this study is the HAZ for children under five. HAZ allows assessment of the long-run and cumulative benefits of complementary feeding, which is the main focus of this study. The HAZ is commonly referred to as a measure of chronic malnutrition where a child with scores below −2SD from the median values of a well-nourished child of the same age and gender is considered to be stunted. We generated the scores specific to child age and sex in line with WHO (2006) growth references using the survey's anthropometric data.

3.2.3 Key Covariates

The key predictors of interest in this study are animal ownership and milk and meat consumption measures by a child. We use food consumption frequency information collected in TNPS to create variables for meat and milk consumption by simply counting the number of days per week a child consumes a particular food type. With regard to animal ownership, we distinguish by using dummies the households that keep different types of large ruminants (cows): meat and mixed (both meat and milk) ruminants. The NPS livestock section collects information on the types of animals a household owns, such as indigenous or improved/exotic, a cow or bull, steers, heifers, male calves and female calves. This data permits us to categorise animals into milk and meat categories and exclude those that do not fit into any category, namely calves. Specifically, meat ruminant owners keep bulls and steers only, and mixed ruminant owners keep milk and meat ruminants.[3]

3.2.4 Control Variables

In the model we controlled for cereal food type due to its predominance in infants and children's diet in Tanzania and which, in addition to protein, has high calories which is also important for child growth. We also controlled for household socioeconomic status (SES) proxied by the wealth index computed from the number of assets owned by a household using principal component analysis (PCA). Socioeconomic status has been broadly shown as a driver of child nutrition status in developed and developing countries (Nkonki *et al.*, 2011; Odgers, 2015). Moreover, we included variables for household- and child-specific characteristics, namely child gender, child dependency ratio, household headship, location and age of the household head, which have been found to be

[3] We excluded heifers from either of the categories for precision. Although heifers are bred for milk production they have not yet started to produce milk and only in very rare cases are slaughtered for meat.

important determinants of child health (Van de Poel *et al.*, 2007*a*; Akombi *et al.*, 2017; Buisman *et al.*, 2019). Consistent with the literature which shows that a mother's education is more important for child health than the father's (Alderman and Headey, 2017; Nepal, 2018), we included dummies for the education levels of the child's mother in the model.[4]. Similarly, we controlled for whether a household has access to adequate sanitation and clean water. Inadequate access to clean and safe water are the major determinants of prevalence of infectious diseases such as diarrhoea in children which in turn affect growth (Checkley *et al.*, 2008; Guerrant *et al.*, 2013). Finally, we controlled for community variables as follows: distance from the household to a health centre or hospital, distance to the nearest population centre, aglo-climatic conditions, Normalized Difference Vegetation Index (NDVI) and community fixed effects. The distance to health care and distance to the nearest population centre respectively, indicates the accessibility of antenatal and postnatal care and market for nutritious foods within the community which are important for child growth. NDVI directly controls for the food production potential (crop yield) in the community which influences child nutrition (Panek and Gozdowski, 2020; Block *et al.*, 2021). Similarly, aglo-climatic conditions capture the potential of the community to produce food.

3.2.5 Estimation Strategy

To assess the role of milk and meat on child growth we follow Grossman (1972) and Rosenzweig and Schultz (1983, 1988) theoretical framework and many other empirical nutrition studies (Mwabu, 2008; Headey *et al.*, 2018) to estimate the child health production function. We specify and estimate a model with and without interactions of the following forms using OLS to capture the direct and mediation effects of milk and meat ruminants owned by the households on the link between the two food types and HAZ.

$$HAZ_{it} = \alpha + \beta_1 Milk_{it} + \beta_2 Meat_{it} + \gamma X_{it} + \delta D + \mu_{it} \tag{3.1}$$

[4]Only the first round of the NPS data collected breastfeeding information. We used breastfeeding information from the first round to identify breastfeeding predictors and use these variables as controls for breastfeeding in our models. We identified the variables, wealth index, mother's education, location and access to health care from a logit regression which explains the probability that a child is breastfed.

$$HAZ_{it} = \alpha + \beta_1 Milk_{it} + \beta_2 Milk_{it} * MixedRuminants_{it} + \beta_3 Meat_{it} + \beta_4 Meat_{it} * MeatRuminants_i$$
$$+\beta_5 MixedRuminants_{it} + \beta_6 MeatRuminants_{it} + \gamma X_{it} + \delta D + \mu_{it} \quad (3.2)$$

where $\beta's$ are the coefficients of our primary interest, X is a vector of controls, D is a vector of community fixed effects and survey-specific dummies, and the last term μ_{it} is the error term.

While the OLS coefficients are useful, they are potentially upward biased and inconsistent because of the endogeneity of food consumption and animal keeping. The decision to keep large ruminants is driven by household and community-specific unobservables such as perceived benefits of animal keeping and prior knowledge of the best practices in animal keeping. Although the Wu-Hausman test results in Table D.1 in the appendix shows that the IV results for animals ownership differ significantly from OLS. Therefore, in the same spirit as Wooldridge (2015); Murtazashvili and Wooldridge (2016) and Murtazashvili and Wooldridge (2016) we proceed to estimate control functions with endogenous treatments in two steps. Specifically, we estimate probit regression for ruminants ownership in the first stage to a generate generalised residual to plug into the second stage OLS regression. We also introduced Mundlak (1978) and Chamberlain (1980) devices into a constant coefficient switching regression model for a panel data as in Murtazashvili and Wooldridge (2016) to account for time-constant unobserved heterogeneity. The empirical specification of the outcome equation in the two regimes — $g = 1$ if a household keeps meat/mixed ruminants, and 0 if does not — reads as follows:

$$HAZ_{it}^{(g)} = X_{it}\beta_g + c_{ig} + \mu_{itg}, \quad i = 1, ..., N; \quad and \quad t = 1, ...T \quad (3.3)$$

where c_{ig} is time constant individual-specific unobserved effects, and μ_{itg} is an idiosyncratic error term, X is a vector of key predictors and controls. β_g is a vector of coefficients in g regimes such that β_1 if a household keeps a specific type of animal and β_0 if not.

Setting $\gamma = \beta_1$ - β_0 and allowing the switching variable to interact with vector X, Mundlak controls and generalised residual, results in the following final specification:

$$HAZ_{it} = X_{it}\beta + h_{it}X_{it}\gamma + \bar{z}_i\rho_0 + h_{it}\bar{z}_i\rho_1 + \delta_0\hat{gr}_{it} + \delta_1 h_{it}\hat{gr}_{it} + \mu_{it} \tag{3.4}$$

where $\bar{z}_i = \sum_{t=1}^{T} z_{it}$, is a vector of Mundlak device, h_{it} is an endogenous switching variable, $\hat{gr}_{it}$ is a generalized residual derived from the first stage probit regression, and μ_{it} is an error term.

We use Tsetse fly presence in a location as an instrumental variable (IV) for ownership of meat ruminants. East Africa is notorious for being prone to Tsetse fly vectors causing sleeping sickness to animals, resulting in animal death and reduced milk and meat yield. The presence of Tsetse fly influences a household's decision to keep livestock in many parts of Tanzania (Malele *et al.*, 2011). Some households in areas prone to Tsetse fly may decide not to keep cows because of the risk attached to it. We use FAO data for Africa containing predicted areas for suitability of three types of Tsetse fly – Fusca, Palpalis and Morsitans – to identify households living in Tsetse fly prone areas.[5] We generated a dummy variable equal to 1 if the area has underlying factors that make it prone to Tsetse flies, without them having to actually be there (See Fig E.1 and Fig. E.2 in the appendix). The evidence shows that it takes time to eradicate/reduce tsetse fly in an area. Tanzania took fifty years to reduce the Tsetse fly population by 43 percent in 16 regions, which is less than one percent annually (Malele *et al.*, 2011). There is also evidence that the spread of tsetse fly across areas is very small or may not happen due to climatic and ecological barriers. Each species of tsetse fly has conditions favouring their existence that differs across areas which limit their spread (FAO, 1992). We, therefore, assume that within the six years of the survey rounds, the chances that areas become completely free of Tsetse or reduced tsetse fly substantially is very small. These small changes, if there is any, are also not captured by the FAO tsetse distribution maps, making our IV time invariant, justifying our choice of Murtazashvili and Wooldridge (2016) control function, which allows modelling the time variant unobserved heterogeneity by including panel level average of time-varying covariates in the model.

Moreover, we use temperature deviation from historical mean to instrument for milk ruminant ownership. The long run temperature deviation was calculated by taking the difference between monthly average temperature and long run monthly average temperature (118 years)[6]. Decades of research have shown that increased temperatures have an impact on animal growth and milk

[5] http://www.fao.org/paat/resources/atlases/tsetse-and-aat/en/

[6] The data for the monthly average maximum near surface temperature from 1901 to 2017 was obtained from AIDDATA(*http://geo.aiddata.org/query/!/*).

production (Rojas-Downing *et al.*, 2017; Henry *et al.*, 2012; Thornton *et al.*, 2009). The vulnerability of mixed ruminants to temperature variations may discourage households from keeping them. The temperature humidity index (THI) is commonly used to assess the effects of heat stress on animals and milk productivity (Silanikove, 2000; West, 2003; Thornton *et al.*, 2021). However, THI captures the effects of weather at a point in time, and its influence on the household's decision may be small. Unlike THI, deviation from the long run average temperature indicates the change in the suitability of an area to support livestock keeping. Evidence also shows that large cattle populations are situated in moisture sub-humid areas where there are no Tsetse fly (Hursey and Slingenbergh, 1995).

The Tsetse fly presence and temperature variation together serve as good instruments for mixed ruminant ownership. Instruments are considered good if they are correlated with endogenous regressor (livestock keeping) but not the error term. Tsetse fly presence and temperature meet these criteria as they only influence HAZ indirectly, through milk and meat animal keeping. One possible violation of using tsetse fly is the likelihood that children living in areas prone to tsetse fly may also have slower growth. The fact that trypanosomiasis is not as common in children as in adults (Cramet, 1982; Franco *et al.*, 2014) makes the instruments still valid. While in rare cases trypanosomiasis can be passed from a mother to a foetus, the effects have been observed in psychomotor development (Cramet, 1982; Lindner and Priotto, 2010). The effect of trypanosomiasis on growth has not been established. Similarly, children living in high-temperature areas are likely to be short. The mechanism through which temperature affects child growth, as has recently been established, is indirectly through productivity channels (Block *et al.*, 2021). We provide the Wald F Statistic and Sagan p-values for weak instrument and identification test in Table D.1 and first stage regression in Table D.2 in the appendix, showing strong instrument for mixed ruminants and relatively weak instrument for meat ruminant.

3.3 Results

Sample Characteristics

Table 3.1 presents the characteristics of the sample used in the study. Nearly 78 percent of the children reside in rural areas, of which 49 percent are male. Of the sampled children, 35 percent are stunted. About 13 percent of the households keep meat ruminants and 35 percent mixed ruminants while 52 percent keep neither meat or mixed ruminants livestock. The average meat and milk consumption is 3 and 1.8 days, respectively. Children consume cereal on average six days a week. Approximately 51 percent of mothers have completed primary education and only 15 percent have secondary education and above. Seventeen percent of children live in female-headed households, where the average age of the household head is 42 years. Children's access to sanitation and clean water is limited to 22 percent and 30 per cent, respectively. On average, the nearest hospital is located 3 km from the household. Sixty-eight percent of children live in a climatic zone that has two rainy seasons per year while the remaining 32 percent live in zones that receive heavy rainfall only once per year.

Descriptive Analysis

Tables 3.2 and 3.3 show the average number of days of meat and milk consumption in different age brackets and household types to which the child belongs – meat and mixed ruminant owners and non-owners. The average frequency of meat consumption was relatively higher than milk in all age groups. Table 3.2 shows that the introduction of solid foods starts earlier than the WHO's recommended period of six months after birth and that there is no substantial difference in frequency of meat and milk feeding for younger and older children. The average frequency for a child's meat consumption ranges from 4.5–4.7 days and 1.7–1.9 days per week depending on age.[7] Mixed ruminant owners have significantly higher milk consumption than meat ruminant owners and ruminant non-owners (Table 3.3). The difference in meat consumption between mixed ruminant and meat ruminant owners is significant only in the last age group [8].

Regression Results

Table 3.4 presents the reduced form regression estimates for model (1). We control for community fixed effects to address the potential correlation between key variables and community characteristics and a survey year dummy in all regressions. While our interest is in the results in columns (6)–(11), it is still important to present the results of the naive regression in columns (1)–(5) to see how the coefficients evolve as we include relevant controls. Starting with the naive regression

[7]The variable measure for meat also includes fish frequency consumption. The higher frequency of meat consumption over milk observed in the descriptive could be a booster from fish consumption. Moreover, unlike milk which is often purchased or reserved explicitly for children, meat is commonly prepared for the whole family with only a small portion served to children (Kulwa *et al.*, 2015).

[8]Exception is for (1) -(3) where non-ruminants owners are consuming more meat than meat owners. It could be possible that, the non-ruminants owners are wealthier than meat owners and buy meat from the markets while animal slaughtering is less frequent in meat ruminants owners households.

Table 3.1: Sample Characteristics

	mean	sd
HAZ	-1.39	1.570
Stunting	0.35	0.477
Meat	3.12	2.335
Milk	1.80	2.771
Cereal	6.23	1.834
Wealth Index	-0.25	2.624
Mother Completed primary	0.51	0.500
Mother Completed secondary and above	0.15	0.362
Female head	0.17	0.377
Head Age	42.73	13.831
Child dependency ratio	0.42	0.137
rural	0.78	0.416
Child=male	49.47	0.500
0-5mo	0.10	0.299
6-11mo	0.11	0.316
12-17mo	0.11	0.318
18-23mo	0.10	0.300
24-36mo	0.19	0.390
37-60mo	0.37	0.487
Sanitation	0.22	0.413
Access to clean water	0.30	0.459
Own meat ruminant	0.13	0.349
Own mixed ruminant	0.35	0.478
Own neither meat nor milk ruminant	0.52	0.499
Distance to nearest village centre	3.38	1.139
Distance to Health Service	2.41	1.582
NDVI	54.11	18.633
aglo-climatic zone 1==bimodal	0.68	0.466
N	4911	

Table 3.2: Average number of days a child consume Meat and Milk

Age group	Meat and Fish		Milk	
	Mean	Std. Dev.	Mean	Std. Dev.
0-5mo	4.68	2.55	1.73	2.64
7-11mo	4.53	2.59	1.83	2.63
12-23mo	4.58	2.55	1.86	2.71
24-35mo	4.70	2.56	1.81	2.59
36-60mo	4.62	2.58	1.79	2.69

Table 3.3: Average Meat and Milk Consumption by Animal Ownership and Age Group

	(1)	(2)	(3)	(4)	(5)	(6)				
	Meat Consumption			Milk Consumption			Mean Difference (T-test)			
	Meat Ruminant	Mixed Ruminants	Non Owners	Meat Ruminant	Mixed Ruminants	Non Owners	(1) - (2)	(5) - (4)	(1) - (3)	(5) - (6)
0-5mo	2.81	3.10	2.85	1.04	2.79	1.37	-0.29	1.76***	-0.04	1.43***
7-11mo	2.95	2.63	3.60	1.12	3.46	1.52	0.323	2.33***	-0.65**	1.94***
12-23mo	3.19	2.91	3.6	1.14	3.1	1.17	0.28	1.96***	-0.31	1.84***
24-35mo	2.90	2.85	3.45	1.06	2.86	1.30	0.052	1.80***	-0.55**	1.55***
36-60mo	3.22	2.53	3.73	0.91	2.70	1.33	0.69***	1.79***	-0.51***	1.37***

coefficients, the association between milk and HAZ is positive and became significant immediately after the first five months since birth while meat is highly significant only at the later stage of child growth. The results slightly change in terms of their economic importance once we included controls.

Table 3.4 shows that the association between milk and HAZ is statistically significant after the first year of life but more significant for the 36–60 months groups. Consistent with recent findings (Headey *et al.*, 2018) we observe that the size of the coefficients for milk is larger for younger children below two years; however, contrary to their findings we find a more significant association for the 36–60 months group than other age groups.[9] This study's findings show that frequent milk consumption increases HAZ of a child by a 0.04 standard deviation for 12–23 months and 0.03 standard deviation for the 24–35 months and 36–60 months age groups. The linear growth from consuming milk for younger children aged 12–23 months is 0.01 standard deviation more than for the older children beyond two years. These results are also supported by many observational and RCT studies suggesting that milk consumption leads to rapid growth in infancy (Hoppe *et al.*, 2006; Grenov *et al.*, 2020; Soczynska *et al.*, 2020; Herber *et al.*, 2020). The limited effect of milk observed for the 0–11 months group could either suggest a shorter period for the accrued benefits of the recent introduction of complementary food to be revealed or complementary food should not be introduced early. It is, therefore, reasonable to argue that feeding children cow's milk can be an effective intervention to reduce growth faltering in the first two years of child life and increase the rate of catch-up growth in Tanzania which, as Leroy *et al.* (2014) show, is less common in

[9]Headey *et al.* (2018) confirms that the stronger association between diet, particularly ASF, and growth should be in the group of 18–23 months because it captures the growth benefits of complementary feeding accumulated over the first two years of life. While we find significant association for this age bracket, we find more significant effects in the last age group.

developing countries.

Table 3.4: OLS Regression Results for HAZ

	(1) 0-5mo	(2) 6-11mo	(3) 12-23mo	(4) 24-35mo	(5) 36-60	(6) 0-5mo	(7) 6-11mo	(8) 12-23mo	(9) 24-35mo	(10) 36-60	(11) Full Model
Milk	0.001	0.063**	0.068***	0.056***	0.050***	-0.024	0.043	0.038**	0.030**	0.028***	0.026***
	(0.030)	(0.025)	(0.017)	(0.015)	(0.008)	(0.033)	(0.029)	(0.019)	(0.013)	(0.010)	(0.008)
Meat	-0.009	0.011	0.030*	0.003	0.043***	-0.019	-0.006	0.002	-0.014	0.024***	0.005
	(0.034)	(0.026)	(0.017)	(0.015)	(0.008)	(0.034)	(0.034)	(0.019)	(0.015)	(0.009)	(0.008)
Cereal						-0.073	-0.000	0.054*	0.040**	0.041***	0.028**
						(0.051)	(0.042)	(0.028)	(0.017)	(0.015)	(0.012)
Child=male						0.193	0.306**	0.297***	0.186***	0.069	0.182***
						(0.176)	(0.145)	(0.090)	(0.066)	(0.048)	(0.048)
Wealth Index						0.093*	0.061	0.077***	0.071***	0.058***	0.066***
						(0.052)	(0.039)	(0.024)	(0.021)	(0.011)	(0.012)
Head Age						0.004	0.003	0.002	0.002	0.002	0.000
						(0.007)	(0.007)	(0.004)	(0.003)	(0.002)	(0.002)
Female Head						0.017	0.142	0.103	0.029	0.046	0.049
						(0.285)	(0.186)	(0.121)	(0.100)	(0.064)	(0.058)
Dependency Ratio						1.234	-0.270	-0.084	-0.292	-0.295	-0.018
						(0.788)	(0.641)	(0.364)	(0.296)	(0.190)	(0.169)
Primary School(Mother)						0.260	-0.184	0.014	0.184**	0.107**	0.107**
						(0.207)	(0.183)	(0.088)	(0.087)	(0.049)	(0.050)
Secondary and above(Mother)						0.263	-0.212	0.170	0.263**	0.267***	0.221***
						(0.280)	(0.282)	(0.164)	(0.132)	(0.074)	(0.076)
Sanitation						-0.119	-0.050	0.179	0.087	0.184***	0.077
						(0.276)	(0.222)	(0.149)	(0.123)	(0.067)	(0.068)
Clean Water						0.313	-0.206	-0.082	-0.054	-0.063	-0.037
						(0.207)	(0.190)	(0.106)	(0.087)	(0.054)	(0.047)
Distance to Hospital						-0.049	0.066	0.040	0.030	0.050**	0.032*
						(0.059)	(0.050)	(0.033)	(0.025)	(0.020)	(0.017)
Rural						-0.011	-0.746***	0.129	-0.027	-0.039	-0.123**
						(0.297)	(0.227)	(0.152)	(0.104)	(0.072)	(0.061)
agloclimatic zone (1=bimodal)						-0.142	0.007	0.168	-0.149*	-0.047	-0.059
						(0.219)	(0.167)	(0.121)	(0.090)	(0.068)	(0.054)
NDVI						0.008	0.000	-0.001	-0.006***	-0.003	-0.000
						(0.005)	(0.006)	(0.003)	(0.002)	(0.002)	(0.001)
HH distance to Major Road						0.002	0.004	-0.001	0.001	0.000	0.000
						(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
Constant	0.141	-0.857***	-2.163***	-1.981***	-1.806***	-0.808	-0.718	-3.158***	-2.082***	-2.011***	-1.977***
	(0.169)	(0.155)	(0.082)	(0.081)	(0.049)	(0.706)	(0.806)	(0.509)	(0.354)	(0.236)	(0.188)
N_clust	414	496	952	1013	2011	414	496	952	1013	2011	4886
Observations	414	496	952	1013	2011	414	496	952	1013	2011	4886

Notes: All specifications are controlled for time and community fixed effects. The standard errors (in parentheses) are clustered at household level * p<0.10, ** p<0.05, *** p<0.01.

On the other hand, the association between meat and HAZ is strongly positively significant but only for the 36–60 months age bracket (column 10). A child who consumes meat more frequently tends to be 0.02 standard deviation taller than a child who consumes less. Our findings differ from multi-country studies (Krebs *et al.*, 2011; Headey *et al.*, 2018), which found meat to be associated with improved growth of children younger than 24 months. In their study, Krebs *et al.* (2011) found that meat consumption at least once or three times in a week is associated with a reduction in stunting. In our case, despite higher average consumption of meat in all age groups, the effect is limited to only older children. The results are, however, consistent with Nseluke (2018) who found meat consumption to be associated with the growth of older children (> 24 months) in Malawi.

Table 3.5: OLS Regression Results for HAZ: Mixed Ruminant Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60
Milk	0.009	-0.028	0.024	0.042	0.006	0.008
	(0.012)	(0.044)	(0.039)	(0.029)	(0.017)	(0.013)
Meat	-0.004	-0.015	-0.032	0.003	-0.018	0.016
	(0.011)	(0.040)	(0.040)	(0.022)	(0.019)	(0.012)
Milk X Own Mixed Ruminant	0.031*	-0.023	0.053	-0.032	0.043*	0.041**
	(0.017)	(0.061)	(0.061)	(0.041)	(0.026)	(0.018)
Meat X Own Mixed Ruminant	0.028*	-0.012	0.076	-0.002	0.015	0.024
	(0.016)	(0.068)	(0.065)	(0.034)	(0.032)	(0.020)
Cereal	0.030***	-0.083	0.004	0.053*	0.041**	0.043***
	(0.012)	(0.051)	(0.042)	(0.027)	(0.017)	(0.015)
Child=male	0.182***	0.186	0.306**	0.316***	0.177***	0.070
	(0.048)	(0.176)	(0.141)	(0.088)	(0.065)	(0.048)
Wealth Index	0.074***	0.107**	0.065*	0.085***	0.081***	0.063***
	(0.013)	(0.055)	(0.039)	(0.026)	(0.021)	(0.011)
Head Age	-0.001	-0.001	0.003	-0.000	0.000	0.001
	(0.002)	(0.007)	(0.007)	(0.004)	(0.004)	(0.002)
Female Head	0.080	0.126	0.158	0.163	0.055	0.061
	(0.059)	(0.292)	(0.191)	(0.119)	(0.103)	(0.066)
Dependency Ratio	-0.017	1.116	-0.206	-0.064	-0.315	-0.283
	(0.169)	(0.774)	(0.633)	(0.356)	(0.299)	(0.187)
Primary School(Mother)	0.089*	0.226	-0.188	-0.019	0.167*	0.100**
	(0.050)	(0.205)	(0.181)	(0.088)	(0.086)	(0.050)
Secondary and above(Mother)	0.215***	0.245	-0.189	0.134	0.250*	0.266***
	(0.076)	(0.276)	(0.284)	(0.164)	(0.129)	(0.074)
Sanitation	0.087	-0.109	-0.029	0.196	0.092	0.193***
	(0.068)	(0.277)	(0.221)	(0.151)	(0.122)	(0.067)
Clean Water	-0.035	0.333*	-0.222	-0.091	-0.048	-0.060
	(0.048)	(0.202)	(0.191)	(0.110)	(0.087)	(0.053)
Distance to Hospital	0.029*	-0.053	0.061	0.039	0.026	0.048**
	(0.017)	(0.059)	(0.049)	(0.034)	(0.026)	(0.020)
Rural	-0.163***	-0.094	-0.771***	0.069	-0.071	-0.057
	(0.060)	(0.295)	(0.227)	(0.150)	(0.105)	(0.075)
agloclimatic zone (1=bimodal)	-0.025	-0.050	0.001	0.219*	-0.109	-0.032
	(0.055)	(0.227)	(0.173)	(0.121)	(0.092)	(0.068)
NDVI	0.000	0.009*	0.000	-0.001	-0.006***	-0.002
	(0.001)	(0.005)	(0.006)	(0.003)	(0.002)	(0.002)
HH distance to Major Road	0.000	0.001	0.004	-0.001	0.001	0.000
	(0.001)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)
Own Mixed Ruminant	-0.001	0.550	-0.421	0.410**	0.051	-0.107
	(0.098)	(0.415)	(0.355)	(0.181)	(0.169)	(0.108)
Constant	-1.925***	-0.674	-0.612	-3.141***	-2.023***	-1.978***
	(0.189)	(0.680)	(0.794)	(0.492)	(0.360)	(0.241)
N_clust	4886	414	496	952	1013	2011
Observations	4886	414	496	952	1013	2011

Notes: All specifications are controlled for time and community fixed effects. The standard errors (in parentheses) are clustered at household level * p<0.10, ** p<0.05, *** p<0.01.

Table 3.5 reports reduced form results for the model with interaction (Eqn. 2). It can be seen that mixed ruminant ownership complements milk consumption among older children in the groups of 24–35 months and 36–60 months. This finding is consistent with studies that show livestock keeping increases consumption of animal source foods (Jones *et al.*, 2018; Christian *et al.*, 2019) and improves child growth (Jin and Iannotti, 2014; Mosites *et al.*, 2015; Kaur *et al.*, 2017; Fierstein *et al.*, 2017; Hossain and Khan, 2020). These results essentially imply that a stable supply of ASF from owning mixed animals benefits children at different growth stages. This may suggest that owning both ruminants relax the household budget constraints by ensuring the self-supply of milk to children. The cost of milk and meat in developing countries is generally higher, which limits its consumption in most families. For instance, the price of meat is 5–6 times higher than the per calorie price of cereals in Africa (Headey *et al.*, 2018). In Tanzania, a litre of milk is about half a dollar in rural areas and a dollar in urban areas, which is unaffordable for most poor households.[10]

On the contrary, the association between keeping meat ruminants only and HAZ is insignificant in all age groups (Table E.1 in the appendix). The lack of association might be driven by the fact that animals, particularly large ruminants, are rarely slaughtered for self-consumption (Århem, 1989; Randolph *et al.*, 2007). These findings are inline with Azzarri *et al.* (2015) who found a significant positive effect of ownership of large ruminants on milk consumption but not meat in Uganda.

The results in Table 3.5 also suggest that other food groups such as cereal do not matter at young ages and breast milk is probably best early in life. The non-causal association between continued breastfeeding and a child's linear growth and development has been widely established (Onyango *et al.*, 1999; Alvarado *et al.*, 2005; Scherbaum and Srour, 2016). We find the lack of association between cereal consumption and growth of younger children questions Mclaren's (1974) influential dietary recommendation in the 1970s emphasising high calorie consumption in children. The current guidelines recommend exclusive breastfeeding for the first six months and the gradual introduction of solid foods thereafter while breastfeeding continues until two years (WHO, 2003). The insignificant coefficient of cereal-based foods for younger children suggests the need to adhere to dietary and feeding guidelines. There is no conclusive evidence on the impact of the early introduction of solid food before six months but it is broadly associated with a higher risk of obesity in later stages of child development (Moorcroft *et al.*, 2011; Papoutsou *et al.*, 2018).

