STOCKHOLM SCHOOL OF ECONOMICS
Department of Economics
5350 Master's thesis in economics
Academic year 2015–2016

Rainfall Shocks and the Effects on Child Anthropometric Measures in Rural Ethiopia

Empirical Evidence of Gender Bias

Margot Kurfess (40791) and Björn Wisaeus (22122)

Abstract

This paper seeks to estimate the effects of rainfall fluctuations on the anthropometric health of children under the age of five in rural Ethiopia. Our interest is to study whether boys and girls experience differential treatment in the intra-household allocation of resources towards health following rainfall shocks in the previous rainy season and whether or not children of different ages are especially sensitive. We investigate how these deviations in rainfall affect children's anthropometric measures, as measured by z-scores for weight-for-height, weight-for-age, and height-for-age. Using survey data from the Demographic Health Survey and rainfall data from NASA, this paper seeks to add to the inconclusive literature on investment in children's health by gender in Sub-Saharan Africa. Ethiopia provides a particularly suitable setting for linking rainfall to income due to its high level of agricultural dependence and households' low capabilities for consumption smoothing. We find that children under the age of five benefit in weight-for-age and height-for-age following a positive rainfall shock, but that female children fare worse in terms of weight-for-age compared to their male counterparts. When looking at age cohorts, newborns are found to be especially sensitive to both wet and dry shocks. While newborn boys benefit in terms of weight-for-age and height-for-age following a positive shock, newborn girls have significantly worse outcomes for the same measures in comparison. Newborns are found to benefit in general from negative rainfall shocks.

Keywords: Rainfall, Gender, Income variability, Sub-Saharan Africa

JEL Classification: D13, J16, I14

Supervisor: Martina Björkman-Nyqvist
Date submitted: May 16, 2016
Date examined: May 25, 2016
Discussants: Moritz-Christian Meyer & Ruben van den Hengel
Examiner: Maria Perrotta Berlin

Acknowledgements

We are grateful to our supervisor, Martina Björkman-Nyqvist for her valuable feedback, enriching discussions, and continuous support throughout the thesis process. We would also like to thank Evelina Bonnier for her invaluable guidance on handling rainfall data, Per-Olov Edlund and Roman Bobilev for their advice on the econometric specification, My Hedlin for discussions regarding the data set, and Nils Westling for imparting his wisdom on using QGIS. All errors are our own.

Contents

1 Introduction **1**

2 Previous research **2**

3 Purpose and research questions **4**

3.1 Purpose 4

3.2 Research questions 5

4 Background **6**

4.1 Demographics and economy 6

4.2 Agriculture and climate 7

4.3 Factors for gender bias 8

5 Conceptual framework **9**

5.1 Health capital production function 9

5.2 Rainfall as an income channel 10

5.3 Rainfall and the disease environment 11

5.4 Expected outcomes 11

6 Data **12**

6.1 DHS data 12

6.2 Rainfall data 13

6.3 Forming the complete data set 15

7 Empirical approach **15**

7.1 Empirical specifications 15

7.2 Variables 17

8 Results **18**

8.1 Descriptive statistics 18

8.2 Effects on anthropometric measures 20

8.3 Effects on anthropometric measures by age 22

8.4 Rainfall shocks and breastfeeding 26

8.5 Summary of results 26

9 Robustness checks **28**

9.1 Rainfall shocks and the disease environment 28

10 Discussion, limitations, and conclusion **30**

10.1 Discussion of results 30

10.2 Limitations of our study and areas for future research 32

10.3 Conclusion and policy implications 33

References **34**

Appendix **38**

List of Figures

6.1 Cluster locations from three DHS surveys: 2000, 2005, and 2010-11 14

8.1 Anthropometric z-scores by gender 19

a Weight-for-height by gender 19

b Weight-for-age by gender 19

c Height-for-age by gender 19

A1 Elevation map of Ethiopia 38

List of Tables

6.1 Observations by survey year 13

8.1 Summary statistics 19

8.2 Anthropometric measures 21

8.3 Weight-for-height by age 23

8.4 Weight-for-age by age 24

8.5 Height-for-age by age 25

8.6 Months of breastfeeding 27

9.1 Probability of diarrhea and fever (logit) 29

1 Introduction

Children represent a crucial link between current and future generations and improving care for young children has been recognized as a fundamental part of achieving the UN Millennium Development Goals (WHO, 2016). Many children worldwide are under-nourished, which can be further exacerbated in times of economic hardship due to weather fluctuations. Extreme weather often disproportionately affects the most vulnerable children and can also illuminate underlying gender bias in some contexts. Our study seeks to identify particularly vulnerable groups of children under the age of five in rural Ethiopia in response to rainfall shocks by exploring two key dimensions, the gender and age of the children.

Rainfall and its variability have been shown to significantly affect households living in developing countries. Ferreira and Schady (2009), for example, find that droughts, recessions, and economic downturns have negative effects on child health and schooling in poorer countries. Wang et al. (2009) study the effect of extreme weather in Sub-Saharan Africa on diarrhea, malnutrition, and mortality rate and find that that extreme precipitation and temperatures have significant impacts on the incidence of diarrhea and malnutrition among children under the age of three in Sub-Saharan Africa. Rainfall variation is especially relevant for people dependent on agricultural production and in certain contexts can be regarded as a suitable proxy for income. Shocks to income are often used to get a better understanding of intra-household resource allocation and are particularly relevant in identifying evidence of gender bias in parental investment.

There is evidence to suggest that differential treatment of girls and boys is more pronounced when households face extreme circumstances due to weather and income shocks (Duflo, 2012; Rose, 1999). In their study on aggregate income shocks and infant mortality in developing countries, Baird et al. (2011) find that female infant mortality is more sensitive than male infant mortality to economic fluctuations, especially during negative shocks to GDP. Young girls are a particularly vulnerable group, as families often disproportionately sacrifice their welfare when faced with resource constraints with the most extreme cases leading to increased rates of female mortality in some contexts (Sen, 1990). While infant mortality is generally lower for girls in Sub-Saharan Africa (Anderson and Ray, 2010), there is some evidence that in certain contexts this phenomenon reverses in response to rainfall shocks (Flatø and Kotsadam, 2014).

Much of the literature has focused on mortality, but less is known about the health of the children that survive. Child health and learning more about its determinants is an important area to study as early life health has been shown to impact many outcomes later in life, such as schooling and labor outcomes (Strauss and Thomas, 1998; Hoddinott and Kinsey, 2001). Early childhood stunting and living in absolute poverty have both been shown to be indicators of poor development and are closely associated with poor cognitive and educational performance in children (Grantham-McGregor et al., 2007). Furthermore, Grantham-McGregor et al. (2007) conclude that these vulnerable groups of children are more likely to do poorly in school, have lower incomes, higher fertility rates, and provide poor care for their children, thus contributing to the inter-generational transmission of poverty. Hoddinott and Kinsey (2001) bring attention to the epidemiological evidence that stature by age three is strongly correlated with attained body size at adulthood (Martorell, 1995, 1999). Stunted body size at adulthood has consequently been shown to be associated with numerous health disadvantages. Poor adult height is correlated with lower earnings and productivity, poorer cognitive outcomes, and premature mortality (Hoddinott and Kinsey, 2001).

The purpose of our study is to contribute to the inconclusive body of literature surrounding gender bias in Sub-Saharan Africa in response to economic fluctuations and we direct our attention towards children that are alive by studying the anthropometric measures (weight-for-height, weight-for-age, and height-for-age) of children under the age of five in rural Ethiopia. Our two research questions aim to determine: i) if there exist any marginal gender effects of positive and negative shocks for children under the age five, and ii) if there are certain age groups that are particularly sensitive to shocks while also identifying any additional gender effects. Using purely exogenous rainfall shocks in rural Ethiopia enables us to explore the differences in child health by gender on a household level and to contribute to the discussion on intra-household resource allocation. There is room for contribution to the topic to better understand the complexity of how rainfall shocks affect child anthropometric measures by gender. To our knowledge, this is the first attempt to conduct an individual-level study on the health of children living in rural areas in Ethiopia.

The remainder of this paper is organized in the following way. In section 2, we will provide an overview of previous research surrounding our topic of study. Following this, we will further elaborate on the purpose and outline the two research questions of our study in section 3. The relevant aspects of Ethiopia's demographics, economy, agriculture, and climate, as well as societal factors that may give reason for household gender bias will be considered in section 4. We will then root our study in a conceptual framework in section 5 and discuss expected outcomes. The data used for this study and the process of creating the data set will be described in section 6, followed by the empirical approach in section 7. Results will be presented in section 8, followed by additional robustness checks in section 9. Finally, a discussion of the results, limitations of our study and suggestions for future research, and concluding remarks including policy implications of the study will be treated in section 10.

2 Previous research

Many studies have exploited the truly exogenous nature of weather to study its effects across a vast range of topics, including child health outcomes. Rainfall variation, in particular, has been been used widely to study topics including: child health measures (Wang et al., 2009; Hoddinott and Kinsey, 2001; Bengtsson, 2010; Jensen, 2000; Rabassa et al., 2014), infant mortality (Rose, 1999; Anderson and Ray, 2010; Flatø and Kotsadam, 2014), education (Björkman-Nyqvist, 2013), violence (Miguel, 2005), conflict (Bonnier et al., 2015), and even voting (Cole et al., 2012).

Authors such as Kudamatsu et al. (2012) and Wang et al. (2009) have used weather variation to study health effects on a macro level. Kudamatsu et al. (2012) use climate data and data from the Demographic and Health Survey (DHS) from 28 African countries to estimate how temperature and rainfall fluctuations affect infant mortality and find that infants are more likely to die when exposed to longer malaria spells in regions prone to malaria and to droughts in arid areas when in utero. In their study on 19 Sub-Saharan African countries, Wang et al. (2009) discuss the ramifications of rainfall events on child health. The authors quantify the impact of extreme rainfall and temperature events on the incidence of diarrhea, malnutrition, and mortality in young children. They specifically use two anthropometric indicators to measure malnutrition: weight-for-height (wasting) and height-for-age (stunting) and find that extreme weather events have a significant impact on diarrheal disease and the incidence of weight-for-height malnutrition.

There are a number of studies that suggest that differential treatment of girls and boys is more pronounced when households face extreme circumstances due to, for example, weather and income shocks (Duflo, 2012; Rose, 1999; Baird et al., 2011). Many authors have explored the relationship between weather shocks and child outcomes by gender, with differing results.

With regard to infant mortality, there are a number of studies that use rainfall shocks as a determinant for child survival in a developing context. Infant mortality is the most extreme result of poor childhood health and is, therefore, particularly relevant for studies on child health measures. In India, Rose (1999) looks at rainfall on excess female mortality and finds that increased rainfall increases the probability that a girl will survive. Rose (1999) further specifies these findings by separating landed and landless households and finds that the effect is most pronounced for landless households.

Despite infant mortality on the whole for Sub-Saharan Africa is lower for girls (Anderson and Ray, 2010), a closer look into economic and weather fluctuations elicits evidence of gender bias. While girls start off with an advantage in terms of infant mortality rates, Baird et al. (2011) find striking results in their study of 59 developing countries using per capita GDP and infant mortality data. The authors find that the mortality of girls is much more sensitive to changes in economic circumstances than that of boys. Their results indicate that a one log-unit change in per capita GDP changes the mortality of boys by approximately 28 percent, while it changes that of girls by approximately 77 percent. Using DHS data on mortality and fertility preferences to investigate how rainfall affects child mortality, Flatø and Kotsadam (2014) find evidence that boys in Sub-Saharan Africa may be treated favorably compared to girls. The authors find a substantial gender bias favoring boys following droughts, but that the difference is only significant in areas where there is a strong stated fertility preference for sons, where fertility desires are low and where there are low levels of female employment.[1]

While some authors find evidence of gender bias in response to economic fluctuations in Sub-Saharan Africa, there are some studies that do not find consistent evidence, contributing to the lack of consensus surrounding the topic. Jensen (2000) looks at rainfall on weight-for-height and educational outcomes in Cote d'Ivoire and finds that school enrollment rates decline by between one-third and one-half while and malnutrition doubles following an adverse rainfall shock (defined as being at least one standard deviation below the historical mean), but does not find significant differences by gender.

