The determinants of sex differences in child stunting in Sub Saharan Africa: a multilevel logistic regression analysis

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ABSTRACT

About 40 percent of children in Sub Saharan Africa is stunted and a large number of studies has found that boys are more likely to be stunted than girls. This study aims to investigate the determinants of this sex difference in stunting. A multilevel logistic regression model with interaction analysis is used on data for 344,748 children living in 31 Sub Saharan countries. It is hypothesized that the sex differences are the result of biological, socio-economic and cultural determinants. The results imply a relation between sex differences in stunting and the duration of breastfeeding, maternal education, diarrhoea prevalence, child age and living in a polygamous household.

1. Introduction

Globally, an estimated 22.9 percent of children younger than five years of age experience stunting (Worldbank Database, Retrieved 2018). This percentage becomes even larger when looking specifically at Sub Saharan Africa, where about 36 percent of children are stunted (UNICEF, 2016). Stunting implies a child is too short for its age and this growth retardation is usually caused by malnutrition and infection. Specifically, when a child has a Height for Age Z-score (HAZ score) that is lower than two standard deviations from the global population average it is said to be stunted (Prendergast & Humphrey, 2014).

1.1 What are the (economic) consequences of stunting?

Stunting causes a large burden on the development of a child. It has been shown that stunting has detrimental effects on neurodevelopment, locomotor skills and increases the child's morbidity and mortality risks. Furthermore, parental stunting in early childhood increases the likelihood of stunted offspring, creating an intergenerational, vicious circle (Prendergast & Humphrey, 2014).

Stunting does not only cause direct detriments to a child's development, but also indirectly creates a large economic burden. Research shows that early childhood stunting is associated with a loss of physical work capacity (Norgan, 2000). Specifically, Worldbank(2006) estimates suggest that a 1 percent loss in adult height due to stunting during childhood, is associated with a loss of 1.4 percent in an individual's economic productivity. In addition, the loss in income due to early childhood stunting is estimated to vary from 22.2 percent for non-poor up to 30.1 percent for children growing up in poor households (Grantham-McGregor *et al.*, 2007). Furthermore, stunting in the first 36 months of life is associated with a decrease of 66 percent in per capita household spending in adult life (Hoddinot *et al.*, 2011). Another study shows that, compared to a control group, adults who received nutritional supplementation during early childhood earn 47 percent higher wages (Hoddinot *et al.*, 2008). Given the large share of child stunting in Sub Saharan Africa, this most likely curbs GDP.

Therefore, it is important to understand the mechanisms influencing child stunting, which will be discussed in more detail below. It is also important to design interventions aimed at preventing it. Interventions are mostly targeted at maternal health, improving infant and young child feeding practices (IYCF), and increasing water, sanitation and hygiene practices (WASH) to counter environmental enteric dysfunction (EED) (Prendergast & Humphrey, 2014). Factors influencing child stunting are to be found in the health, socioeconomic, political, cultural and environmental context.

1.2 Sex differences in stunting

Stunting may directly be caused by malnutrition and infection. These in turn are influenced by the circumstances a child is living in. Despite these contexts being largely similar for boys and girls, many studies on stunting in Sub Saharan Africa report higher stunting rates among boys than among girls (Espo *et al* (2002), Wamani *et al.* (2004), Ukwuani and Suchindran (2003), Ngare and Muttunga (1999)). To examine the presence of a systematic sex difference in child stunting, a meta-analysis among 10 Sub Saharan countries over a period from 1995-2003 was conducted using the Demographic Health Survey. This study established that boys are more likely to be stunted than girls (Wamani *et al.*, 2007) and paved the way for more research confirming this finding (Demissie *et al.* (2013), Bukusuba *et al.* (2017), Schrijner & Smits (2018)).

Many studies report on sex differences in stunting and find higher odds for boys than for girls to be stunted. These odds ratios also vary among studies which focus on different regions, as can be seen from Table 1.2. Hence, it seems likely that factors specific to the context in which a child grows up, play a significant role in stunting prevalence. This study will take these context factors into account as well. Furthermore, some context factors are hypothesized to have a different effect on boys than on girls. The specific context factors and their effect on child stunting will be discussed in more detail in the next section.