[10]Prices are based on the descriptive statistics (not reported) of the price of milk at the district level computed from the household food expenditure section.

Table 3.6: Second Stage Control function Regression Results for HAZ: Mixed Ruminant Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60
Milk X Own Mixed Ruminant	0.036**	-0.019	0.063	-0.031	0.050*	0.044**
	(0.016)	(0.064)	(0.059)	(0.037)	(0.027)	(0.019)
Meat X Own Mixed Ruminant	0.030*	-0.013	0.075	0.004	0.018	0.024
	(0.018)	(0.068)	(0.062)	(0.037)	(0.032)	(0.020)
Milk	0.007	-0.030	0.019	0.043*	0.004	0.006
	(0.012)	(0.044)	(0.040)	(0.026)	(0.018)	(0.013)
Meat	-0.005	-0.015	-0.027	-0.002	-0.018	0.015
	(0.012)	(0.039)	(0.040)	(0.025)	(0.019)	(0.013)
Cereal	0.028**	-0.084	-0.001	0.052*	0.038**	0.043***
	(0.013)	(0.051)	(0.040)	(0.031)	(0.017)	(0.014)
Own Mixed Ruminant	-0.124	0.971	0.506	0.258	0.060	-0.346
	(0.293)	(1.713)	(1.477)	(0.855)	(0.548)	(0.348)
Residual	0.241	-0.201	-0.535	0.157	0.144	0.263
	(0.226)	(1.349)	(1.111)	(0.597)	(0.390)	(0.239)
Residual X Mixed Ownership	-0.315**	-0.110	-0.047	-0.155	-0.289	-0.216
	(0.143)	(0.739)	(0.642)	(0.335)	(0.237)	(0.148)
Constant	-1.870***	-0.636	-0.534	-3.093***	-1.957***	-1.962***
	(0.236)	(0.687)	(0.781)	(0.432)	(0.367)	(0.262)
Observations	4870	414	493	948	1009	2006
N_clust	4640	414	493	940	1001	2001
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Community FE	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak Devices	Yes	Yes	Yes	Yes	Yes	Yes

The standard errors (in parentheses) are clustered at household level * p<0.10, ** p<0.05, *** p<0.01.

Tables 3.6 and 3.7 present the second stage control function results for causal association. Consistent with Table 3.5, the consumption of milk is effective in promoting growth for older children above 24 months living in households which own mixed ruminants. For these age groups, in particular 24–35 months, most children are weaned in Tanzania, and cow's milk is likely used to substitute breastmilk when a child stops breastfeeding for a smooth transition into early childhood. The positive effect of milk on the growth of older children could be due to its effectiveness in treating malnutrition and promoting growth (Hoppe *et al.*, 2006; Mølgaard *et al.*, 2011; Michaelsen *et al.*, 2011). The age brackets that we found milk to have an effect corresponds to the catch-up growth window from past undernutrition. During catch-up growth, a child requires all type II minerals in balance and milk's rich bioavailable minerals are easily absorbed into the body tissues (Michaelsen

Table 3.7: Second Stage Control function Regression Results for HAZ: Meat Ruminant Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60mo
Meat X Own Meat Ruminants	0.023	0.123	0.044	0.004	-0.030	0.007
	(0.019)	(0.096)	(0.081)	(0.055)	(0.040)	(0.025)
Meat	-0.000	-0.041	-0.011	0.000	-0.012	0.021*
	(0.009)	(0.036)	(0.036)	(0.021)	(0.016)	(0.011)
Own Meat Ruminants	0.342*	-0.253	0.242	0.256	0.640**	0.310
	(0.202)	(0.826)	(0.609)	(0.398)	(0.292)	(0.226)
Residual	-0.130	-0.193	0.137	-0.293	0.031	-0.056
	(0.149)	(0.450)	(0.501)	(0.359)	(0.266)	(0.186)
Residual X Own Meat Ruminants	0.038	-0.029	-0.394	0.386	-0.090	0.073
	(0.143)	(0.478)	(0.548)	(0.384)	(0.279)	(0.165)
Cereal	0.023*	-0.082	-0.008	0.053*	0.031*	0.036***
	(0.013)	(0.051)	(0.039)	(0.030)	(0.017)	(0.013)
Constant	-1.989***	-0.453	-0.811	-3.287***	-2.046***	-1.978***
	(0.237)	(0.737)	(0.720)	(0.429)	(0.370)	(0.269)
Observations	4870	414	493	948	1009	2006
N_clust	4640	414	493	940	1001	2001
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Community FE	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak Devices	Yes	Yes	Yes	Yes	Yes	Yes

The standard errors (in parentheses) are clustered at household level * p<0.10, ** p<0.05, *** p<0.01.

et al., 2011). Milk protein is of higher quality than meat (Azzarri *et al.*, 2015) and has a special way of stimulating circulating insulin-like growth factor (IGF)-I production (Michaelsen *et al.*, 2011). Specifically, milk contains type II minerals such as potassium, phosphorus, magnesium and zinc in high quantities and lactose, which are essential for growth (Park, 2009; Muehlhoff *et al.*, 2013; Pfeuffer and Watzl, 2018).

These results differ from Azzarri *et al.* (2015) which show that ownership of large ruminants has no effect on the probability of stunting in Uganda. The RCT study in Kenya also shows no significant gain in growth among children aged 11 – 40 months after consuming milk and meat for five months (Long *et al.*, 2012). In our case, the effects of milk remain robust even after controlling for factors associated with breastfeeding,[11]. For meat ruminants ownership, we find that its effects on growth is insignificant across all age groups (Table 3.7), which is different from RCT studies (Tang *et al.*,

[11]We established this by controlling for the predictors of breastfeeding in our regressions as explained in Section 2 of Chapter 3.

2014; Tang and Krebs, 2014; Tang *et al.*, 2018) which found significant effect of meat on growth of younger children under 12 months. The insignificant results is probably due to the weak instrument for meat ruminant ownership. Similarly, the positive significant coefficient for meat consumption among non-ruminant owners could be explained by the fact that most non-livestock owners are also relatively wealthier households and can purchase meat from the market .

The complimentary effect of mixed ruminant ownership on milk consumption we observe may be explained by the potential channels through which mixed animal ownership affects child growth. The first channel may be direct through milk consumption from own production, and the second is indirect through income generated from livestock activities. Owning both milk and meat animals may provide households with diversified income sources to purchase ASF, particularly milk from the market. For example, oxen are often rented out for animal traction, generating income for households to spend on milk during seasons when the household's milk animals are not producing milk. Adesina (1992) showed that households who own draft oxen have a higher income than non-owners in West Africa. Other studies also show that oxen generate up to 75 percent of livestock-derived income compared to milk cattle (Randela, 2003). Keeping only milk animals may imply that supply and consumption of milk stops during a cow's gestation period and when their milk has dried up.

3.4 Conclusion

Poor nutrition claims the life of over a million children every year globally. In response to a high malnutrition rate, an increasing amount of research has been undertaken to understand the interaction between food consumption and child growth. In this study, we assessed the effect on child growth of consuming milk and meat in Tanzania. In particular, we tested for the differential mediating effects of different animal keeping practices – meat and mixed animal keeping – on the link between milk or meat consumption and child growth.

The results show that milk consumption plays a greater role in promoting child growth soon after transiting from breastfeeding. The effect of milk consumption is significant for older children: 24–35 months and 36–60 months, and more effective if a child lives in a household that keeps mixed ruminants. Moreover, we find that the complementarity effect of ownership of meat ruminants is insignificant.

An important message that emerges from these results is that milk consumption should not substitute breastfeeding as the effects are only limited to some stages during growth. The adherence to exclusive breastfeeding and continued breastfeeding in the first 1 000 days is vital. The main effects of meat and milk consumption are statistically insignificant. The impact of milk consumption is therefore is contingent on animal ownership in Tanzania. This means that a stable and frequent supply of milk apart from the market is required, and depends on own consumption. Mixed animal keeping enhances the gains from milk consumption as the supply becomes more stable, while keeping meat animals on their own might be ineffective.

Our results support previous studies which demonstrate that ASF consumption and animal ownership are associated with child growth. We observe a relatively significant impact of milk on growth despite the low-frequency average milk consumption among children. This result has implications that interventions for scaling up milk consumption could help address the high stunting rate in Tanzania and other developing countries. One potential policy channel is to encourage the transfer of livestock to non-animal keeper's households through subsidisation, or donation as in the case of the One Cow per Poor Family programme in Rwanda (Argent *et al.*, 2014). However, based on our findings, more desirable outcomes are likely to be realised when transfers include both milk and meat animals. In the past, similar programmes have been reported to increase consumption of ASF, provide a more stable income and supply of ASF to households and contribute to poverty reduction (Rawlins *et al.*, 2014; Kafle *et al.*, 2016; Jodlowski *et al.*, 2016; Adesogan *et al.*, 2020).

While a transfer of livestock could be feasible in rural settings, its implementation might be challenging in urban areas. Again, despite the nutritional benefits of livestock keeping, its environmental sustainability poses even more challenges. Livestock keeping comes at the cost of environmental destruction (Sakadevan and Nguyen, 2017; Tullo *et al.*, 2019; Grossi *et al.*, 2019) and can have adverse effects on child health. The literature suggests that exposure to large herds of animals is associated with an increased risk of diarrhoea because of poor sanitation (Conan *et al.*, 2017; Rukambile *et al.*, 2020). High animal faecal contamination in community water sources in areas with a high density animal population is a common outcome in most observational studies (Schriewer *et al.*, 2015; Barnes *et al.*, 2018). To balance the nutritional needs and environmental preservation, interventions that target to improve productivity could be a viable policy option. For example, efforts to transform the livestock sector from traditional, less productive, large herds of cattle to the more productive and environmentally friendly small herds of improved variety should be promoted. Increased productivity translates to lower milk and other ASF prices, leading to increased access to such foods even for non-farmers in rural and urban areas.

The main limitation of this study is that our classification of animal into meat and mixed ruminants did not account for whether the animal produced milk in the last 12 months, the quantity of milk produced, nor seasonality. Similarly, the classification does not indicate whether animals were slaughtered and consumed within the household or not. We also fail to directly control for breastmilk and birth weight in the estimation, but instead controlled for the factors associated with breastfeeding.

CHAPTER 4

EX-ANTE INEQUALITY OF OPPORTUNITY IN CHILD MALNUTRITION IN TANZANIA: THE ROLE OF ACCESS TO WATER AND SANITATION

4.1 Introduction

The recent 2020 Global Nutrition Report shows large and persistent inequality in malnutrition in LMICs (Micha *et al.*, 2020). Location is one of the major highlighted factors describing inequality patterns where higher stunting rates are observed in children residing in rural areas. The overall inequality in malnutrition is explained largely by mean differences between urban–rural areas, yet it is possible that inequality within urban areas might be higher despite its higher mean. The low proportion of poor children and high socioeconomic gradients in urban areas often increases the malnutrition inequality in urban areas compared to rural areas (Bitrán *et al.*, 2005). Several studies confirmed higher levels of inequality within urban areas (Menon *et al.*, 2000; Fotso, 2007; Van de Poel *et al.*, 2007*b*). According to Fotso (2006) the within urban inequality is larger than the overall rural–urban gap in malnutrition.

Economists emphasise that inequality should be addressed based on type because various inequality sources may have different consequences on society and the economy (Brunori *et al.*, 2013). In doing so, they attempted to separate from a composite measure of inequality, inequality of opportunity (IoP) and inequality due to effort. Inequality of opportunity has its roots in the work of Roemer (1993, 1998, 2002) which describes it as inequality due to factors called 'circumstances' which are those factors beyond an individual's control. Income is one of several circumstances leading to illegitimate inequality (Fleurbaey and Schokkaert, 2011; Schokkaert, 2015). Inequality due to effort stems from factors for which an individual can be held responsible, such as eating habits in terms of quality and quantity of food. Hence, inequality of opportunity is viewed as illegitimate, while inequality due to effort is legitimate. That is, individuals should be compensated for circumstance-driven inequality and rewarded for effort-driven inequality. In line with this view, factors such as residence and access to basic services are exogenous to a child, and thus the inequality in nutrition during childhood is attributable to circumstances and is, therefore, unfair.

The equality of opportunity principle requires that there should be no differences in the nutrition outcomes due to differences in circumstances among children. However, inequality of opportunity in child nutrition in low- and middle income countries (LMICs) has a regional dimension, often driven by inequality in service delivery. Geographical inequalities in access to safe water, sanitation and hygiene (WASH) are evident in regional, national, subnational and rural and urban areas, with large disparities observed in sub-Saharan Africa (WHO/UNICEF, 2015; Deshpande *et al.*, 2020). Inadequate WASH has been associated with poor child growth manifested in bouts of diarrhoea (Kumar and Vollmer, 2013; Fink *et al.*, 2011), infectious diseases (Waruiru *et al.*, 2004; Russell and Azzopardi, 2019) and environmental enteropathy (Mbuya and Humphrey, 2016; Lin *et al.*, 2013; Humphrey, 2009). An estimated 361 000 deaths of children under the age of five in LMICs in 2012 were attributable to inadequate WASH (WHO, 2014*b*).

The association between WASH and child linear growth has been documented in both observational and experimental studies in LMICs. For instance, a linear relationship between open defecation rates in villages and the growth of under-five children was found in a randomised control trial study in India, Indonesia, Mali and Tanzania (Gertler *et al.*, 2015). Similarly, children in Tanzania and Peru without adequate WASH were shorter and had more diarrhoea episodes than those with improved access (Mshida *et al.*, 2018; Checkley *et al.*, 2004), while in Ethiopia, they were wasted but not stunted (van Cooten *et al.*, 2019). Having access to adequate sewage but not clean water correlated with a lower likelihood of being stunted in Ethiopia, India, Peru and Vietnam (Dearden *et al.*, 2017). Evidence also shows that increasing access to clean water without improved sanitation does not reduce stunting (Checkley *et al.*, 2004).

While the role of WASH on average child health has been widely established, the extent to which it contributes to within and between rural and urban undernutrition disparities has not been well studied. Inequality of opportunity studies that focus on children broadly treat WASH components as an opportunity only, rather than circumstances (Contreras *et al.*, 2012; Ersado and Aran, 2014; Amara *et al.*, 2017). However, in practical terms, social planners can view WASH as opportunities that need to be equalised but for children WASH are circumstances that limit their growth potential. This study adds to the existing knowledge by estimating inequality of opportunity in child nutrition in Tanzania using WASH as one of the circumstances. We carefully show how WASH coverage and distribution influences inequality. Given the importance of understanding the needs of different population subgroups, we decompose the inequality of opportunity by region types. The study, therefore, fills the gap of knowledge in the inequality of opportunity literature that overlooks the fact that children in rural and urban areas could be affected by different circumstances and that addressing inequality in such areas might require different policy interventions. Additionally, for the first time, this study explicitly shows how and to what extent price fluctuations circumstance factors shape inequality of opportunity in child health in rural and urban areas.

To quantify the level of inequality of opportunity in nutrition in rural and urban areas, we estimated the dissimilarity index (D-Index) proposed by Paes de Barros *et al.* (2009). The index was then decomposed using Oaxaca (1973) and Shapley decomposition methods. The decomposition analysis is insightful because it highlights the contribution of each circumstance to the health inequality for policy priority and intervention to close the gap. Evidence supports the idea that the goal to break the intergenerational cycles of poverty can be effectively achieved through equalising opportunities during early life stages rather than later in life (Crookston *et al.*, 2013; Conti *et al.*, 2019). Circumstances that affect current generation opportunities are likely to shape circumstances that the next generations will face. Health inequalities during childhood persist throughout the life course to adulthood (Case *et al.*, 2002) and thus perpetuate the intergenerational transmission of poor health (Richter and Körholz, 2015; Alemán-Díaz *et al.*, 2016). Research has shown that being stunted during childhood is associated with low cognitive ability (Kar *et al.*, 2008; Nyaradi *et al.*, 2013) and low education attainment (Alderman *et al.*, 2009; Nandi *et al.*, 2015; Behrman, 1996), poor health (Lanigan and Singhal, 2009; Koletzko *et al.*, 2017), and poor labor outcomes (Galler *et al.*, 2012) in adulthood.

The findings show that stunting is more unequally distributed across circumstances in urban than rural areas. The results also show that WASH plays a greater role in shaping inequality of opportunity in rural than urban areas, accounting for 42 percent of the total inequality of opportunity in rural areas. Child age and household wealth follow; each respectively contributes 22 percent and 14 percent. The circumstances with the largest contribution in urban areas is a child's gender which contributes 30 percent to inequality followed by price fluctuations which contributes 17 percent. The intergenerational aspects of health, breastfeeding and socioeconomic status each contribute 12 percent to total inequality in malnutrition in urban areas. To understand whether the distribution of WASH opportunities explains the observed rural–urban inequality of opportunity in nutrition, we estimated the Human Opportunity Index (HOI). The findings show a significant gap in coverage of WASH opportunities favouring urban areas suggesting a stronger link between access to these opportunities and rural–urban inequality in malnutrition.

The main takeaway of this paper is that different policy interventions would best address inequality in malnutrition in Tanzania in rural and urban areas. The findings suggest that it could be easy to reduce inequality in rural areas by increasing access to WASH services. In urban areas, this would require changing intergenerational circumstances which are more pronounced in these areas. Nevertheless, the large contribution of food prices on inequality in urban areas indicates that price stabilisation policies may be helpful to reduce inequality in these areas.

4.2 Literature

The literature on child health inequality is dominated by studies on socioeconomic inequality in health (Wagstaff *et al.*, 1991; Wagstaff and Watanabe, 1999; Zere and McIntyre, 2003; Hong and Mishra, 2006; Van de Poel *et al.*, 2008; Van de Poel and Speybroeck, 2009; Subramanyam *et al.*, 2010; Kamal, 2011; Pathak and Singh, 2011). This literature is grounded in the principle that there should be no differences in child outcomes based on the level of income of the household to which a child belongs. The rank dependent concentration indices are used to measure inequality across different socioeconomic groups. Wagstaff regression-based decomposition (Wagstaff *et al.*, 2001) and Recentered Influence Function (RIF) decomposition techniques (Fortin *et al.*, 2011) have been widely used to decompose the rank dependent indices into contributing factors. Studies forming part of this strand of literature show that household income has a strong relationship with child health inequality – children from the lower income quintiles have a higher likelihood of being malnourished than those from higher income quintiles (Nkonki *et al.*, 2011; Odgers, 2015; Angdembe *et al.*, 2019). Some studies document that the relationship between household income and child health becomes stronger as the child ages; the health of children from low-income quintiles deteriorates as they get older (Case *et al.*, 2002; Currie and Stabile, 2003). Studies that focus on rural and urban areas have shown that the contribution of household income to child health inequality tends to be higher in urban than rural areas (Menon *et al.*, 2000; Fotso, 2007; Van de Poel *et al.*, 2007*b*).

Socioeconomic inequalities in health literature are a subset of the emerging literature on the inequality of opportunity (IoP). Unlike IoP, socioeconomic inequalities in health literature do not treat inequality emanating from factors such as water and sanitation as undesirable unless it is linked to income inequalities (Aizawa, 2019). The IoP literature gained momentum recently following the development of more robust methodologies to measure inequality of opportunity (Paes de Barros *et al.*, 2007, 2009; Ferreira and Gignoux, 2014, 2011). Singh (2011) is among the few studies that adopted the concept of inequality of opportunity to estimate inequality in nutrition in India. Other studies include Sanoussi (2017) in Togo, Sudan (Ebaidalla, 2019), Ethiopia (Hussien *et al.*, 2016), Chile (Contreras *et al.*, 2012), South Africa (Zoch, 2015), Algeria, (Abdelkhalek *et al.*, 2018), China (Eriksson *et al.*, 2014), and for the Arab countries (Assaad *et al.*, 2012; Hlasny and Intini, 2015). The general finding in most of these studies is the persistence of large spatial disparities in inequality between regions, and factors such as parental education and wealth appear to be the common influential circumstances.

Andersen *et al.* (2017) study used demographic health surveys for 60 developing countries and found a higher level of inequality of opportunity in Latin America compared to the rest of the world and significant lower inequality in sub-Saharan Africa. They also found family background to be the main contributor to inequality in Latin America but not in sub-Saharan Africa. The gender of a child was shown to influence access to school and immunisation opportunities in few of the 47 countries under study (Hoyos and Narayan, 2011). Household affluence contributes to the large between types inequality of opportunity in child malnutrition in five of the ten developing Asian countries (Aizawa, 2019) [1].

4.3 Data

4.3.1 Tanzania National Panel Survey (TNPS)

This study uses the 2008/09 Tanzania Integrated Living Standard Measurement Survey (ILSM) by the World Bank.[2] The survey collects a wide range of information on household characteristics, food and non-food expenditure, child's parents' background, anthropometric information, child-specific characteristics and community variables such as hospital availability. The survey covered 3 265 households. The summary statistics of the sample used in the analysis is given in Table 4.1. The results show a significant gap in the prevalence of stunting between rural and urban areas.

[1]Type or sometimes referred group circumstances refer to individuals who share the same circumstances.

[2]One of the main interests of this study was to explore the contribution of early life factors – breastfeeding and vaccination – on the inequality of opportunity. Breastfeeding and vaccination variables were only collected in the first round of the survey (2008/09). We therefore restricted the analysis to the first round only.

On average more children in urban areas are exclusively breastfed than in rural areas. Similarly, a significantly higher proportion of children in urban areas have access to clean water and adequate sanitation than those in rural areas. Household size in rural areas is significantly larger than in urban areas. The food price difference between the two regions is also significant, where higher prices are seen in urban areas. In terms of consumption levels, urban households are better off compared to rural households.

Table 4.1: Summary Statistics of the Variables

Variable	Variable Definition	Full Sample	Urban	Rural	Rural-Urban
Stunting	Height for Age Z Score<-2SD	0.42	0.322	0.454	0.132***
Maize price	Median price at district level in TSHS	7.02	7.025	7.016	-0.009
Consumption(log)	Household consumption in TSHS	14.56	14.980	14.413	-0.567***
Breastfeeding	1 if a child was exclusively breastfed for six months	0.30	0.315	0.292	-0.023
Vaccination	1 if a child received a polio or measles vaccine	0.93	0.934	0.935	0.001
Age at birth	1 if age at birth less than 18years	0.02	0.017	0.020	0.003
Mother Education	Years of schooling of a mother	5.657	7.443	5.039	-2.404***
Water	1 if a household has access to piped water, bottled water , protected well, spring water, cart with tank or tanker-truck	0.64	0.847	0.569	-0.279***
Health care	1 if there is a hospital/ dispensary in the village	0.55	0.516	0.356	-0.160
Sanitation	1 if the household has access to improved sanitation: flush toilet, ventilated pit latrine, pit latrine with slab or composting toilet	0.88	0.742	0.542	-0.200***
Household size	The number of people in the household	6.95	5.972	7.289	1.316***
Age(0-5)	The age of a child between 0 and 5 months	0.05	0.028	0.052	0.025**
Age(6-24)	The age of a child between 6 and 24 months	0.31	0.302	0.309	0.007
Age(25-36)	The age of a child between 25 and 36 month	0.22	0.215	0.216	0.001
Age(37-60)	The age of a child between 37 and 60 months	0.43	0.455	0.422	-0.033
Child=male	The gender of the child: 1=male; 0=female	0.52	0.549	0.473	-0.076
N			2017		

4.3.2 Measuring Child Nutrition

The outcome variable for this study is binary, indicating whether a child is stunted or not. According to WHO (2006), a child with a HAZ below −2SD is defined as being stunted – indicating chronic malnutrition. The focus on stunting is motivated by the high prevalence rate in Tanzania and its strong correlation with future opportunities. Unlike acute malnutrition where the consequences can be reversed through timely treatments, the consequences of chronic malnutrition tend to persist over time (Andersen *et al.*, 2017).

4.3.3 Circumstance Variables

Following the previous literature (Aizawa, 2019; Syeda *et al.*, 2020), we use breastfeeding as a circumstance. Breastfeeding improves the child's immunity against infectious diseases and reduces the risk of various forms of malnutrition (Stuebe, 2009; Scherbaum and Srour, 2016). Based on WHO

(2013) recommendations, a child should be exclusively breastfed for six months, and breastfeeding should continue until two years; however, most children in Tanzania receive suboptimal feeding (Shirima *et al.*, 2001; Victor *et al.*, 2013; Dede and Bras, 2020). Studies found both overlapping and interaction between malnutrition and infectious diseases. Hence, we include the vaccination circumstance factor because of its role in improving immunity against infectious diseases in not only nourished but in particular malnourished children (Savy *et al.*, 2009; Prendergast, 2015).

The literature widely established food price as an important determinant of child malnutrition (Grace *et al.*, 2014; Lee *et al.*, 2016; Woldemichael *et al.*, 2017; Brenton and Nyawo, 2021). In Chapter 2, we also provided evidence of the negative impact of food price on child growth in Tanzania. We, therefore, use maize price as another circumstance factor that proxies the quality and quantity of diet available to a child. The maize price was derived from household food expenditure information. Additionally, we include the mother's education and age at birth, which are especially important intergenerational circumstance factors. At the household level we use household consumption and household size, as the relevance of these variables on child growth and development has been widely documented in several studies (Horton, 1986; Agee, 2010; Iftikhar *et al.*, 2017; Costa *et al.*, 2018; Kirk *et al.*, 2018).

While variables for access to basic services are commonly treated as opportunities in inequality of opportunity studies (Contreras *et al.*, 2012; Ersado and Aran, 2014; Amara *et al.*, 2017), in this study WASH are considered as both circumstances and opportunities. Inadequate water and sanitation expose a child to infectious diseases and parasites that prevent the body's absorption of the nutrients a child receives (Andersen *et al.*, 2017; Mshida *et al.*, 2018). Similar to previous studies (Victora *et al.*, 2005; Van de Poel *et al.*, 2007*b*), we consider a household as having access to clean water if the primary source of water is either piped water, bottled water, protected dug well and spring water, a cart with tank or a drum and tanker-truck.

Finally, we use child age and gender as circumstances. The research established that the growth of children from high- and low-income families begins to differ once breastfeeding stops and a child depends on nutritious food. From the age of six months, the gap in child growth between high- and low-income families tends to increase before it starts to stabilise at 30 months (Andersen *et al.*, 2017). The gender of a child also regularly emerges as a determinant of child growth in developing countries where cultural preferences for a specific gender are predominant.

4.4 Methods

4.4.1 Dissimilarity Index and Human Opportunity Index

Drawing on the methodological framework (World Bank, 2006; Paes de Barros *et al.*, 2009; Yalonetzky, 2012; Barros *et al.*, 2008) we compute the D-index to quantify the inequality of opportunity among circumstances and the HOI to assess the coverage of these opportunities. Following Paes de Barros *et al.* (2009), the D-index measures the weighted absolute differences in groups' means for different circumstances from the population mean. It describes the misallocated opportunities that need to be redistributed, given the circumstances to ensure equitable access to these opportunities.

We estimate the D-index in three steps. In the first step, for a set of f m circumstances $(x_1, x_2, x_3, ..., x_m)$, we estimate the conditional probabilities of each circumstance using the Logit model,

$$Ln\left(\frac{Pr(\,I=1|x_1,x_2,....,x_m)}{1-Pr(I=1|x_1,x_2,....,x_m)}\right)=\sum_{k=1}^{m}h_k(x_k) \tag{4.1}$$

In the second step, we use the coefficients obtained in the first step to predict the probability of access to opportunity for each child in the sample.

$$\hat{p}=\frac{Exp\left(\beta_0+\sum_{k=1}^{\hat{m}}X_{ki}\hat{\beta}_k\right)}{1+Exp\left(\beta_0+\sum_{k=1}^{\hat{m}}X_{ki}\hat{\beta}_k\right)} \tag{4.2}$$

In the final step, we estimate the probability for access to opportunity for the overall population and the D-index.

$$\bar{p}=\sum_{i=1}^{n}w_i\hat{p}_i \tag{4.3}$$

$$D=\frac{1}{2\bar{p}}\sum_{i=1}^{n}w_i|\hat{p}_i-\bar{p}| \tag{4.4}$$

where $\hat{p_i}$ is the average predicted probability of an outcome variable for unique circumstance i, $\bar{p}$ is the average probability for the population, and w_i is the sample weight. D-index ranges from 0 to 1 ($0-100$ in percentage). $D=0$ implies equality of opportunity — a child's probability to access opportunities is not affected by circumstances such as residence, family income and parent education.