There have also been a number of studies devoted towards studying if children of different ages are affected differently. In a review, Martorell (1999) finds that children are vulnerable to malnutrition in utero, but are shielded against malnutrition right after birth if breastfed. After three to six months of age, malnutrition once again increases the faltering of children's growth rates. From the age of three, children seem more resistant to these shocks. Hoddinott and Kinsey (2001) examine the impact of the 1994-96 drought in Zimbabwe on the growth rates of children aged 12-60 months, with particular attention to children aged 12-24 months. Using a panel data set of households in rural Zimbabwe, the authors find that children aged 12-24 months lose 1.5-2 cm of growth following a drought, but they do not find effects for children aged 24-60 months. Bengtsson (2010) uses time-series of rainfall to estimate the effects on children's body weight by gender in rural Tanzania and finds that female children are particularly vulnerable to weather-induced changes in rural production. The results show that the income elasticity of body weight is highest among female children up to ten years old and lowest among adolescents and young male adults.[2]

There are two channels through which the negative effects due to negative rainfall shocks

[1] Stated fertility preference variables are created using responses about ideal gender makeup of children from the DHS survey questionnaires.

[2] The results are significant for the reduced form estimates and show that a 10% decrease in income reduces the body weight of female children about 0.4 kg while it only decreases 0.2 kg for male children.

can be manifested: through biological consequences and/or through parental behavior. From a biological perspective, there is some debate as to whether or not boys and girls are disproportionately affected by the disease environment at a young age. On the other hand, differences in health outcomes can also be due to the way parents allocate resources to their children.

Many authors who use rainfall variation as a key independent variable utilize robustness checks to further strengthen the link between rainfall and income and to disentangle potential health effects arising from the disease environment. Rose (1999) controls for this hypothesis by dropping observations who have experienced flooding and does not find support for the biological argument. Björkman-Nyqvist (2013) also discusses this possible explanation in her study on the effects of rainfall shocks on school enrollment in Uganda where she finds that girls are adversely affected by negative rainfall shocks. In order to control for diseases affecting boys and girls differently, Björkman-Nyqvist (2013) compares the number of days that boys and girls reported being sick in periods of rainfall shocks and, similarly, does not find support for the biological explanation for different outcomes due to resilience to rainfall-induced diseases.

Rabassa et al. (2014) examine the effects of weather shocks using rainfall on children's anthropometric measures in Nigeria using the Demographic and Health Survey. They find that rainfall shocks have a statistically significant and robust impact on child health using both weight-for-height and height-for-age as outcome variables. The authors also investigate the role of the disease environment in health outcomes by estimating the effects of rainfall shocks on the incidence of diarrhea, finding that higher-than-normal rains significantly increase the incidence of diarrhea. In addition, they also include current year's rainfall shock in their econometric specification, which the authors argue is linked to the disease environment and not the income channel, as last year's rainfall is arguably the most relevant variable for income in agriculturally dependent areas. Finally, the authors test if the shocks affect boys and girls differently and they conclude that there is no gender-based discrimination in intra-household health resource allocation.

While many authors find evidence for differential treatment between boys and girls in response to weather fluctuations in Sub-Saharan Africa, some test for gender bias and do not find any evidence for it. The topic is far from resolved and differs greatly depending on the context, providing a basis for further investigating potential differences in health outcomes by gender, which may be attributed to differential treatment within the household.

3 Purpose and research questions

In this section, we will specify our purpose in terms of how it fits into the existing literature and outline our two main research questions.

3.1 Purpose

From the existing literature, it appears that there may be more than meets the eye when it comes to gender bias and the intra-household allocation of resources in Sub-Saharan Africa. When families are faced with extreme weather events and their livelihoods are affected through the impact on resources, many previous studies find significant changes in health effects. It has been shown that those affected by rainfall shocks significantly differ across a range of health outcomes when compared to those who have not experienced significant changes in rainfall in general in Sub-Saharan Africa (Kudamatsu et al., 2012; Wang et al., 2009; Rabassa et al., 2014; Jensen, 2000). It has also been shown that anthropometric measures and infant mortality may systematically differ by gender in response to rainfall shocks as evidenced by a number of studies, even when these metrics do not show evidence of gender bias against girls at the baseline (Flatø and Kotsadam, 2014; Bengtsson, 2010; Baird et al., 2011). Another dimension which has been shown to identify groups particularly sensitive to shocks is age. Research suggests that age may also play a role in the sensitivity of children to rainfall shocks (Hoddinott and Kinsey, 2001; Martorell, 1995, 1999).

The purpose of our study is to explore both dimensions of gender and age in the hopes of shedding light into gender bias in the allocation of resources within households in Sub-Saharan African when families are faced with rainfall shocks. We aim to do so by examining the differing effects between girls and boys under the age of five in rural Ethiopia in terms of anthropometric measures (weight-for-height, weight-for-age, and height-for-age) in response to both positive and negative rainfall shocks.

There are certain characteristics of Ethiopia that make it a particularly suitable setting for this study. Firstly, much of the population is vulnerable to economic shocks, as it is one of the poorest nations in the world with very high measures of poverty (World Bank, 2014a) and little opportunity for consumption smoothing (Dercon, 2004; Demeke et al., 2011). Secondly, rainfall serves as a good proxy for income in the Ethiopian setting due to its high degree of dependence on rain-fed agriculture. Finally, the rural population comprises roughly 81% of the total population of 97 million people (World Bank, 2014a), making the rural population a large and highly relevant sample for this study.

3.2 Research questions

Given the broader discussions surrounding rainfall and economic shocks in Sub-Saharan Africa, differential treatment between girls and boys, and certain age groups of children being more sensitive to shocks, we find two research questions to be particularly relevant in contributing to the current state of knowledge in these areas, which we will outline below.

First research question

Our first research question seeks to add to the literature regarding gender bias in Sub-Saharan Africa by examining whether the health of boys and girls is affected differently in rural Ethiopia. As previously mentioned, many authors have found evidence of gender bias in Sub-Saharan Africa, but there are some studies that have not found evidence of gender differences in terms of child health (see e.g. Jensen, 2000; Rabassa et al., 2014). There seems to be room to further explore this topic, as there is not a coherent trend within Sub-Saharan Africa regarding the differential treatment of boys and girls in response to rainfall shocks. This leads us to contribute to the field by addressing the following research question:

1. Are the anthropometric measures of boys and girls differently affected by positive and negative rainfall shocks in rural Ethiopia?

We aim to address this question by estimating the effects of rainfall shocks on three anthropometric measures for children under the age of five: weight-for-height, weight-for-age, height-for-age. We will then identify whether or not there is a significant marginal effect for female children.

Second research question

Our second research question explores the topic of whether certain age groups of children are differently affected by rainfall shocks in terms of their anthropometric health outcomes and if there are any differences by gender. The motivation for furthering this study in this direction is twofold. Firstly, there is substantial medical evidence as well as findings within economics that indicate that the severity of health effects depends on when the shock is experienced and that young children are especially vulnerable (Grantham-McGregor et al., 1999; Martorell et al., 1994; Beaton, 1993). Secondly, there are a number of findings from similar studies in Sub-Saharan Africa that suggest that younger children are particularly sensitive to rainfall shocks (Hoddinott and Kinsey, 2001; Bengtsson, 2010; Jensen, 2000). For these reasons, we would like to further our study to investigate whether boys and girls of different ages differ in their anthropometric health outcomes following rainfall shocks. This provides the basis for our second research question:

2. Are the anthropometric measures of boys and girls of different ages differently affected by positive and negative rainfall shocks in rural Ethiopia?

In order to address this question, we will estimate the effects of rainfall shocks on the anthropometric measures of children of different ages using year age cohorts. As with our first research question, we are interested in seeing whether or not there are significant effects by gender and what those effects are.

4 Background

This section will provide background for Ethiopia across a number of dimensions that will shed light on why Ethiopia is a suitable setting to add to the literature on intra-household resource allocation in Sub-Saharan Africa. Many of the characteristics detailed will also be relevant for our study in terms of the data used, the empirical approach, as well as the discussion. We will provide an overview of the general demographics and state of the the Ethiopian economy, followed by a deeper look into the role of agriculture and climate for economic growth and household income. We will then look at the overall state of education and employment as well as fertility preferences, paying particular attention to discrepancies along gender that may indicate or lead to gender bias within households.

4.1 Demographics and economy

Ethiopia, with a population of nearly 97 million people, is the second most populous country in Africa (World Bank, 2016). It is divided into nine regions along ethnic territories and is highly diverse in terms of ethnicity and religion. Ethiopia is comprised of over 80 ethnic groups with the two largest groups, Oromo and Amhara, making up almost 60% of the population and the three major religions are Ethiopian Orthodox (43.5%), Muslim (33.9%), and Protestant (18.5%) (Central Intelligence Agency, 2016). Ethiopia's rural population makes up a relatively large proportion of the total population with rural inhabitants accounting for 81% compared to the Sub-Saharan Africa average of 63% (World Bank, 2014b).

Ethiopia is one of the poorest countries in the world (World Bank, 2014a). Within Sub-Saharan Africa, Gross Domestic Product (GDP) per capita is relatively low at $573 compared to the average of $1,775 for Sub-Saharan Africa (World Bank, 2014a). On the household level, there has been some research that explores the effect of weather shocks on the ability to smooth food consumption, which indicates that Ethiopian households are sensitive to economic shocks. Dercon (2004) examines the effects of rainfall shocks on consumption growth in rural Ethiopia using panel data from 1989-1997 and finds evidence that lagged rainfall shocks affect current growth. The results indicate that rainfall shocks not only affect food consumption in the current period, but also that the impact persists for many years after.[3] Demeke et al. (2011) analyze the effect of rainfall shocks on Ethiopian rural households' food security and vulnerability over time using panel data from 1994-2004. Using an index for food security, the authors' analysis shows that rainfall variability has a significant impact in putting households in a cycle of food insecurity and a state of vulnerability. The low GDP of Ethiopia and the findings from these studies strengthen the argument for rainfall being a good proxy for income, as households are vulnerable to weather shocks in terms of consumption smoothing.

4.2 Agriculture and climate

Looking further into Ethiopia's agriculture and climate, it is apparent that Ethiopia's agriculture is greatly affected by weather shocks. Ethiopia is highly dependent on agriculture for production, with the value added percentage of agriculture to GDP being significantly higher in Ethiopia than the average for Sub-Saharan Africa (41.9% compared to 14.6%) (World Bank, 2014b). In addition, Ethiopia is landlocked and is not rich in minerals. In general, landlocked countries tend to have lower per capita incomes, higher poverty, and larger rural populations, which are all true for Ethiopia (Diao et al., 2007). Since Ethiopia lacks growth opportunities from mineral resources, this leaves agriculture as the primary source of growth and income. In combination, this provides support for Ethiopia's high level of agricultural dependence since there do not exist other obvious channels of income from, for example, fishing or from mineral resources. Finally, Ethiopian agriculture is heavily dependent on rainfall, with irrigated agriculture accounting for less than 1 percent of the country's total cultivated land, suggesting that shocks to rainfall and other climatic factors during the growing season can have especially drastic ramifications leading to food shortages and famine (Yesuf et al., 2008).

Understanding the climate and weather trends in Ethiopia is integral when using exogenous rainfall shocks as key independent variables. Ethiopia is diverse not only in terms of rainfall, but also in terrain, rainy seasons, and agriculture. Most of Ethiopia experiences one main wet season called *kiremt* from June to September while parts of northern and central Ethiopia also have a secondary wet season with sporadic rainfall from March to May called the *belg* season (Tadesse et al., 2006). The southern regions experience two distinct wet seasons in March-May and in October-December (called the *bega* season). The southeastern part of the country, on the other hand, receives very little rainfall throughout the year (McSweeney et al., 2010). Elevation also varies greatly throughout Ethiopia. In the appendix, Figure A1 represents the elevation throughout the country, which shows a high degree of variation in elevation throughout the country in part due to the Ethiopian Highlands that run through the middle of the country. There are four agricultural subsectors in Ethiopia which are all dependent on rainfall: staple crops (cereals, root crops, pulses, and oil crops), livestock, traditional exportables such as coffee, and nontraditional exportables (selected fruits and vegetables, cotton, chat, sesame seed, sugar, and other horticultural products) (Diao and Pratt, 2007).

The disease environment in Ethiopia is also varied, partly due to the diversity in climatic regions and varied topography. Taken together, pneumonia, diarrhea, acute upper respira-

[3] 10% lower rainfall 4-5 years prior has a one percentage point impact on current growth rates.

tory tract infection, acute febrile illness, and malaria account for 64% of of morbidity for children under the age of five, with malaria being one of the larger sources of morbidity and mortality in the country (MoH, 2006). The prevalence of malaria varies by rainfall and temperature (see e.g. Kudamatsu et al. (2012) or Thomson et al. (2005) for investigations on the effects of climate on malaria in an African setting). In addition to rainfall and temperature, topography also affects the prevalence of malaria. Burlando (2015) finds that the varying topography of Ethiopia provides a varied disease environment in terms of malaria, which is one of Ethiopia's most burdening diseases. Also pneumonia is found to vary with weather, with important factors being sunshine (Paynter et al., 2013) and rainfall(Currie and Jacups, 2003). When studying child health, it is important to not only consider diseases such as malaria or pneumonia, but also diarrhea as this is considered one of the more important sources of childhood under-nutrition (Institute for Health Metrics and Evaluation, 2010).