Table 1.2: Overview of studies' findings in sex differences in stunting

Study	**Region**	**Odds ratio of the gender difference**
Bukusuba *et al*(2017)	Southwest Uganda	2.2
Chirande *et al.* (2015)	Tanzania	1.39
Cruz *et al.* (2017)	Central region, Mozambique	4.01
Demissie *et al.*(2013)	Somali, Ethiopië	1.45
Espo *et al.* (2002)	Rural Malawi	1.9
Ukwamni & Suchindran (2003)	Nigeria	1.32
Wamani *et al.(*2004)	Rural Uganda	2
Wamani *et al.*(2007)	Sub Sahara Africa (selected countries)	1.16

Although many studies report on sex differences in stunting, little is known about the determinants of these sex differences. Therefore, the research question this thesis aims to answer is: What are the determinants of sex differences in child stunting in Sub Saharan Africa? The thesis will not only focus on demographic and health factors known to be related to child stunting but will also examine the role of the circumstances in which a child grows up.

In the next section, the theoretical framework will be presented, discussing the literature on stunting and theories on sex differences in stunting. Section three will discuss the data and methodology used and section four will present descriptive statistics and the results of the analysis. In section five these results are discussed and section six concludes.

2. Theoretical framework

This section discusses the literature on stunting. First, the focus will be on the causes of stunting and the role of the context. Then the theory on sex differences in child stunting will be discussed.

2.1 The determinants of stunting

Stunting may be caused directly by malnutrition and infections. It has been found that food insecurity, as measured by a lack of access to food, is an important predictor of child stunting. In particular, children in food-insecure households had 2.4 times higher odds of being stunted than children in food-secure households (Bukusuba *et al.*, 2017). This study was focussed on Southwest Uganda. Other studies in Ethiopia (Jemal *et al.*, 2016), Ghana (Gillespie *et al.*, 2013), Nepal (Singh *et al.*, 2014) and Malaysia (Naser *et al.*, 2014) have found similar results.

To truly understand the causes of stunting, a deeper understanding of the context is necessary. Child stunting does not have a simple cause, but rather may be the outcome of a complex set of determinants on the health, socioeconomic, demographic, political, cultural and environmental level (Stewart *et al.*, 2013). These contextual determinants will be discussed below.

2.1.1 Health

Child and maternal health or lack thereof are an important marker for child stunting. Most importantly, many studies found a direct link from maternal health to child health (Prendergast and Humphrey, 2014). In particular, research suggests that 20 percent of child stunting originates *in utero* (Christian *et al.,*2013) and that maternal undernutrition is linked to an increased likelihood of childhood mortality and stunting (Black *et al.*, 2008). One way to capture this effect, is by measuring maternal stature. A lower maternal stature, as measured by the length of the mother, is associated with a lower HAZ score of her child (Addo *et al.*, 2013). Research also shows that the birth interval affects child health. A study showed higher haemoglobin levels for girls, when the preceding birth interval was longer (Afeworki *et al.*, 2015). Research also shows that the birth interval has an effect on the odds of stunting. Specifically, a short preceding birth interval (< 24 months) is associated with higher odds of stunting than a larger interval (>24 months) (Chirande *et al.*, 2015). Short birth intervals may be risky because maternal nutrient reserves may deplete, and hence her breastmilk is less nutritional. Short birth intervals also lead to closely spaced other children, which may result in less care for the infant (Dewey *et al.*, 2007).

Child health factors are also an important contextual factor influencing stunting prevalence. A marker for health and a key determinant of child stunting is the prevalence of infections.This is associated with a 1.4 percent increase in the odds of stunting (Bukusuba *et al.*, 2017). Additionally, research suggests that the likelihood of stunting increases when children experience episodes of diarrhoea, especially in the first two years of life. This is because diarrhoea decreases absorption of key nutrients, which causes amongst others malnutrition and growth faltering if not replaced (Dewey and Mayers, 2011). Specifically, pooled analysis with data from five countries in nine different years, shows that having five or more episodes of diarrhoea in the first two years, explains 25 percent of stunting at age two (Checkley *et al.*, 2008). Stunting prevalence is also affected by whether children have received vaccinations and if they received Vitamin A supplements in the first two months after delivery, as those have been found to reduce stunting prevalence (Berendsen *et al.*, 2016).