The HOI measures the average coverage rate (prevalence) of opportunities discounted by how equitably (D-index) the opportunities are distributed among the population. In other words, it represents the average coverage of opportunities that are distributed independently of a child's circumstances. Thus, HOI is a product of average access rate $\bar{p}$ and $D - index$ and equals coverage if $D = 0$ and decreases as D increases. Eqn 4.5 implies that interventions can target to increase $\bar{p}$ or reducing D.

$$HOI = \bar{p}(1 - D) \tag{4.5}$$

4.4.2 Shapley and Oaxaca Decomposition

We decompose the inequality of opportunity of a child's nutrition into its sources using the Shapley decomposition (Shorrocks, 1982). This technique allows us to establish the marginal contribution of each circumstance to the inequality of opportunity. Unlike other decomposition methods widely used in the literature, for example, Wagstaff decomposition, the Shapley decomposition satisfies the path-dependent property – additively decomposable (the marginal contribution of each circumstance and group adds exactly to the total inequality) (Shorrocks, 2013; Davillas and Jones, 2020). In addition to the Shapley decomposition, the Oaxaca-Blinder decomposition (Oaxaca, 1973; Blinder, 1973) was applied to the D-index to gauge the rural and urban-specific inequality of opportunity. The Oaxaca decomposition also produces counterfactual estimates such that for each region, the counterfactual is calculated using its coefficients and the distribution of the circumstances of the other region. That is, counterfactual for rural areas is calculated using the coefficient of circumstances in rural areas and distribution of circumstances in urban areas, and similar for urban. The counterfactuals help to tell whether the observed rural–urban difference in inequality of opportunity is driven by the difference in the distribution of the circumstances or the size of the effect of the circumstances in the two areas (Juárez and Soloaga, 2014).

4.5 Results

4.5.1 Descriptive Results

The distribution of HAZ in rural and urban areas is shown in Figures 4.1 and 4.2 and by age groups in Figure 4.3. The scores in both rural and urban areas are skewed to the left, indicating a significant proportion of stunted (below −2SD) and relatively fewer severely stunted (below −3SD) children. Figure 4.2 shows that 45 percent of children in rural areas are stunted compared to 32 percent in urban areas. Similarly, 19 percent of children in rural areas are severely stunted and only 9 percent in urban areas.

We also find that stunting increases with the child's age (Figure 4.3). The likelihood of children aged 6–36 months being stunted is higher than the other age groups — 48 and 47 percent of children aged 6–24 months and 25–36 months are stunted, respectively. A similar pattern is observed for severe stunting where 20 percent of children aged 6–24 months and 17 percent of children aged 25–36 months are severely stunted compared to 14 and 15 percent of children aged 0–5 months and 37–60 months, respectively.

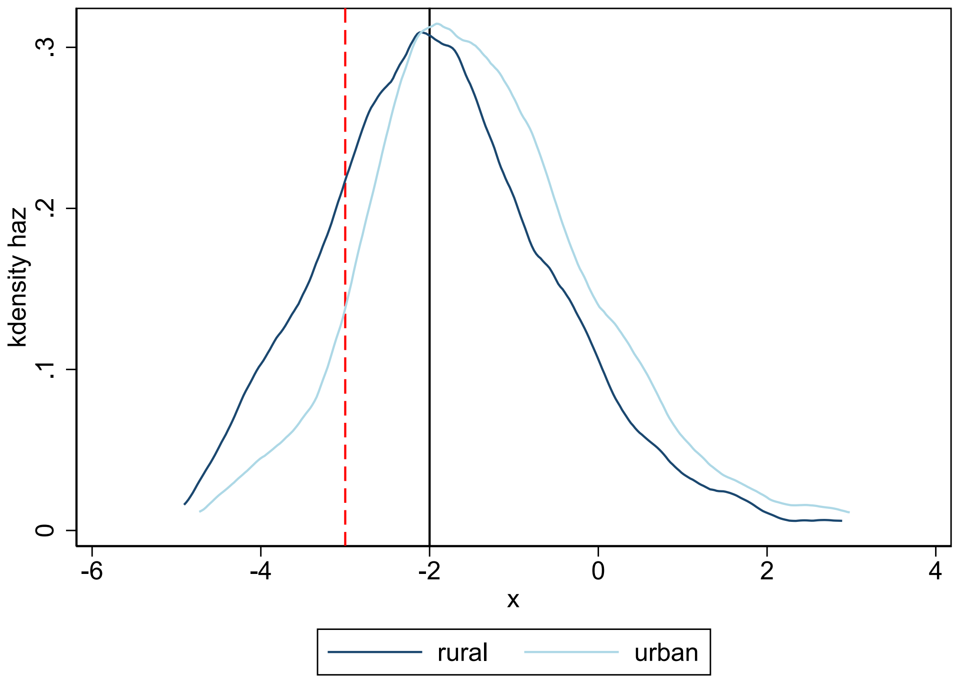


Figure 4.1: Distribution of Height for Age Z-scores

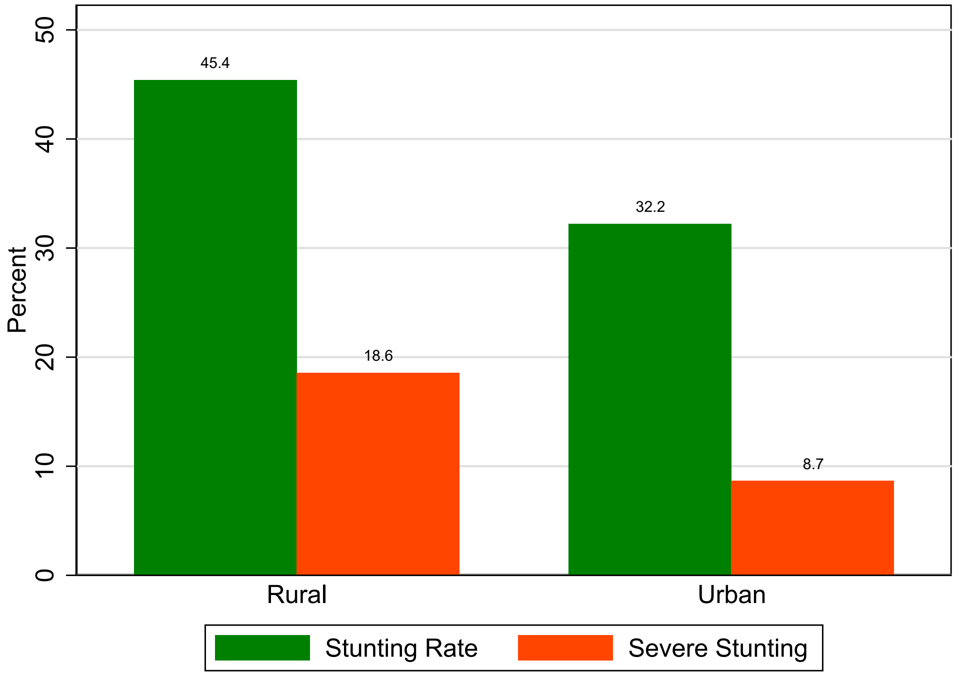


Figure 4.2: Proportion of stunted children in rural and urban areas

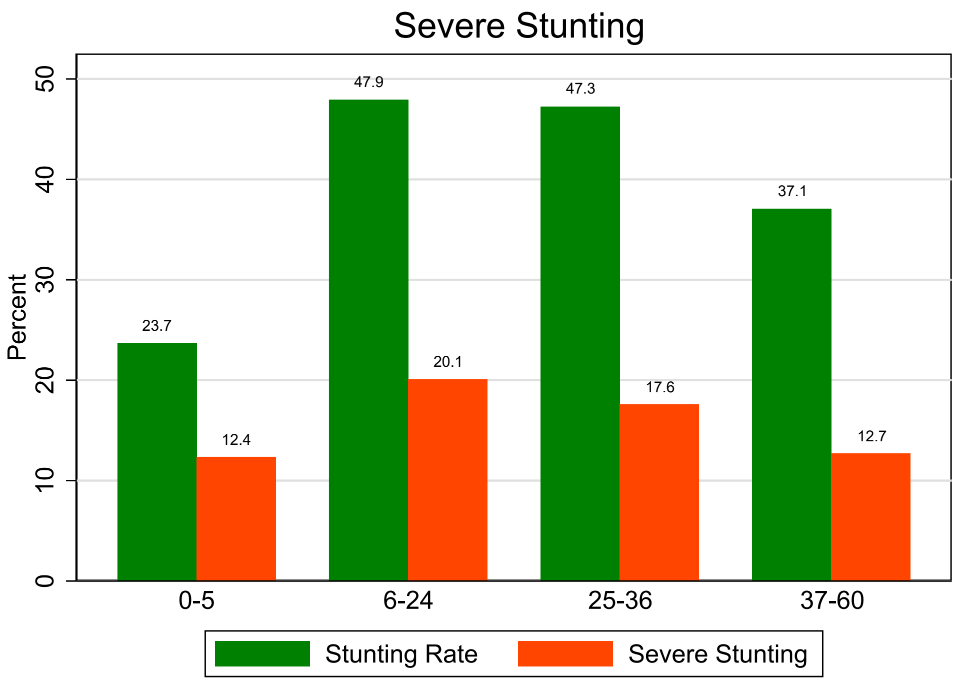


Figure 4.3: Proportion of stunted children across age groups

4.5.2 Determinants of Stunting

Before delving into the analysis of inequality of opportunity, we first present the correlates of stunting in Table 4.2. Household consumption and access to clean and safe water significantly reduce the likelihood of being stunted in rural areas. Maize price increases the likelihood of stunting in urban children. Likewise, children of younger mothers are likely to be stunted. The association is, however, significant only in urban areas. Relative to younger children 0–5 months, the likelihood of children being stunted increases with age until 36 months and slightly declines afterwards in rural areas. Children aged 6–24 months in urban areas are 2.3 times more likely to be stunted than younger children 0–5 months.

4.5.3 Inequality of Opportunity and Decomposition

Table 4.3 shows that the value of the adaptive D-index is 0.2, indicating that a rather large part of the inequality in opportunity in child health is due to circumstances. In other words, 20 percent of the circumstance-driven inequality needs to be redistributed from non-stunted to stunted children to attain equality of opportunity. The top panel of Table 4.3 presents the results of the Oaxaca-Blinder-like decomposition of inequality of opportunity in child health within rural and urban areas. The estimates for each group (rural and urban) are given by the diagonal values, and the rest are the counterfactual estimates. The inequality of opportunity for rural and urban areas is 0.035 and 0.046, respectively, implying that stunting is more unequally distributed across circumstances in urban than rural areas. This finding supports the literature on socioeconomic inequality in malnutrition which established higher inequality in urban than rural areas (Menon *et al.*, 2000; Fotso, 2007; Van de Poel *et al.*, 2007*b*). Given that it is unlikely that all circumstances affecting child health are included in the analysis, the values of the D-index presented should be regarded as a lower bound estimate.

Table 4.4 presents the results of the Shapley decomposition of the inequality of opportunity in stunting. The results of the full sample indicate water and sanitation as major contributors to the inequality, which explains 36 percent of the total inequality. Household income accounts for 24 percent of the inequality, followed by child's age which explains 15 percent. Child gender appear far more important than the intergenerational variables for mother's education and age at birth, contributing 9 percent of the variation compared to 3 percent emanating from intergenerational

Table 4.2: Logit Regression Results for Stunting in Rural and Urban Areas

	(1) Full Sample	(2) Rural	(3) Urban
Maize price	0.641*	0.410	2.351**
	(0.344)	(0.359)	(1.037)
Consumption(log)	-0.277***	-0.251**	-0.183
	(0.081)	(0.102)	(0.179)
Breastfeeding	-0.152	-0.088	-0.254
	(0.105)	(0.121)	(0.244)
Vaccination	-0.142	-0.249	0.267
	(0.210)	(0.236)	(0.518)
Age at birth	0.066	-0.241	1.270*
	(0.335)	(0.386)	(0.658)
Mother Education	-0.043	-0.029	-0.076
	(0.030)	(0.037)	(0.058)
Water	-0.304***	-0.316***	0.076
	(0.098)	(0.108)	(0.274)
Health care	0.067	0.072	0.078
	(0.095)	(0.109)	(0.203)
Sanitation	-0.506***	-0.402	-0.347
	(0.176)	(0.329)	(0.244)
Household size	0.015	0.009	0.022
	(0.013)	(0.015)	(0.038)
Age(0-5)	1.222***	1.106***	2.342**
	(0.266)	(0.285)	(1.091)
Age(6-24)	1.200***	1.205***	1.920*
	(0.272)	(0.293)	(1.094)
Age(25-36)	0.779***	0.784***	1.485
	(0.263)	(0.281)	(1.088)
Age(37-60)	-0.314***	-0.225**	-0.612***
	(0.093)	(0.107)	(0.196)
Constant	-0.974	0.346	-15.710**
	(2.617)	(2.893)	(7.223)
N_clust	2017	1528	489
Observations	2017	1528	489

Standard errors in parentheses *p<0.10 **p<0.05 ***p<0.01.
Standard errors are clustered at Individual level

Table 4.3: Decomposition of Inequality of opportunity in stunting (Oaxaca-like decomposition)

	Coefficients	
Distribution	Rural	Urban
Rural	0.03478	0.04568
Urban	0.03027	0.04554
Method		Absolute
PdB (Dissimilarity index)		0.087996
ws (adapted DI)		0.156823

variables.

The disaggregated analysis by region type in columns (5) and (7), however, displays different patterns. Access to clean water and improved sanitation contribute 42 percent of the inequality of opportunity in rural areas; while 22 and 14 percent of the inequality of opportunity in rural areas emanate from child age and household consumption, respectively. The rest of the circumstances contribute a relatively small amount ranging from 2 to 5 percent. Unlike rural areas, child's gender and price fluctuations are the leading contributors in the urban areas, contributing about 30 percent and 18 percent, respectively. Intergenerational factors, breastfeeding and a household's socioeconomic status each contribute 12 percent of the total inequality.

Table 4.5 shows that the opportunity in access to clean water is limited to only 55 percent of children in rural areas, with 2.9 percent of the opportunities being misallocated among circumstance groups. Similarly, for urban areas, 81 percent of the children have the opportunity for access to clean water, with only 3 percent of the opportunities needing to be reallocated to attain equality. The results also show that despite relatively similarities within rural–urban dissimilarity indices, there is higher inequality of opportunity across region types emanating from unequal coverage of water services. Furthermore, 84 percent of children in rural and 99 percent in urban areas have the opportunity to live in a house with improved sanitation. The overall dissimilarity indices in both regions are small implying that the coverage of improved sanitation is relatively equally distributed across children's circumstances. There is homogeneity in the distribution of opportunities in access to health care across circumstances in both regions but it is limited to only 50 percent of the children.

Table 4.4: Shapley Decomposition of Inequality of Opportunity in Stunting

	Full Sample		Urban		Rural	
Variable	Value	percentage	Value	percentage	Value	percentage
Maize Price	0.005	5.27%	0.025	17.95%	0.003	4.73%
Consumption	0.021	23.53%	0.016	11.67%	0.011	14.29%
Breastfeeding	0.005	5.74%	0.017	12.43%	0.002	3.33%
Vaccination	0.000	0.21%	0.008	5.89%	0.001	1.94%
Mother Education and Age at Birth	0.002	2.79%	0.016	11.55%	0.002	3.32%
WASH	0.032	36.36%	0.000	-0.33%	0.031	41.50%
Health Care	0.000	0.16%	0.001	0.69%	0.001	0.70%
Household Size	0.002	2.19%	0.007	4.75%	0.002	2.80%
Child Age	0.013	15.09%	0.006	4.25%	0.016	22.36%
Child Gender	0.008	8.65%	0.041	29.97%	0.004	5.05%
TOTAL	0.088	100.00%	0.137	100.00%	0.074	100.00%

Table 4.5: Inequality of Opportunity in the Access of Basic Services in Rural and Urban

	Water			Sanitation			Health Care		
	C	D	HOI	C	D	HOI	C	D	HOI
Rural	56.8	2.9	55.2	86.0	1.8	84.4	54.9	5.5	51.9
Urban	83.5	3.0	81.0	99.0	0.5	98.6	53.3	4.9	50.7

Note: Coverage (C), Dissemilarity (D) and Human Opportunity Index (HOI)

4.6 Discussion

The goal of improving child health is as important as that of reducing inequality in health (Goal 4). Yet, in Tanzania, despite the progressive reduction in malnutrition over the last two decades, large health disparities persist across regions and socioeconomic profiles. This mismatch confirms Van de Poel *et al.* (2008)'s argument that reduction in the rate of malnutrition does not guarantee a reduction in child health inequalities. Moreover, policies that address poor average health might be different from those required to reduce the inequality in poor health, as the latter involves multi-sectoral dimensions (Speybroeck *et al.*, 2010). This necessitates the need for a clear understanding of the underlying causes and factors aggravating child health inequality in Tanzania.

In this study, we analysed and decomposed the inequality of opportunity in child malnutrition and linked it with the measures for child's access to basic services; clean water, sanitation and health care. We adopted the Dissimilarity index and Human Opportunity Index, to estimate IoP and decompose the inequality using the Oaxaca and Shapley decomposition techniques. We find that 20 percent of the circumstance-driven inequality needs to be redistributed from non-stunted to stunted children to attain equality of opportunity. The decomposition between regions shows that stunting is more unequally distributed in urban than in rural areas. These results confirm the findings of the studies on socioeconomic inequality in child health (Menon *et al.*, 2000; Fotso, 2007; Van de Poel *et al.*, 2007*b*).

The Shapley decomposition further reveals that the circumstances that influence inequality in child malnutrition are different in rural and urban areas. Water, sanitation and child age represent 66 percent of the total inequality in rural areas, of which 42 percent of the inequality results from water and sanitation on its own. The leading contribution of water and sanitation on the inequality of opportunity supports evidence for a strong linkage between water, hygiene and sanitation (WASH) and child growth suggested in the literature (Kwami *et al.*, 2019; Smith and Haddad, 2015; Rah *et al.*, 2015).

The larger contribution of water on the inequality in the rural areas could be explained by a significant gap in the coverage of clean water favouring urban areas revealed by HOI analysis. These findings suggest that while in urban areas patterns are 'fixed' by household factors and gender discrimination, in rural areas the pattern can change enormously by intervening in access to clean water, rather than relying on household attitudes and intergenerational poverty traps to resolve the inequality problem. The low and relatively equal within regions inequality of opportunity in access to water further emphasises that improved equality in child health outcomes can be achieved by increasing clean water coverage and improved sanitation in rural areas. This could be an effective policy option, perhaps because it is not generally challenging to reach poorer households than wealthier households. Poor households are likely to be impacted by the universal provision of water and sanitation services given the nature of the community level circumstances they face. WASH services are probably the least needed by richer households because they are commonly available to them — additional availability of WASH services might add less improvement to child growth in richer households than poor households. It could also be more difficult to convince people to change social patterns such as family structure and gender preferences than externally improve water provision quality.

Increasing coverage without considering socioeconomic profiles may not lead to the intended results. It is possible that intervention that will reach richer households first before poor households will exacerbate inequality of opportunity in HAZ rather than reducing it. It is also true that the duration for the inequality to reduce would be longer – only until poor households begin to catch up after the intervention has had the maximum impact on the richer households (Victora *et al.*, 2000). Monteiro *et al.* (2009) reported that approximately two-thirds of the decline of stunting from 37 to 7 percent in Brazil between 1996 and 2007 was the result of the increased supply of water and sanitation services for people in the lowest wealth quintiles. Experience also shows that investing in the quality of water and sanitation yields only a modest impact on improving child outcomes than wider community coverage interventions (WHO, 2014*b*, 2019).

Unexpectedly, we find that in urban areas, the gender of a child contributes more than a quarter of the inequality of opportunity in child malnutrition. The results are intriguing because, despite evidence that male children are more likely to be stunted than female children in sub-Saharan Africa (Espo *et al.*, 2002; Zere and McIntyre, 2003; Wamani *et al.*, 2004, 2007), the impact of gender discrimination on child health outcomes could be expected to be more prevalent in rural areas where sex preference cultural norms are still embraced. Less of these events are expected to be seen in urban areas due to the high literacy of the parents, exposure and cultural diversity. The son sex preference is widely established in other less developed countries such as Bangladesh, India, China and Pakistan; however, it is less pronounced in sub-Saharan Africa (Filmer *et al.*, 2008). Nonetheless, these findings are similar to those reported in Tunisia (Amara *et al.*, 2017) but differ from a study by Ersado and Aran (2014) in Egypt who find female children are more likely to be stunted than male. These results are also in line with Hoyos and Narayan (2011) who showed that the gender of a child influences access to basic services opportunities in 47 countries, including Tanzania.

Intergenerational aspects and early life child feeding practices are also far more important in urban compared to rural areas. Maternal years of education has been widely shown as a strong predictor of child health (Schultz, 2002). While education interventions seem important in both rural and urban areas, reaching disadvantaged children in urban areas offers more potential for narrowing the inequality. More educated mothers are likely to provide good parental care and ensure effective utilisation of treatment and prevention services (Caldwell, 1979, 1994). Education can also have spillover effects to equalise opportunities across other circumstances such as breastfeeding and childbearing age, which appear to be important determinants of child growth (Boyle *et al.*, 2006).

Provision of nutritional education has proved effective in improving child health in Malawi and Pakistan (Khan *et al.*, 2013; Ragasa *et al.*, 2019).

Another interesting result that emerges from our analysis is the large contribution from price fluctuations on the inequality of opportunity in urban areas – representing about 18 percent of the total inequality – exceeding household circumstance variables. These results correspond to the supplementary analysis provided in Table G.1 in the appendix and confirm the earlier findings in Chapter 2. We found that maize price fluctuations negatively affects the growth of the children from food non-producers – of which the majority are urban dwellers – while the impact is positive for children from food-producing households. It has also been demonstrated elsewhere that relatively higher food prices in urban areas compared to rural areas in most developing countries increases the vulnerability of urban children (Cohen and Garrett, 2010; Stage *et al.*, 2010). These findings imply that policies that stabilise food prices can offer leverage for improving equality of opportunity in child malnutrition. More importantly, the implementation of such policies should deliver maximum benefit to vulnerable children from urban poor households.

Household income or wealth was found to be the leading contributor of child health inequality in most studies on socioeconomic inequality in child health (Kien *et al.*, 2016; Rizal and van Doorslaer, 2019) and inequality of opportunity (Hussien *et al.*, 2016; Aizawa, 2019) in other developing countries. In this study, however, we find that the contribution of household consumption is relatively small compared to the contribution of basic services in both full samples and disaggregated analysis by region type. These findings might explain the persistence of the high stunting rate and inequalities in the country despite the significant decline in poverty levels in the last 25 years. Reducing poverty without considering its multidimensional aspect might not yield the intended outcomes, given the strong link between stunting and different aspects of poverty.

4.7 Conclusion

Inequality of opportunity in child malnutrition in Tanzania is attributable to a different set of circumstances in rural and urban areas. This study suggests that for the effective reduction of inequality of opportunity, public health interventions should consider different underlying levels and causes of child malnutrition inequality between subgroups and the potential impact different interventions can have on children from rural and urban areas. Policies that address the needs of specific groups should more effectively reduce inequality than a blanket one-size fits all approach. While increasing coverage of access to water and sanitation has the potential to improve a child's linear growth in rural areas, due to the complex nature of malnutrition, a multidimensional approach that integrates WASH into nutrition actions should be prioritised. The integrated WASH and nutrition interventions are largely supported by WHO (2015) and the positive impact is highlighted in the randomised studies from Bangladesh and Kenya (Luby *et al.*, 2018; Null *et al.*, 2018). Behavioural change promotion interventions, in addition to food price stabilisation policies, may help reduce inequality of opportunity in urban areas. However, given that WASH can be externally improved, it is relatively easier to address malnutrition in rural than urban areas. Due to the intergenerational nature of the factors causing malnutrition, behavioural change is required in urban areas and this is difficult and takes time. The success of such interventions heavily depends on the sustained frequency of contact between the behaviour change promoters and individuals – the effect is reduced or disappears once contact stops (Luby *et al.*, 2008, 2009).

CHAPTER 5

CONCLUSION AND RESEARCH IMPLICATIONS

5.1 Introduction

More than 30 per cent of under-five children in Tanzania are stunted, with a higher prevalence in rural than urban areas. These rates are unacceptably high, threatening the health and welfare of future generations in Tanzania, given the strong link between stunting and later lifetime outcome. The pace at which stunting is reducing is extremely unsatisfactory, despite several public health interventions in place. Tanzania has recorded an average annual reduction rate (AARR) in stunting of 0.08 per cent over the last 25 years (50–34 per cent from 1990/91 to 2015/16), which is less than the targeted AARR of 4 per cent that was set to meet the SDGs. At the current reduction rate achieving zero stunting by the end of 2030 is very unlikely. This thesis explains the persistence of stunting and its spatial distribution in Tanzania. The study highlights some of the least explored, yet important, factors influencing child growth and inequality and possible pathways to address it in three chapters. Specifically, this thesis aims to explore the following: (i) the heterogeneous effect of food price fluctuation s on the growth of children from households who produce food and those who do not; (ii) the effects of animal source foods (meat and milk) on child growth and whether livestock keeping mediates these effects; and (iii) the role of water and sanitation in explaining inequality of opportunity in stunting in rural and urban Tanzania.

5.2 Chapter Summaries

The literature provides some evidence that high food prices lead to deterioration in child growth as households cut back their consumption of macro and micronutrients to cope with the shock. However, this literature is too generalised. It obscures useful information by assuming that children from food-producing and food non-producing households fare the same when food prices increase. Chapter 2 of this thesis addresses this knowledge gap in most previous studies and argues that high food prices could have a heterogeneous effect on children from food producers and food non-producers. To test for this, we pooled the three rounds of the Tanzania National Panel Survey and use information on household food consumption in the last seven days to classify food producers and food non-producers.

The results show that maize price fluctuation exert a differential impact on the children from food producers and non-producers. Specifically, the findings show that the effect of maize price fluctuation on the growth of children of food producers is less negative than for the children of food non-producers. Deducing from the main and interaction effect coefficients, we argue that, while increased maize prices reduce the linear growth of children from food non-producers, the effect on food producers is less negative and thus should be interpreted as a protective effect. These findings are consistent with Yamauchi and Larson (2019) who examined the impact of the 2007/08 crisis on child growth in Indonesia.

Chapter 2 also tests for age and gender-specific impact of soaring prices on the growth of children in households that produced food and those that did not. Children of different age groups have different dietary and energy requirements. An adequate supply of energy-rich and micronutrient food is crucial in the first 1 000 days of life. The analysis by age was conducted by grouping children into four age brackets (0–6 months, 6–24 months, 24–35 months and 36–60 months). The results indicate that higher maize prices reduced the HAZ of children of food producers aged 25–36 months less significantly than HAZ of children of food non-producers. For Tanzania, this age bracket corresponds to the weaning period at which most children start to depend fully on food consumed by adults. Similarly, due to the biological differences between male and female children and culturally related gender preferences, the effect of maize price may differ by child gender. In Chapter 2, we find evidence for differential effects of maize price fluctuation on boys and girls from food non-producers, suggesting a possibility of differential treatment of children conditional on gender depending on the economic conditions stressed by Becker (1981). Probably, in Tanzania, parents invest more resources on boys than girls when food is scarce as in the case of farming households in India (Behrman, 1988) where boys were found eating better than girls in lean agricultural seasons when food insecurity is high. More evidence of differential gender treatment is also documented in Mangyo (2008) and Aurino (2017) in Asia but is lacking in sub-Saharan Africa. While no research explicitly assesses how the gender of a child influences feeding practices in the household, the evidence for son preferences is documented in many parts of Tanzania (Msuya, 2019; Mwageni *et al.*, 2001; Mulema, 2014). The cultural norms which view a son as an asset and a daughter as a liability have, over time, influenced household investment in children in favour of boys, with a detrimental impact on girls' mental and physical health (Msuya, 2019).