4.3 Factors for gender bias

There are many key aspects of life in Ethiopia where there exist inequalities between genders, which may contribute to gender bias when parents allocate household resources to their children. In this section, we will give an overview of education, literacy, child labor, workforce participation, and fertility preferences in Ethiopia.

Education varies considerably across a number of factors in Ethiopia. According to the final report on the Demographic and Health Survey, wealth is the most important indicator for education with the largest variation in education stemming from the different wealth quintiles in the population. Type of residence is also an important determinant for education with attendance ratios varying greatly between urban and rural areas. For example, in urban areas 28 percent of females and 15 percent of males have no education, while 58 percent of females and 44 percent of males have no education in rural areas. Gender also plays a role in educational attainment, but has differing effects depending on the education level. Females have higher educational attainment for primary school education (65% compared to 64% for males), while males have higher secondary school education (14% compared to 13% for females). Taking both wealth and gender into account paints a starker picture. Only 27 percent of females in the wealthiest households have no education, compared with 69 percent in the poorest households. For males, 14 percent of those in the wealthiest households have no education, compared with 54 percent in the poorest households.

Literacy rates also vary by gender. While 65 percent of men aged 15-59 are literate, only 38 percent of women are literate as of the 2011 DHS Final Report (Central Statistical Agency [Ethiopia] and ICF International, 2011). Child labor also shows variation by gender. For all children age 5-14, the percentage engaged in labor is higher among males (31 percent) than females (24 percent), with the proportion of children engaged in labor being substantially higher among rural children (30 percent) than urban children (13 percent). Employment varies considerably by gender. The most recent 2011 DHS survey shows that 80.4% of men responded that they are currently employed while only 37.6% of women were employed at the time of the survey. While there are many factors that contribute to the proportion of women working, one of the most crucial indicators is type of residence. Almost 50% of urban women work while only 34% of rural women responded that they were working at the time of the survey (Central Statistical Agency [Ethiopia] and ICF International, 2011). This imbalance in workforce participation may provide a basis for gender discrimination in parental investment in children since the perceived value later in life may be higher for boys.

Fertility preferences may also contribute to potential differential treatment of children by gender. In a study on fertility preferences across fifty less-developed countries, Fuse (2010) uses DHS data on fertility preferences and finds that, while the vast majority of mothers in Ethiopia prefer a balance of sons and daughters (55.9%), there is a relatively large proportion of mothers at 22% who have a preference for sons, especially when compared to the 7.6% of mothers who prefer daughters. While stated fertility preferences are not always directly linked to fertility behavior (Rossi and Rouanet, 2015), the relatively high level of son preference provides a basis for investigating whether or not gender bias plays a role in gender bias in health outcomes.

Finally, there have been some studies that look at the effects of weather and food aid on child health by gender in Ethiopia specifically. The studies, however, have yielded inconclusive results regarding gender bias, although it must be noted these have mainly been focused on food aid. Yamano et al. (2005) examine the effects of crop damage and food aid on children's health in rural Ethiopia. The authors find significant evidence that food aid increases the height of children aged 6-24 months. In regard to gender differences, they find that girls' height suffers less than boys', but they are unable to identify whether these gender differences are attributable to differences in biological resilience or to intra-household resource allocation. Another study looking at the agricultural environment and food aid, Quisumbing (2003) uses panel data from rural Ethiopia to compare the effects of rainfall and livestock shocks on two different types of food aid on child nutrition by gender. She finds that households invest proceeds from free distribution food aid in girls' nutrition, while they invest earnings from food-for-work programs in boys' nutrition. The effects of the gender of the aid recipient are not conclusive, but provide a basis for further investigating parental investment in children by gender in Ethiopia.

5 Conceptual framework

In this section, we will present the framework used to study how rainfall shocks might affect the ways in which parents invest in their children's health. We will then discuss the two possible channels through which rainfall can affect health outcomes: the income channel and the disease environment. We will also propose projected outcomes for this study based on the conceptual framework and previous research.

5.1 Health capital production function

In line with much of the literature in this area, we apply the health production framework introduced by Grossman (1972) where health capital accumulates over time. An individual's health is not only dependent on actions in the current time period, but is also a function of action in previous periods as well as the amount of health capital the individual is endowed with at birth. An individual's current amount of health capital can be expressed as

$$H_{it} = f(H_{it-1}, I_{it}, E_t) \tag{5.1}$$

Where current health capital, H_{it}, is a function of health capital accumulated over past periods, H_{it-1}; I_{it} represents investments in health; and E_t represents the disease environment. We apply it to children under the age of five where investments can be seen to come from the parents.

At birth, an individual's health can be seen as determined by factors such as genetics, community characteristics, and environmental conditions experienced early in life. Parents can affect their child's health only through investment, which is determined by factors such as household resources, time devoted to childcare, community characteristics and also the current disease environment, as parents may respond to changes in it by increasing or decreasing investments in child health.

A rainfall shock affects crop yields, which in turn affects the amount of resources a family has available. Therefore, the shock affects a child's health through the investment term, where a positive shock is expected to increase available resources for investment and a negative shock is expected to decrease available resources for investment. As a rainfall may affect the expected returns from farm work, we may also see that a rainfall shock affects investment in the amount of time spent on childcare. Parental investments can take the form of monetary investments as well as investments in time spent caring for children.

A key feature of this model is the link between health capital and an individual's productivity, where a larger stock of health capital is associated with higher productivity. This is due to experiencing fewer sick days and having higher productivity when working. The cumulative nature of the health capital, combined with the link between health capital and productivity, sheds light on potential motivations for parental investment in children's health, as a healthier child will be able to contribute with more resources at a later stage. As male and female children may face different returns to their amount of health capital, parents may choose to invest differentially in their children's health depending on the gender of the child. We should note that an individual can participate in market activities and non-market activities when working, in which case higher productivity does not necessarily imply being engaged in formal employment.

5.2 Rainfall as an income channel

As described in the background section, Ethiopia is highly agriculturally dependent and the population has very limited possibilities to smooth consumption over time. This means that a smaller harvest than usual acts as a negative income shock, reducing household resources. As Ethiopia's agriculture is almost entirely rain-fed with only one percent of its agriculture being irrigated, deviations from average rainfall will have an impact on family resources through crop yields. Rainfall affects the crop growth during the current growing season, which is then harvested at the end of that season. The full effects on crop production following a rainfall shock, therefore, materialize the year following the shock. Most of the literature in the area uses rainfall lagged one year to proxy for a current income shock (Rose, 1999; Rabassa et al., 2014; Flatø and Kotsadam, 2014). When Flatø and Kotsadam (2014) use rainfall shocks that occur before and after the lagged rainfall measure, they do not find any statistically significant effects on infant mortality. The use of lagged rainfall shocks seeks to obviate many of the confounding effects due to the disease environment, which can be argued to be primarily linked to current rainfall shocks.

In the framework outlined above, income affects the amount of resources that parents can invest in their children's health. Variation in rainfall affects the amount of available resources in agriculturally dependent areas and, consequently, affects households' ability to invest in their children's health. Furthermore, rainfall shocks may influence how much time the parents need to spend working in order to provide enough resources to the family. During times of drought, parents may need to spend more time seeking alternative ways of providing income for the family, reducing the time available for childcare.

5.3 Rainfall and the disease environment

Rainfall does not only affect the people of Ethiopia through the income channel, but it also affects them via the disease environment. Many of the common diseases in Sub-Saharan Africa increase in prevalence during times of heavier rain and higher temperatures (Kudamatsu et al., 2012). A positive rainfall shock, therefore, cannot be thought of only as increasing income through more crop yields, but it also is likely to affect health negatively through the disease environment, captured by E_t in the model set up above. While a negative rainfall shock is expected to have a negative effect on income, the effect on disease are more mixed. On the one hand, a decrease in rainfall may decrease the prevalence of diseases such as malaria and other vector-borne diseases, while, on the other hand, the prevalence of diarrhea may increase. Bengtsson (2010) investigates whether malaria drives the effects of variation in rainfall on body weight and finds that, while there is some effect, it does not drive the results.

As the main focus of our paper is to study the effects of rainfall shocks by gender, a general increase or decrease in diseases does not pose a problem for our study if children of both genders are thought to be affected equally by the disease environment. If a positive shock leads to an increase in the disease environment, the negative effects from diseases will attenuate the overall effect of more rain and bias results downward. Conversely, a decrease in the disease environment during a negative rainfall shock may mitigate some of the negative effects of the lower rainfall on crop production. Others studies have addressed this, finding no significant difference between boys and girls sensitivity to changes in the disease environment (Rose, 1999; Björkman-Nyqvist, 2013; Rabassa et al., 2014). While there has not been an overwhelming amount of evidence to support the theory that girls are more resilient to disease in similar studies to our own, we will address this potential explanation in our robustness check section.

It is clear that rainfall may not only affect a child's health status through the income channel by affecting crop production, it also may work through the disease environment by affecting the prevalence of diseases such as pneumonia, malaria, and diarrhea. In agriculturally dependent areas, the income channel is generally believed to be most affected by rainfall shocks in the previous year, while the disease environment is more directly influenced by rainfall shocks in the current year.

5.4 Expected outcomes

Based on the conceptual framework and previous research, we propose a number of projected outcomes. It should be noted, however, that the contextual factors and characteristics of a country are complex and may play a large role in the differing findings in terms of differential treatment throughout Sub-Saharan Africa. To the best of our knowledge, there has not been a study investigating the effects of rainfall shocks on child anthropometric measures in Ethiopia, making it difficult to root our hypotheses within this particular context. There are, however, a number of findings from the previous research that give rise to our predictions.

Generally speaking, we expect a negative rainfall shock to have a negative impact on children's health. In terms of our conceptual framework, a negative rainfall shock is expected to decrease income and, hence, also decrease resources available to spend on children's health. This would be in line with the rather unified findings from other studies (Rose, 1999; Bengtsson, 2010; Anderson and Ray, 2010; Flatø and Kotsadam, 2014). Conversely, we expect a positive rainfall shock to increase income and, consequently, increase the amount of resources available for investing in children's health, thereby leading to an increase in children's anthropometric measures.

For the first research question, we expect to find differences in health outcomes by gender following rainfall shocks. This is due to parents of children of different genders facing different returns from investing in their children's health. We expect males to be benefit from positive rainfall shocks to a greater extent than girls, and girls to be more adversely affected by negative rainfall shocks. With regard to this prediction, the literature is not as unified. When looking specifically at gender differences in studies on anthropometric measures, Rabassa et al. (2014), for example, do not find any differences in weight-for-height between genders, but Bengtsson (2010) finds that the weight of female children is more adversely affected after a negative rainfall shock, and a positive shock is not as beneficial for females as it is for male children.

Considering the second research question, we also expect younger children to be more sensitive to shocks than their older peers, as suggested by the literature (Hoddinott and Kinsey, 2001; Martorell, 1999; Bengtsson, 2010). Similar to our prediction for the first research question, we expect girls to be more adversely affected by rainfall shocks.

6 Data

In this section, we will provide detailed insight into the data used to carry out the analysis. There are two main sources of data: the Demographic and Health Survey data and rainfall data from NASA.

6.1 DHS data

The household survey data comes from three rounds of the standard surveys carried out by the Demographic and Health Survey (DHS) program in Ethiopia. Standard DHS surveys are nationally representative household surveys and are typically carried out every five years, providing data across a broad range of topics and indicators. The surveys used in this study are from 2000, 2005, and 2010-11 in Ethiopia. The total number of households surveyed is 44,495. Since our subjects of interest are children under the age of five, the relevant data comes from the data sets on all children under the age of five from each of three survey rounds which we merged into one data set, providing data on children born in 1995-2011.

The relevant data used for this study comes from self-reported information from women in the age range 15-49 regarding birth history, education, employment, and certain health indicators. The dependent variables of interest are children's anthropometric measures: the z-scores for weight-for-height (WHZ), weight-for-age (WAZ), and height-for-age (HAZ). All anthropometric measure z-scores are calculated by DHS using the CDC Standard Deviation-derived Growth Reference Curves derived from the NCHS/FELS/CDC Reference Population. Health measurements regarding height and weight of children are taken at the time of the survey. Children born less than 24 months prior to the survey are measured lying down and children born 24 months or more prior to the survey are measured standing up (Measure DHS/ICF International, 2013).