Nutritional status is also affected by feeding practices. The WHO recommends exclusive breastfeeding for the first six months of a child's life, which is associated with lower stunting prevalence (Bukusuba *et al.*, 2017). This period should be followed by the introduction of complementary food in addition to continued breastfeeding (Prendergast and Humphrey, 2014). However, infant and young child feeding practices (IYCF) are often poor in low income countries (Marriot *et al.,* 2012). Prolonged breastfeeding may be used as a substitute supply of nutrients in situations where food is not available or suitable feeding practices are not known or not practiced. However, prolonged breastfeeding is associated with higher odds of stunting as breastmilk alone does not give enough nutrients to children above the age of six months (Girma *et al.,* (2002), Teshome *et al.*, (2009)). Other literature also suggests the possibility that weaker children are breastfed longer (Marquis, 1997). Prolonged breastfeeding is thus hypothesized to be associated with higher odds of stunting.

Lastly, the quality of the healthcare system has a considerable impact on the likelihood of child stunting (Stewart *et al.,* 2013). In an environment where stunting often goes unrecognized because a short stature is the norm (de Onis *et al.*, 2016), skilled healthcare providers have large added value in stunting recognition and prevention. However, in many countries stunting assessment is limited due to lack of knowledge and a lack of time caused by overburdening of the few healthcare providers available (de Onis, 2012).

2.1.2 Socio economic status

On the socio-economic level, various contextual factors play a role. For instance, several studies have found that a households' socio-economic status (SES) is a prominent predictor of child stunting (Bukusuba *et al.,* (2017), Wamani *et al.* (2007)). Since socio-economic status is often clustered among households in a certain region (Schrijner & Smits, 2018) it is essential to also look at SES at regional level.

One socio-economic indicator is maternal education. The educational level of a child's mother is found to be an important predictor of child stunting. Maternal education influences child nutritional status, as better educated mothers are predicted to have lower odds of having stunted children (Wamani *et al.* (2004) (2007), Chirande *et al.,* 2015)). Through formal education, knowledge about child health can be passed on to women, increasing their understanding of health issues (Abuya, 2011). The same logic holds for men and indeed research suggests that better educated men are less likely to have stunted offspring (Wamani *et al.* (2004), Schrijner & Smits (2018)). Often, educational level is clustered in regions and thus it is important to measure it at the regional level as well, following the work of Schrijner & Smits (2018).

Research suggests that paternal employment has a positive effect on child nutritional status, as it has been found that the likelihood of stunting decreases when fathers have a job other than agricultural (Chirande *et al.,* (2015), Schrijner & Smits (2018)). This positive effect is likely due to the increase in household income, leading to more resources to be spend on food. The effects of maternal employment on child stunting have been mixed. A recent study in Tanzania shows an increase in the odds of stunting (Chirande *et al.* (2015), whereas another study on Sub Saharan Africa found a decrease in the odds of stunting (Schijner & Smits, 2018). This may be because working mothers may on the one hand increase household income, in line with the reasoning for paternal employment. On the other hand, they have less time to provide proper care for young children (LaMontagne *et al.,* (1998) Smith *et al.* (2005)).

As discussed above, generating more household income will lead to more economic resources to be spend on food and childcare. Due to a large variety in income and a large informal sector in Sub Saharan Africa, household income is difficult to measure, and a better proxy is household wealth. Studies consistently show that a higher level of development, both at the household and regional level, is related to lower stunting prevalence (e.g. Wamani *et al.* (2007), Chirande *et al.* (2015), Demissie *et al.* (2013), Cruz *et al.* (2017)).

2.1.3 Demographic factors

Family size and structure influence the nutritional status of children living in a household, since family size provides the context the child grows up in and functions as a mediator providing support (Thomson *et al.*, 1997). The following measures capture the effects of family size and structure on child stunting.

First, single motherhood is associated with a lower nutritional status for children (Finlay *et al.*, (2016), Monasch & Boerma (2004)), which is likely due to constraints in time and money of the mother to invest in her children (Bronte-Tinkew & DeJong, 2004).

Second, many children live in a household with a co-residing grandparent (Schrijner & Smits, 2018). According to the 'grandmother support hypothesis' and the 'classical grandmother hypothesis', having a grandmother present in the household is beneficial for children as they support their daughters in rearing children, leading to better nutritional status for grandchildren. Recent research has indeed found grandparental residence was associated with lower odds of stunting (Schrijner & Smits, 2018).

Third, mixed results have been found for the effect of living in a polygamous household on child stunting. On the one hand, polygamy is found to lead to higher stunting prevalence among children This may be due to increases in the uncertainty over genetic relatedness, leading to conflicts and increased competition over resources (Schrijner & Smits, (2018), Strassmann (2011)). Other research, however, suggests that there are no differences in child stunting among monogamous and polygamous households (Lawson *et al.*, 2015). This may be because only rich men can pay for having more wives (Svedberg, 1990), and these richer households are expected to have more resources to provide sufficient nutrition for offspring. Polygamy at the household level will be included in the model to test which effect is stronger.