To understand the potential mechanism through which maize price affects children's growth, we extended the analysis in Chapter 2 to explore how maize price affects children's diets. We constructed two measures for food security: (i) household diet diversity (HDDS) and (ii) calories of maize per adult equivalent consumed by the household in the last seven days. For this study and in the case of Tanzania, maize calories are used as a proxy for low diet diversity. There is evidence that when food prices increase, households reduce the variety of foods they consume and rely more on energy-rich foods. In Tanzania, maize is the cheapest and most widely consumed staple and thus, when prices are higher, households are likely to rely on maize intake while reducing their consumption of other food types. The results indicate that the impact of maize price on child growth across producers and non-producers works through a differential effect on diet diversity and share of calories of maize consumption. High maize prices force food non-producers to reduce the diversity of their diets while enabling food producers to diversify their diets.

Ecker and Qaim (2011) established that increases in the price of main staples tend to reduce households' intake of micronutrients. In this regard, Chapter 2 also examined whether the consumption of micronutrients among children was affected differently depending on the type of household to which they belong. We find that the effect of maize price fluctuation on micronutrient intake of children from food non-producers is negative, and positive for food producers. The results suggest that food non-producers increased consumption of energy-rich food and cut back consumption of food rich in micronutrients. In contrast, food producers consumed less energy-rich foods and increased micronutrient consumption in response to high prices. Studies on food security that use the same data used in this thesis similarly show that high food prices on micronutrient intake and diet diversity were more severe in urban areas (Romano and Carraro, 2015; Rudolf, 2019).

Chapter 3 examined the mediation effects of animal ownership on the link between meat and milk consumption and child growth. We compared the growth of children from households who own meat and mixed ruminants (both meat and milk). Most existing studies did not make such a distinction. Consistent with the literature which shows that the impact of different investment on a child differs depending on the stage of a child's development (Headey *et al.*, 2018; Alderman and Headey, 2018), we disaggregated the analysis into five child age brackets; 0–5 months, 6–11 months, 12–23 months, 24–35 months and 36–60 months. This classification allows for an examination of whether the effect is heterogeneous across different age groups.

The results indicate that the effects of milk on HAZ is significant if a child comes households that keep mixed ruminants. The effect is, however, limited only to older children 24–35 months and 36–60 months. At this age, most children are weaned, suggesting intuitively that a steady supply of milk does not lead to a significant change in growth in younger children who are still breastfed. Cow's milk may serve as a substitute nutrient supplier for breastmilk after weaning when a child starts becoming dependent on other foods consumed by adult household members. These age brackets also correspond to the catch-up growth window for recovery from past malnutrition. During catch-up growth, a child requires all type II minerals in balance and milk's rich bioavailable minerals are easily absorbed into the body tissues (Michaelsen *et al.*, 2011). These findings suggest that, in Tanzania, milk can be used to treat malnutrition and reduce the stunting rate. There is further evidence showing that milk effectively treats undernutrition and promotes growth (Hoppe *et al.*, 2006; Mølgaard *et al.*, 2011; Michaelsen *et al.*, 2011). Nevertheless, we did not find a significant effect of meat ruminants ownership on HAZ in all age groups.

Chapter 4 explored the inequality of opportunity in malnutrition and the contribution of access to water and sanitation circumstance factors on the inequality. The contribution of other factors: household wealth, child demographic characteristics, household size, breastfeeding, vaccinations, mother's education and market fluctuationss were also estimated. The dependent variable in this chapter is a dummy equal to 1 if a child is stunted and 0 otherwise. For this chapter only the first wave of the NPS data was used in the estimation because the other two did not collect information on breastfeeding, which is an important early life investment explaining child health. This thesis adopted the D-index proposed by Barros *et al.* (2008) and the Shapely decomposition method to decompose the inequality of opportunity into contributing factors and quantify the inequality of opportunity. The thesis finds that 20 per cent of the inequality of opportunity needs to be distributed to achieve equality.

The decomposition revealed policy-relevant findings showing that the circumstances which affect children differ between rural and urban areas. A large share of inequality of opportunity in rural areas emanates from access to water and sanitation – contributing about 42 per cent of the inequality of opportunity. Child age is responsible for 22 per cent of the inequality of opportunity in rural areas. Mother's education, breastfeeding and market fluctuations are far more important in urban than in rural areas. In urban areas 30 per cent of the inequality of opportunity emanates from child gender and 18 per cent from market fluctuations, while intergenerational variables – mother's education and age at birth and early life child feeding practices – each contribute 12 per cent. Strikingly, the contribution of household's wealth appeared to be relatively low compared to access to basic services in rural areas, contrary to what has been widely established in the socioeconomic inequality literature (Kien *et al.*, 2016; Rizal and van Doorslaer, 2019).

5.3 Limitations of the Study

The main limitation of this thesis is the data. As previously highlighted, the first three waves of the NPS data were used in the analysis. At the time of the analysis, only four waves were produced and released for public use. However, the fourth wave 2014/15 was refreshed and contained a new sample frame and thus could not be used. It is plausible that significant changes might have occurred since the 2012/13 survey. Another set of limitations is chapter-specific methodological issues. In chapter 2, the household classification into food producers and food non-producers was based on information about whether a household consumed a particular food from their own stock or had to purchase from the market. This approach might classify households as food non-producers if they had nothing in stock during the survey. Similarly, in Chapter 3, the classification of households into meat and mixed ruminant owners did not account for whether the animal produced milk in the last 12 months, the quantity of milk produced and seasonality. The same applies to the case of meat animals; the classification does not indicate whether animals were slaughtered and consumed within the household or not. In the estimation, the study failed to directly control for breastmilk and birth weight due to data unavailability; instead, we controlled for factors associated with breastfeeding in Chapter 3.

5.4 Research Implications

The findings of this study have an implication on the realisation of SDGs particularly for reducing malnutrition and inequality in Tanzania. Each chapter uniquely provides insights into the potential mechanism to attain these goals. For overtime the literature that suggests that smallholder farmers are net buyers has influenced the way policies are implemented in developing countries and Tanzania is no exception. The focus has been on policies such as export bans that force prices down to increase food affordability. This study's results highlighted the need to reconsider such policies to account for the heterogeneous nature of the effects of high food prices across population subgroups to allow farmers to exploit the gains from the free market. As chapter 2 shows, children from households that do not produce food are disproportionately more affected than those from households that do. Food production mediated the interaction between food prices and child growth, as farmers consume their own produce and take advantage of high prices by selling part of their produce to the market to increase the diversity of their diets . The study highlighted that targeted subsidy and food aid programmes could be more effective to reduce the damage caused by high food prices. Tanzania has the NFRA which ensures national food security by releasing food stocks into the market. The study proposes extending and aligning the NFRA mandate with infants and young children nutrition policies to provide food aid to children of food non-producers and urban poor. Similarly, the release of the stocks of food should be implemented to ensure that the impact is felt by the targeted poor and vulnerable food non-producers.

The results of this study make a case for age-sensitive nutritional policies and interventions. In all three chapters, age emerged as an important determinant of child nutrition. As Chapter 2 demonstrates, children in food non-producing households transitioning from breastfeeding are more vulnerable to price fluctuations than other age groups. The findings also revealed that the effect of high prices on the growth of children from non-producing household works through the reduction of diet diversity and micronutrients consumption. However, Chapter 3 shows that living in a mixed ruminant owner household reduces the risk of growth faltering in this age group. This has implications for policy and intervention. Policymakers can endeavour to reduce growth faltering that occurs during transitioning stage by ensuring a stable supply of milk to children. Animal transfers offer an avenue to increase homestead milk production. Rwanda's 'One Cow per Poor Family' is a good example of successful animal transfer programmes that yielded the intended results (Argent *et al.*, 2014). The programme led to a significant increase in milk consumption and child growth among recipient households. Tanzania could draw a lesson from this programme and implement a similar intervention but may consider combining milk and meat ruminants to ensure a greater nutritional impact. A similar intervention programme proved effective in Zambia (Jodlowski *et al.*, 2016); households who received dairy cows with a bull, and female meat goats with one male were found to have higher diet diversity.

This study also supports several policy initiatives underway to provide an enabling environment for improving the productivity of homestead livestock production due its potential to alleviate malnutrition. Policymakers may also see the need to broaden the scope of the countrywide iron and salt supplementation programme to include animal source foods to increase the uptake, particularly among poor non-livestock keepers, and/or campaign for milk and meat consumption.

Furthermore, the findings of this thesis suggest that policies that address different needs of rural and urban population subgroups can effectively reduce inequality of opportunity in malnutrition in Tanzania. It appears that the inequality of opportunity in rural and urban areas is caused by different underlying factors, with the gap in rural areas contributed to, by a large extent, the unequal distribution of access to water and sanitation. These results provide the rationale for increased government expenditure on water and sanitation in rural areas to address malnutrition and improve overall child health. The high contribution of sanitation on inequality of opportunity malnutrition highlights an important risk factor posed by livestock keeping. Livestock keeping correlates with overall household sanitation and could lead to poor child growth.

5.5 Proposed Future Research

Chapter 2 had to rely on household measures of food consumption: HDDS and calories per adult equivalent. It would be worth exploring child's specific dietary measures to see whether the effects remain or intra-household allocation of food prevails during shocks to protect children. With respect to Chapter 3, the focus was restricted to only meat and milk as an ASF and ownership of large ruminant animals. An extension to this chapter could be to incorporate other ASF and explore the mediation role of other animals such as pigs, rabbits and chickens that have been found relevant elsewhere in non-causal studies (Bundala *et al.*, 2020; Hetherington *et al.*, 2017). Similarly, the analysis in Chapter 3 is disaggregated by child age. Further research could examine the effects by gender of a child as well as that of the livestock owner, given some evidence that assets managed by women are more likely to contribute to child health than those in men's hands. Chapter 4 examined inequality of opportunity at a point in time. A dynamics analysis to examine how inequality of opportunity and the contribution of water and sanitation has changed over time after a decade of investment in basic services could also be useful. The subsequent NPS surveys after 2008/09 do not permit this type of analysis unless one ignores the early life circumstance factors for breastfeeding and vaccination. Combining the DHS with NPS data could facilitate such exploration to add more insight to the findings in this thesis. Additionally, malnutrition in Tanzania demonstrates a spatial pattern. In this thesis, the lowest level for spatial disaggregation is rural and urban. Modelling malnutrition using spatial models such as geographical weighted regression models, which produce location-specific determinant variables, could be relevant for policy.

Despite the limitations, the thesis used the available information in the survey to explore important nutritional policy questions. The thesis highlighted insightful findings to inform policy design and formulation to improve the nutritional status of children under age five in Tanzania. The thesis highlighted the heterogeneous impact of high maize prices on the growth of children from food-producing and food non-producing households. This thesis also provides evidence on how animal keeping can complement consumption of ASF and lead to higher growth in children. In addition, the thesis provides evidence on the large contribution of WASH on the inequality of opportunity in stunting in rural areas. In the urban area, the thesis proved that market fluctuationss and intergenerational circumstances are responsible for large inequalities in urban areas. Based on the findings, the thesis strongly argues for different policy interventions based on the livelihood activity of the household to which a child belongs, areas of residence and child gender, to achieve maximum impact on reducing malnutrition in Tanzania.

REFERENCES

Abdelkhalek, T., Lassassi, M. *et al.* (2018). Inequality of opportunity in early childhood development in algeria over time. In: *Economic Research Forum Working Papers*, 1254.

Adams, R., Almeida, H. and Ferreira, D. (2009). Understanding the relationship between founder–ceos and firm performance. *Journal of empirical Finance*, vol. 16, no. 1, pp. 136–150.

Adesina, A.A. (1992). Oxen cultivation in semi-arid west africa: profitability analysis in mali. *Agricultural Systems*, vol. 38, no. 2, pp. 131–147.

Adesogan, A.T., Havelaar, A.H., McKune, S.L., Eilittä, M. and Dahl, G.E. (2020). Animal source foods: Sustainability problem or malnutrition and sustainability solution? perspective matters. *Global Food Security*, vol. 25, p. 100325.

Agee, M.D. (2010). Reducing child malnutrition in nigeria: combined effects of income growth and provision of information about mothers' access to health care services. *Social science & medicine*, vol. 71, no. 11, pp. 1973–1980.

Aizawa, T. (2019). Ex-ante inequality of opportunity in child malnutrition: New evidence from ten developing countries in asia. *Economics & Human Biology*, vol. 35, pp. 144–161.

Akalu, G., Taffesse, S., Gunaratna, N.S. and De Groote, H. (2010). The effectiveness of quality protein maize in improving the nutritional status of young children in the ethiopian highlands. *Food and Nutrition Bulletin*, vol. 31, no. 3, pp. 418–430.

Akombi, B.J., Agho, K.E., Hall, J.J., Wali, N., Renzaho, A. and Merom, D. (2017). Stunting, wasting and underweight in sub-saharan africa: a systematic review. *International journal of environmental research and public health*, vol. 14, no. 8, p. 863.

Aksoy, M.A. and Isik-Dikmelik, A. (2008). *Are low food prices pro-poor? Net food buyers and sellers in low-income countries*. The World Bank.

Akter, S. and Basher, S.A. (2014). The impacts of food price and income shocks on household food security and economic well-being: Evidence from rural bangladesh. *Global Environmental Change*, vol. 25, pp. 150–162.

Akter, S., Syed Abul, B. *et al.* (2013). The impacts of the global food and financial crises on household food security and economic well-being: evidence from bangladesh. Tech. Rep., University Library of Munich, Germany.

Alderman, H. and Headey, D. (2018). The timing of growth faltering has important implications for observational analyses of the underlying determinants of nutrition outcomes. *PloS one*, vol. 13, no. 4, p. e0195904.

Alderman, H. and Headey, D.D. (2017). How important is parental education for child nutrition? *World Development*, vol. 94, pp. 448–464.

Alderman, H., Hoogeveen, H. and Rossi, M. (2009). Preschool nutrition and subsequent schooling attainment: longitudinal evidence from tanzania. *Economic Development and Cultural Change*, vol. 57, no. 2, pp. 239–260.

Alderman, H., Lokshin, M. and Radyakin, S. (2011). Tall claims: Mortality selection and the height of children in india. *Economics & Human Biology*, vol. 9, no. 4, pp. 393–406.

Alderman, H.H., Elder, L.K., Goyal, A., Herforth, A.W., Hoberg, Y.T., Marini, A., Ruel Bergeron, J., Saavedra Chanduvi, J., Shekar, M., Tiwari, S. *et al.* (2013). Improving nutrition through multisectoral approaches. Tech. Rep., The World Bank.

Alem, Y. and Söderbom, M. (2012). Household-level consumption in urban ethiopia: the effects of a large food price shock. *World Development*, vol. 40, no. 1, pp. 146–162.

Alemán-Díaz, A.Y., Toczydlowska, E., Mazur, J., Frasquilho, D., Melkumova, M., Holmqvist, G. *et al.* (2016). Why income inequalities matter for young people's health: A look at the evidence. *Italy: Unicef*, pp. 6–9.

Alexander, D. (2010). The impact of the economic crisis on the world's poorest countries. *Global Policy*, vol. 1, no. 1, pp. 118–120.

Ali, E. and Awade, N.E. (2019). Credit constraints and soybean farmers' welfare in subsistence agriculture in togo. *Heliyon*, vol. 5, no. 4, p. e01550.

Alvarado, B.E., Zunzunegui, M.V., Delisle, H. and Osorno, J. (2005). Growth trajectories are influenced by breast-feeding and infant health in an afro-colombian community. *The Journal of nutrition*, vol. 135, no. 9, pp. 2171–2178.

Amara, M., Jemmali, H. *et al.* (2017). On the decomposition and dynamics of inequality of opportunities: A special focus on early childhood health and nutrition in tunisia. In: *Economic Research Forum Working Papers*, 1093.

Amugsi, D.A., Dimbuene, Z.T., Kimani-Murage, E.W., Mberu, B. and Ezeh, A.C. (2017). Differential effects of dietary diversity and maternal characteristics on linear growth of children aged 6–59 months in sub-saharan africa: a multi-country analysis. *Public health nutrition*, vol. 20, no. 6, pp. 1029–1045.

Amugsi, D.A., Mittelmark, M.B. and Lartey, A. (2014). Dietary diversity is a predictor of acute malnutrition in rural but not in urban settings: evidence from ghana. *Child Care Practices, Resources for Care, and Nutritional Outcomes in Ghana: Findings from Demographic and Health Surveys*.

Andersen, L.E., Griffin, A., Krause, J.J. and Montekio, G.O. (2017). Measuring equality of opportunity in early childhood: A methodological proposal using demographic and health surveys. Tech. Rep., Development Research Working Paper Series.

Angdembe, M.R., Dulal, B.P., Bhattarai, K. and Karn, S. (2019). Trends and predictors of inequality in childhood stunting in nepal from 1996 to 2016. *International journal for equity in health*, vol. 18, no. 1, p. 42.

Argent, J., Augsburg, B. and Rasul, I. (2014). Livestock asset transfers with and without training: Evidence from rwanda. *Journal of Economic Behavior & Organization*, vol. 108, pp. 19–39.

Århem, K. (1989). Maasai food symbolism: the cultural connotations of milk, meat, and blood in the pastoral maasai diet. *Anthropos*, pp. 1–23.

Arndt, C., Benfica, R., Maximiano, N., Nucifora, A.M. and Thurlow, J.T. (2008). Higher fuel and food prices: impacts and responses for mozambique. *Agricultural Economics*, vol. 39, pp. 497–511.

Arndt, C., Hussain, M.A., Salvucci, V. and Østerdal, L.P. (2016). Effects of food price shocks on child malnutrition: The mozambican experience 2008/2009. *Economics & Human Biology*, vol. 22, pp. 1–13.

Arneson, R.J. (1989). Equality and equal opportunity for welfare. *Philosophical studies*, vol. 56, no. 1, pp. 77–93.

Arneson, R.J. (1990). Liberalism, distributive subjectivism, and equal opportunity for welfare. *Philosophy & public affairs*, pp. 158–194.

Asfaw, S., Shiferaw, B., Simtowe, F. and Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from tanzania and ethiopia. *Food policy*, vol. 37, no. 3, pp. 283–295.

Assaad, R., Krafft, C., Hassine, N.B. and Salehi-Isfahani, D. (2012). Inequality of opportunity in child health in the arab world and turkey. *Middle East Development Journal*, vol. 4, no. 02, p. 1250006.

Attanasio, O., Di Maro, V., Lechene, V. and Phillips, D. (2013). Welfare consequences of food prices increases: Evidence from rural mexico. *Journal of Development Economics*, vol. 104, pp. 136–151.

Aurino, E. (2017). Do boys eat better than girls in india? longitudinal evidence on dietary diversity and food consumption disparities among children and adolescents. *Economics & Human Biology*, vol. 25, pp. 99–111.

Azzarri, C., Zezza, A., Haile, B. and Cross, E. (2015). Does livestock ownership affect animal source foods consumption and child nutritional status? evidence from rural uganda. *The Journal of Development Studies*, vol. 51, no. 8, pp. 1034–1059. `https://doi.org/10.1080/00220388.2015.1018905`.
Available at: `https://doi.org/10.1080/00220388.2015.1018905`

Baffes, J., Kshirsagar, V. and Mitchell, D. (2017). What drives local food prices? evidence from the tanzanian maize market. *The World Bank Economic Review*, vol. 33, no. 1, pp. 160–184.

Bailey, R., Benton, T., Challinor, A., Elliott, J., Gustafson, D., Hiller, B., Jones, A., Jahn, M., Kent, C., Lewis, K. *et al.* (2015). Extreme weather and resilience of the global food system (2015). final project report from the uk-us taskforce on extreme weather and global food system resilience, the global food security programme, uk. *Extreme weather and resilience of the global* *food system (2015). Final project report from the UK-US Taskforce on extreme weather and global food system resilience, The Global Food Security programme, UK.*

Balagtas, J.V., Bhandari, H., Cabrera, E.R., Mohanty, S. and Hossain, M. (2014). Did the commodity price spike increase rural poverty? evidence from a long-run panel in bangladesh. *Agricultural Economics*, vol. 45, no. 3, pp. 303–312.

Baldos, U.L.C. and Hertel, T.W. (2014). Global food security in 2050: the role of agricultural productivity and climate change. *Australian Journal of Agricultural and Resource Economics*, vol. 58, no. 4, pp. 554–570.

Baltenweck, I., Enahoro, D., Frija, A. and Tarawali, S. (2020). Why is production of animal source foods important for economic development in africa and asia? *Animal Frontiers*, vol. 10, no. 4, pp. 22–29.

Bandara, J.S. and Cai, Y. (2014). The impact of climate change on food crop productivity, food prices and food security in south asia. *Economic Analysis and Policy*, vol. 44, no. 4, pp. 451–465.

Bandiera, O., Burgess, R., Das, N., Gulesci, S., Rasul, I. and Sulaiman, M. (2013). Can basic entrepreneurship transform the economic lives of the poor? Tech. Rep., IZA discussion paper.

Banerjee, A., Duflo, E., Chattopadhyay, R. *et al.* (2011). Targeting the hard-core poor: An impact assessment [internet]; 2011 [citado 2018 nov. 1]. *Disponible en: Disponible en: https://www. povertyactionlab. org/sites/default/files/publications/110-% 20November% 202011_0. pdf.*

Barnes, A.N., Anderson, J.D., Mumma, J., Mahmud, Z.H. and Cumming, O. (2018). The association between domestic animal presence and ownership and household drinking water contamination among peri-urban communities of kisumu, kenya. *PloS one*, vol. 13, no. 6, p. e0197587.

Barros, R.P., Vega, J.M. and Saavedra, J. (2008). Measuring inequality of opportunities for children. *Washington, DC: World Bank.*

Basu, K. and Wong, M. (2015). Evaluating seasonal food storage and credit programs in east indonesia. *Journal of Development Economics*, vol. 115, pp. 200–216.

Becker, G.S. (1981). *A Treatise on the Family.* Harvard university press.

Behrman, J.R. (1988). Intrahousehold allocation of nutrients in rural india: Are boys favored? do parents exhibit inequality aversion? *Oxford Economic Papers*, vol. 40, no. 1, pp. 32–54.

Behrman, J.R. (1996). The impact of health and nutrition on education. *The World Bank Research Observer*, vol. 11, no. 1, pp. 23–37.

Belesova, K., Gasparrini, A., Sié, A., Sauerborn, R. and Wilkinson, P. (2017). Household cereal crop harvest and children's nutritional status in rural burkina faso. *Environmental health*, vol. 16, no. 1, pp. 1–11.

Benson, T., Mugarura, S. and Wanda, K. (2008). Impacts in uganda of rising global food prices: the role of diversified staples and limited price transmission. *Agricultural Economics*, vol. 39, pp. 513–524.

Bergstrom, K. (2020). The role of inequality for poverty reduction.

Bevis, L.E., Naschold, F. and Rao, T. (2019). An unequal burden: Intra-household dimensions of seasonal health in tanzania. *Food Policy*, vol. 89, p. 101766.

Bhalla, G., Handa, S., Angeles, G. and Seidenfeld, D. (2018). The effect of cash transfers and household vulnerability on food security in zimbabwe. *Food policy*, vol. 74, pp. 82–99.

Bibi, S., Cockburn, J., Coulibaly, M. and Tiberti, L. (2010). The impact of the increase in food prices on child poverty and the policy response in mali. In: *Child welfare in developing countries*, pp. 247–296. Springer.

Bitrán, R., Giedion, U., Valenzuela, R. and Monkkonen, P. (2005). Keeping health in an urban environment: Public health challenges for the urban poor. *The urban poor in Latin America*, pp. 179–195.

Black, M.M. (2003). Micronutrient deficiencies and cognitive functioning. *The Journal of nutrition*, vol. 133, no. 11, pp. 3927S–3931S.

Blinder, A.S. (1973). Wage discrimination: reduced form and structural estimates. *Journal of Human resources*, pp. 436–455.

Block, S., Haile, B., You, L. and Headey, D. (2021). Heat shocks, maize yields, and child height in tanzania. *Food Security*, pp. 1–17.

Block, S.A., Kiess, L., Webb, P., Kosen, S., Moench-Pfanner, R., Bloem, M.W. and Timmer, C.P. (2004). Macro shocks and micro outcomes: child nutrition during indonesia's crisis. *Economics & Human Biology*, vol. 2, no. 1, pp. 21–44.

Boerma, J.T., Sommerfelt, A.E. and Bicego, G.T. (1992). Child anthropometry in cross-sectional surveys in developing countries: an assessment of the survivor bias. *American Journal of Epidemiology*, vol. 135, no. 4, pp. 438–449.

Bouis, H.E. (2000). Improving human nutrition through agriculture: the role of international agricultural research. conference summary and recommendations. *Food and Nutrition Bulletin*, vol. 21, no. 4, pp. 550–567.

Boyle, M.H., Racine, Y., Georgiades, K., Snelling, D., Hong, S., Omariba, W., Hurley, P. and Rao-Melacini, P. (2006). The influence of economic development level, household wealth and maternal education on child health in the developing world. *Social science & medicine*, vol. 63, no. 8, pp. 2242–2254.

Branson, W.H., Guerrero, I. and Gunter, B.G. (1999). *Tanzania-Social sector review.* The World Bank.

Braun, K.V., Erler, N.S., Kiefte-de Jong, J.C., Jaddoe, V.W., van den Hooven, E.H., Franco, O.H. and Voortman, T. (2016). Dietary intake of protein in early childhood is associated with growth trajectories between 1 and 9 years of age. *The Journal of Nutrition*, vol. 146, no. 11, pp. 2361–2367.

Brenton, P. and Nyawo, M. (2021). Cereal prices and child undernutrition in ethiopia. *The Journal of Development Studies*, pp. 1–18.

Brinkman, H.-J., De Pee, S., Sanogo, I., Subran, L. and Bloem, M.W. (2009). High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. *The Journal of nutrition*, vol. 140, no. 1, pp. 153S–161S.

Broaddus-Shea, E., Manohar, S., Thorne-Lyman, A., Nonyane, B.A., Winch, P., Shrestha, B. and West Jr, K.P. (2019). Livestock ownership and children's intakes of animal source foods in nepal (p10-057-19). *Current developments in nutrition*, vol. 3, no. Supplement_1, pp. nzz034–P10.

Brown, M.E. and Kshirsagar, V. (2015). Weather and international price shocks on food prices in the developing world. *Global Environmental Change*, vol. 35, pp. 31–40.

Brunori, P., Ferreira, F.H. and Peragine, V. (2013). Inequality of opportunity, income inequality, and economic mobility: Some international comparisons. In: *Getting development right*, pp. 85–115. Springer.

Buisman, L.R., Van de Poel, E., O'Donnell, O. and van Doorslaer, E.K. (2019). What explains the fall in child stunting in sub-saharan africa? *SSM-population health*, vol. 8, p. 100384.

Bundala, N., Kinabo, J., Jumbe, T., Rybak, C. and Sieber, S. (2020). Does homestead livestock production and ownership contribute to consumption of animal source foods? a pre-intervention assessment of rural farming communities in tanzania. *Scientific African*, vol. 7, p. e00252.

Caldwell, J.C. (1979). Education as a factor in mortality decline an examination of nigerian data. *Population studies*, pp. 395–413.