As some of the data is based on mothers' recollection of their children's health, the data may suffer from recall error. For the disease indicators used in our robustness checks, the data is based on mothers' recall on children's health up to two weeks prior to the survey. For the child's age, there is a risk that the mother does not perfectly recall the age of the child. Given that we are only looking at the age of the child in terms of their age in years, we do not believe this to be a very problem significant for our data. Had we looked at age in months, this would have warranted greater concern.

We focus on all children under the age of five where the age groups range from 0-4 (where a "0-year-old" is a newborn who has not yet turned one). Since we are interested in the effects of rainfall shocks on child health, we exclude children who have died from the data set. After excluding these observations (2,977 observations) and omitting errors in our data (1,715 observations), the data set contains 27,091 observations. There is, however, only anthropometric data (weight-for-height, weight-for-age, and height-for-weight) on 21,639 children so the observations missing anthropometric data are also dropped from the data. Using the guidelines set out by the WHO (de Onis, 2006), all biologically implausible values were also removed (22 observations).[4] Finally, all urban observations (about 15% of the sample) were removed since the primary interest of this study is the effects on the rural population, which is the most likely to be affected by rainfall shocks with respect to the income channel.

Table 6.1: Observations by survey year

Survey year	Freq.	Percent	Cum.
2000	7,179	38.89	38.89
2005	3,277	17.75	56.64
2010-11	8,006	43.36	100.00
Total	18,462	100.00	

The final data set contains 18,462 observations and the breakdown by survey year is presented in Table 6.1. We observe that many of the children missing weight-for-height data were part of the 2005 survey, skewing the distribution of data over time. The households were surveyed in clusters across the country for each survey round. For both the 2000 and 2005 survey rounds, there were 540 cluster areas and, for the 2010-11 survey, there were 650 cluster areas.

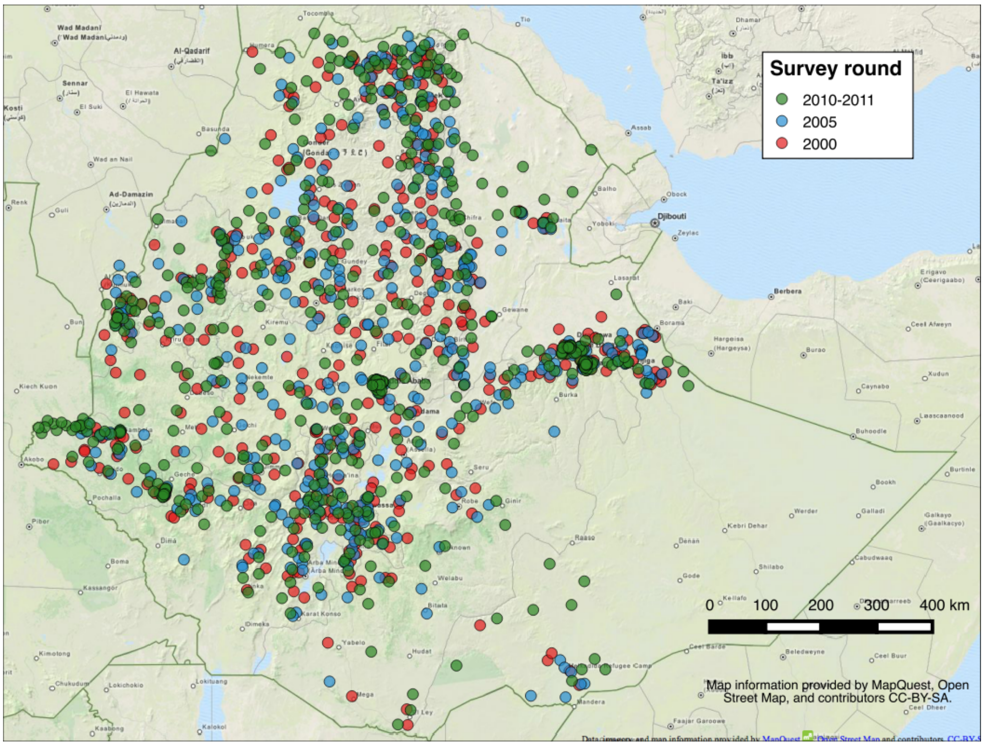
In addition to the rich data gathered through the questionnaires, the DHS survey also contains GPS data on each cluster surveyed in each survey round. This GPS data enables us to match clusters to local rainfall data. Each cluster location is randomized within a 10km radius for rural clusters and 5km for urban clusters to maintain the confidentiality of survey respondents. Figure 6.1 shows the survey cluster for each of the three survey rounds. All survey rounds cover roughly the same areas across Ethiopia, but we can see that there are some regions where there are very few clusters, such as the Southeastern part of the country. The regions where there are few survey clusters have very low populations and are, therefore, not highly represented.

6.2 Rainfall data

The rainfall data used comes from the Tropical Rainfall Measurement Mission Project (TRMM), which is a joint mission between NASA and the Japan Aerospace Exploration

[4] Data were excluded if a child's HAZ was below –6 or above +6, WAZ was below –6 or above +5, or WHZ was below –5 or above +5).

Figure 6.1: Cluster locations from three DHS surveys: 2000, 2005, and 2010-11



Map created by authors in QGIS using data from DHS.

Agency (JAXA) started in 1998 to study rainfall for weather and climate research. We used daily rainfall estimates from 1998-2011 (rainfall data is available starting in 1998 when the TRMM mission was started) at a 0.25° x 0.25° grid level (which is equal to approximately 28 x 27 km in Ethiopia).[5]

Rainfall data comes in the form of NetCDF raster data. These are data sets that cannot be read by traditional statistical programs such as Stata. Therefore, we used the program R to convert the raster data into numerical matrix data in order to merge the roughly 5,000 daily rainfall data sets by longitude and latitude. After converting each of the daily rainfall data sets, we merged them into monthly rainfall data by summing the daily rainfall (mm/day) into total monthly rainfall (mm/month).

After aggregating the rainfall data by month, we then summed the rainfall for the months that lie in the rainy season for most of Ethiopia, which we defined as between March and September. As Ethiopia spans a large geographical area and also has large variation in topography across the country, the length and timing of the different growing seasons varies depending on climate and what crops are grown. While some parts of the country are best characterized by having one to two growing seasons, other parts can be described as having as many as four growing seasons over the course of a year.

While acknowledging the potential impact this may have on how the timing of rain may have on the income channel described earlier, accounting for this variation is beyond the scope of a master's thesis. However, for large parts of the country, simply treating the period from March to September serves as a good approximation of the growing period as

[5]Calculated using latitude/longitude converter from the National Hurricane Center at NOAA.

it captures both of the largest rainy seasons, the *kiremt* (June - September) and *belg* (March - May) seasons (Tadesse et al., 2006).

6.3 Forming the complete data set

In order to match the rainfall data to the area in which the survey response was recorded, thus linking the survey outcome to rainfall shocks, we spatially matched the rainfall data to the GPS locations of the survey. We did this using the program QGIS (Quantum Geographic Information System). The NASA rainfall data comes as a set of centrum coordinates for each square in the grid of rainfall data. We form a set of square polygons around these centrum coordinates, creating a set of polygons exactly matching up to the areas for the rainfall data (this set of polygons is commonly referred to as a "fishnet"). We then use the coordinates from this set of polygons to determine which square of rainfall data each DHS cluster resides in, allowing us to categorize the rainfall data to these clusters. Having created this match between the different sets of GPS coordinates we then merge the survey data with the rainfall data using our "mold." The final data set contains data for each child under the age of five from the three survey rounds with rainfall data from 1998-2011 for each individual's survey cluster.

7 Empirical approach

In this section, we will outline the empirical specifications used to address both research questions, followed by detailed descriptions of the variables used.

7.1 Empirical specifications

In order to address our first research question, we run the regression 7.1 for children under the age of five living in rural Ethiopia. It is run over our three anthropometric measures: the z-scores for weight-for-height, weight-for-age, and height-for-age. The regressions for each of the three measures are identical in structure. Using the regression with weight-for-height as the dependent variable as a template, the regression is as follows:

$$\begin{aligned} WHZ_{ijt} = \alpha + \beta_1 Female_i + \beta_2 Wet_{jt-1} + \beta_3 Wet_{jt-1} * Female_i \\ + \beta_4 Dry_{jt-1} + \beta_5 Dry_{jt-1} * Female_i + \chi_{ij} + \varsigma_d + \gamma_t + \varepsilon_{ijt} \end{aligned} \tag{7.1}$$

Where:

- $WHZijt$ = weight-for-height standard deviation from the international reference median for child i in cluster j at survey round t
- $Female_i$ = binary variable for being female
- Wet_{jt-1} = binary variable for 0.5 standard deviation above the mean rainfall in cluster j at time $t-1$; effect of being male conditional on experiencing a wet shock in time period $t-1$

- $Wet_{jt-1} * Female_i$ = marginal effect of being female conditional on experiencing a wet shock in time period $t-1$
- Dry_{jt-1} = binary variable for 0.5 standard deviation below the mean rainfall in cluster j at time $t-1$; effect of being male conditional on experiencing a dry shock in time period $t-1$
- $Dry_{jt-1} * Female_i$ = marginal effect of being female conditional on experiencing a dry shock in time period $t-1$
- χ_{ij} = child characteristics (age, month of birth, birth order, and family size)
- ς_d = regional fixed effects
- γ_t = fixed effects for survey round and survey month
- ε_{ijt} = the error term for individual i in cluster j at survey time t

Rainfall shocks in the previous year, Wet_{jt-1} and Dry_{jt-1}, are interacted with a binary variable indicating sex of the child with the variable $Female_i$ taking the value of one if the child is female. These interaction terms are included to determine the conditional effects for boys and girls of rainfall shocks on health outcomes. The coefficients for both positive and negative rainfall shocks (Wet_{t-1} and Dry_{t-1}) capture the conditional effects of receiving a shock if male, while the coefficients for the interaction terms ($Wet_{jt-1} * Female_i$ and $Dry_{jt-1} * Female_i$) capture the marginal conditional effect of receiving a shock if female. It is important to note that, by using interaction terms, the coefficients of Wet_{jt-1} and Dry_{jt-1} do not capture the average effect of rainfall shocks as they would in a linear-additive model (Brambor et al., 2006).

We are interested in studying the effects of a relatively wet or dry rainy season last year on the anthropometric measures of children under the age of five. Last year's rainfall measures are captured by the terms Wet_{jt-1} and Dry_{jt-1}, which are dummy variables for whether or not a child experienced a positive or negative rainfall shock in the previous year. Rainfall shocks are referred to as rainy seasons (March - September) with rainfall above or below half a standard deviation from the long term average rainfall in that grid cell, over the years for which there is available rainfall data (1998-2011).[6] The time period $t-1$ is chosen as rainfall shocks lagged one year back are used to capture the effects of last year's rainfall on this year's income.

In order to answer our second research question we run regressions similar to the one outlined in equation 7.1, this time running the regressions separately for children by children's age in years. This allows us to see whether any effects vary with children's age and if there are any differences among children of different ages and gender. Note that for this second round of regressions, χ_{ij} no longer includes dummies for the age of the child.

We include controls for family size, birth order, and age. We run all regressions using fixed effects for region, survey year, survey month, and month of birth. We show the coefficients for rainfall shocks, birth order, family size and the constants in the tables. The standard errors are clustered by the rainfall grid cells in which the survey clusters are located in a given survey round.

[6] We chose one half standard deviation from the mean as our definition of a rainfall shock as this allowed for enough variation in rainfall to affect livelihood, yet gives us enough observations to conduct statistical analysis.

7.2 Variables

We will explain the differences among the three anthropometric measures used for this study as well as guidelines for interpretation outlined by the World Health Organization (WHO). We will then provide justifications for using a wide range of control variables.

Outcome variables

The outcome variables of interest are anthropometric measures as specified by the WHO. Specifically, we use the measures weight-for-height, weight-for-age, and height-for-age. They offer some different possibilities for interpretation. For this study, the z-scores from the international reference median are used. The most relevant interpretations of anthropometric measures in Ethiopia and in our sample are the interpretation of low levels of each measure since children under the age of five in Ethiopia have relatively low anthropometric outcomes compared to the international medians for each measure.

Weight-for-height

The weight-for-height measure gives us an indication of the prevalence of wasting, most commonly associated with acute starvation or disease (de Onis and Blössner, 1997). We, therefore, mainly use this measure as an indicator of health fluctuations in the short run. According to the World Health Organization (1997), this measure typically peaks in prevalence during a child's second year of life. A weight-for-height prevalence exceeding 5% is alarming since there is also a tendency for this measure to move in parallel with child mortality (Toole and Malkki, 1992).