Fourth, the birth order and the number of siblings influence the nutritional status of children (Schrijner & Smits (2018), Chirande *et al.*, (2015)). This can be explained by the 'resource dilution hypothesis' (Blake, (1981) (1989), Heer (1985)). According to this hypothesis, for any given amount of economic resources, less can be given to each child the more children the household consists of (Bronte-Tinkew & DeJong, 2004). Thus, when a child has more siblings and/or when it is younger (born later), the nutritional status is expected to be lower.

Fifth, a missing father has detrimental effects on child nutrition (Schrijner and Smits, 2018). The literature makes a distinction between an absent father and a deceased father. It has been argued that children which do not see their father regularly, for example because the father works in a different region or country, have lower HAZ-scores. The reason posed is that a father's status in the local community can be used to improve food security for children, but this status cannot be used when the father works and lives elsewhere (Dearden et al., 2011). Children whose father has passed away also have lower HAZ scores, because a deceased father decreases both household income and time available to rear children(Ainsworth and Semali, 2000).

Lastly, the age of both the child and the mother are of importance. Mixed results have been found for the effect of child age on stunting. Some studies show that the odds of stunting increase with age (Demissie *et al.* 2013), yet other studies show that there is a non-linear relation between child age and odds of stunting (Schrijner & Smits (2018), Olack *et al.* (2011)). It is theorized that the introduction of complementary food after the first six months of life leads to more responsibility for children to feed themselves, yet they often do not have adequate amounts of solid food available (Olack *et al.,* 2011). Young mothers, especially those in adolescence who are themselves still growing, are at increased risk of maternal stunting and subsequently of having stunted offspring (Gigante *et al.* (2005), Rah *et al.* (2008)). After adolescence, these negative effects subside. Hence, a U-shape effect of maternal age on child stunting age is expected and also found in Schrijner and Smits (2018).

2.1.4 Other contextual factors

First, from a political economy perspective, both political and economic stability are important factors ensuring food security and thus influencing child stunting prevalence. Particularly, government effectivity and power structures influence food security (Maxwell (1999), Milman *et al*. (2005), Petrou & Kupek (2010), Stewart *et al.*, (2013)), as do policies and interventions from a national and international level (Stewart *et al.,* 2013). Furthermore, food prices and income fluctuations are directly linked to food security (Iannotti *et al.,* 2012). Hence, stressing the importance of economic stability.

Second, societal and cultural influences have an effect on the likelihood of child stunting. Cultural beliefs heavily influence how parents educate their children and how children are fed. For instance, culture and societal beliefs influence what parents perceive to be healthy and unhealthy feeding practices. These beliefs are shaped by the views of individuals surrounding the primary caregiver (McLorg & Bryant (1989) Kerr *et al.* (2008), Fouts & Brookshire (2009) Stewart *et al.*, 2013)). Another important factor is female empowerment and the status of women in society (Stewart *et al.*, 2013). A review of the literature in South Asia (Cunningham *et al.,* 2015) and empirical research on women's empowerment in agriculture in Ghana (Malapit *et al.*, 2015) show, however, that the impact of female empowerment depends on conceptualization and measurement domains. For instance, in Bangladesh the domains 'leadership in the community' and 'control of resources' appear to be the most important determinants of improved child nutrition, whereas in Nepal 'control over income' is found to be correlated with HAZ-scores. Furthermore, empowerment is often found to be correlated to nutritional quality, such as quality of food and diversity of diet, rather than nutritional status (Malapit *et al.,* 2015). Results on the effect of female empowerment on child nutritional status are mixed (Schrijner & Smits, (2018), Mukkerjee & Das (2008), Malapit *et al.* (2015)), which may be due to differences in conceptualization and measurement. It is important, however, to include a measure of female empowerment into the analysis as women are traditionally the primary caregivers of children in Sub Saharan Africa and provide economic support (Kanidyoti, 1988). They have a large influence on child nutrition and thus, it has been argued that female empowerment increases the nutritional status of children. This study therefore hypothesises that a lower degree of female empowerment is associated with higher odds of stunting.