Caldwell, J.C. (1994). How is greater maternal education translated into lower child mortality? *Health transition review*, vol. 4, no. 2, pp. 224–229.

Case, A., Lubotsky, D. and Paxson, C. (2002). Economic status and health in childhood: The origins of the gradient. *American Economic Review*, vol. 92, no. 5, pp. 1308–1334.

Cawley, A., O'Donoghue, C., Heanue, K., Hilliard, R. and Sheehan, M. (2018). The impact of extension services on farm-level income: An instrumental variable approach to combat endogeneity concerns. *Applied Economic Perspectives and Policy*, vol. 40, no. 4, pp. 585–612.

Chamberlain, G. (1980). Analysis of covariance with qualitative data. *The Review of Economic Studies*, vol. 47, no. 1, pp. 225–238.

Checkley, W., Buckley, G., Gilman, R.H., Assis, A.M., Guerrant, R.L., Morris, S.S., Mølbak, K., Valentiner-Branth, P., Lanata, C.F., Black, R.E. *et al.* (2008). Multi-country analysis of the effects of diarrhoea on childhood stunting. *International journal of epidemiology*, vol. 37, no. 4, pp. 816–830.

Checkley, W., Gilman, R.H., Black, R.E., Epstein, L.D., Cabrera, L., Sterling, C.R. and Moulton, L.H. (2004). Effect of water and sanitation on childhood health in a poor peruvian peri-urban community. *The Lancet*, vol. 363, no. 9403, pp. 112–118.

Chegere, M.J. and Stage, J. (2020). Agricultural production diversity, dietary diversity and nutritional status: Panel data evidence from tanzania. *World Development*, vol. 129, p. 104856.

Choudhury, S. and Headey, D.D. (2018). Household dairy production and child growth: Evidence from bangladesh. *Economics & Human Biology*, vol. 30, pp. 150–161.

Christiaensen, L., Demery, L. and Kuhl, J. (2011). The (evolving) role of agriculture in poverty reduction—an empirical perspective. *Journal of development economics*, vol. 96, no. 2, pp. 239–254.

Christian, A.K., Wilson, M.L., Aryeetey, R.N. and Jones, A.D. (2019). Livestock ownership, household food security and childhood anaemia in rural ghana. *PloS one*, vol. 14, no. 7, p. e0219310.

Cogneau, D. and Jedwab, R. (2012). Commodity price shocks and child outcomes: the 1990 cocoa crisis in cote d'ivoire. *Economic Development and Cultural Change*, vol. 60, no. 3, pp. 507–534.

Cohen, G.A. (1989). On the currency of egalitarian justice. *Ethics*, vol. 99, no. 4, pp. 906–944.

Cohen, M.J. and Garrett, J.L. (2010). The food price crisis and urban food (in) security. *Environment and Urbanization*, vol. 22, no. 2, pp. 467–482.

Compton, J., Wiggins, S. and Keats, S. (2010). Impact of the global food crisis on the poor: what is the evidence. *London, ODI*, vol. 99, p. 99.

Conan, A., O'Reilly, C.E., Ogola, E., Ochieng, J.B., Blackstock, A.J., Omore, R., Ochieng, L., Moke, F., Parsons, M.B., Xiao, L. *et al.* (2017). Animal-related factors associated with moderate-to-severe diarrhea in children younger than five years in western kenya: A matched case-control study. *PLoS neglected tropical diseases*, vol. 11, no. 8, p. e0005795.

Conti, G., Mason, G. and Poupakis, S. (2019). Developmental origins of health inequality. Tech. Rep., IZA Discussion Papers.

Contreras, D., Puentes, E., Larrañaga, O. and Rau, T. (2012). The evolution of opportunities for children in chile, 1990-2006. *Cepal Review*.

Cornia, G.A., Deotti, L. and Sassi, M. (2016). Sources of food price volatility and child malnutrition in niger and malawi. *Food Policy*, vol. 60, pp. 20–30.

Cornia, G.A., Deotti, L. *et al.* (2008). *Millet prices, public policy and child malnutrition: the case of Niger in 2005*. UNICEF, Innocenti Research Centre.

Costa, M.E., Trumble, B., Kaplan, H. and Gurven, M.D. (2018). Child nutritional status among births exceeding ideal family size in a high fertility population. *Maternal & child nutrition*, vol. 14, no. 4, p. e12625.

Cramet, R. (1982). Sleeping sickness in children and its long term after-effects. apropos 110 personal observations at fontem hospital (cameroon). *Medecine tropicale: revue du Corps de sante colonial*, vol. 42, no. 1, pp. 27–31.

Crookston, B.T., Penny, M.E., Alder, S.C., Dickerson, T.T., Merrill, R.M., Stanford, J.B., Porucznik, C.A. and Dearden, K.A. (2010). Children who recover from early stunting and children who are not stunted demonstrate similar levels of cognition. *The Journal of nutrition*, vol. 140, no. 11, pp. 1996–2001.

Crookston, B.T., Schott, W., Cueto, S., Dearden, K.A., Engle, P., Georgiadis, A., Lundeen, E.A., Penny, M.E., Stein, A.D. and Behrman, J.R. (2013). Postinfancy growth, schooling, and cognitive achievement: Young lives. *The American journal of clinical nutrition*, vol. 98, no. 6, pp. 1555–1563.

Cumming, O. and Cairncross, S. (2016). Can water, sanitation and hygiene help eliminate stunting? current evidence and policy implications. *Maternal & child nutrition*, vol. 12, pp. 91–105.

Cumming, O. and Curtis, V. (2018). Implications of wash benefits trials for water and sanitation. *The Lancet Global Health*, vol. 6, no. 6, pp. e613–e614.

Currie, J. and Stabile, M. (2003). Socioeconomic status and child health: why is the relationship stronger for older children? *American Economic Review*, vol. 93, no. 5, pp. 1813–1823.

Dabla-Norris, M.E., Kochhar, M.K., Suphaphiphat, M.N., Ricka, M.F. and Tsounta, M.E. (2015). *Causes and consequences of income inequality: A global perspective*. International Monetary Fund.

Dangour, A.D., Watson, L., Cumming, O., Boisson, S., Che, Y., Velleman, Y., Cavill, S., Allen, E. and Uauy, R. (2013). Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. *Cochrane Database of Systematic Reviews*, , no. 8.

Dasi, T., Selvaraj, K., Pullakhandam, R. and Kulkarni, B. (2019). Animal source foods for the alleviation of double burden of malnutrition in countries undergoing nutrition transition. *Animal Frontiers*, vol. 9, no. 4, pp. 32–38.

Davillas, A. and Jones, A.M. (2020). Ex ante inequality of opportunity in health, decomposition and distributional analysis of biomarkers. *Journal of Health Economics*, vol. 69, p. 102251.

de Beer, H. (2012). Dairy products and physical stature: a systematic review and meta-analysis of controlled trials. *Economics & Human Biology*, vol. 10, no. 3, pp. 299–309.

De Brauw, A. (2011). Migration and child development during the food price crisis in el salvador. *Food Policy*, vol. 36, no. 1, pp. 28–40.

De Bruyn, J., Bagnol, B., Darnton-Hill, I., Maulaga, W., Thomson, P.C. and Alders, R. (2018). Characterising infant and young child feeding practices and the consumption of poultry products in rural tanzania: A mixed methods approach. *Maternal & child nutrition*, vol. 14, no. 2, p. e12550.

De Hoyos, R.E. and Medvedev, D. (2009). *Poverty effects of higher food prices: a global perspective*. The World Bank.

De Janvry, A. and Sadoulet, E. (2010). Agricultural growth and poverty reduction: Additional evidence. *The World Bank Research Observer*, vol. 25, no. 1, pp. 1–20.

De Lucia Rolfe, E., de França, G.V.A., Vianna, C.A., Gigante, D.P., Miranda, J.J., Yudkin, J.S., Horta, B.L. and Ong, K.K. (2018). Associations of stunting in early childhood with cardiometabolic risk factors in adulthood. *PloS one*, vol. 13, no. 4, p. e0192196.

Dearden, K.A., Schott, W., Crookston, B.T., Humphries, D.L., Penny, M.E., Behrman, J.R. *et al.* (2017). Children with access to improved sanitation but not improved water are at lower risk of stunting compared to children without access: a cohort study in ethiopia, india, peru, and vietnam. *BMC public health*, vol. 17, no. 1, p. 110.

Deaton, A. (1989). Rice prices and income distribution in thailand: a non-parametric analysis. *The Economic Journal*, vol. 99, no. 395, pp. 1–37.

Dede, K.S. and Bras, H. (2020). Exclusive breastfeeding patterns in tanzania: Do individual, household, or community factors matter? *International Breastfeeding Journal*, vol. 15, pp. 1–11.

Deshpande, A., Miller-Petrie, M.K., Lindstedt, P.A., Baumann, M.M., Johnson, K.B., Blacker, B.F., Abbastabar, H., Abd-Allah, F., Abdelalim, A., Abdollahpour, I. *et al.* (2020). Mapping geographical inequalities in access to drinking water and sanitation facilities in low-income and middle-income countries, 2000–17. *The Lancet Global Health*, vol. 8, no. 9, pp. e1162–e1185.

Dewey, K.G. and Huffman, S.L. (2009). Maternal, infant, and young child nutrition: combining efforts to maximize impacts on child growth and micronutrient status.

Di Falco, S., Veronesi, M. and Yesuf, M. (2011). Does adaptation to climate change provide food security? a micro-perspective from ethiopia. *American Journal of Agricultural Economics*, vol. 93, no. 3, pp. 829–846.

Diao, X. and Kennedy, A. (2016). Economywide impact of maize export bans on agricultural growth and household welfare in tanzania: A dynamic computable general equilibrium model analysis. *Development Policy Review*, vol. 34, no. 1, pp. 101–134.

Dietrich, S. and Schmerzeck, G. (2019). Cash transfers and nutrition: The role of market isolation after weather shocks. *Food Policy*, vol. 87, p. 101739.

Dror, D.K. and Allen, L.H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food and nutrition bulletin*, vol. 32, no. 3, pp. 227–243.

Dubbert, C. (2019). Participation in contract farming and farm performance: Insights from cashew farmers in ghana. *Agricultural Economics*, vol. 50, no. 6, pp. 749–763.

Dumas, S.E., Kassa, L., Young, S.L. and Travis, A.J. (2018). Examining the association between livestock ownership typologies and child nutrition in the luangwa valley, zambia. *PloS one*, vol. 13, no. 2, p. e0191339.

Dworkin, R. (1981). What is equality? part 1: Equality of welfare. *Philosophy & public affairs*, pp. 185–246.

Eaton, J.C., Rothpletz-Puglia, P., Dreker, M.R., Iannotti, L., Lutter, C., Kaganda, J. and Rayco-Solon, P. (2019). Effectiveness of provision of animal-source foods for supporting optimal growth and development in children 6 to 59 months of age. *Cochrane Database of Systematic Reviews*, , no. 2.

Ebaidalla, E.M. (2019). Inequality of opportunity in child health in sudan. Tech. Rep. 2019/86, WIDER Working Paper.

Ecker, O. and Qaim, M. (2011). Analyzing nutritional impacts of policies: an empirical study for malawi. *World Development*, vol. 39, no. 3, pp. 412–428.

Eisenberg, J.N., Scott, J.C. and Porco, T. (2007). Integrating disease control strategies: balancing water sanitation and hygiene interventions to reduce diarrheal disease burden. *American Journal of Public Health*, vol. 97, no. 5, pp. 846–852.

Eldukhery, I., Elamin, N.H., Kherallah, M. and Abur, A. (2010). Impact of high food prices on farmers in the near east. *FAO: USA*.

Ellis, F. and White, P. (2000). Vulnerability to hunger and policy responses in an era of global instability: southern africa and the '3 fs crisis. In: *Chronic Poverty Research Centre conference on Ten Years Of 'War Against Poverty': What Have We Learned Since*, pp. 2010–2020.

Eriksson, J.G., Forsen, T., Tuomilehto, J., Osmond, C. and Barker, D.J. (2001). Early growth and coronary heart disease in later life: longitudinal study. *Bmj*, vol. 322, no. 7292, pp. 949–953.

Eriksson, T., Pan, J. and Qin, X. (2014). The intergenerational inequality of health in china. *China Economic Review*, vol. 31, pp. 392–409.

Ersado, L. and Aran, M. (2014). *Inequality of opportunity among Egyptian children.* The World Bank.

Espo, M., Kulmala, T., Maleta, K., Cullinan, T., Salin, M.-L. and Ashorn, P. (2002). Determinants of linear growth and predictors of severe stunting during infancy in rural malawi. *Acta paediatrica*, vol. 91, no. 12, pp. 1364–1370.

Esrey, S.A. (1996). Water, waste, and well-being: a multicountry study. *American journal of epidemiology*, vol. 143, no. 6, pp. 608–623.

Fanzo, J., Hawkes, C., Udomkesmalee, E., Afshin, A., Allemandi, L., Assery, O., Baker, P., Battersby, J., Bhutta, Z., Chen, K. *et al.* (2018). 2018 global nutrition report: Shining a light to spur action on nutrition. Tech. Rep., Bristol, UK: Development Initiatives.

FAO (1992). Training manual for tsetse control personnel control volume 1. `https://www.fao.org/3/p5178e/P5178E00.htm#TOC`. Accessed: 2021-10-30.

FAO (2008). Nutrition country profile united republic of tanzania, 2008.

FAO (2010). High food prices and the food crisis-experiences and lessons learned. *Rome: Food and Agriculture OrganizaTion of The United Nations, Rome.*

FAO (2013*a*). *Dietary Protein Quality Evaluation in Human Nutrition: Report of an FAO Expert Consultation, 31 March-2 April, 2011, Auckland, New Zealand.* Food and Agriculture Organization of the United Nations.

FAO (2013*b*). Synthesis of guiding principles on agriculture programming for nutrition.

Feachem, R.G., Bradley, D.J., Garelick, H., Mara, D.D. *et al.* (1983). *Sanitation and disease: health aspects of excreta and wastewater management.* John Wiley and Sons.

Fenske, N., Burns, J., Hothorn, T. and Rehfuess, E.A. (2013). Understanding child stunting in india: a comprehensive analysis of socio-economic, nutritional and environmental determinants using additive quantile regression. *PloS one*, vol. 8, no. 11, p. e78692.

Ferreira, F.H. and Gignoux, J. (2011). The measurement of inequality of opportunity: Theory and an application to latin america. *Review of Income and Wealth*, vol. 4, no. 57, pp. 622–657.

Ferreira, F.H. and Gignoux, J. (2014). The measurement of educational inequality: Achievement and opportunity. *The World Bank Economic Review*, vol. 28, no. 2, pp. 210–246.

FEWS NET (2018). Tanzania market fundamentals summary. Tech. Rep., Famine Early Warning Systems Network.

Fewtrell, L., Kaufmann, R.B., Kay, D., Enanoria, W., Haller, L. and Colford Jr, J.M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet infectious diseases*, vol. 5, no. 1, pp. 42–52.

Fierstein, J.L., Eliasziw, M., Rogers, B.L. and Forrester, J.E. (2017). Nonnative cattle ownership, diet, and child height-for-age: Evidence from the 2011 uganda demographic and health survey. *The American journal of tropical medicine and hygiene*, vol. 96, no. 1, pp. 74–82.

Filmer, D., Friedman, J. and Schady, N. (2008). *Development, modernization, and son preference in fertility decisions*. The World Bank.

Fink, G., Günther, I. and Hill, K. (2011). The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986–2007. *International journal of epidemiology*, vol. 40, no. 5, pp. 1196–1204.

Fleurbaey, M. and Schokkaert, E. (2011). Equity in health and health care. In: *Handbook of health economics*, vol. 2, pp. 1003–1092. Elsevier.

Fortin, N., Lemieux, T. and Firpo, S. (2011). Decomposition methods in economics. In: *Handbook of labor economics*, vol. 4, pp. 1–102. Elsevier.

Fotso, J.-C. (2006). Child health inequities in developing countries: differences across urban and rural areas. *International journal for equity in health*, vol. 5, no. 1, p. 9.

Fotso, J.-C. (2007). Urban–rural differentials in child malnutrition: trends and socioeconomic correlates in sub-saharan africa. *Health & Place*, vol. 13, no. 1, pp. 205–223.

Franco, J.R., Simarro, P.P., Diarra, A. and Jannin, J.G. (2014). Epidemiology of human african trypanosomiasis. *Clinical epidemiology*, vol. 6, p. 257.

Freeman, M.C., Garn, J.V., Sclar, G.D., Boisson, S., Medlicott, K., Alexander, K.T., Penakalapati, G., Anderson, D., Mahtani, A.G., Grimes, J.E. *et al.* (2017). The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *International journal of hygiene and environmental health*, vol. 220, no. 6, pp. 928–949.

Frempong, R.B. and Annim, S.K. (2017). Dietary diversity and child malnutrition in ghana. *Heliyon*, vol. 3, no. 5, p. e00298.

Fuller, J.A., Westphal, J.A., Kenney, B. and Eisenberg, J.N. (2015). The joint effects of water and sanitation on diarrhoeal disease: a multicountry analysis of the d emographic and h ealth s urveys. *Tropical Medicine & International Health*, vol. 20, no. 3, pp. 284–292.

Galasso, E. and Wagstaff, A. (2019). The aggregate income losses from childhood stunting and the returns to a nutrition intervention aimed at reducing stunting. *Economics & Human Biology*, vol. 34, pp. 225–238.

Galler, J.R., Bryce, C., Waber, D.P., Zichlin, M.L., Fitzmaurice, G.M. and Eaglesfield, D. (2012). Socioeconomic outcomes in adults malnourished in the first year of life: a 40-year study. *Pediatrics*, vol. 130, no. 1, pp. e1–e7.

Gelaw, F. and Sileshi, M. (2013). Impact of grain price hikes on poverty in rural ethiopia. *African Journal of Agricultural and Resource Economics*, vol. 8, no. 311-2016-5560, pp. 69–89.

George, C.M., Oldja, L., Biswas, S., Perin, J., Lee, G.O., Kosek, M., Sack, R.B., Ahmed, S., Haque, R., Parvin, T. *et al.* (2015). Geophagy is associated with environmental enteropathy and stunting in children in rural bangladesh. *The American journal of tropical medicine and hygiene*, vol. 92, no. 6, pp. 1117–1124.

Gertler, P., Shah, M., Alzua, M.L., Cameron, L., Martinez, S. and Patil, S. (2015). How does health promotion work? evidence from the dirty business of eliminating open defecation. Tech. Rep., National Bureau of Economic Research.

Gillespie, S., Harris, J. and Kadiyala, S. (2019). The agriculture-nutrition disconnect in india: What do we know? *Gates Open Res*, vol. 3, no. 1115, p. 1115.

Gordon, A., Demissie, S. and Tadesse, M. (2007). Marketing systems for fish from lake tana, ethiopia: Opportunities for marketing and livelihoods. *IPMS Working Paper; 2*.

Gørgens, T., Meng, X. and Vaithianathan, R. (2012). Stunting and selection effects of famine: A case study of the great chinese famine. *Journal of development Economics*, vol. 97, no. 1, pp. 99–111.

Gould, W.T. (1998). African mortality and the newurban penalty'. *Health & place*, vol. 4, no. 2, pp. 171–181.

Grace, D., Domínguez Salas, P. and Alonso, S. (2018). The influence of livestock-derived foods on the nutrition of mothers and infants in developing countries during the first 1,000 days. Tech. Rep., International Livestock Research Institute.

Grace, K., Brown, M. and McNally, A. (2014). Examining the link between food prices and food insecurity: A multi-level analysis of maize price and birthweight in kenya. *Food Policy*, vol. 46, pp. 56–65.

Grantham-McGregor, S., Cheung, Y.B., Cueto, S., Glewwe, P., Richter, L., Strupp, B., Group, I.C.D.S. *et al.* (2007). Developmental potential in the first 5 years for children in developing countries. *The lancet*, vol. 369, no. 9555, pp. 60–70.

Grenov, B., Larnkjær, A., Mølgaard, C. and Michaelsen, K.F. (2020). Role of milk and dairy products in growth of the child. *Global Landscape of Nutrition Challenges in Infants and Children*, vol. 93, pp. 77–90.

Grossi, G., Goglio, P., Vitali, A. and Williams, A.G. (2019). Livestock and climate change: impact of livestock on climate and mitigation strategies. *Animal Frontiers*, vol. 9, no. 1, pp. 69–76.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political economy*, vol. 80, no. 2, pp. 223–255.

Guerrant, R.L., DeBoer, M.D., Moore, S.R., Scharf, R.J. and Lima, A.A. (2013). The impoverished gut—a triple burden of diarrhoea, stunting and chronic disease. *Nature reviews Gastroenterology & hepatology*, vol. 10, no. 4, pp. 220–229.

Gunaratna, N.S., De Groote, H., Nestel, P., Pixley, K.V. and McCabe, G.P. (2010). A meta-analysis of community-based studies on quality protein maize. *Food Policy*, vol. 35, no. 3, pp. 202–210.

Gundry, S., Wright, J. and Conroy, R. (2004). A systematic review of the health outcomes related to household water quality in developing countries. *Journal of water and health*, vol. 2, no. 1, pp. 1–13.

Hadley, C., Linzer, D.A., Belachew, T., Mariam, A.G., Tessema, F. and Lindstrom, D. (2011). Household capacities, vulnerabilities and food insecurity: Shifts in food insecurity in urban and rural ethiopia during the 2008 food crisis. *Social Science & Medicine*, vol. 73, no. 10, pp. 1534–1542.

Hadley, C., Stevenson, E.G.J., Tadesse, Y. and Belachew, T. (2012). Rapidly rising food prices and the experience of food insecurity in urban ethiopia: impacts on health and well-being. *Social Science & Medicine*, vol. 75, no. 12, pp. 2412–2419.

Haileselassie, M., Redae, G., Berhe, G., Henry, C.J., Nickerson, M.T., Tyler, B. and Mulugeta, A. (2020). Why are animal source foods rarely consumed by 6-23 months old children in rural communities of northern ethiopia? a qualitative study. *PloS one*, vol. 15, no. 1, p. e0225707.

Harttgen, K., Klasen, S. *et al.* (2012). Analyzing nutritional impacts of price and income related shocks in malawi and uganda. *Regional Bureau for Africa (UNDP/RBA) Working Paper*, vol. 14.

Harttgen, K., Lang, S. and Seiler, J. (2017). Selective mortality and undernutrition in low-and middle-income countries. Tech. Rep., Working Papers in Economics and Statistics.

Hasan, S.A. (2019). Price hike of staple food, nutritional impact and consumption adjustment: evidence from the 2005–2010 rice price increase in rural bangladesh. *Applied Economics*, vol. 51, no. 8, pp. 743–761.

Headey, D., Chiu, A. and Kadiyala, S. (2012). Agriculture's role in the indian enigma: help or hindrance to the crisis of undernutrition? *Food Security*, vol. 4, no. 1, pp. 87–102.

Headey, D. and Fan, S. (2010). *Reflections on the global food crisis: How did it happen? How has it hurt? And how can we prevent the next one?*, vol. 165. Intl Food Policy Res Inst.

Headey, D. and Hirvonen, K. (2016). Is exposure to poultry harmful to child nutrition? an observational analysis for rural ethiopia. *PloS one*, vol. 11, no. 8, p. e0160590.

Headey, D., Hirvonen, K. and Hoddinott, J. (2018). Animal sourced foods and child stunting. *American Journal of Agricultural Economics*, vol. 100, no. 5, pp. 1302–1319.

Headey, D. and Masters, W.A. (2019). *Agriculture and undernutrition through the lens of economics*, vol. 1876. Intl Food Policy Res Inst.

Headey, D., Nguyen, P., Kim, S., Rawat, R., Ruel, M. and Menon, P. (2017). Is exposure to animal feces harmful to child nutrition and health outcomes? a multicountry observational analysis. *The American journal of tropical medicine and hygiene*, vol. 96, no. 4, pp. 961–969.

Headey, D. and Palloni, G. (2019). Water, sanitation, and child health: evidence from subnational panel data in 59 countries. *Demography*, vol. 56, no. 2, pp. 729–752.

Headey, D.D. (2013). *The impact of the global food crisis on self-assessed food security.* The World Bank.

Headey, D.D. (2016). *Food prices and poverty.* The World Bank.

Headey, D.D. and Alderman, H.H. (2019). The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents. *The Journal of nutrition*, vol. 149, no. 11, pp. 2020–2033.

Heckert, J., Olney, D.K. and Ruel, M.T. (2019). Is women's empowerment a pathway to improving child nutrition outcomes in a nutrition-sensitive agriculture program?: Evidence from a randomized controlled trial in burkina faso. *Social Science & Medicine*, vol. 233, pp. 93–102.

Heidkamp, R.A., Ayoya, M.A., Teta, I.N., Stoltzfus, R.J. and Marhone, J.P. (2015). Complementary feeding practices and child growth outcomes in haiti: an analysis of data from demographic and health surveys. *Maternal & child nutrition*, vol. 11, no. 4, pp. 815–828.

Henley, E., Taylor, J. and Obukosia, S. (2010). The importance of dietary protein in human health: Combating protein deficiency in sub-saharan africa through transgenic biofortified sorghum. In: *Advances in food and nutrition research*, vol. 60, pp. 21–52. Elsevier.

Henriques, A., Teixeira, V., Cardoso, H.F. and Azevedo, A. (2018). The influence of stunting on obesity in adulthood: results from the epiporto cohort. *Public health nutrition*, vol. 21, no. 10, pp. 1819–1826.

Henry, B., Charmley, E., Eckard, R., Gaughan, J.B. and Hegarty, R. (2012). Livestock production in a changing climate: adaptation and mitigation research in australia. *Crop and Pasture Science*, vol. 63, no. 3, pp. 191–202.

Herber, C., Bogler, L., Subramanian, S. and Vollmer, S. (2020). Association between milk consumption and child growth for children aged 6–59 months. *Scientific reports*, vol. 10, no. 1, pp. 1–9.

Hetherington, J.B., Wiethoelter, A.K., Negin, J. and Mor, S.M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in sub-saharan africa. *Agriculture & Food Security*, vol. 6, no. 1, pp. 1–11.

Hlasny, V. and Intini, V. (2015). Opportunities for early childhood development in arab countries: profile and evolution of inequality and its sources. *Available at SSRN 2752317*.

Hoddinott, J., Alderman, H., Behrman, J.R., Haddad, L. and Horton, S. (2013). The economic rationale for investing in stunting reduction. *Maternal & child nutrition*, vol. 9, pp. 69–82.

Hoddinott, J., Headey, D. and Dereje, M. (2015). Cows, missing milk markets, and nutrition in rural ethiopia. *The Journal of Development Studies*, vol. 51, no. 8, pp. 958–975.

Hoddinott, J., Maluccio, J., Behrman, J.R., Martorell, R., Melgar, P., Quisumbing, A.R., Ramirez-Zea, M., Stein, A.D., Yount, K.M. *et al.* (2011). The consequences of early childhood growth failure over the life course. *Washington, DC: International Food Policy Research Institute Discussion Paper*, vol. 1073, p. 5.

Hoddinott, J., Rosegrant, M. and Torero, M. (2012). Hunger and malnutrition.

Holloway, G., Shankar, B. and Rahmanb, S. (2002). Bayesian spatial probit estimation: a primer and an application to hyv rice adoption. *Agricultural Economics*, vol. 27, no. 3, pp. 383–402.

Hong, R. and Mishra, V. (2006). Effect of wealth inequality on chronic under-nutrition in cambodian children. *Journal of Health, Population and Nutrition*, pp. 89–99.

Hoppe, C., Mølgaard, C. and Michaelsen, K.F. (2006). Cow's milk and linear growth in industrialized and developing countries. *Annual review of nutrition*, vol. 26, no. errata.

Hörnell, A., Lagström, H., Lande, B. and Thorsdottir, I. (2013). Protein intake from 0 to 18 years of age and its relation to health: a systematic literature review for the 5th nordic nutrition recommendations. *Food & nutrition research*, vol. 57, no. 1, p. 21083.