Weight-for-age

Weight-for-age reflects body mass relative to chronological age. The measure is influenced by both the height of the child (height-for-age) and his or her weight (weight-for-height), and is a combination of the other two anthropometric measures included in our study. Weight-for-age is a combination of weight-for-height and height-for-age and can at times overlap in interpretation with the other two measures, making its interpretation complex (de Onis and Blössner, 1997). A short-term reduction in weight-for-age, for example, reveals a change in weight-for-height while the worldwide variation of low weight-for-age and its age distribution are similar to those of low height-for-age (de Onis and Blössner, 1997). Both weight-for-age and height-for-age capture the long-term health and nutritional status of a given individual or population.

Height-for-age

Height-for-age, generally speaking, captures the prevalence of stunting or a failure to reach linear growth and is often the result of poor health or nutritional conditions (de Onis and Blössner, 1997). In the Global Database on Child Growth and Malnutrition report published by the WHO, De Onis and Blössner also note that, in many developing settings, the prevalence of low height-for-age starts to increase at the age of about three months and that the process of stunting slows down at around three years of age, after which mean heights typically return to the levels of the reference group. Height-for-age indicates chronic malnutrition and is considered a good proxy for long-term health (Rabassa et al., 2014).

Control variables

A set fixed effects and control variables are included in the regression to control for effects that are likely to vary across a number of characteristics, including regional and time-specific characteristics.

We include regional fixed effects to control for differences across regions. As noted in the background section, the Ethiopian regions are largely divided by ethnic boundaries. Ideally, we would include fixed effects for the different religions or ethnicities in Ethiopia, but the variables are missing significant data and would greatly limit the number of observations included in the regressions.

With regard to time-varying characteristics, fixed effects for survey year, survey month, and birth month are included in the regression. Dummy variables for survey year are included to control for trends over time and dummies for survey month are included to account for systematic health differences in time of year when children are measured. Dummy variables for month of birth are also included, as there may be systematic differences between children born during different times of the year with respect to the disease environment and growing seasons. The month of the year the child is born may be correlated with the diseases he or she is exposed to as well as if/when the child is born in the growing season, making any potential systematic effects of birth month an important factor to control for. After taking the controls into account, the error term, ε_{ijt}, is assumed to be uncorrelated with the variation in rainfall.

We include the variable for birth order, which is defined as the order in which a child is born among the total number of children ever born, including any children who have died. It is included to control for what order the child is born within a family since there may be systematic differences in intra-household resource allocation according to when the child is born. We also include a variable for family size, which is defined as the total number of living children at the time of the survey in a given family. It is included to account for any differences there may be in small families versus large families.

8 Results

In this section, a more in-depth look into the data will be provided through descriptive statistics, followed by the results from the specifications outlined in the empirical approach. First, the estimates for the effects of rainfall shocks on the anthropometric measures of children under the age of five in our sample will be presented. Then the effects will be parsed further by looking at the effects for different age cohorts and determining if there are any marginal gender effects conditional on rainfall shocks.

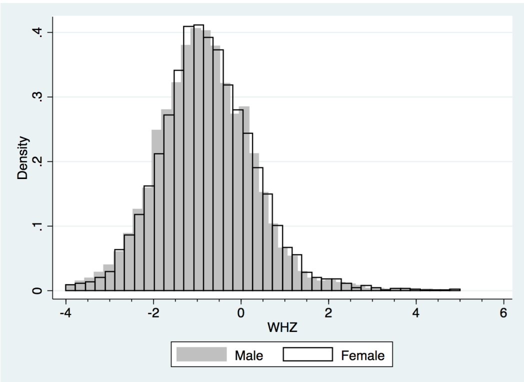
8.1 Descriptive statistics

Table 8.1 shows the descriptive statistics for our variables. From the table, we can see the average, standard deviation, minimum, and maximum rainfall in Ethiopia for the survey years as well as the year before the surveys, the average order of birth, and average family size for the sample. We see that some areas of Ethiopia received remarkably little rainfall during the rainy season in the survey years and the year before the survey years, as seen by the minimum values of 79.73 and 40.87 millimeters, respectively. The birth order variable denotes the placement of the child within the family, meaning that the average child is born fourth out of the total number of children. We see that the sample is almost balanced in terms of the proportion of males and females. Table 8.1 also shows the means and standard deviations for each of the anthropometric measures studied. Since the anthropometric measures are standardized to the international reference median, the negative means reflect that, in general, Ethiopian children are more malnourished and stunted compared to children worldwide.

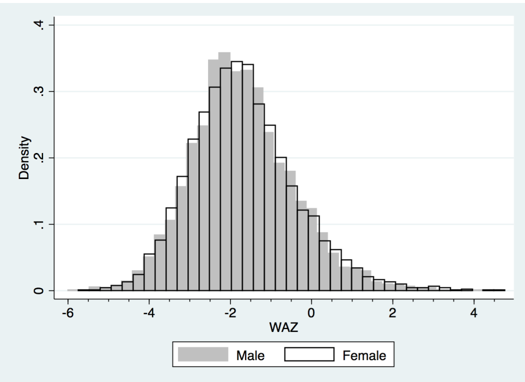
Table 8.1: Summary statistics

	mean	sd	min	max
Rainfall t	937.78	335.00	79.73	2063.16
Rainfall t-1	838.38	334.32	40.87	1680.75
Female	0.49	0.50	0.00	1.00
Birth order	4.20	2.60	1.00	18.00
Family size	3.89	2.15	1.00	12.00
WHZ	-0.79	1.08	-3.99	5.00
WAZ	-1.69	1.27	-5.91	4.77
HAZ	-1.77	1.68	-5.99	5.84
Observations	18,462			

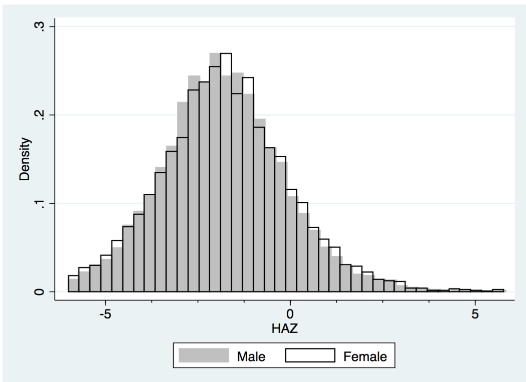
Figure 8.1: Anthropometric z-scores by gender



(a) Weight-for-height by gender



(b) Weight-for-age by gender



(c) Height-for-age by gender

Created by authors in Stata using data from DHS.

The figures contained in Figure 8.1 give a visual overview of how the anthropometric z-scores are distributed by gender. We see that all of the anthropometric z-scores in our sample are skewed heavily to the left, echoing what is found in Table 8.1, which is that Ethiopian children are relatively more malnourished and stunted compared to the international median for each measure.

8.2 Effects on anthropometric measures

We begin by looking at the effects of lagged rainfall shocks on child health in rural villages and will focus on differences between boys and girls under the age of five to address the first research question of our study. For this part, we will run a least squares estimation on each of the z-scores for weight-for-height, weight-for-age, and height-for-age over the full sample. Multiplicative interaction terms are used in order to capture the conditional effects for boys and girls given both positive and negative rainfall shocks. The results from the three regressions are presented in Table 8.2 and the main findings will be discussed below.

The main finding from the results presented in Table 8.2 is that boys benefit on the whole from a positive rainfall shock the year before, as evidenced by the coefficients for Wet_{t-1} in columns 2 and 3. Boys gain 0.115 standard deviations in weight-for-age and 0.168 standard deviations in height-for-age following a wet shock, both at the 5% level. We find no statistically significant effects for the weight-for-height z-score.

The interaction terms indicate whether there are any differences in response to the rainfall shocks between children of different genders. We note that for our weight-for-age, the coefficient on the interaction term $Wet_{t-1} * Female$ is -0.119, indicating that girls do not reap the same benefits as boys do following a wet shock. It is statistically significant at the 5% level. The interaction term for our height-for-age z-score in not statistically significant, however, not indicating any difference in effect between genders for this measure.

It is worth discussing that we find statistically significant effects for both our weight-for-age z-score and height-for-age z-score, as this may help in explaining why we do not see any effect on our weight-for-height z-score following rainfall shocks. If both weight and height fluctuate in the short run, the interpretation of the weight-for-height z-score becomes difficult as both the numerator and denominator change. As noted earlier, weight-for-height is often used as a short-term measure due to height being regarded as fixed in the short run. Our results suggest that this might not be the case, as we find both weight and height to fluctuate in the short run.

The coefficients for the binary variables for being female are significant for both weight-for-height (WHZ) and height-for-age (HAZ), which gives some indication that female children who have not experienced either a wet or dry shock have slightly higher weight-for-height and height-for-age measures than their male counterparts in the sample. However, the magnitude of the coefficients is very small at 0.0578 and 0.0744 standard deviations, respectively.

In addition, the coefficients for the two main control variables, birth order and family size, are significant across anthropometric measures. The coefficients for birth order are all small and negative, indicating that being born later within the family has a slight negative effect on health, as measured by the three anthropometric measures. Conversely, the positive coefficients for family size indicate that being born into a larger family has a slightly positive effect on anthropometric measures, with the magnitude of the effect being largest for height-for-age at a 0.0946 standard deviation increase.

Table 8.2: Anthropometric measures

	Anthropometric measures		
	(1)	(2)	(3)
Variables	WHZ	WAZ	HAZ
Female	0.0578**	0.0445	0.0744*
	(0.0270)	(0.0280)	(0.0380)
Wet_{t-1}	0.00889	0.115**	0.168**
	(0.0491)	(0.0556)	(0.0786)
Wet_{t-1}*Female	-0.0526	-0.119**	-0.120
	(0.0525)	(0.0577)	(0.0796)
Dry_{t-1}	-0.0341	-0.0160	-0.00209
	(0.0328)	(0.0394)	(0.0472)
Dry_{t-1}*Female	0.0372	0.0104	-0.0142
	(0.0336)	(0.0359)	(0.0489)
Birth order	-0.0218***	-0.0584***	-0.0752***
	(0.00699)	(0.00870)	(0.0116)
Family size	0.0183**	0.0667***	0.0946***
	(0.00860)	(0.0110)	(0.0148)
Constant	-0.404***	-0.835***	-0.705***
	(0.0652)	(0.0797)	(0.102)
Observations	18,462	18,462	18,462
R-squared	0.063	0.178	0.176
Age FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes
Birth month FE	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered by survey cluster ID

8.3 Effects on anthropometric measures by age

Further specifying the above results by age sheds light on whether or not children of certain ages are particularly vulnerable when faced with rainfall shocks and whether that effect differs by gender, corresponding to our second research question. The results for each anthropometric measure are presented in their respective tables with a column for each age cohort.

Weight-for-height

The results for the regressions run on weight-for-height by age cohort are presented in Table 8.3. As with the first set of regressions, we do not find any statistically significant effects for our weight-for-height z-score. As hypothesized above, this may be due to both weight and height fluctuating in the short run.

Weight-for-age

The results for the regressions run on weight-for-age by age cohort are presented in Table 8.4. We find that newborn boys are greatly benefited by a positive rainfall shock, as seen by the large and highly statistically significant coefficient on Wet_{t-1}. Following a positive rainfall shock, newborn boys are expected to have an increase in their weight-for-age z-score by 0.445 standard deviations, which is significant at the 1% level. As before, we turn to our interaction term to see if there is any differential effect for girls. We find that, compared to boys, the effect on girls is 0.518 standard deviations lower following a positive rainfall shock, significant at the 1% level.

Unexpectedly, we find a positive albeit much smaller effect on newborns weight-for-age z-score following a negative rainfall shock, which is significant at the 10% level. We find no indication of any differential effect for girls, as seen on the insignificant interaction term $Dry_{t-1} * Female$. We find four-year-olds to be negatively affected by a negative rainfall shock, again with no indication of a differential effect between boys and girls.

Height-for-age

The results for the regressions run on height-for-age by age cohort are presented in Table 8.5. As for our weight-for-age measure, we find that newborn boys greatly benefit from a positive rainfall shock during last year's rainy season. Newborn boys who have faced a unexpectedly wet rainy season last year are expected to have a 0.481 standard deviations higher height-for-age z-score. Again, we see that girls do not benefit like boys do, as captured by the negative coeffeicient of -0.393 on the interaction term $Wet_{t-1} * Female$. We find that newborns benefit from a negative rainfall shock, with no indication of any differential effect between boys and girls.

In terms of our control variables, they are similar to the ones in our regressions run over all age groups.