Third, environmental factors play a role. The environment a child grows up in is very important to healthy growth. Specifically, environmental contamination, for instance through open defecation, is detrimental to child health and growth (Spears (2013), Stewart *et al.,* (2013)). Worldwide, open defecation is common practice for 1 billion people (WHO, 2014). In Sub Saharan Africa, 23 percent of the population practices open defecation (Worldbank database, 2015). It is linked to an increased likelihood of 'environmental enteropathy disorder'(EED), a chronic disorder decreasing the ability of the small intestine to absorb nutrients, caused by recurrent contamination with faeces. This EED in turn increases the likelihood of malnutrition and stunting (Humphrey, 2009). Hence, increased sanitation should have a positive effect on stunting reduction. Indeed, a randomized controlled trial in Mali showed that an improvement in sanitation of going from open defecation practice towards toilet use, lead to a stunting reduction of six percentage points (Pickering et al., 2015). Additionally, environmental factors such as population density (Spears, 2013), degree of urbanisation and climate change (UNSCN, 2010) are also significant contributors to malnutrition (Stewart *et al*, 2013).

As discussed, the context children live in influences child stunting, but it does not explain sex differences. The next subsection will discuss and apply the theories explaining sex differences in stunting in more depth.

2.2 The determinants of sex differences in stunting

This section will discuss the theories that may explain sex differences in stunting. First, differences in vulnerability between the sexes will be discussed. Next, the role of socio-economic status is explained using the Trivers Willard hypothesis. Lastly the role of culture is discussed.

2.2.1 Differences in vulnerability

As discussed in section 2.1, child and maternal health conditions are important contextual factors determining a child's nutritional status. However, health conditions may also explain sex differences in stunting prevalence. Studies have found epidemiological evidence suggesting that young boys are more vulnerable to adverse health outcomes than young girls (Elsmen *et al.* (2004), Killbride *et al.* (1997)). Hence, negative health outcomes should affect boys more than girls. This subsection will discuss health factors hypothesized to influence sex differences in stunting.

Section 2.1.1 discussed that diarrhoea is an important marker for child health. Episodes of diarrhoea are found to increase the odds of stunting as they lower the absorption of key nutrients (Dewey and Mayers, 2011). Following the argument that adverse health outcomes may affect male children more than female children, it is hypothesized that diarrhoea episodes increase the odds of stunting more for boys than for girls.

Preterm born males and those with low birthweight have been found to be worse off than their female counterparts (Elsmén *et al.,* 2007). *In utero* health conditions are important for child health after birth. It has been estimated that 20 percent of stunting originates *in utero* (Prendergast & Humphrey, 2014). Worse *in utero* conditions lead to higher risks of stunting and wasting and can be observed by low birth size and a child being born preterm (Espo *et al.*, (2002), Christian *et al.* (2013)). Hence, it is expected that birth size negatively affects a boy's nutritional status more than a girl's nutritional status.

It was argued that family size and structure are important for child growth, as they provide support and the context a child grows up in (Thomson *et al.*,1997). Differences in vulnerability between boys and girls are likely to lead to girls being better able to cope with hard family conditions. Hence, it is argued that sex differences are larger when children grow up in more difficult family situations. For example, when children live in a family with a missing father.

Taken together these differences in vulnerability lead to the following core hypothesis:
Hypothesis 1: The sex difference in the odds of stunting is larger for children growing up in harsh conditions, at the detriment of boys. These conditions include worse health conditions and harsher family conditions, such as large family size and single motherhood.

2.2.2 The role of socio-economic status

One other possible explanation for the sex difference in stunting can be found in the Trivers-Willard hypothesis. According to this hypothesis, there are variations in the reproductive successfulness of males and females based on the conditions the mother lives in. Specifically, at the higher, wealthier end of the societal hierarchy where living conditions are better, natural selection favours boys as they are expected to outperform their female counterpart in reproductive success. However, at the lower socioeconomic end, natural selection favours girls, especially in settings where females have more chance to marry a partner with a higher socio-economic status than males (Trivers & Willard, 1973).