Horton, S. (1986). Child nutrition and family size in the philippines. *Journal of Development economics*, vol. 23, no. 1, pp. 161–176.

Horton, S. and Steckel, R. (2013). *How Much Have Global Problems Cost the World?* Cambridge University Press.

Hossain, M.B. and Khan, J.R. (2020). Association between household livestock ownership and childhood stunting in bangladesh–a spatial analysis. *Journal of Tropical Pediatrics*, vol. 66, no. 3, pp. 248–256.

Hoyos, A. and Narayan, A. (2011). Inequality of opportunities among children: How much does gender matter. Tech. Rep., Working Paper 76511. The world bank, Washington.

Humphrey, J.H. (2009). Child undernutrition, tropical enteropathy, toilets, and handwashing. *The Lancet*, vol. 374, no. 9694, pp. 1032–1035.

Humphrey, J.H., Mbuya, M.N., Ntozini, R., Moulton, L.H., Stoltzfus, R.J., Tavengwa, N.V., Mutasa, K., Majo, F., Mutasa, B., Mangwadu, G. *et al.* (2019). Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural zimbabwe: a cluster-randomised trial. *The Lancet Global Health*, vol. 7, no. 1, pp. e132–e147.

Hursey, B. and Slingenbergh, J. (1995). The tsetse fly and its effects on agriculture in sub-saharan africa. *World Animal Review*, pp. 67–73.

Hussien, A., Ayele, G. *et al.* (2016). Inequality of opportunity in child health in ethiopia. Tech. Rep., University Library of Munich, Germany.

Iannotti, L.L., Lutter, C.K., Stewart, C.P., Riofrío, C.A.G., Malo, C., Reinhart, G., Palacios, A., Karp, C., Chapnick, M., Cox, K. *et al.* (2017). Eggs in early complementary feeding and child growth: a randomized controlled trial. *Pediatrics*, vol. 140, no. 1.

Iftikhar, A., Bari, A. and Iqbal Bano, Q.M. (2017). Impact of maternal education, employment and family size on nutritional status of children. *Pakistan Journal of Medical Sciences*, vol. 33, no. 6, p. 1401.

Ilman, A.S. and Wibisono, I.D. (2019). Reducing stunting through trade reforms: Analysis of food prices and stunting prevalence in indonesia. Tech. Rep., Center for Indonesian Policy Studies.

Iqbal, M.Z. (2018). The effects of 2016-2017 rice price increase on household welfare and poverty in rural bangladesh. Tech. Rep., Agricultural and Applied Economics Association.

Ivanic, M. and Martin, W. (2008). *Implications of higher global food prices for poverty in low-income countries.* The World Bank.

Ivanic, M. and Martin, W. (2014). *Short-and long-run impacts of food price changes on poverty.* The World Bank.

Ivanic, M., Martin, W. and Zaman, H. (2012). Estimating the short-run poverty impacts of the 2010–11 surge in food prices. *World Development*, vol. 40, no. 11, pp. 2302–2317.

Jacoby, H.G. (2013). *Food prices, wages, and welfare in rural India.* The World Bank.

Jayachandran, S. and Pande, R. (2017). Why are indian children so short? the role of birth order and son preference. *American Economic Review*, vol. 107, no. 9, pp. 2600–2629.

Jensen, R.T., Miller, N.H. *et al.* (2008). The impact of the world food price crisis on nutrition in china. Tech. Rep., Center for International Development at Harvard University.

Jin, M. and Iannotti, L.L. (2014). Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science & Medicine*, vol. 105, pp. 16–21.

Jodlowski, M., Winter-Nelson, A., Baylis, K. and Goldsmith, P.D. (2016). Milk in the data: food security impacts from a livestock field experiment in zambia. *World Development*, vol. 77, pp. 99–114.

Jones, A.D., Agudo, Y.C., Galway, L., Bentley, J. and Pinstrup-Andersen, P. (2012). Heavy agricultural workloads and low crop diversity are strong barriers to improving child feeding practices in the bolivian andes. *Social science & medicine*, vol. 75, no. 9, pp. 1673–1684.

Jones, A.D., Colecraft, E.K., Awuah, R.B., Boatemaa, S., Lambrecht, N.J., Adjorlolo, L.K. and Wilson, M.L. (2018). Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in ghana. *Maternal & child nutrition*, vol. 14, no. 3, p. e12604.

Juárez, F.W.C. and Soloaga, I. (2014). iop: Estimating ex-ante inequality of opportunity. *The Stata Journal*, vol. 14, no. 4, pp. 830–846.

Kabunga, N.S., Ghosh, S. and Webb, P. (2017). Does ownership of improved dairy cow breeds improve child nutrition? a pathway analysis for uganda. *PloS one*, vol. 12, no. 11, p. e0187816.

Kafle, K., Winter-Nelson, A. and Goldsmith, P. (2016). Does 25 cents more per day make a difference? the impact of livestock transfer and development in rural zambia. *Food Policy*, vol. 63, pp. 62–72.

Kamal, S. (2011). Socio-economic determinants of severe and moderate stunting among under-five children of rural bangladesh. *Malaysian journal of nutrition*, vol. 17, no. 1.

Kansanga, M.M., Kangmennaang, J., Kerr, R.B., Lupafya, E., Dakishoni, L. and Luginaah, I. (2020). Agroecology and household production diversity and dietary diversity: Evidence from a five-year agroecological intervention in rural malawi. *Social Science & Medicine*, p. 113550.

Kar, B.R., Rao, S.L. and Chandramouli, B. (2008). Cognitive development in children with chronic protein energy malnutrition. *Behavioral and Brain Functions*, vol. 4, no. 1, p. 31.

Karfakis, P., Velazco, J., Moreno, E. and Covarrubias, K. (2011). Impact of increasing prices of agricultural commodities on poverty. Tech. Rep., Food and Agriculture Organization of the United Nations, Agricultural ....

Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O. and Rahut, D. (2018). Measuring farm and market level economic impacts of improved maize production technologies in ethiopia: Evidence from panel data. *Journal of agricultural economics*, vol. 69, no. 1, pp. 76–95.

Kaur, M., Graham, J.P. and Eisenberg, J.N. (2017). Livestock ownership among rural households and child morbidity and mortality: an analysis of demographic health survey data from 30 sub-saharan african countries (2005–2015). *The American journal of tropical medicine and hygiene*, vol. 96, no. 3, pp. 741–748.

Keino, S., Plasqui, G., Ettyang, G. and van den Borne, B. (2014). Determinants of stunting and overweight among young children and adolescents in sub-saharan africa. *Food and nutrition bulletin*, vol. 35, no. 2, pp. 167–178.

Kennedy, G., Ballard, T. and Dop, M.C. (2011). *Guidelines for measuring household and individual dietary diversity*. Food and Agriculture Organization of the United Nations.

Khamis, A.G., Mwanri, A.W., Ntwenya, J.E. and Kreppel, K. (2019). The influence of dietary diversity on the nutritional status of children between 6 and 23 months of age in tanzania. *BMC pediatrics*, vol. 19, no. 1, pp. 1–9.

Khan, A.Z., Rafique, G., Qureshi, H. and Badruddin, S.H. (2013). A nutrition education intervention to combat undernutrition: Experience from a developing country. In: *Annals of Nutrition and Metabolism*, vol. 63, pp. 432–433. KARGER ALLSCHWILERSTRASSE 10, CH-4009 BASEL, SWITZERLAND.

Khara, T., Mwangome, M., Ngari, M. and Dolan, C. (2018). Children concurrently wasted and stunted: A meta-analysis of prevalence data of children 6–59 months from 84 countries. *Maternal & child nutrition*, vol. 14, no. 2, p. e12516.

Kidane, D. and Woldemichael, A. (2020). Does inflation kill? exposure to food inflation and child mortality. *Food Policy*, p. 101838.

Kien, V.D., Lee, H.-Y., Nam, Y.-S., Oh, J., Giang, K.B. and Minh, H.V. (2016). Trends in socioeconomic inequalities in child malnutrition in vietnam: findings from the multiple indicator cluster surveys, 2000–2011. *Global health action*, vol. 9, no. 1, p. 29263.

Kim, S.S., Nguyen, P.H., Tran, L.M., Abebe, Y., Asrat, Y., Tharaney, M. and Menon, P. (2019). Maternal behavioural determinants and livestock ownership are associated with animal source food consumption among young children during fasting in rural ethiopia. *Maternal & child nutrition*, vol. 15, no. 2, p. e12695.

Kim, S.S., Rawat, R., Mwangi, E.M., Tesfaye, R., Abebe, Y., Baker, J., Frongillo, E.A., Ruel, M.T. and Menon, P. (2016). Exposure to large-scale social and behavior change communication interventions is associated with improvements in infant and young child feeding practices in ethiopia. *PloS one*, vol. 11, no. 10, p. e0164800.

Kingdom, J.C., McQueen, J., Connell, J.M. and Whittle, M.J. (1993). Fetal angiotensin ii levels and vascular (type i) angiotensin receptors in pregnancies complicated by intrauterine growth retardation. *BJOG: An International Journal of Obstetrics & Gynaecology*, vol. 100, no. 5, pp. 476–482.

Kirk, A., Kilic, T. and Carletto, C. (2018). Composition of household income and child nutrition outcomes evidence from uganda. *World development*, vol. 109, pp. 452–469.

Koletzko, B., Brands, B., Grote, V., Kirchberg, F.F., Prell, C., Rzehak, P., Uhl, O., Weber, M., Project, E.N.P. *et al.* (2017). Long-term health impact of early nutrition: the power of programming. *Annals of Nutrition and Metabolism*, vol. 70, no. 3, pp. 161–169.

Krebs, N.F., Mazariegos, M., Chomba, E., Sami, N., Pasha, O., Tshefu, A., Carlo, W.A., Goldenberg, R.L., Bose, C.L., Wright, L.L. *et al.* (2012). Randomized controlled trial of meat compared with multimicronutrient-fortified cereal in infants and toddlers with high stunting rates in diverse settings. *The American journal of clinical nutrition*, vol. 96, no. 4, pp. 840–847.

Krebs, N.F., Mazariegos, M., Tshefu, A., Bose, C., Sami, N., Chomba, E., Carlo, W., Goco, N., Kindem, M., Wright, L.L. *et al.* (2011). Meat consumption is associated with less stunting among toddlers in four diverse low-income settings. *Food and nutrition bulletin*, vol. 32, no. 3, pp. 185–191.

Kulwa, K.B., Mamiro, P.S., Kimanya, M.E., Mziray, R. and Kolsteren, P.W. (2015). Feeding practices and nutrient content of complementary meals in rural central tanzania: implications for dietary adequacy and nutritional status. *BMC pediatrics*, vol. 15, no. 1, pp. 1–11.

Kumar, N., Harris, J. and Rawat, R. (2015). If they grow it, will they eat and grow? evidence from zambia on agricultural diversity and child undernutrition. *The journal of development studies*, vol. 51, no. 8, pp. 1060–1077.

Kumar, S. and Vollmer, S. (2013). Does access to improved sanitation reduce childhood diarrhea in rural india? *Health Economics*, vol. 22, no. 4, pp. 410–427.

Kwami, C.S., Godfrey, S., Gavilan, H., Lakhanpaul, M. and Parikh, P. (2019). Water, sanitation, and hygiene: linkages with stunting in rural ethiopia. *International journal of environmental research and public health*, vol. 16, no. 20, p. 3793.

Lanigan, J. and Singhal, A. (2009). Early nutrition and long-term health: A practical approach: Symposium on 'early nutrition and later disease: Current concepts, research and implications'. *Proceedings of the Nutrition Society*, vol. 68, no. 4, pp. 422–429.

Lee, H.-H., Lee, S.A., Lim, J.-Y. and Park, C.-Y. (2016). Effects of food price inflation on infant and child mortality in developing countries. *The European journal of health economics*, vol. 17, no. 5, pp. 535–551.

Lee, R., Singh, L., van Liefde, D., Callaghan-Gillespie, M., Steiner-Asiedu, M., Saalia, K., Edwards, C., Serena, A., Hershey, T. and Manary, M.J. (2018). Milk powder added to a school meal increases cognitive test scores in ghanaian children. *The Journal of nutrition*, vol. 148, no. 7, pp. 1177–1184.

Leinonen, I., Iannetta, P.P., MacLeod, M., Rees, R.M., Russell, W., Watson, C. and Barnes, A.P. (2020). Regional land use efficiency and nutritional quality of protein production. *Global Food Security*, vol. 26, p. 100386.

Leon-Quinto, T., Magnan, C. and Portha, B. (1998). Altered activity of the autonomous nervous system as a determinant of the impaired β-cell secretory response after protein-energy restriction in the rat. *Endocrinology*, vol. 139, no. 8, pp. 3382–3389.

Leroy, J.L., Ruel, M., Habicht, J.-P. and Frongillo, E.A. (2014). Linear growth deficit continues to accumulate beyond the first 1000 days in low-and middle-income countries: global evidence from 51 national surveys. *The Journal of nutrition*, vol. 144, no. 9, pp. 1460–1466.

Leroy, J.L., Ruel, M., Habicht, J.-P. and Frongillo, E.A. (2015). Using height-for-age differences (had) instead of height-for-age z-scores (haz) for the meaningful measurement of population-level catch-up in linear growth in children less than 5 years of age. *BMC pediatrics*, vol. 15, no. 1, pp. 1–11.

Li, H., Stein, A.D., Barnhart, H.X., Ramakrishnan, U. and Martorell, R. (2003). Associations between prenatal and postnatal growth and adult body size and composition. *The American journal of clinical nutrition*, vol. 77, no. 6, pp. 1498–1505.

Li, H. and Zhao, J. (2018). Rebound effects of new irrigation technologies: The role of water rights. *American Journal of Agricultural Economics*, vol. 100, no. 3, pp. 786–808.

Lin, A., Arnold, B.F., Afreen, S., Goto, R., Huda, T.M.N., Haque, R., Raqib, R., Unicomb, L., Ahmed, T., Colford Jr, J.M. *et al.* (2013). Household environmental conditions are associated with enteropathy and impaired growth in rural bangladesh. *The American journal of tropical medicine and hygiene*, vol. 89, no. 1, pp. 130–137.

Lindner, A.K. and Priotto, G. (2010). The unknown risk of vertical transmission in sleeping sickness—a literature review. *PLoS neglected tropical diseases*, vol. 4, no. 12, p. e783.

Long, J.K., Murphy, S.P., Weiss, R.E., Nyerere, S., Bwibo, N.O. and Neumann, C.G. (2012). Meat and milk intakes and toddler growth: a comparison feeding intervention of animal-source foods in rural kenya. *Public health nutrition*, vol. 15, no. 6, pp. 1100–1107.

Louwman, M.W., van Dusseldorp, M., van de Vijver, F.J., Thomas, C.M., Schneede, J., Ueland, P.M., Refsum, H. and van Staveren, W.A. (2000). Signs of impaired cognitive function in adolescents with marginal cobalamin status. *The American journal of clinical nutrition*, vol. 72, no. 3, pp. 762–769.

Lovo, S. and Veronesi, M. (2019). Crop diversification and child health: empirical evidence from tanzania. *Ecological economics*, vol. 158, pp. 168–179.

Luby, S.P., Agboatwalla, M., Bowen, A., Kenah, E., Sharker, Y. and Hoekstra, R.M. (2009). Difficulties in maintaining improved handwashing behavior, karachi, pakistan. *The American journal of tropical medicine and hygiene*, vol. 81, no. 1, pp. 140–145.

Luby, S.P., Mendoza, C., Keswick, B.H., Chiller, T.M. and Hoekstra, R.M. (2008). Difficulties in bringing point-of-use water treatment to scale in rural guatemala. *The American journal of tropical medicine and hygiene*, vol. 78, no. 3, pp. 382–387.

Luby, S.P., Rahman, M., Arnold, B.F., Unicomb, L., Ashraf, S., Winch, P.J., Stewart, C.P., Begum, F., Hussain, F., Benjamin-Chung, J. *et al.* (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural bangladesh: a cluster randomised controlled trial. *The Lancet Global Health*, vol. 6, no. 3, pp. e302–e315.

Luebker, M. *et al.* (2012). Income inequality, redistribution and poverty. Tech. Rep., World Institute for Development Economic Research (UNU-WIDER).

Lustig, N. (2012). Rising food prices and children's welfare. *CHILD POVERTY AND INEQUALITY NEW PERSPECTIVES*, p. 125.

Macharia, E., Gbegbelegbe, S., Massawe, S.C., Wanjiku, J., Karugia, J.T. and Freeman, H. (2009). Food prices: Eastern and southern africa defy global trends. *Food Prices Update; 01/2009.*

MAFAP (2013). Review of food and agricultural policies in the united republic of tanzania.

Malapit, H.J.L., Kadiyala, S., Quisumbing, A.R., Cunningham, K. and Tyagi, P. (2015). Women's empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in nepal. *The journal of development studies*, vol. 51, no. 8, pp. 1097–1123.

Malele, I., Nyingilili, H. and Msangi, A. (2011). Factors defining the distribution limit of tsetse infestation and the implication for livestock sector in tanzania. *African journal of agricultural research*, vol. 6, no. 10, pp. 2341–2347.

Maltsoglou, I., Dawe, D. and Tasciotti, L. (2010). *Household level impacts of increasing food prices in Cambodia*. FAO.

Mangyo, E. (2008). Who benefits more from higher household consumption? the intra-household allocation of nutrients in china. *Journal of Development Economics*, vol. 86, no. 2, pp. 296–312.

Mani, S. (2012). Is there complete, partial, or no recovery from childhood malnutrition?–empirical evidence from indonesia. *Oxford Bulletin of Economics and Statistics*, vol. 74, no. 5, pp. 691–715.

Mara, D., Lane, J., Scott, B. and Trouba, D. (2010). Sanitation and health. *PLoS Med*, vol. 7, no. 11, p. e1000363.

Marquis, G.S., Ventura, G., Gilman, R.H., Porras, E., Miranda, E., Carbajal, L. and Pentafiel, M. (1990). Fecal contamination of shanty town toddlers in households with non-corralled poultry, lima, peru. *American journal of public health*, vol. 80, no. 2, pp. 146–149.

Martin, W. and Ivanic, M. (2010). The food price crisis, poverty and agricultural trade policy. In: *Food Crises and the WTO: World Trade Forum*, pp. 25–48.

Martorell, R., Horta, B.L., Adair, L.S., Stein, A.D., Richter, L., Fall, C.H., Bhargava, S.K., Biswas, S.D., Perez, L., Barros, F.C. *et al.* (2010). Weight gain in the first two years of life is an important predictor of schooling outcomes in pooled analyses from five birth cohorts from low-and middle-income countries. *The Journal of nutrition*, vol. 140, no. 2, pp. 348–354.

Martorell, R., Khan, L.K. and Schroeder, D.G. (1994). Reversibility of stunting: epidemiological findings in children from developing countries. *European journal of clinical nutrition*, vol. 48, pp. S45–57.

Mbuya, M.N. and Humphrey, J.H. (2016). Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries. *Maternal & child nutrition*, vol. 12, pp. 106–120.

Mclaren, D. (1974). The great protein fiasco. *The Lancet*, vol. 304, no. 7872, pp. 93–96.

Menon, P., Bamezai, A., Subandoro, A., Ayoya, M.A. and Aguayo, V.M. (2015). Age-appropriate infant and young child feeding practices are associated with child nutrition in i ndia: insights from nationally representative data. *Maternal & child nutrition*, vol. 11, no. 1, pp. 73–87.

Menon, P., Ruel, M.T. and Morris, S.S. (2000). Socio-economic differentials in child stunting are consistently larger in urban than in rural areas. *Food and Nutrition Bulletin*, vol. 21, no. 3, pp. 282–289.

Micha, R., Mannar, V., Afshin, A., Allemandi, L., Baker, P., Battersby, J., Bhutta, Z., Chen, K., Corvalan, C., Di Cesare, M. *et al.* (2020). 2020 global nutrition report: action on equity to end malnutrition. Tech. Rep., Development Initiatives.

Michaelsen, K.F., Nielsen, A.-L.H., Roos, N., Friis, H. and Mølgaard, C. (2011). Cow's milk in treatment of moderate and severe undernutrition in low-income countries. In: *Milk and milk products in human nutrition*, vol. 67, pp. 99–111. Karger Publishers.

Michelson, H.C. (2017). Influence of neighbor experience and exit on small farmer market participation. *American Journal of Agricultural Economics*, vol. 99, no. 4, pp. 952–970.

Miller, L.C., Joshi, N., Lohani, M., Singh, R., Bhatta, N., Rogers, B., Griffiths, J.K., Ghosh, S., Mahato, S., Singh, P. *et al.* (2016). Head growth of undernourished children in rural nepal: association with demographics, health and diet. *Paediatrics and International Child Health*, vol. 36, no. 2, pp. 91–101.

Minot, N. (2010). Staple food prices in tanzania. Tech. Rep..

Misaki, E., Apiola, M. and Gaiani, S. (2016). Technology for small scale farmers in tanzania: a design science research approach. *The Electronic Journal of Information Systems in Developing Countries*, vol. 74, no. 1, pp. 1–15.

Mølgaard, C., Larnkjær, A., Arnberg, K. and Michaelsen, K.F. (2011). Milk and growth in children: effects of whey and casein. In: *Milk and Milk Products in Human Nutrition*, vol. 67, pp. 67–78. Karger Publishers.

Monteiro, C.A., Benicio, M.H.D., Konno, S.C., Silva, A.C.F.d., Lima, A.L.L.d. and Conde, W.L. (2009). Causes for the decline in child under-nutrition in brazil, 1996-2007. *Revista de saude publica*, vol. 43, pp. 35–43.

Moorcroft, K.E., Marshall, J.L. and McCormick, F.M. (2011). Association between timing of introducing solid foods and obesity in infancy and childhood: a systematic review. *Maternal & child nutrition*, vol. 7, no. 1, pp. 3–26.

Moradi, A. *et al.* (2010). *Selective Mortality Or Growth After Childhood?: What Really is Key to Understand the Puzzlingly Tall Adult Heights in Sub-Saharan Africa.* Centre for the Study of African Economies.

Mosha, T., Laswai, H. and Dakiyo, S. (1998). Breastfeeding, weaning practices and anthropometric status of children in morogoro district, tanzania. *Ecology of food and nutrition*, vol. 37, no. 4, pp. 309–338.

Mosites, E., Thumbi, S.M., Otiang, E., McElwain, T.F., Njenga, M., Rabinowitz, P.M., Rowhani-Rahbar, A., Neuhouser, M.L., May, S., Palmer, G.H. *et al.* (2016). Relations between household livestock ownership, livestock disease, and young child growth. *The Journal of nutrition*, vol. 146, no. 5, pp. 1118–1124.

Mosites, E.M., Rabinowitz, P.M., Thumbi, S.M., Montgomery, J.M., Palmer, G.H., May, S., Rowhani-Rahbar, A., Neuhouser, M.L. and Walson, J.L. (2015). The relationship between livestock ownership and child stunting in three countries in eastern africa using national survey data. *PLoS One*, vol. 10, no. 9, p. e0136686.

Moya, M. (2016). Lysine genetically enriched cereals for improving nutrition in children under 5years in low-and middle-income countries. *J Nutr Health Food Eng*, vol. 5, no. 2, p. 00164.

Mshida, H.A., Kassim, N., Mpolya, E. and Kimanya, M. (2018). Water, sanitation, and hygiene practices associated with nutritional status of under-five children in semi-pastoral communities tanzania. *The American journal of tropical medicine and hygiene*, vol. 98, no. 5, pp. 1242–1249.

Msuya, N.H. (2019). Preference for son: A principal form of gender discrimination and violations of women's rights in tanzania. *Institute of Judicial Administration Journal*, vol. 2, no. 1, pp. 89–100.

Muehlhoff, E., Bennett, A., McMahon, D. *et al.* (2013). *Milk and dairy products in human nutrition.* Food and Agriculture Organization of the United Nations (FAO).

Mulema, J. (2014). Son preference, childbearing behavior and respondent socio-demographic characteristics in morogoro, tanzania. *ABC Journal of Advanced Research*, vol. 3, no. 1, pp. 9–13.

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica: journal of the Econometric Society*, pp. 69–85.

Murphy, S.P. and Allen, L.H. (2003). Nutritional importance of animal source foods. *The Journal of nutrition*, vol. 133, no. 11, pp. 3932S–3935S.

Murtazashvili, I. and Wooldridge, J.M. (2016). A control function approach to estimating switching regression models with endogenous explanatory variables and endogenous switching. *Journal of Econometrics*, vol. 190, no. 2, pp. 252–266.

Musara, J., Musemwa, L., Mushunje, A., Mutenje, M. and Pfukwa, C. (2019). Sorghum value chain analysis in semi-arid zimbabwe. *South African Journal of Agricultural Extension*, vol. 47, no. 1, pp. 164–178.

Muslimatun, S. and Wiradnyani, L.A.A. (2016). Dietary diversity, animal source food consumption and linear growth among children aged 1–5 years in bandung, indonesia: A longitudinal observational study. *British Journal of Nutrition*, vol. 116, no. S1, pp. S27–S35.

Mwabu, G. (2007). Health economics for low-income countries. *Handbook of development economics*, vol. 4, pp. 3305–3374.

Mwabu, G. (2008). The production of child health in kenya: a structural model of birth weight. *Journal of African Economies*, vol. 18, no. 2, pp. 212–260.

Mwageni, E.A., Ankomah, A. and Powell, R.A. (2001). Sex preference and contraceptive behaviour among men in mbeya region, tanzania. *BMJ Sexual & Reproductive Health*, vol. 27, no. 2, pp. 85–89.

Nakelse, T., Dalton, T.J., Hendricks, N.P. and Hodjo, M. (2018). Are smallholder farmers better or worse off from an increase in the international price of cereals? *Food Policy*, vol. 79, pp. 213–223.

Nandi, A., Ashok, A., Kinra, S., Behrman, J.R. and Laxminarayan, R. (2015). Early childhood nutrition is positively associated with adolescent educational outcomes: evidence from the andhra pradesh child and parents study (apcaps). *The Journal of nutrition*, vol. 146, no. 4, pp. 806–813.

NBS (2012). National panel survey wave 2, 2010-2011. Tech. Rep., National Bureau Of Statistics; Dar es Salaam, Tanzania.

NBS (2014). National panel survey wave 2, 2014-2015. Tech. Rep., National Bureau Of Statistics; Dar es Salaam, Tanzania.

Nepal, A.K. (2018). What matters more for child health: A father's education or mother's education? *World Development Perspectives*, vol. 10, pp. 24–33.

Neumann, C., Harris, D.M. and Rogers, L.M. (2002). Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutrition research*, vol. 22, no. 1-2, pp. 193–220.

Ngure, F.M., Humphrey, J.H., Mbuya, M.N., Majo, F., Mutasa, K., Govha, M., Mazarura, E., Chasekwa, B., Prendergast, A.J., Curtis, V. *et al.* (2013). Formative research on hygiene behaviors and geophagy among infants and young children and implications of exposure to fecal bacteria. *The American journal of tropical medicine and hygiene*, vol. 89, no. 4, pp. 709–716.

Nicholson, C., Mwangi, L., Staal, S. and Thornton, P. (2003). Cow ownership and child nutritional status in kenya. *Research Bulletin*, pp. 11–2003.

Nkonki, L.L., Chopra, M., Doherty, T.M., Jackson, D. and Robberstad, B. (2011). Explaining household socio-economic related child health inequalities using multiple methods in three diverse settings in south africa. *International journal for equity in health*, vol. 10, no. 1, p. 13.

Nozick, R. and Williams, B. (1975). *23. Anarchy, State and Utopia.* Princeton University Press.

Nseluke, M.H. (2018). *A Tall Order: Improving Child Linear Growth.* PhD dissertation, Maastricht University.