Table 8.3: Weight-for-height by age

	Weight-for-height by age				
	(1)	(2)	(3)	(4)	(5)
Dep. var WHZ	0-year-olds	1-year-olds	2-year-olds	3-year-olds	4-year-olds
Female	0.173**	0.132**	-0.0158	-0.0144	0.0238
	(0.0749)	(0.0671)	(0.0548)	(0.0540)	(0.0565)
Wet_{t-1}	0.0800	-0.0366	-0.00271	0.0793	-0.0100
	(0.125)	(0.114)	(0.0843)	(0.0822)	(0.0828)
Wet_{t-1}*Female	-0.260	-0.0968	0.0884	-0.0575	-0.00878
	(0.162)	(0.141)	(0.112)	(0.107)	(0.102)
Dry_{t-1}	0.0216	-0.0348	-0.0556	-0.0501	-0.0814
	(0.0721)	(0.0691)	(0.0606)	(0.0521)	(0.0570)
Dry_{t-1}*Female	-0.0215	0.0368	0.0893	0.0824	0.00929
	(0.0916)	(0.0839)	(0.0707)	(0.0669)	(0.0694)
Birth order	-0.0245	-0.0643***	-0.0372***	-0.0112	0.00530
	(0.0221)	(0.0183)	(0.0144)	(0.0114)	(0.0110)
Family size	0.00824	0.0701***	0.0386**	0.0132	-0.00752
	(0.0263)	(0.0226)	(0.0174)	(0.0146)	(0.0141)
Constant	-0.0225	-1.282***	-0.894***	-0.653***	-0.917***
	(0.136)	(0.127)	(0.102)	(0.103)	(0.102)
Observations	3,621	3,526	3,656	3,956	3,703
R-squared	0.079	0.047	0.037	0.028	0.035
Region FE	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes	Yes	Yes
Birth month FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered by survey cluster ID

Table 8.4: Weight-for-age by age

	Weight-for-age by age				
	(1)	(2)	(3)	(4)	(5)
Dep. var WAZ	0-year-olds	1-year-olds	2-year-olds	3-year-olds	4-year-olds
Female	0.257***	0.183***	-0.0704	-0.134**	0.00484
	(0.0779)	(0.0700)	(0.0661)	(0.0594)	(0.0586)
Wet_{t-1}	0.445***	0.00503	0.0730	0.0685	0.0569
	(0.120)	(0.0948)	(0.100)	(0.102)	(0.0846)
Wet_{t-1}*Female	-0.518***	0.0657	-0.0167	-0.182	0.000627
	(0.157)	(0.126)	(0.129)	(0.121)	(0.117)
Dry_{t-1}	0.141*	-0.0656	-0.0436	-0.0327	-0.110*
	(0.0786)	(0.0734)	(0.0768)	(0.0578)	(0.0657)
Dry_{t-1}*Female	-0.106	-0.00145	0.113	0.0373	0.0403
	(0.0944)	(0.0873)	(0.0851)	(0.0738)	(0.0737)
Birth order	-0.0511**	-0.0964***	-0.0901***	-0.0475***	-0.0278**
	(0.0248)	(0.0198)	(0.0190)	(0.0146)	(0.0120)
Family size	0.0497*	0.102***	0.114***	0.0566***	0.0412***
	(0.0297)	(0.0242)	(0.0233)	(0.0182)	(0.0155)
Constant	-0.684***	-2.456***	-2.029***	-1.671***	-1.979***
	(0.151)	(0.148)	(0.135)	(0.119)	(0.117)
Observations	3,621	3,526	3,656	3,956	3,703
R-squared	0.160	0.080	0.058	0.050	0.067
Region FE	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes	Yes	Yes
Birth month FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered by survey cluster ID

Table 8.5: Height-for-age by age

	Height-for-age by age				
	(1)	(2)	(3)	(4)	(5)
Dep. var HAZ	0-year-olds	1-year-olds	2-year-olds	3-year-olds	4-year-olds
Female	0.245***	0.171*	-0.0857	-0.0136	0.0616
	(0.0843)	(0.0928)	(0.0899)	(0.0825)	(0.0863)
Wet_{t-1}	0.481***	0.0816	0.127	0.0201	0.128
	(0.139)	(0.143)	(0.171)	(0.147)	(0.146)
Wet_{t-1}*Female	-0.393**	0.204	-0.144	-0.271	0.0249
	(0.170)	(0.181)	(0.197)	(0.169)	(0.186)
Dry_{t-1}	0.171**	-0.0981	-0.00178	0.00589	-0.108
	(0.0867)	(0.0977)	(0.0988)	(0.0818)	(0.0923)
Dry_{t-1}*Female	-0.130	-0.0376	0.0892	-0.0534	0.0800
	(0.103)	(0.116)	(0.116)	(0.105)	(0.107)
Birth order	-0.0444*	-0.0868***	-0.111***	-0.0779***	-0.0591***
	(0.0254)	(0.0265)	(0.0260)	(0.0223)	(0.0181)
Family size	0.0562*	0.0946***	0.155***	0.0915***	0.0837***
	(0.0311)	(0.0320)	(0.0322)	(0.0275)	(0.0240)
Constant	-0.958***	-2.396***	-2.018***	-2.032***	-2.232***
	(0.188)	(0.198)	(0.189)	(0.166)	(0.172)
Observations	3,621	3,526	3,656	3,956	3,703
R-squared	0.117	0.082	0.066	0.059	0.073
Region FE	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes	Yes	Yes
Birth month FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered by survey cluster ID

8.4 Rainfall shocks and breastfeeding

We study the effects of rainfall shocks on breastfeeding by gender in order to see if this channel may help in explaining our results for newborns. Breastfeeding is one type of parental investment in children's health and, if significant results are found by gender, may provide an indication of differential treatment for boys and girls. We study how a lagged rainfall shock affects newborns in order to see if this drives the results.

There is substantive medical research detailing the benefits of breast milk for infants and young children (Victora et al., 1987; Kramer et al., 2001). Breast milk not only provides necessary nutrition, but it also can help protect children against diseases (Kim, 2010). While breastfeeding is especially critical for infants in the first six months of life, it has been shown that children under the age of two who are not breastfed have a higher risk of mortality and that exclusive breastfeeding has greater benefits than when breastfeeding complements other foods and liquids (Black et al., 2003).

We use the following specification to explore any differences by gender in breastfeeding following lagged rainfall shocks for newborns:

$$\begin{aligned} Breastfeeding_{ijt} = \alpha + \beta_1 Female_i + \beta_2 Wet_{jt-1} + \beta_3 Wet_{jt-1} * Female_i + \beta_4 Dry_{jt-1} \\ + \beta_5 Dry_{jt-1} * Female_i + \chi_{ij} + \varsigma_d + \gamma_t + \varepsilon_{ijt} \end{aligned} \tag{8.1}$$

The results for this regression are presented in Table 8.6 and as we can see we do not find any statistically significant effects of lagged rainfall shocks on newborn children.

8.5 Summary of results

The results yield a number of significant effects and trends, especially when the regressions are specified by both gender and age. The regressions age cohort draw out more nuanced effects and enable us to see more specifically which groups benefit the most and which are the most vulnerable. In general, boys benefit more than girls conditional on rainfall shocks in terms of health outcomes, particularly in weight-for-age and height-for-age outcomes.

There are three key findings in the results. Firstly, boys benefit in terms of weight-for-age and height-for-age following a year with higher-than-average rainfall, while girls do worse in comparison to males who have experienced a wet shock in terms of weight-for-age. We see this from the positive coefficients for the Wet_{t-1} term for weight-for-age and height-for-age z-scores, coupled with a negative coefficient on the interaction term $Wet_{t-1} * Female$ for weight-for-age in Table 8.2. This finding relates to our first research question. Secondly, we find that when further investigating this effect by age cohorts, our results suggest that newborn boys are especially advantaged following a positive rainfall shock in the previous rainy season. This is evidenced by the positive coefficients for Wet_{t-1} in Table 8.4 as well as in Table 8.5, for the columns reporting the results for newborn boys. Females do not see the same benefits, as indicated by the negative coefficients on $Wet_{t-1} * Female$ in the corresponding tables. This relates to our second research question.

Finally, we also find that there is some evidence that newborns also benefit from dry shocks in the previous year as well. The results found in Table 8.4 on weight-for-age and Table 8.5 on height-for-age suggest that newborns benefit in terms of health from a dry rainy season

Table 8.6: Months of breastfeeding

	Months of breastfeeding
Dep. var.	Months of breastfeeding
Female	0.0949
	(0.143)
Wet_{t-1}	-0.335
	(0.218)
Wet_{t-1}*Female	0.242
	(0.284)
Dry_{t-1}	-0.135
	(0.141)
Dry_{t-1}*Female	0.0121
	(0.180)
Birth order	0.0398
	(0.0396)
Family size	-0.0347
	(0.0491)
Constant	2.742***
	(0.287)
Observations	3,560
R-squared	0.432
Region FE	Yes
Survey year FE	Yes
Survey month FE	Yes
Birth month FE	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered by survey cluster ID

in the previous year with increases of 0.141 and 0.171 standard deviations, respectively. For this finding, we do not find any significant differences between boys and girls.

9 Robustness checks

A set of robustness checks are carried out to further explore the relationship between rainfall and the disease environment in order to strengthen the argument for rainfall being a proxy for investment in this setting.

9.1 Rainfall shocks and the disease environment

Two robustness checks are used to ensure that the disease environment is not driving our results by checking the probabilities of having diarrhea and fever and investigating whether there are any marginal effects for girls. We test for the probabilities of having diarrhea and fever using data on whether or not children have had either of these in the two weeks prior to the survey round. Due to lack of data on the children from the 2005 and 2010-11 surveys, there is only data on 7,175 children from the 2000 survey round. These robustness checks are to see if there are differences in the prevalence of key disease indicators, which can indicate effects of the disease environment. We want to check if different responses to the disease environment are driving our results. It must be noted, however, that since the data is only available for children surveyed in 2000, the results are not representative for the sample used in the main specifications.

A logit regression model is used to measure the probabilities of having both diarrhea and fever since they are binary variables taking the value of one if the child has had either symptom in the two weeks preceding the survey. The specification outlined in equation 9.1 is the same for both outcome variables, having had diarrhea and fever in the two weeks preceding the survey.

Rainfall shocks from the current year are used since these shocks are the most relevant for any potential effects on diseases. The variables captured by χ_{ij}, ς_d, and γ_t are the same as in the main specification 7.1 outlined in the empirical approach section, except that survey year fixed effects are no longer included since there is only data from the 2000 survey round. As before, ε_{ijt} represents the error term and standard errors are clustered by survey ID.

$$\begin{aligned} Diarrhea_{ijt} = \alpha + \beta_1 Female_i + \beta_2 Wet_{jt} + \beta_3 Wet_{jt} * Female_i + \beta_4 Dry_{jt} \\ + \beta_5 Dry_{jt} * Female_i + \chi_{ij} + \varsigma_d + \gamma_t + \varepsilon_{ijt} \end{aligned} \tag{9.1}$$

Probability of diarrhea

After running the logit regression on the incidence of diarrhea, the results presented in column 1 of Table 9.1 do not indicate any difference in the probability of having had diarrhea in the two weeks leading up to the survey after experiencing a rainfall shock for either boys or girls. This provides a basis for the results not being driven by rainfall affecting children's health through the incidence of diarrhea, strengthening the argument that the results can be attributed to changes in intra-household resource allocation.

Probability of fever

Fever is one of the main symptoms of malaria, which is one of the most prominent diseases caused by high rainfall. This robustness check is to see if there is a significant marginal effect by gender in the probability of having had fever in the last two weeks.

Table 9.1: Probability of diarrhea and fever (logit)

	Probability of diarrhea and fever	
	(1)	(2)
VARIABLES	Diarrhea	Fever
Female	-0.110	-0.128*
	(0.0910)	(0.0755)
Wet_t	-0.216	-0.328**
	(0.149)	(0.140)
Wet_t*Female	0.154	0.194
	(0.141)	(0.124)
Dry_t	-0.133	-0.120
	(0.133)	(0.136)
Dry_t*Female	0.0291	0.128
	(0.140)	(0.119)
Birth order	0.135***	0.135***
	(0.0212)	(0.0213)
Family size	-0.208***	-0.172***
	(0.0269)	(0.0273)
Constant	-1.229***	-0.364**
	(0.152)	(0.150)
Observations	7,175	7,171
Region FE	Yes	Yes
Survey month FE	Yes	Yes
Birth month FE	Yes	Yes

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Standard errors clustered by survey cluster ID

The results from the logit regression on incidence of fever presented in column 2 of Table 9.1 reveal some interesting results. We find a that a positive rainfall shock in the current period has a negative effect on the probability of having had a fever during the past two weeks leading up to the survey. We do not find any indication that boys and girls are affected differently, as indicated by the lack of significance for the $Wet_t * Female$ interaction term. For females who have not experienced either a wet or dry shock in the previous year, the coefficient for the *Female* variable suggests that they are less prone to having a fever than males.