Null, C., Stewart, C.P., Pickering, A.J., Dentz, H.N., Arnold, B.F., Arnold, C.D., Benjamin-Chung, J., Clasen, T., Dewey, K.G., Fernald, L.C. *et al.* (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural kenya: a cluster-randomised controlled trial. *The Lancet Global Health*, vol. 6, no. 3, pp. e316–e329.

Nuss, E.T. and Tanumihardjo, S.A. (2010). Maize: a paramount staple crop in the context of global nutrition. *Comprehensive reviews in food science and food safety*, vol. 9, no. 4, pp. 417–436.

Nyaradi, A., Li, J., Hickling, S., Foster, J. and Oddy, W.H. (2013). The role of nutrition in children's neurocognitive development, from pregnancy through childhood. *Frontiers in human neuroscience*, vol. 7, p. 97.

Nyaruhucha, C., Mamiro, P., Kerengi, A. and Shayo, N. (2006). Nutritional status of underfive children in a pastoral community in simanjiro district, tanzania. *Tanzania Journal of Health Research*, vol. 8, no. 1, pp. 32–36.

Oaxaca, R. (1973). Male-female wage differentials in urban labor markets. *International economic review*, pp. 693–709.

Odgers, C.L. (2015). Income inequality and the developing child: Is it all relative? *American Psychologist*, vol. 70, no. 8, p. 722.

Omotilewa, O.J., Ricker-Gilbert, J., Ainembabazi, J.H. and Shively, G.E. (2018). Does improved storage technology promote modern input use and food security? evidence from a randomized trial in uganda. *Journal of development economics*, vol. 135, pp. 176–198.

Ong, K.K., Langkamp, M., Ranke, M.B., Whitehead, K., Hughes, I.A., Acerini, C.L. and Dunger, D.B. (2009). Insulin-like growth factor i concentrations in infancy predict differential gains in body length and adiposity: the cambridge baby growth study. *The American journal of clinical nutrition*, vol. 90, no. 1, pp. 156–161.

Onyango, A.W., Esrey, S.A. and Kramer, M.S. (1999). Continued breastfeeding and child growth in the second year of life: a prospective cohort study in western kenya. *The Lancet*, vol. 354, no. 9195, pp. 2041–2045.

Orazem, P., Glewwe, P., Patrinow, H. and Lomborg, B. (2009). Global crises, global solutions: Costs and benefits.

Outes, I. and Porter, C. (2013). Catching up from early nutritional deficits? evidence from rural ethiopia. *Economics & Human Biology*, vol. 11, no. 2, pp. 148–163.

Paciorek, C.J., Stevens, G.A., Finucane, M.M., Ezzati, M., Group, N.I.M.S. *et al.* (2013). Children's height and weight in rural and urban populations in low-income and middle-income countries: a systematic analysis of population-representative data. *The Lancet Global Health*, vol. 1, no. 5, pp. e300–e309.

Paes de Barros, R., De Carvalho, M. and Franco, S. (2007). Preliminary notes on the measurement of socially-determined inequality of opportunity when the outcome is discrete. *Unpublished manuscript. Rio de Janeiro: IPEA*.

Paes de Barros, R., Ferreira, F., Vega, J.M. and Chanduvi, J.S. (2009). Measuring inequality of opportunity in latin america and the caribbean, the world bank, washington dc., 2009. *The World Bank*.

Palloni, A., Milesi, C., White, R.G. and Turner, A. (2009). Early childhood health, reproduction of economic inequalities and the persistence of health and mortality differentials. *Social science & medicine*, vol. 68, no. 9, pp. 1574–1582.

Panek, E. and Gozdowski, D. (2020). Analysis of relationship between cereal yield and ndvi for selected regions of central europe based on modis satellite data. *Remote Sensing Applications: Society and Environment*, vol. 17, p. 100286.

Papoutsou, S., Savva, S.C., Hunsberger, M., Jilani, H., Michels, N., Ahrens, W., Tornaritis, M., Veidebaum, T., Molnár, D., Siani, A. *et al.* (2018). Timing of solid food introduction and association with later childhood overweight and obesity: The idefics study. *Maternal & Child Nutrition*, vol. 14, no. 1, p. e12471.

Park, Y.W. (2009). *Bioactive components in milk and dairy products*. John Wiley & Sons.

Pasqualino, M., Shaikh, S., Islam, M.T., Parvin, S., Ali, H., McGready, J., Hossain, M.I. and Palmer, A. (2020). Household livestock and fishpond ownership are associated with consumption of eggs, milk, and fish, but not meat, among infants 6–12 months of age in rural bangladesh. *Current Developments in Nutrition*, vol. 4, no. Supplement_2, pp. 884–884.

Pathak, P.K. and Singh, A. (2011). Trends in malnutrition among children in india: growing inequalities across different economic groups. *Social science & medicine*, vol. 73, no. 4, pp. 576–585.

Perkins, J.M., Jayatissa, R. and Subramanian, S. (2018). Dietary diversity and anthropometric status and failure among infants and young children in sri lanka. *Nutrition*, vol. 55, pp. 76–83.

Pfeuffer, M. and Watzl, B. (2018). Nutrition and health aspects of milk and dairy products and their ingredients. *Ernahrungs Umschau*, vol. 65, no. 2, pp. 22–33.

Pimpin, L., Jebb, S., Johnson, L., Wardle, J. and Ambrosini, G.L. (2016). Dietary protein intake is associated with body mass index and weight up to 5 y of age in a prospective cohort of twins, 2. *The American journal of clinical nutrition*, vol. 103, no. 2, pp. 389–397.

Pinstrup-Andersen, P. (2013). Can agriculture meet future nutrition challenges? *The European Journal of Development Research*, vol. 25, no. 1, pp. 5–12.

Pitt, M. and Rosenzweig, M.R. (1986). Agricultural prices, food consumption, and the health and productivity of indonesian farmers. *Agricultural household models: Extensions, applications and policy*, pp. 153–82.

Pitt, M.M. (1997). Estimating the determinants of child health when fertility and mortality are selective. *Journal of Human Resources*, pp. 129–158.

Prendergast, A.J. (2015). Malnutrition and vaccination in developing countries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 370, no. 1671, p. 20140141.

Prentice, A.M., Ward, K.A., Goldberg, G.R., Jarjou, L.M., Moore, S.E., Fulford, A.J. and Prentice, A. (2013). Critical windows for nutritional interventions against stunting. *The American of Clinical Nutrition*, vol. 97, no. 5, pp. 911–918.

Ragasa, C., Aberman, N.-L. and Mingote, C.A. (2019). Does providing agricultural and nutrition information to both men and women improve household food security? evidence from malawi. *Global food security*, vol. 20, pp. 45–59.

Rah, J.H., Cronin, A.A., Badgaiyan, B., Aguayo, V.M., Coates, S. and Ahmed, S. (2015). Household sanitation and personal hygiene practices are associated with child stunting in rural india: a cross-sectional analysis of surveys. *BMJ open*, vol. 5, no. 2.

Rajmil, L., De Sanmamed, M.-J.F., Choonara, I., Faresjö, T., Hjern, A., Kozyrskyj, A.L., Lucas, P.J., Raat, H., Séguin, L., Spencer, N. *et al.* (2014). Impact of the 2008 economic and financial crisis on child health: a systematic review. *International journal of environmental research and public health*, vol. 11, no. 6, pp. 6528–6546.

Randela, R. (2003). An economic assessment of the value of cattle to the rural communities in the former venda region. *Development Southern Africa*, vol. 20, no. 1, pp. 89–103.

Randolph, T.F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J., Cole, D., Demment, M., Omore, A., Zinsstag, J. and Ruel, M. (2007). Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of animal science*, vol. 85, no. 11, pp. 2788–2800.

Rashid, S., Minot, N. *et al.* (2010). Are staple food markets in africa efficient? spatial price analyses and beyond. Tech. Rep., Michigan State University, Department of Agricultural, Food, and Resource ....

Rawlins, R., Pimkina, S., Barrett, C.B., Pedersen, S. and Wydick, B. (2014). Got milk? the impact of heifer international's livestock donation programs in rwanda on nutritional outcomes. *Food policy*, vol. 44, pp. 202–213.

Rawls, J. (1971). A theory of justice. cambridge, ma: Belknap press of harvard university press.

Richter, L.M., Daelmans, B., Lombardi, J., Heymann, J., Boo, F.L., Behrman, J.R., Lu, C., Lucas, J.E., Perez-Escamilla, R., Dua, T. *et al.* (2017). Investing in the foundation of sustainable development: pathways to scale up for early childhood development. *The lancet*, vol. 389, no. 10064, pp. 103–118.

Richter, M. and Körholz, D. (2015). The social dimension of adolescent health: challenges for paediatric research and practice. *Klinische Pädiatrie*, vol. 227, no. 04, pp. 193–198.

Rizal, M.F. and van Doorslaer, E. (2019). Explaining the fall of socioeconomic inequality in childhood stunting in indonesia. *SSM-population health*, vol. 9, p. 100469.

Roemer, J. (1998). Equality of opportunity. In: *Handbook of income distribution*, vol. 2, pp. 217–300. Elsevier.

Roemer, J.E. (1993). A pragmatic theory of responsibility for the egalitarian planner. *Philosophy & Public Affairs*, pp. 146–166.

Roemer, J.E. (2002). Equality of opportunity: A progress report. *Social Choice and Welfare*, vol. 19, no. 2, pp. 455–471.

Rojas-Downing, M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, vol. 16, pp. 145–163.

Rolland-Cachera, M., Deheeger, M., Akrout, M. and Bellisle, F. (1995). Influence of macronutrients on adiposity development: a follow up study of nutrition and growth from 10 months to 8 years of age. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*, vol. 19, no. 8, p. 573.

Rolland-Cachera, M.F. and Michaelsen, K.F. (2019). Protein intake in young children and later health: importance of the time window for programming adiposity. *The American journal of clinical nutrition*, vol. 110, no. 5, pp. 1263–1264.

Romano, D. and Carraro, A. (2015). Price shocks, vulnerability and food and nutrition security among rural and urban households in tanzania. Tech. Rep., Italian Association of Agricultural and Applied Economics (AIEAA).

Rosenzweig, M.R. and Schultz, T.P. (1983). Estimating a household production function: Heterogeneity, the demand for health inputs, and their effects on birth weight. *Journal of political economy*, vol. 91, no. 5, pp. 723–746.

Rosenzweig, M.R. and Schultz, T.P. (1988). The stability of household production technology: A replication. *The Journal of Human Resources*, vol. 23, no. 4, pp. 535–549.

Rudolf, R. (2019). The impact of maize price shocks on household food security: Panel evidence from tanzania. *Food Policy*, vol. 85, pp. 40–54.

Ruel, M.T., Alderman, H., Maternal, Group, C.N.S. *et al.* (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *The lancet*, vol. 382, no. 9891, pp. 536–551.

Rukambile, E., Muscatello, G., Sintchenko, V., Thomson, P.C., Maulaga, W., Mmassy, R., DE BRUYN, J., Kock, R., Darnton-Hill, I. and Alders, R. (2020). Determinants of diarrhoeal diseases and height-for-age z-scores in children under five years of age in rural central tanzania. *Journal of Preventive Medicine and Hygiene*, vol. 61, no. 3, p. E409.

Russell, F. and Azzopardi, P. (2019). Wash: a basic human right and essential intervention for child health and development. *The Lancet Global Health*, vol. 7, no. 4, p. e417.

Saha, K.K., Frongillo, E.A., Alam, D.S., Arifeen, S.E., Persson, L.Å. and Rasmussen, K.M. (2008). Appropriate infant feeding practices result in better growth of infants and young children in rural bangladesh. *The American journal of clinical nutrition*, vol. 87, no. 6, pp. 1852–1859.

Sahn, D.E. and Alderman, H. (1997). On the determinants of nutrition in mozambique: The importance of age-specific effects. *World Development*, vol. 25, no. 4, pp. 577–588.

Sakadevan, K. and Nguyen, M.-L. (2017). Livestock production and its impact on nutrient pollution and greenhouse gas emissions. In: *Advances in agronomy*, vol. 141, pp. 147–184. Elsevier.

Salazar, L., Aramburu, J., González-Flores, M. and Winters, P. (2015). Food security and productivity: impacts of technology adoption in small subsistence farmers in bolivia. Tech. Rep., IDB working paper series.

Sanoussi, Y. (2017). Measurement and analysis of inequality of opportunity in access of maternal and child health care in togo. *BMC health services research*, vol. 17, no. 2, p. 699.

Sariyev, O., Loos, T.K. and Khor, L.Y. (2021). Intra-household decision-making, production diversity, and dietary quality: a panel data analysis of ethiopian rural households. *Food Security*, vol. 13, no. 1, pp. 181–197.

Savy, M., Edmond, K., Fine, P.E., Hall, A., Hennig, B.J., Moore, S.E., Mulholland, K., Schaible, U. and Prentice, A.M. (2009). Landscape analysis of interactions between nutrition and vaccine responses in children. *The Journal of nutrition*, vol. 139, no. 11, pp. 2154S–2218S.

Sawaya, A.L., Sesso, R., Florêncio, T.M.d.M.T., Fernandes, M.T. and Martins, P.A. (2005). Association between chronic undernutrition and hypertension. *Maternal & child nutrition*, vol. 1, no. 3, pp. 155–163.

Scherbaum, V. and Srour, M.L. (2016). The role of breastfeeding in the prevention of childhood malnutrition. In: *Hidden Hunger*, vol. 115, pp. 82–97. Karger Publishers.

Schokkaert, E. (2015). Equality of opportunity, a flexible framework. *Health economics*, vol. 24, no. 10, pp. 1250–1252.

Schriewer, A., Odagiri, M., Wuertz, S., Misra, P.R., Panigrahi, P., Clasen, T. and Jenkins, M.W. (2015). Human and animal fecal contamination of community water sources, stored drinking water and hands in rural india measured with validated microbial source tracking assays. *The American journal of tropical medicine and hygiene*, vol. 93, no. 3, pp. 509–516.

Schroeder, D.G., Martorell, R. and Flores, R. (1999). Infant and child growth and fatness and fat distribution in guatemalan adults. *American Journal of epidemiology*, vol. 149, no. 2, pp. 177–185.

Schultz, T.P. (1984). Studying the impact of household economic and community variables on child mortality. Tech. Rep., Center Discussion Paper.

Schultz, T.P. (2002). Why governments should invest more to educate girls. *World development*, vol. 30, no. 2, pp. 207–225.

Semba, R.D. (2016). The rise and fall of protein malnutrition in global health. *Annals of Nutrition and Metabolism*, vol. 69, no. 2, pp. 79–88.

Semba, R.D., de Pee, S., Sun, K., Sari, M., Akhter, N. and Bloem, M.W. (2008). Effect of parental formal education on risk of child stunting in indonesia and bangladesh: a cross-sectional study. *The lancet*, vol. 371, no. 9609, pp. 322–328.

Sen, A. (1979). Utilitarianism and welfarism. *The journal of Philosophy*, vol. 76, no. 9, pp. 463–489.

Sen, A. (1985). Well-being, agency and freedom: The dewey lectures 1984. *The journal of philosophy*, vol. 82, no. 4, pp. 169–221.

Sesso, R., Barreto, G.P., Neves, J. and Sawaya, A.L. (2004). Malnutrition is associated with increased blood pressure in childhood. *Nephron Clinical Practice*, vol. 97, no. 2, pp. c61–c66.

Seymour, G., Masuda, Y.J., Williams, J. and Schneider, K. (2019). Household and child nutrition outcomes among the time and income poor in rural bangladesh. *Global food security*, vol. 20, pp. 82–92.

Shirima, R., Greiner, T., Kylberg, E. and Gebre-Medhin, M. (2001). Exclusive breast-feeding is rarely practised in rural and urban morogoro, tanzania. *Public Health Nutrition*, vol. 4, no. 2, pp. 147–154.

Shorrocks, A.F. (1982). Inequality decomposition by factor components. *Econometrica: Journal of the Econometric Society*, pp. 193–211.

Shorrocks, A.F. (2013). Decomposition procedures for distributional analysis: a unified framework based on the shapley value. *The Journal of Economic Inequality*, vol. 11, no. 1, pp. 99–126.

Sibhatu, K.T., Krishna, V.V. and Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, vol. 112, no. 34, pp. 10657–10662.

Silanikove, N. (2000). Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock production science*, vol. 67, no. 1-2, pp. 1–18.

Singh, A. (2011). Inequality of opportunity in indian children: The case of immunization and nutrition. *Population Research and Policy Review*, vol. 30, no. 6, pp. 861–883.

Skoufias, E., Tiwari, S. and Zaman, H. (2011). Crises, food prices, and the income elasticity of micronutrients: estimates from indonesia. *The World Bank Economic Review*, vol. 26, no. 3, pp. 415–442.

Smith, L.C. and Haddad, L. (2015). Reducing child undernutrition: past drivers and priorities for the post-mdg era. *World Development*, vol. 68, pp. 180–204.

Smith, L.C., Ruel, M.T. and Ndiaye, A. (2005). Why is child malnutrition lower in urban than in rural areas? evidence from 36 developing countries. *World development*, vol. 33, no. 8, pp. 1285–1305.

Soczynska, I., Dai, D., O'Connor, D.L., Birken, C.S. and Maguire, J.L. (2020). Age of cow milk introduction and growth among 3–5-year-old children. *Public Health Nutrition*, pp. 1–7.

Som, S.V., Van Der Hoeven, M., Laillou, A., Poirot, E., Chan, T., Polman, K., Ponce, M.C. and Wieringa, F.T. (2021). Adherence to child feeding practices and child growth: A retrospective cohort analysis in cambodia. *Nutrients*, vol. 13, no. 1, p. 137.

Somova, L. and Moodley, K. (2000). The effect of protein-energy malnutrition on development of hypertension, glucose metabolism and insulin sensitivity in genetically hypertensive rats. *Nutrition, metabolism, and cardiovascular diseases: NMCD*, vol. 10, no. 4, pp. 188–194.

Speybroeck, N., Konings, P., Lynch, J., Harper, S., Berkvens, D., Lorant, V., Geckova, A. and Hosseinpoor, A.R. (2010). Decomposing socioeconomic health inequalities. *International journal of public health*, vol. 55, no. 4, pp. 347–351.

Stage, J., Stage, J. and Mcgranahan, G. (2010). Is urbanization contributing to higher food prices? *Environment and Urbanization*, vol. 22, no. 1, pp. 199–215.

Stoltzfus, R.J., Chwaya, H.M., Albonico, M., Schulze, K.J., Savioli, L. and Tielsch, J.M. (1997). Serum ferritin, erythrocyte protoporphyrin and hemoglobin are valid indicators of iron status of school children in a malaria-holoendemic population. *The Journal of nutrition*, vol. 127, no. 2, pp. 293–298.

Stryker, D. and Amin, M. (2013). Tanzania national food reserve agency's role in assuring food security. *Associates for International Resources and Development, Arlington, Massachusetts.*

Stuebe, A. (2009). The risks of not breastfeeding for mothers and infants. *Reviews in obstetrics and gynecology*, vol. 2, no. 4, p. 222.

Su, B. and Heshmati, A. (2013). Analysis of the determinants of income and income gap between urban and rural china. *China Economic Policy Review*, vol. 2, no. 01, p. 1350002.

Subramanyam, M.A., Kawachi, I., Berkman, L.F. and Subramanian, S. (2010). Socioeconomic inequalities in childhood undernutrition in india: analyzing trends between 1992 and 2005. *PloS one*, vol. 5, no. 6, p. e11392.

Svensson, V., Ek, A., Forssen, M., Ekbom, K., Cao, Y., Ebrahim, M., Johansson, E., Nero, H., Hagströmer, M., Ekstedt, M. *et al.* (2014). Infant growth is associated with parental education but not with parental adiposity–early stockholm obesity prevention project. *Acta Paediatrica*, vol. 103, no. 4, pp. 418–425.

Swindale, A. and Bilinsky, P. (2006). *Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide*. Food and Nutrition Technical Assistance (FANTA).

Swinnen, J. and Squicciarini, P. (2012). Mixed messages on prices and food security. *Science*, vol. 335, no. 6067, pp. 405–406.

Switkowski, K.M., Jacques, P.F., Must, A., Fleisch, A. and Oken, E. (2019). Associations of protein intake in early childhood with body composition, height, and insulin-like growth factor i in mid-childhood and early adolescence. *The American journal of clinical nutrition*, vol. 109, no. 4, pp. 1154–1163.

Syeda, B., Agho, K., Wilson, L., Maheshwari, G.K. and Raza, M.Q. (2020). Relationship between breastfeeding duration and undernutrition conditions among children aged 0–3 years in pakistan. *International Journal of Pediatrics and Adolescent Medicine*.

Tan, Y.V., Flannagan, C.A., Pool, L.R. and Elliott, M.R. (2018). Accounting for selection bias due to death in estimating the effect of wealth shock on cognition for the health and retirement study. *arXiv preprint arXiv:1812.08855*.

Tang, M., Hendricks, A.E. and Krebs, N.F. (2018). A meat-or dairy-based complementary diet leads to distinct growth patterns in formula-fed infants: a randomized controlled trial. *The American journal of clinical nutrition*, vol. 107, no. 5, pp. 734–742.

Tang, M. and Krebs, N.F. (2014). High protein intake from meat as complementary food increases growth but not adiposity in breastfed infants: a randomized trial. *The American journal of clinical nutrition*, vol. 100, no. 5, pp. 1322–1328.

Tang, M., Sheng, X.-Y., Krebs, N.F. and Hambidge, K.M. (2014). Meat as complementary food for older breastfed infants and toddlers: a randomized, controlled trial in rural china. *Food and Nutrition Bulletin*, vol. 35, no. 4_suppl3, pp. S188–S192.

Tefera, T., Kanampiu, F., De Groote, H., Hellin, J., Mugo, S., Kimenju, S., Beyene, Y., Boddupalli, P.M., Shiferaw, B. and Banziger, M. (2011). The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. *Crop protection*, vol. 30, no. 3, pp. 240–245.

TFNC (2012). Tanzania assessment for scaling up nutrition. Tech. Rep., Tanzania Food and Nutrition Centre (TFNC).

TFNC (2015). Tanzania national nutrition survey 2014. Tech. Rep., United Republic of Tanzania.

TFNC (2019). Tanzania national nutrition survey 2018. Tech. Rep., United Republic of Tanzania.

Thomas, K.J. (2020). Child deaths in the past, their consequences in the present, and mortality conditions in sub-saharan africa. *Proceedings of the National Academy of Sciences*, vol. 117, no. 9, pp. 4453–4455.

Thornton, P., Nelson, G., Mayberry, D. and Herrero, M. (2021). Increases in extreme heat stress in domesticated livestock species during the twenty-first century. *Global Change Biology*.

Thornton, P.K., van de Steeg, J., Notenbaert, A. and Herrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural systems*, vol. 101, no. 3, pp. 113–127.

Tibaingana, A., Kele, T. and Makombe, G. (2018). Storage practices and their bearing on small-holder farmers: Postharvest analysis in uganda. *South African Journal of Agricultural Extension*, vol. 46, no. 2, pp. 45–56.

Tiwari, S. and Zaman, H. (2010). *The impact of economic shocks on global undernourishment*. The World Bank.

Torlesse, H., Kiess, L. and Bloem, M.W. (2003). Association of household rice expenditure with child nutritional status indicates a role for macroeconomic food policy in combating malnutrition. *The Journal of nutrition*, vol. 133, no. 5, pp. 1320–1325.

Tullo, E., Finzi, A. and Guarino, M. (2019). Environmental impact of livestock farming and precision livestock farming as a mitigation strategy. *Science of the total environment*, vol. 650, pp. 2751–2760.

UNICEF *et al.* (2018). Levels and trends in child malnutrition. Tech. Rep., eSocialSciences.

United Nations (2016). Transforming our world: The 2030 agenda for sustainable development. Tech. Rep., United Nations: New York, NY, USA.

URT (2015). Tanzania livestock modernization initiative. Tech. Rep., Ministry of Livestock and Fisheries Development,United Republic of Tanzania.

URT (2016). Multisectoral nutrition action plan (nmnap) from evidence to policy to action july 2016 - june 2021. Tech. Rep., United Republic of Tanzania.

USDA (2018). Grain and feed annual: 2018 tanzania corn, wheat and rice report. Tech. Rep., United States Department of Agriculture.

van Cooten, M.H., Bilal, S.M., Gebremedhin, S. and Spigt, M. (2019). The association between acute malnutrition and water, sanitation, and hygiene among children aged 6–59 months in rural e thiopia. *Maternal & child nutrition*, vol. 15, no. 1, p. e12631.

Van de Poel, E., Hosseinpoor, A.R., Jehu-Appiah, C., Vega, J. and Speybroeck, N. (2007*a*). Malnutrition and the disproportional burden on the poor: the case of ghana. *International journal for equity in health*, vol. 6, no. 1, p. 21.

Van de Poel, E., Hosseinpoor, A.R., Speybroeck, N., Van Ourti, T. and Vega, J. (2008). Socioeconomic inequality in malnutrition in developing countries. *Bulletin of the World Health Organization*, vol. 86, pp. 282–291.

Van de Poel, E., O'Donnell, O. and Van Doorslaer, E. (2007*b*). Are urban children really healthier? evidence from 47 developing countries. *Social science & medicine*, vol. 65, no. 10, pp. 1986–2003.

Van de Poel, E. and Speybroeck, N. (2009). Decomposing malnutrition inequalities between scheduled castes and tribes and the remaining indian population. *Ethnicity & health*, vol. 14, no. 3, pp. 271–287.

VanDerslice, J. and Briscoe, J. (1995). Environmental interventions in developing countries: interactions and their implications. *American journal of epidemiology*, vol. 141, no. 2, pp. 135–144.

Varijakshapanicker, P., Mckune, S., Miller, L., Hendrickx, S., Balehegn, M., Dahl, G.E. and Adesogan, A.T. (2019). Sustainable livestock systems to improve human health, nutrition, and economic status. *Animal Frontiers*, vol. 9, no. 4, pp. 39–50.

Victor, R., Baines, S.K., Agho, K.E. and Dibley, M.J. (2013). Determinants of breastfeeding indicators among children less than 24 months of age in tanzania: a secondary analysis of the 2010 tanzania demographic and health survey. *BMJ open*, vol. 3, no. 1.

Victor, R., Baines, S.K., Agho, K.E. and Dibley, M.J. (2014). Factors associated with inappropriate complementary feeding practices among children aged 6–23 months in t anzania. *Maternal & child nutrition*, vol. 10, no. 4, pp. 545–561.

Victora, C.G., Adair, L., Fall, C., Hallal, P.C., Martorell, R., Richter, L., Sachdev, H.S., Maternal, Group, C.U.S. *et al.* (2008). Maternal and child undernutrition: consequences for adult health and human capital. *The lancet*, vol. 371, no. 9609, pp. 340–357.

Victora, C.G., De Onis, M., Hallal, P.C., Blössner, M. and Shrimpton, R. (2010). Worldwide timing of growth faltering: revisiting implications for interventions. *Pediatrics*, vol. 125, no. 3, pp. e473–e480.

Victora, C.G., Fenn, B., Bryce, J. and Kirkwood, B.R. (2005). Co-coverage of preventive interventions and implications for child-survival strategies: evidence from national surveys. *The Lancet*, vol. 366, no. 9495, pp. 1460–1466.

Victora, C.G., Vaughan, J.P., Barros, F.C., Silva, A.C. and Tomasi, E. (2000). Explaining trends in inequities: evidence from brazilian child health studies. *The Lancet*, vol. 356, no. 9235, pp. 1093–1098.

Wagstaff, A., Doorslaer, v.E. and Watanabe, N. (2001). *On decomposing the causes of health sector inequalities with an application to malnutrition inequalities in Vietnam*. The World Bank.

Wagstaff, A., Paci, P. and Van Doorslaer, E. (1991). On the measurement of inequalities in health. *Social science & medicine*, vol. 33, no. 5, pp. 545–557.

Wagstaff, A. and Watanabe, N. (1999). *Socioeconomic inequalities in child malnutrition in the developing world*. The World Bank.