10 Discussion, limitations, and conclusion

In this section we will conclude by providing our own interpretations for the patterns found in the results. We will also discuss the internal and external validity as well as the limitations of the study, including suggestions for extensions or areas for future research. Finally, we will conclude with remarks on how our study contributes to the existing body of work surrounding differences in child health by gender and age following rainfall shocks as well as the policy implications of our findings.

10.1 Discussion of results

While many of the findings of our study echo aspects of previous research on gender differences in health in the wake of weather fluctuations, some of the findings contribute new or uncommon indications to the literature. We will highlight the commonalities with previous research as well as deviations from our expected outcomes and previous findings and will discuss potential explanations for our findings. We will also discuss the implications of the robustness checks.

The results presented in Table 8.2 on anthropometric measures address our first research question and enable us to see the broad strokes of gender bias in intra-household resource allocation towards health and nutrition. From this first set of regressions, it becomes apparent that boys reap benefits in critical health measures such as weight-for-age and height-for-age when families experience a positive rainfall shock. While an increase in rainfall significantly benefits boys, there is some indication that this benefit is skewed towards boys given the negative coefficient for girls' weight-for-age measures given a wet shock. This general finding provides an indication that additional income may be allocated to more towards boys rather than to girls. In terms of the conceptual framework, this would be described as parents getting more resources due to the positive rainfall shocks, which are then predominantly invested in male children. We hypothesize that one reason for this may be due to different returns from investing in a child's health depending whether it is a boy or a girl due to, for example, greater employment opportunities either in the workforce or at home.

When we address our second research question to investigate if the effects vary for boys and girls of different ages, we uncover more nuanced findings. One of the most coherent findings stemming from the regressions run by age is that newborn boys greatly benefit from lagged positive rainfall shocks, as evidenced by their relatively large gains to weight-for-age and height-for-age z-scores. This is consistent with previous research which has found that younger children are more sensitive to shocks.

The results by age cohort paint an even starker picture for differential treatment among boys and girls, especially for newborns. The most pronounced differences arise following wet shocks, as we can see that newborn girls fare significantly worse than boys who have also experienced wet shocks. This suggests that additional resources are being transferred mainly towards boys following wet years, contributing to the significant discrepancies in weight-for-age and height-for-age measures. The findings from the second set of regressions by age cohort help explain the results found in the initial regressions in Table 8.2 by identifying which groups of boys and girls are driving the differences by gender for children under the age five. In terms of the conceptual framework, the same reasoning discussed above applies with parents investing in children with more promising returns to investment.

While there are many aspects of the results that align with previous research and the expected outcomes previously outlined, one of the main deviations of our findings is the lack of conclusive evidence of poor health outcomes following dry shocks. One might have expected to find generally poorer health outcomes following dry rainy seasons, as similar studies have found (Hoddinott and Kinsey, 2001; Jensen, 2000). A potential explanation that for this that is particularly relevant in the Ethiopian context may be that food aid programs help smooth consumption to some degree. In Ethiopia, there is a substantial food aid network dedicated to offsetting the health dangers of droughts. According to statistics from USAID on food assistance in Ethiopia, 7.9 million people are covered by the Ethiopian government-led Productive Safety Net Program (PSNP), which is supported by USAID and many other organizations (USAID, 2016). Food aid may be an omitted variable that partially shields the negative health effects that are often associated with drier-than-average rainy seasons and droughts.

Not only is there lack of evidence for negative effects following dry shocks, but the results suggest that newborns actually benefit from dry shocks. Furthermore, there is little indication of gender bias, as evidenced by the lack of significance for the interacted terms with gender. One explanation for this surprising finding is that mothers may spend more time at home during dry years, potentially leading more attentive child care. It may be the case that mothers are on the margin of agricultural production and work more during wet years and less during dry years. Another related explanation which we explored was the role of breastfeeding, which may increase as a result of mothers staying home more during dry years. The lack of significant findings from the specification, however, suggest that there are not significant changes in the amount of breastfeeding for newborns in response to rainfall shocks.

Another deviation from previous research is that the anthropometric measures associated with long-term health, weight-for-age and height-for-age, are the most significantly affected by rainfall shocks lagged one year. Many studies use weight-for-height as a short-term measure for health (see e.g. Rabassa et al., 2014; Jensen, 2000; Wang et al., 2009) based on the assumption that weight is most affected in the short run and that height changes slowly over time. Changed to height are often the result of chronic malnutrition rather than temporary health shocks (de Onis and Blössner, 1997). Our results, however, suggest that both weight and height are affected by relatively recent rainfall shocks, as evidenced by the lack of significance for weight-for-height and the significant effects found for weight-for-age and height-for-age. This may indicate that a recent rainfall shock affects both short-term and long-term health.

The main control variables included throughout the results, birth order and family size, provide insight into household dynamics that affect health outcomes. The results suggest that being born later among one's siblings slightly decreases a children's health outcomes. An intuitive explanation for this is that parents invest more in first-born children since there is only one child consuming family resources. As the family grows, however, children share finite family resources, such as nutritional, monetary, and time investments. The small positive effects found for the family size variable, however, suggest that children born into larger families fare better in terms of anthropometric measures. This seems to, at first, dispel the notion that children who share resources with more family members suffer from poorer health outcomes. One reason for the opposite directions may be due to the fact that the birth order variable records the birth order of the child taking into account any children who may have died, whereas the family size variable is defined as the total number of living children within a family. The difference in the direction of the two effects, therefore, may be attributed to omitted variable bias in the form of infant mortality. It may be the case that parents that have a large number of children who are still alive at the time of the survey are well equipped to provide adequate health resources to their children, thus causing the children to attain better health outcomes compared to families with fewer living children.

Finally, we find few indications any differences by gender in susceptibility to the disease environment when looking at the probabilities of having symptoms of the two of the most prevalent diseases in Ethiopia. While children are less likely to have a fever following a wet shock in the current year, there is no significant effect by gender as suggested by the insignificant coefficient on the interacted term for having experienced a wet shock and being female.

10.2 Limitations of our study and areas for future research

One of the key strengths of this paper lies in the use of rainfall as an exogenous shock to income and the implications that follow for the ability to achieve internal validity. As rainfall has been used in several contexts and found to affect income in various settings, including Ethiopia, we believe that it serves as a good exogenous shock to income in our study. However, there are still factors that may affect the results for our study and we will try to address the more important ones in this section.

While the findings from this study appear robust, we conduct additional robustness checks for two potential confounding factors in the disease environment, there are areas where the study was limited by scope and data availability. Furthermore, there are areas where the study could be extended and ways in which the arguments could be strengthened. Our study may also be subject to mis-specification and bias resulting from omitted variables.

We begin by mentioning the potential impact of the disease environment on child health and how it may affect boys and girls differently, as discussed previously in the paper. We attempt to control for this in the robustness check section by running regressions on self-reported measures serving as proxies for some of the most prominent diseases in Ethiopia. The fact that the disease measures are self-reported may pose a problem as the disease variables may suffer from recall error due to difficulty remembering whether one's child was sick or not in the weeks preceding the survey. Data is also only available on the health measures for the 2000 survey, which limits our ability to control for these disease indicators across the full sample.

A further limitation mentioned in the discussion of the results is controlling for the role of food aid, which is likely to be an influential factor in Ethiopia. As mentioned, food aid reaches a significant proportion of the population. This may cloud our results, offsetting part of a negative nutritional effect that may have otherwise occurred following a dry year. A potential topic for further research would therefore be to incorporate information on food aid when assessing the effects of rainfall shocks on child health in Ethiopia or in other contexts where food aid is especially prevalent.

Turning attention to external validity, the varied results regarding gender bias following weather fluctuations in Sub-Saharan Africa suggest that there are not firmly established trends in the allocation of resources at the household level across countries. Previous research in the region indicates that the context of a country can influence whether or not there is gender bias in resource allocation towards health and the nature of these effects. While gender bias is found in many settings, there is much more to be learned in terms of why it is found in some contexts and not in others. Since there is relatively little research on gender bias following economic shocks in Ethiopia, there are no clear investment behaviors to which this study is able to anchor. Nonetheless, our study adds to the accumulating body of research finding evidence of gender bias in Sub-Saharan Africa in response to economic and weather fluctuations.

As a result, we believe that one of the most exciting areas for future research would be to look at the complex contextual factors that make up societies where children live. Flatø and Kotsadam (2014) only find significant differences in infant mortality in communities where there is a strong preference for sons, where fertility desires are low, and in areas where there are low levels of female employment. Wang et al. (2009) also control for the distance to health service providers and find that better access to health services reduces the incidence of malnutrition. All of these variables are available within the DHS survey data, but we were unable to incorporate them due to the scope of the project. Integrating this information would be a valuable extension of this study and could help shed light on indicators for parental investment. Further research in this area could help to identify in which communities girls are likely to suffer disproportionately in times of distress and better direct policy efforts to address gender bias in the intra-household allocation of health resources.

10.3 Conclusion and policy implications

We study the effect of positive and negative rainfall shocks, as defined by rainfall above or below at least one half standard deviation from the average rainfall in an area, on the health of children under the age of five in rural Ethiopia. Rainfall is exploited as an exogenous shock to income in Ethiopia, as the country is highly agriculturally dependent and variations in rainfall are strongly linked to income. Since Ethiopia is one of the poorest countries in the world, households are left with little possibility to smooth consumption, putting the health of children at risk during times of economic hardship.

We measure children's health using three anthropometric measures: the z-scores for weight-for-height, weight-for-age and height-for-age. Our paper adds to the literature by studying differences in health outcomes of children under the age of five by gender in response to rainfall shocks in the previously unexplored setting of Ethiopia. We contribute further by devoting formal attention to whether children of different ages are affected differently while still estimating the effects by gender. While our results provide empirical evidence of gender bias in intra-household resource allocation, there still remain important gaps in the knowledge in this area that may further explain these differences.

We find that children under the age of five benefit from a positive rainfall shock in the previous rainy season in terms of weight-for-age and height-for-age, suggesting that a recent rainfall shock impacts both weight and height. While boys under the age of five benefit in terms of health outcomes from a wet shock, there is evidence that girls under the age of five fare worse in terms of weight-for-age compared to boys who have experienced a wet shock. When looking at age cohorts, our results suggest that newborns are particularly sensitive to rainfall shocks and that there is differential treatment for boys and girls in the allocation of resources towards health and nutrition. While newborn boys benefit from wet shocks in their weight-for-age and height-for-age measures with increased z-scores of 0.445 and 0.481 standard deviations, respectively, there is evidence that girls do not reap the same benefits of increased resources. Compared to boys who have experienced a positive rainfall shock, the weight-for-age and height-for-age measures are significantly less at -0.518 and -0.393. Finally, newborns in general gain in weight-for-age and height-for-age following dry shocks and there is no significant difference by gender, which may be a result of mothers spending more time at home during dry seasons.

Although rainfall provides a good exogenous shock to household income, we must note that it may not be the only channel through which it affects households. The effects of rainfall on the disease environment may be the most important concern for our topic of study and we address the potential impact of it on boys and girls. While we do not find any indication that changes in the disease environment drive our results, we cannot rule out the possibility. Our study would benefit from further analysis controlling for the disease environment, adding to the robustness of our results.

Our findings provide a basis for key policy implications. While food aid may alleviate the negative income shocks from dry years at the household level, it may not necessarily address the underlying tendencies toward gender bias. Given that the results show pronounced gender bias following increased resources due to rainfall, food aid may in fact exacerbate gender bias by similarly increasing resources which may then be reallocated towards boys. This may further disadvantage young girls in terms of long-term health outcomes given the suggestions from the results of this study. Alternatively, policies aimed at increasing female employment and education may be more fruitful for eliminating gender bias in the long run. While our study does not identify these factors as indicators for gender bias, there is support from the literature on the intra-household allocation of resources that suggests that these factors may play a significant role in parents' investment decisions.

We hope that this paper provides a small contribution to the state of knowledge, allowing for steps to be taken to ensure that children of different genders are provided with equal opportunities in life.

References

Anderson, S. and D. Ray (2010). Missing Women: Age and Disease. *Review of Economic Studies 77*(4), 1262–1300.

Baird, S., J. Friedman, and N. Schady (2011). Aggregate Income Shocks and Infant Mortality in the Developing World. *Review of Economics and Statistics 93*(3), 847–856.

Beaton, G. (1993). Which Age Groups Should be Targeted for Supplementary Feeding. *Nutritional Issues in Foreign Aid.*

Bengtsson, N. (2010). How Responsive is Body Weight to Transitory Income Changes? Evidence from Rural Tanzania. *Journal of Development Economics 92*(1), 53–61.

Björkman-Nyqvist, M. (2013). Income Shocks and Gender Gaps in Education: Evidence from Uganda. *Journal of Development Economics 105*, 237–253.

Black, R. E., S. S. Morris, and J. Bryce (2003). Where and Why are 10 million Children Dying every Year? *The Lancet 361*(9376), 2226–2234.

Bonnier, E., J. Poulsen, T. Rogall, and M. Stryjan (2015). Preparing for Genocide: Community Work in Rwanda. *No. 2015: 1. Working Paper, Department of Economics, Uppsala University.*

Brambor, T., W. R. Clark, and M. Golder (2006). Understanding Interaction Models: Improving Empirical Analyses. *Political analysis 14*(1), 63–82.

Burlando, A. (2015). The Disease Environment, Schooling, and Development Outcomes: Evidence from Ethiopia. *Journal of Development Studies 51*(12), 1563–1584.

Central Intelligence Agency (2016). World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/et.html. [Accessed: April 27, 2016].

Central Statistical Agency [Ethiopia] and ICF International (2011). Ethiopia Demographic and Health Survey 2011 Final Report.

Cole, S., A. Healy, and E. Werker (2012). Do Voters Demand Responsive Governments? Evidence from Indian Disaster Relief. *Journal of Development Economics 97*(2), 167–181.

Currie, B. J. and S. P. Jacups (2003). Intensity of Rainfall and Severity of Melioidosis, Australia. *Emerging Infectious Diseases 9*(12), 1538–1542.

de Onis, M. (2006). *WHO Child Growth Standards: Length/Height-for-age, Weight-for-age, Weight-for-length, Weight-for-height and Body Mass Index-for-age.* World Health Organization.

de Onis, M. and M. Blössner (1997). WHO Global Database on Child Growth and Malnutrition. *World Health Organization.*

Demeke, A. B., A. Keil, and M. Zeller (2011). Using Panel Data to Estimate the Effect of Rainfall Shocks on Smallholders Food Security and Vulnerability in Rural Ethiopia. *Climatic Change 108*(1-2), 185–206.

Dercon, S. (2004). Growth and Shocks: Evidence from Rural Ethiopia. *Journal of Development Economics 74*(2), 309–329.

Diao, X., P. B. Hazell, D. Resnick, and J. Thurlow (2007). *The Role of Agriculture in Development: Implications for Sub-Saharan Africa*, Volume 153. Intl Food Policy Res Inst.

Diao, X. and A. N. Pratt (2007). Growth Options and Poverty Reduction in Ethiopia: An Economy-wide Model Analysis. *Food Policy 32*(2), 205–228.

Duflo, E. (2012). Women's Empowerment and Economic Development. *Journal of Economic Literature 50*(4), 1051–1079.

Ferreira, F. H. and N. Schady (2009). Aggregate Economic Shocks, Child Schooling, and Child Health. *The World Bank Research Observer*.

Flatø, M. and A. Kotsadam (2014). Droughts and Gender Bias in Infant Mortality in Sub-Saharan Africa. *Memorandum, Department of Economics, University of Oslo.*

Fuse, K. (2010). Variations in Attitudinal Gender Preferences for Children across 50 Less-Developed Countries. *Demographic Research 23*, 1031–1048.

Grantham-McGregor, S., Y. B. Cheung, S. Cueto, P. Glewwe, L. Richter, B. Strupp, I. C. D. S. Group, et al. (2007). Developmental Potential in the First 5 Years for Children in Developing Countries. *The Lancet 369*(9555), 60–70.

Grantham-McGregor, S. M., L. C. Fernald, and K. Sethuraman (1999). Effects of Health and Nutrition on Cognitive and Behavioural Development in Children in the First Three Years of Life. Part 1: Low Birthweight, Breastfeeding, and Protein-Energy Malnutrition. *Food and Nutrition Bulletin 20*(1), 53–75.

Grossman, M. (1972). On the Concept of Health Capital and the Demand for Health. *Journal of Political Economy 80*(2), 223–255.

Hoddinott, J. and B. Kinsey (2001). Child Growth in the Time of Drought. *Oxford Bulletin of Economics and Statistics 63*(4), 409–436.

Institute for Health Metrics and Evaluation (2010). Global Burden of Diseases Profile: Ethiopia. Retrieved from http://www.healthdata.org/sites/default/files/files/country_profiles/GBD/ihme_gbd_country_report_ethiopia.pdf. [Accessed: May 2, 2016].

Jensen, R. (2000). Agricultural Volatility and Investments in Children. *American Economic Review 90*(2), 399–404.

Kim, Y. S. (2010). The Impact of Rainfall on Early Child Health. *Job market paper, University of Maryland, Maryland.*

Kramer, M. S., B. Chalmers, E. D. Hodnett, Z. Sevkovskaya, I. Dzikovich, S. Shapiro, J.-P. Collet, I. Vanilovich, I. Mezen, T. Ducruet, et al. (2001). Promotion of Breastfeeding Intervention Trial (PROBIT): a randomized trial in the Republic of Belarus. *Journal of the American Medical Association 285*(4), 413–420.

Kudamatsu, M., T. Persson, and D. Strömberg (2012). Weather and Infant Mortality in Africa.

Martorell, R. (1995). History and Design of the INCAP Longitudinal Study.

Martorell, R. (1999). The Nature of Child Malnutrition and its Long-Term Implications. *Food and nutrition Bulletin 20*(3), 288–292.

Martorell, R., L. K. Khan, and D. G. Schroeder (1994). Reversibility of Stunting: Epidemiological Findings in Children from Developing Countries. *European Journal of Clinical Nutrition 48*, S45–57.

McSweeney, C., M. New, and G. Lizcano (2010). UNDP Climate Change Country Profiles: Ethiopia. Retrieved from http://country-profiles.geog.ox.ac.uk/. [Accessed: April 26, 2016].

Measure DHS/ICF International (2013). Standard Recode Manual for DHS VI.

Miguel, E. (2005). Poverty and Witch Killing. *Review of Economic Studies 72*(4), 1153–1172.

MoH, F. D. E. (2006). National Five-Year Strategic Plan for Malaria Prevention and Control in Ethiopia.

National Hurricane Center. Latitude/Longitude Distance Calculator. Retrieved from http://www.nhc.noaa.gov/gccalc.shtml. [Accessed: March 29, 2016].

Paynter, S., P. Weinstein, R. Ware, M. Lucero, V. Tallo, H. Nohynek, A. Barnett, C. Skelly, E. Simoes, P. Sly, et al. (2013). Sunshine, Rainfall, Humidity and Child Pneumonia in the Tropics: Time-series Analyses. *Epidemiology and Infection 141*(06), 1328–1336.

Quisumbing, A. R. (2003). Food Aid and Child Nutrition in Rural Ethiopia. *World Development 31*(7), 1309–1324.

Rabassa, M., E. Skoufias, and H. Jacoby (2014). Weather and Child Health in Rural Nigeria. *Journal of African Economies 23*(4), 464–492.

Rose, E. (1999). Consumption Smoothing and Excess Female Mortality in Rural India. *Review of Economics and Statistics 81*(1), 41–49.

Rossi, P. and L. Rouanet (2015). Gender Preferences in Africa: A Comparative Analysis of Fertility Choices. *World Development 72*, 326–345.

Sen, A. (1990). More than 100 million Women are Missing. *The New York Review of Books.*

Strauss, J. and D. Thomas (1998). Health, Nutrition, and Economic Development. *Journal of Economic Literature 36*(2), 766–817.

Tadesse, M., B. Alemu, G. Bekele, T. Tebikew, J. Chamberlin, and T. Benson (2006). *Atlas of the Ethiopian Rural Economy.* Intl Food Policy Res Inst.

Thomson, M. C., S. J. Mason, T. Phindela, and S. J. Connor (2005). Use of Rainfall and Sea Surface Temperature Monitoring for Malaria Early Warning in Botswana. *American Journal of Tropical Medicine and Hygiene 73*(1), 214–221.

Toole, M. J. and R. M. Malkki (1992). Famine-Affected, Refugee, and Displaced Populations: Recommendations for Public Health Issues. *Centers for Disease Control (United States)[CDC].*

Tropical Rainfall Measurement Mission Project (TRMM). Daily TRMM and Others Rainfall Estimate (3B42 V7 derived), version 7. Retrieved from http://disc.gsfc.nasa.gov/datacollection/TRMM_3B42_daily_V7.shtml. [Accessed March 5, 2016].

USAID (2016). Food Assistance Factsheet: Ethiopia. Retrieved from https://www.usaid.gov/ethiopia/food-assistance. [Accessed: May 15, 2016].

Victora, C., J. P. Vaughan, C. Lombardi, S. C. Fuchs, L. Gigante, P. Smith, L. Nobre, A. Teixeira, L. Moreira, and F. Barros (1987). Evidence for Protection by Breast-feeding against Infant Deaths from Infectious Diseases in Brazil. *The Lancet 330*(8554), 319–322.

Wang, L., S. Kanji, and S. Bandyopadhyay (2009). The Health Impact of Extreme Weather Events in Sub-Saharan Africa. *World Bank Policy Research Working Paper Series, Vol.(2009).*

WHO (2016). Early Child Development. Retrieved from http://www.who.int/maternal_child_adolescent/topics/child/development/en/. [Accessed: May 9, 2016].

World Bank (2014a). World Development Indicators: Ethiopia. Retrieved from http://databank.worldbank.org/data/reports.aspx?source=2&country=ETH&series=&period=. [Accessed: April 27, 2016].

World Bank (2014b). World development indicators: Sub-Saharan Africa. Retrieved from http://data.worldbank.org/region/SSA. [Accessed: April 27, 2016].

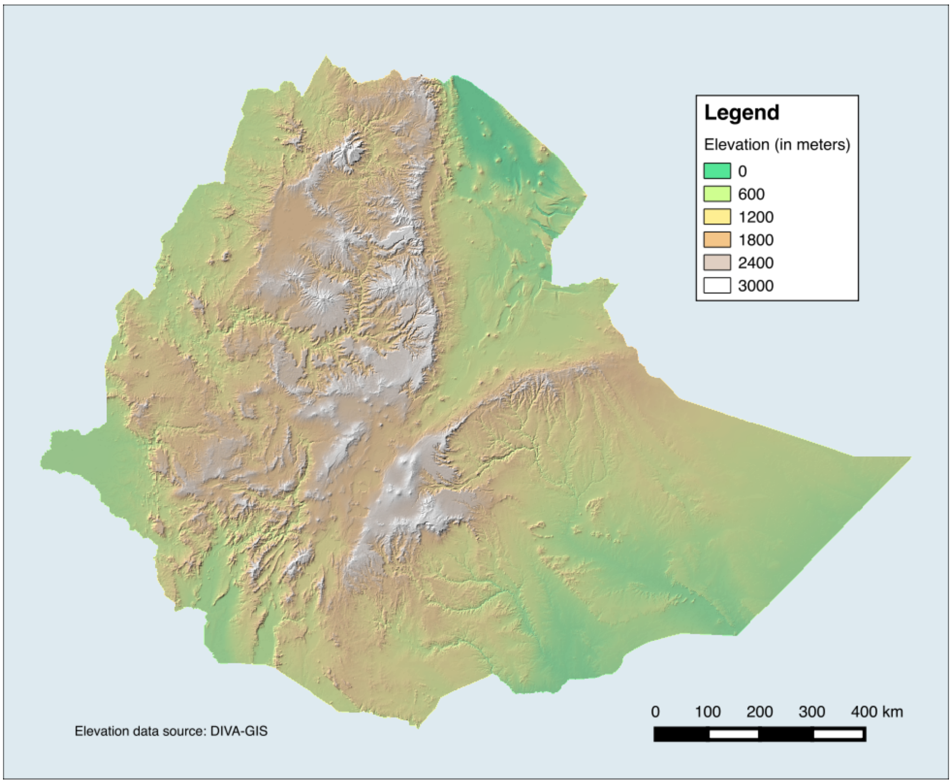
World Bank (2016). Population Ranking Table. Retrieved from http://data.worldbank.org/data-catalog/Population-ranking-table. [Accessed: April 27, 2016].

Yamano, T., H. Alderman, and L. Christiaensen (2005). Child Growth, Shocks, and Food Aid in Rural Ethiopia. *American Journal of Agricultural Economics 87*(2), 273–288.

Yesuf, M., S. Di Falco, T. Deressa, C. Ringler, and G. Kohlin (2008). *The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia.* Intl Food Policy Res Inst.

Appendix

Figure A1: Elevation map of Ethiopia



Map created by authors in QGIS using elevation data from DIVA-GIS.