Wamani, H., Åstrøm, A.N., Peterson, S., Tumwine, J.K. and Tylleskär, T. (2007). Boys are more stunted than girls in sub-saharan africa: a meta-analysis of 16 demographic and health surveys. *BMC pediatrics*, vol. 7, no. 1, p. 17.

Wamani, H., Tylleskär, T., Åstrøm, A.N., Tumwine, J.K. and Peterson, S. (2004). Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural uganda. *International journal for equity in health*, vol. 3, no. 1, p. 9.

Warren, A.M. and Frongillo, E.A. (2017). Mid-level actors and their operating environments for implementing nutrition-sensitive programming in ethiopia. *Global food security*, vol. 13, pp. 66–73.

Waruiru, C., Newton, C., Forster, D., New, L., Winstanley, P., Mwangi, I., Marsh, V. and Winstanley, M. (2004). Control of infectious causes of childhood disability in developing countries.

In: *The infectious etiology of chronic diseases: defining the relationship, enhancing the research, and mitigating the effects: workshop summary*, vol. 8, p. 99. National Academies Press.

Webb, P., Block, S. *et al.* (2003). Nutrition knowledge and parental schooling as inputs to child nutrition in the long and short run. *Nutrition Working Paper*, vol. 3, pp. 1–31.

Weber, M., Grote, V., Closa-Monasterolo, R., Escribano, J., Langhendries, J.-P., Dain, E., Giovannini, M., Verduci, E., Gruszfeld, D., Socha, P. *et al.* (2014). Lower protein content in infant formula reduces bmi and obesity risk at school age: follow-up of a randomized trial. *The American journal of clinical nutrition*, vol. 99, no. 5, pp. 1041–1051.

Weindl, I., Ost, M., Wiedmer, P., Schreiner, M., Neugart, S., Klopsch, R., Kühnhold, H., Kloas, W., Henkel, I.M., Schlüter, O. *et al.* (2020). Sustainable food protein supply reconciling human and ecosystem health: A leibniz position. *Global Food Security*, vol. 25, p. 100367.

West, J.W. (2003). Effects of heat-stress on production in dairy cattle. *Journal of dairy science*, vol. 86, no. 6, pp. 2131–2144.

WHO (2002). Infant and young child nutrition: global strategy on infant and young child feeding. *Report by the Secretariat*.

WHO (2003). *Global strategy for infant and young child feeding*. World Health Organization.

WHO (2006). Who child growth standards based on length/height, weight and age. *Acta paediatrica (Oslo, Norway: 1992). Supplement*, vol. 450, p. 76.

WHO (2013). Unicef/who/the world bank group joint child malnutrition estimates: levels and trends in child malnutrition. Tech. Rep., World Health Organization.

WHO (2014*a*). Global nutrition targets 2025: Stunting policy brief. Tech. Rep., World Health Organization.

WHO (2014*b*). *Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low-and middle-income countries*. World Health Organization.

WHO (2015). Usaid. improving nutrition outcomes with better water, sanitation and hygiene. practical solutions for policies and programme. geneva: Who; 2015.

WHO (2019). *Sanitation and Health: Where to from here?* World Health Organization.

WHO/UNICEF (2015). *Progress on sanitation and drinking water: 2015 update and MDG assessment*. World Health Organization.

Wilson, R.T. and Lewis, J. (2015). The maize value chain in tanzania. Tech. Rep., Food and Agriculture Organization (FAO).

Wodon, Q. and Zaman, H. (2008). *Rising food prices in sub-Saharan Africa: Poverty impact and policy responses*. The World Bank.

Woertz, E., Soler, E., Farrés, O. and Busquets, A. (2014). The impact of food price volatility and food inflation on southern and eastern mediterranean countries.

Woldemichael, A., Kidane, D. and Shimeles, A. (2017). A tax on children? the effects of food price inflation on child health. Tech. Rep., African Development Bank Working Paper Series.

Wolf, J., Prüss-Ustün, A., Cumming, O., Bartram, J., Bonjour, S., Cairncross, S., Clasen, T., Colford Jr, J.M., Curtis, V., De France, J. *et al.* (2014). Systematic review: assessing the impact of drinking water and sanitation on diarrhoeal disease in low-and middle-income settings: systematic review and meta-regression. *Tropical medicine & international health*, vol. 19, no. 8, pp. 928–942.

Wooldridge, J.M. (2015). Control function methods in applied econometrics. *Journal of Human Resources*, vol. 50, no. 2, pp. 420–445.

World Bank (2004). Supply chain development in tanzania. Tech. Rep., The World Bank.

World Bank (2006). *World development report 2006: equity and development*, vol. 28. World Bank Publications.

World Bank (2008). Rising food and fuel prices: Addressing the risks to future generations.

Yalonetzky, G. (2012). A dissimilarity index of multidimensional inequality of opportunity. *The Journal of Economic Inequality*, vol. 10, no. 3, pp. 343–373.

Yamauchi, F. and Larson, D.F. (2019). Long-term impacts of an unanticipated spike in food prices on child growth in indonesia. *World Development*, vol. 113, pp. 330–343.

Yoshida, W.B., Müller, S.S., Carvalho, I., Fabris, V.E., Naresse, L.E. and Maffei, F.H.d.A. (1995). Tensile strength and histological changes of abdominal aorta of malnourished rats. *Cardiovascular Surgery*, vol. 3, no. 4, pp. 437–439.

Zaki, S.A., Chaaban, J., Nasreddine, L. and Chalak, A. (2014). The impact of food price increases on nutrient intake in lebanon. *Agricultural and Food Economics*, vol. 2, no. 1, p. 3.

Zanello, G., Shankar, B. and Poole, N. (2019). Buy or make? agricultural production diversity, markets and dietary diversity in afghanistan. *Food Policy*, p. 101731.

Zere, E. and McIntyre, D. (2003). Inequities in under-five child malnutrition in south africa. *International journal for equity in health*, vol. 2, no. 1, p. 7.

Zereyesus, Y.A., Embaye, W.T., Tsiboe, F. and Amanor-Boadu, V. (2017). Implications of non-farm work to vulnerability to food poverty-recent evidence from northern ghana. *World Development*, vol. 91, pp. 113–124.

Zoch, A. (2015). Life chances and class: Estimating inequality of opportunity for children and adolescents in south africa. *Development Southern Africa*, vol. 32, no. 1, pp. 57–75.

Zongrone, A., Winskell, K. and Menon, P. (2012). Infant and young child feeding practices and child undernutrition in bangladesh: insights from nationally representative data. *Public health nutrition*, vol. 15, no. 9, pp. 1697–1704.

APPENDIX A

STUNTED CHILDREN IN DIFFERENT HAZ AND AGE CATEGORIES

Table A.1: Proportion of Stunted Children in different HAZ categories by age

Year = 2008	Rural					Urban				
age group	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total
6-23mo	214	192	36	3	445	69	64	18	3	154
	48.09	43.15	8.09	0.67	100	44.81	41.56	11.69	1.95	100
	30.75	28.7	28.57	37.5	29.69	38.55	22.46	25.35	42.86	28.41
24-60mo	482	477	90	5	1,054	110	221	53	4	388
	45.73	45.26	8.54	0.47	100	28.35	56.96	13.66	1.03	100
	69.25	71.3	71.43	62.5	70.31	61.45	77.54	74.65	57.14	71.59
Total	696	669	126	8	1,499	179	285	71	7	542
	46.43	44.63	8.41	0.53	100	33.03	52.58	13.1	1.29	100
	100	100	100	100	100	100	100	100	100	100
Year = 2010										
	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total
	249	285	73	11	618	50	88	35	5	178
6-23mo	40.29	46.12	11.81	1.78	100	28.09	49.44	19.66	2.81	100
	33.74	29.66	43.2	61.11	32.77	35.97	29.24	46.05	71.43	34.03
	489	676	96	7	1,268	89	213	41	2	345
24-60mo	38.56	53.31	7.57	0.55	100	25.8	61.74	11.88	0.58	100
	66.26	70.34	56.8	38.89	67.23	64.03	70.76	53.95	28.57	65.97
	738	961	169	18	1,886	139	301	76	7	523
Total	39.13	50.95	8.96	0.95	100	26.58	57.55	14.53	1.34	100
	100	100	100	100	100	100	100	100	100	100
Year = 2012										
	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total	HAZ<-2	-2<=HAZ<0	0<HAZ<2	HAZ>2	Total
	310	278	85	16	689	85	111	38	9	243
6-23mo	44.99	40.35	12.34	2.32	100	34.98	45.68	15.64	3.7	100
	34.52	24.98	42.93	76.19	30.9	39.91	30.25	37.62	81.82	35.12
	588	835	113	5	1,541	128	256	63	2	449
24-60mo	38.16	54.19	7.33	0.32	100	28.51	57.02	14.03	0.45	100
	65.48	75.02	57.07	23.81	69.1	60.09	69.75	62.38	18.18	64.88
	898	1,113	198	21	2,230	213	367	101	11	692
Total	40.27	49.91	8.88	0.94	100	30.78	53.03	14.6	1.59	100
	100	100	100	100	100	100	100	100	100	100

APPENDIX B

CORRELATION ANALYSIS AND DIFFERENCE IN MEAN

Table B.1: Correlation Between Constructed Prices and Community Prices

	Maize Price (Computed)	Maize Price (Community)
Maize Price (Computed)	1.000	
Maize Price(Community)	0.744	1.000

Table B.2: Changes in HDDS, Revenue and Quantity of Maize Sold (Averages)

Year		2008	2012	diff(p-value)
nonproducer	HDDS	9.3	8.9	0.0015
producer		7.3	7.5	0.0139
Maize	Quantity Sold	454.2	781.9	0.0016
	Revenue	102211.9	275939.6	0.0000

Table B.3: First-stage regression summary statistics

Variable	R-sq.	Adjusted R-sq.	Partial R-sq.	F(1,6702)	Prob > F
producer	0.4141	0.4132	0.0147	99.6856	0.0000

Critical Values	# of endogenous regressors: 1
Ho: Instruments are weak	# of excluded instruments: 1
	5% 10% 20% 30%
2SLS relative bias	(not available)
	10% 15% 20% 25%
2SLS Size of nominal 5% Wald test	16.38 8.96 6.66 5.53
LIML Size of nominal 5% Wald test	16.38 8.96 6.66 5.53

APPENDIX C

CHOW TEST FOR SEASONALITY

Table C.1: Chow Test

	df	F	P>F
Season	1	0.21	0.6465
Season X Maize Price	1	0.39	0.5314
Season X Producer X Maize	1	1.07	0.3017
Season X Consumption(log)	1	0.25	0.6146
Season X Household Size	1	1.77	0.1828
Season X Education	1	0.57	0.4491
Season X Head Age	1	0.63	0.4275
Season X producer	1	1.1	0.2935
Season X Male headed	1	0.04	0.84
Overall	9	1.54	0.1284
Denominator	6827		

APPENDIX D

OLS REGRESSIONS AND ASSESSMENT OF IV QUALITY

Table D.1: Assessment of Validity of the Instruments

Test		Own mixed ruminant	Own meat ruminant	Milk	Meat
Endogeneity	Durbin (score) chi2(1)	7.45 (0.006)	7.235(0.007)	.065 (0.798)	.019 (0.890)
	Wu-Hausman F(1,5228)	7.43(0.006)	7.225(0.007)	.065 (0.780)	.0189 (0.891)
Specification tests for the Instruments(Tsetse fly and Temperature Variations					
Instruments are weak	Cragg-Donald Wald F statistic)	28.11(0.000)			
Underidentification test	Chi-sq(1)	(p-value = 0.000)			
overidentification test	Sargan statistic	(p-value = 0.000)			

Table D.2: First Stage Regression Results

	(1) Mixed Ruminant	(2) Meat Ruminant
Temperature variation	-0.016***	
	(0.005)	
Tsetse fly Present	-0.304***	-0.176**
	(0.067)	(0.084)
Cereal	0.049***	0.003
	(0.017)	(0.021)
Wealth Index	-0.114***	-0.181***
	(0.020)	(0.029)
Primary School(Mother)	0.631***	0.616***
	(0.073)	(0.087)
Secondary and above(Mother)	0.111	0.643***
	(0.111)	(0.157)
Child=male	0.026	-0.045
	(0.064)	(0.078)
Rural	0.781***	1.332***
	(0.095)	(0.169)
Female Head	-0.724***	-0.870***
	(0.085)	(0.114)
Dependency Ratio	-0.888***	0.303
	(0.258)	(0.318)
NDVI	0.001	0.002
	(0.002)	(0.003)
aglo-climatic zone (1=bimodal)	-0.414***	-0.796***
	(0.080)	(0.092)
Sanitation	-0.492***	-0.358**
	(0.099)	(0.146)
Clean Water	-0.275***	0.028
	(0.077)	(0.105)
Distance to Market	0.396***	0.343***
	(0.037)	(0.052)
Head Age	0.032***	0.036***
	(0.003)	(0.003)
Distance to Hospital	0.040*	0.035
	(0.023)	(0.028)
Constant	-2.737***	-4.707***
	(0.321)	(0.419)
Observations	4886	4886

Notes: The standard errors (in parentheses) are clustered at household level
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

APPENDIX E

FIRST STAGE REGRESSION RESULTS

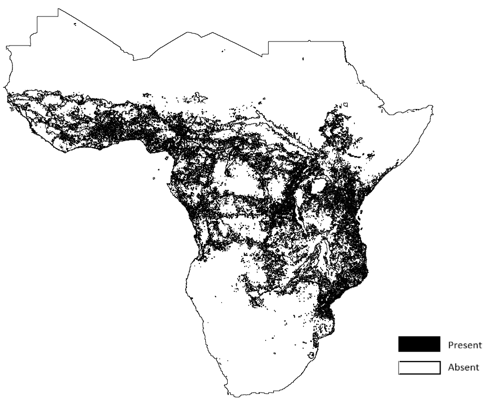


Figure E.1: Distribution of Tsetse fly in Africa

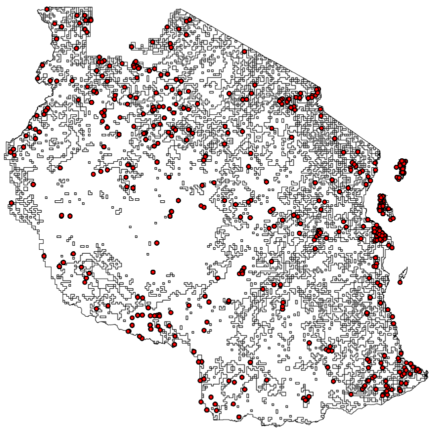


Figure E.2: Tsetse fly and Study Sample Distributions in Tanzania

Table E.1: OLS Results for HAZ: Meat Ruminant Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60mo
Meat X Own Meat Ruminants	0.023	0.137	0.046	0.001	-0.029	0.007
	(0.021)	(0.091)	(0.066)	(0.050)	(0.041)	(0.022)
Meat	0.000	-0.041	-0.014	0.002	-0.012	0.021**
	(0.009)	(0.036)	(0.038)	(0.020)	(0.016)	(0.010)
Cereal	0.025**	-0.082	-0.002	0.055*	0.031*	0.036**
	(0.012)	(0.051)	(0.044)	(0.028)	(0.017)	(0.015)
Wealth Index	0.079***	0.082*	0.080**	0.097***	0.086***	0.068***
	(0.012)	(0.049)	(0.039)	(0.024)	(0.020)	(0.011)
Primary School(Mother)	0.102**	0.225	-0.173	0.020	0.164*	0.101**
	(0.050)	(0.200)	(0.181)	(0.089)	(0.085)	(0.049)
Secondary and above(Mother)	0.223***	0.269	-0.145	0.179	0.245*	0.264***
	(0.077)	(0.271)	(0.277)	(0.165)	(0.132)	(0.073)
Child=male	0.183***	0.203	0.297**	0.312***	0.172***	0.070
	(0.048)	(0.177)	(0.145)	(0.088)	(0.065)	(0.048)
Rural	-0.174***	0.049	-0.836***	0.066	-0.097	-0.071
	(0.062)	(0.289)	(0.223)	(0.153)	(0.108)	(0.078)
Female Head	0.078	0.016	0.227	0.143	0.059	0.071
	(0.059)	(0.275)	(0.191)	(0.121)	(0.101)	(0.065)
Dependency Ratio	-0.029	1.322*	-0.247	0.011	-0.351	-0.306*
	(0.167)	(0.781)	(0.653)	(0.366)	(0.300)	(0.184)
NDVI	-0.001	0.009*	-0.001	-0.001	-0.007***	-0.003*
	(0.001)	(0.005)	(0.006)	(0.003)	(0.002)	(0.002)
agloclimatic zone (1=bimodal)	0.008	-0.135	0.034	0.232*	-0.046	0.022
	(0.055)	(0.225)	(0.175)	(0.119)	(0.090)	(0.069)
Sanitation	0.094	-0.131	0.009	0.182	0.115	0.193***
	(0.069)	(0.280)	(0.225)	(0.153)	(0.120)	(0.066)
Clean Water	0.001	0.264	-0.150	-0.039	-0.001	-0.033
	(0.051)	(0.216)	(0.204)	(0.107)	(0.092)	(0.054)
Distance to Market	0.052*	-0.094	0.148*	0.051	0.064	0.020
	(0.029)	(0.092)	(0.089)	(0.047)	(0.044)	(0.026)
Head Age	-0.002	0.004	0.002	0.001	-0.001	-0.000
	(0.002)	(0.007)	(0.007)	(0.004)	(0.003)	(0.002)
Distance to Hospital	0.024	-0.042	0.052	0.034	0.018	0.042**
	(0.017)	(0.059)	(0.050)	(0.034)	(0.026)	(0.021)
Own Meat Ruminants	0.191*	-0.624	-0.009	0.275	0.586***	0.308**
	(0.115)	(0.532)	(0.418)	(0.260)	(0.212)	(0.133)
Constant	-2.000***	-0.507	-0.933	-3.308***	-2.061***	-1.951***
	(0.203)	(0.730)	(0.795)	(0.499)	(0.367)	(0.259)
Observations	4886	414	496	952	1013	2011
N_clust	4640	414	496	952	1013	2011

Notes: All specifications are controlled for survey year and community fixed effects. The standard errors (in parentheses) are clustered at household level
* p<0.10, ** p<0.05, *** p<0.01.

APPENDIX F

SECOND STAGES REGRESSION RESULTS

Table F.1: Second Stage Control function regression results for HAZ: Mixed Ruminants Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60
Milk	0.007	-0.030	0.019	0.043*	0.004	0.006
	(0.012)	(0.044)	(0.040)	(0.026)	(0.018)	(0.013)
Meat	-0.005	-0.015	-0.027	-0.002	-0.018	0.015
	(0.012)	(0.039)	(0.040)	(0.025)	(0.019)	(0.013)
Milk X Own Mixed Ruminant	0.036**	-0.019	0.063	-0.031	0.050*	0.044**
	(0.016)	(0.064)	(0.059)	(0.037)	(0.027)	(0.019)
Meat X Own Mixed Ruminant	0.030*	-0.013	0.075	0.004	0.018	0.024
	(0.018)	(0.068)	(0.062)	(0.037)	(0.032)	(0.020)
Cereal	0.028**	-0.084	-0.001	0.052*	0.038**	0.043***
	(0.013)	(0.051)	(0.040)	(0.031)	(0.017)	(0.014)
Child=male	0.181***	0.182	0.298**	0.317***	0.179***	0.069
	(0.043)	(0.175)	(0.146)	(0.078)	(0.066)	(0.053)
Wealth Index	0.067***	0.117	0.096	0.077**	0.078***	0.053***
	(0.014)	(0.079)	(0.061)	(0.033)	(0.025)	(0.014)
Head Age	-0.000	-0.004	-0.003	0.000	0.000	0.003
	(0.003)	(0.015)	(0.010)	(0.008)	(0.005)	(0.003)
Female Head	0.048	0.196	0.327	0.133	0.049	0.008
	(0.081)	(0.461)	(0.311)	(0.227)	(0.126)	(0.094)
Dependency Ratio	-0.019	1.124	-0.239	-0.093	-0.320	-0.269
	(0.189)	(0.776)	(0.600)	(0.410)	(0.307)	(0.189)
Primary School(Mother)	0.104*	0.183	-0.288	0.001	0.163	0.126*
	(0.056)	(0.260)	(0.246)	(0.128)	(0.117)	(0.066)
Secondary and above(Mother)	0.227***	0.211	-0.328	0.152	0.252*	0.293***

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	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60
	(0.077)	(0.317)	(0.300)	(0.185)	(0.145)	(0.081)
Sanitation	0.074	-0.099	-0.071	0.203	0.085	0.187**
	(0.062)	(0.283)	(0.221)	(0.154)	(0.127)	(0.075)
Clean Water	-0.030	0.338	-0.195	-0.086	-0.049	-0.060
	(0.049)	(0.207)	(0.173)	(0.121)	(0.088)	(0.057)
Distance to Hospital	0.031**	-0.058	0.050	0.042	0.027	0.052***
	(0.015)	(0.060)	(0.052)	(0.032)	(0.026)	(0.018)
Rural	-0.097	-0.163	-1.015**	0.124	-0.038	0.028
	(0.085)	(0.523)	(0.420)	(0.223)	(0.162)	(0.115)
agloclimatic zone (1=bimodal)	-0.042	0.015	0.138	0.203	-0.101	-0.070
	(0.073)	(0.340)	(0.310)	(0.175)	(0.125)	(0.096)
NDVI	0.000	0.009*	0.001	-0.001	-0.006***	-0.002
	(0.002)	(0.005)	(0.005)	(0.003)	(0.002)	(0.002)
HH distance to Major Road	0.000	0.001	0.004	-0.001	0.001	0.000
	(0.001)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)
Own Mixed Ruminant	-0.124	0.971	0.506	0.258	0.060	-0.346
	(0.293)	(1.713)	(1.477)	(0.855)	(0.548)	(0.348)
Residual	0.241	-0.201	-0.535	0.157	0.144	0.263
	(0.226)	(1.349)	(1.111)	(0.597)	(0.390)	(0.239)
Residual X Mixed Ownership	-0.315**	-0.110	-0.047	-0.155	-0.289	-0.216
	(0.143)	(0.739)	(0.642)	(0.335)	(0.237)	(0.148)
Constant	-1.870***	-0.636	-0.534	-3.093***	-1.957***	-1.962***
	(0.236)	(0.687)	(0.781)	(0.432)	(0.367)	(0.262)
Observations	4870	414	493	948	1009	2006
N_clust	4640	414	493	940	1001	2001

All specifications are controlled for survey year, community fixed effects. The standard errors (in parentheses) are clustered at household level * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table F.2: Second Stage Control function regression results for HAZ: Meat Ruminants Ownership

	(1) Full Model	(2) 0-5mo	(3) 6-11mo	(4) 12-23mo	(5) 24-35mo	(6) 36-60mo
Meat X Own Meat Ruminants	0.023	0.123	0.044	0.004	-0.030	0.007
	(0.019)	(0.096)	(0.081)	(0.055)	(0.040)	(0.025)
Meat	-0.000	-0.041	-0.011	0.000	-0.012	0.021*
	(0.009)	(0.036)	(0.036)	(0.021)	(0.016)	(0.011)
Residual	-0.130	-0.193	0.137	-0.293	0.031	-0.056
	(0.149)	(0.450)	(0.501)	(0.359)	(0.266)	(0.186)
Cereal	0.023*	-0.082	-0.008	0.053*	0.031*	0.036***
	(0.013)	(0.051)	(0.039)	(0.030)	(0.017)	(0.013)
Wealth Index	0.080***	0.084	0.085**	0.097***	0.085***	0.068***
	(0.011)	(0.052)	(0.041)	(0.023)	(0.021)	(0.013)
Primary School(Mother)	0.096**	0.204	-0.188	0.015	0.165*	0.101*
	(0.048)	(0.211)	(0.194)	(0.105)	(0.087)	(0.057)
Secondary and above(Mother)	0.214***	0.248	-0.194	0.175	0.247*	0.266***
	(0.076)	(0.282)	(0.251)	(0.174)	(0.131)	(0.084)
Child=male	0.181***	0.197	0.295**	0.318***	0.172***	0.068
	(0.044)	(0.178)	(0.147)	(0.078)	(0.065)	(0.052)
Rural	-0.194***	0.023	-0.852***	0.035	-0.090	-0.075
	(0.063)	(0.300)	(0.247)	(0.129)	(0.115)	(0.085)
Female Head	0.091*	0.043	0.246	0.154	0.060	0.072
	(0.055)	(0.276)	(0.177)	(0.139)	(0.105)	(0.068)
Dependency Ratio	-0.043	1.295	-0.259	-0.064	-0.357	-0.294
	(0.190)	(0.792)	(0.592)	(0.395)	(0.302)	(0.186)
NDVI	-0.001	0.009*	-0.000	-0.001	-0.007***	-0.003*
	(0.002)	(0.005)	(0.005)	(0.004)	(0.002)	(0.002)
agloclimatic zone (1=bimodal)	0.047	-0.078	0.021	0.276*	-0.044	0.034
	(0.072)	(0.268)	(0.246)	(0.159)	(0.099)	(0.088)

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	(1)	(2)	(3)	(4)	(5)	(6)
	Full Model	0-5mo	6-11mo	12-23mo	24-35mo	36-60mo
Sanitation	0.095	-0.135	-0.086	0.209	0.113	0.204***
	(0.062)	(0.279)	(0.211)	(0.139)	(0.121)	(0.075)
Clean Water	0.007	0.272	-0.135	-0.035	0.000	-0.030
	(0.049)	(0.217)	(0.177)	(0.120)	(0.093)	(0.057)
Distance to Market	0.051*	-0.097	0.136	0.052	0.063	0.021
	(0.028)	(0.092)	(0.099)	(0.050)	(0.044)	(0.031)
Head Age	-0.002	0.003	0.002	0.000	-0.001	-0.000
	(0.002)	(0.007)	(0.006)	(0.004)	(0.004)	(0.002)
Distance to Hospital	0.024	-0.042	0.049	0.034	0.017	0.042**
	(0.015)	(0.060)	(0.054)	(0.032)	(0.026)	(0.018)
Own Meat Ruminants	0.342*	-0.253	0.242	0.256	0.640**	0.310
	(0.202)	(0.826)	(0.609)	(0.398)	(0.292)	(0.226)
Residual X Own Meat Ruminants	0.038	-0.029	-0.394	0.386	-0.090	0.073
	(0.143)	(0.478)	(0.548)	(0.384)	(0.279)	(0.165)
Constant	-1.989***	-0.453	-0.811	-3.287***	-2.046***	-1.978***
	(0.237)	(0.737)	(0.720)	(0.429)	(0.370)	(0.269)
Observations	4870	414	493	948	1009	2006
N_clust	4640	414	493	940	1001	2001

All specifications are controlled for survey year, community fixed effects. The standard errors (in parentheses) are clustered at household level * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

APPENDIX G

SHAPLEY DECOMPOSITION BY PRODUCERS AND NON PRODUCERS

Table G.1: Shapley Decomposition of Inequality of Opportunity in Stunting

	Full sample		Maize Producers		Maize non-Producers	
Variable	Value	percentage	Value	percentage	Value	percentage
Maize price	0.003	4.44%	0.003	3.21%	0.035	22.67%
Consumption	0.010	13.80%	0.014	17.67%	0.001	0.76%
Breastfeeding	0.002	3.29%	0.005	5.85%	0.008	5.37%
Vaccination	0.001	1.75%	0.000	0.30%	0.004	2.65%
Mother education & Age at birth	0.006	8.57%	0.010	11.85%	0.038	24.64%
WASH	0.030	40.41%	0.029	35.81%	0.002	1.50%
Health care	0.001	0.69%	0.001	1.27%	0.005	3.07%
Household size	0.002	2.16%	0.003	3.13%	0.005	2.89%
Child age	0.014	19.64%	0.011	13.58%	0.019	12.45%
Child Gender	0.004	5.24%	0.006	7.32%	0.037	23.94%
TOTAL	0.074	100%	0.081	100%	0.156	100%