However, studies testing the Trivers-Willard hypothesis show mixed results. Studies focussing on contemporary United States have found no evidence for biased parental investment (Freese & Powell, (1999), Keller *et al.*, (2001)). Yet, a study focussed on northern Kenya measuring breastfeeding frequency and quality did find evidence supporting the Trivers-Willard hypothesis (Fujita *et al.*, 2012). Another study found a decrease in the natural sex ratio at birth (the number of boys born divided by the number of girls born) due to prenatal shocks, such as the presence of civil conflict during pregnancy. It was argued that this finding can be partially explained by the natural selection effect of the Trivers Willard hypothesis. However, differences in vulnerability and the finding that worse *in utero* conditions affect boys more than girls, may also plays a role in decreasing the sex ratio at birth (Valente, 2015). These mixed results might partly be explained by a difference in explanatory variables. In the American studies the TW-hypothesis is tested by focussing on educational investment and income, which are behavioural explanations. The parents decide how much to invest in their children's education and this decision may be influenced by factors other than the TW-hypothesis too, or not be influenced by it at all. On the other hand, Fujita *et al.* (2012) and Valente (2015) focussed on a biological explanation of the TW-hypothesis. Breastmilk quality and living conditions in the womb are determined biologically and cannot be decided upon by parents. It has also been cautiously argued that contemporary United States may in general not fulfil the scope conditions for the theory (Freese & Powell, 1999). Additionally, sociobiological theories, such as the Trivers-Willard hypothesis, have been criticized for being "*untestable, and therefore unscientific*" (Gould 1997, p. 51) as they offer little more than post hoc explanations.

Despite this academic debate, the Trivers-Willard hypothesis may still contribute to explaining sex differences in stunting in Sub Saharan Africa. It has been shown quantitatively that sex differences in stunting prevalence tend to be more pronounced among lower socio-economic groups within a country at the detriment of boys (Wamani *et al.*, 2007). Furthermore, qualitative evidence among the Mukogodo, an ethnic group in Kenya with low socio-economic status, suggests that sex-biased parental investment is indeed present, as daughters seem to be favoured over sons (Cronk, 1989).

Most importantly for this thesis, it will be tested whether under difficult circumstances, child sex indeed influences the nutritional status of children in this sample. Specifically, if the child sex is male the odds of stunting should be higher compared to when the sex is female, in line with findings of previous studies (Wamani *et al.*, (2006), Demissie *et al.* (2013), Bukusuba *et al.* (2017), Schrijner & Smits (2018)).

The TW-hypothesis suggests sex differences in stunting to be more pronounced among low socio-economic strata than among high socio-economic strata. It has indeed been shown that boys are more stunted than girls and that this distinction seems to be larger in low socio-economic groups at the detriment of boys (Wamani *et al.*, 2007). Therefore, this thesis will test this by focussing on the indicators of socio-economic status; household assets, parental education and parental employment. The following core hypothesis can made.

Hypothesis 2: Girls in low socio-economic strata are less likely to be stunted compared to boys, however this sex difference becomes smaller in higher socio economic strata.

2.2.3 The role of culture

As discussed before, culture can have a large influence on child nutrition. However in Sub Saharan Africa it may also explain sex differences in stunting. In many Sub Saharan countries, women play an important role in generating agricultural output and the share of female labour in agriculture is generally high, though much variation among countries exists (Doss & SOFA Team, 2011). In a region where agricultural output remains a large share of GDP, this implies an important role for females.

It was hypothesized that this large share of female agricultural output implies a unique and important role for women in the Sub-Saharan African economy (Boserup, 1970: Ch. 2). This in turn "*is reflected in the social and cultural web of customs and legal rights that determine gender relations"* (Svedberg, 1990, p.481). For instance, in many regions in Sub Saharan Africa polygamy is common practice. In this theory, female labour is seen as the scarce recourse and thus output and wealth can be increased by adding wives and through early marriage. (Boserup, 1970: Ch. 2). There is a certain value to females, which is amongst others reflected by the custom of bride price (Svedberg, 1990). Bride prices vary across countries and can on average be as high as four times annual household income (Anderson, 2007). The effects of culture on sex differences in child nutrition are captured as follows.

First, wealthy men increase their status by adding wives, creating a certain value to women (Boserup, 1970, Ch.2). This enables women to marry a man with a higher socioeconomic status at the detriment of men with low socioeconomic status, who cannot find a woman to marry. Hence, the reproductive success of men with low socioeconomic status in polygamous cultures is expected to be lower compared to that of men living in monogamous cultures. According to the TW hypothesis, this should lead to cultural and biological preferences for women and wealthy men and thus better nutritional status for girls especially at the lower end of the socioeconomic hierarchy. Hence, the effect of polygamy prevalence on nutritional status of children should be different for boys and girls.

Second, it could also be that the valuable female labour leads to favouritism of parents and other members of society towards girls, such as noted in the study of the Mukogodo (Cronk, 1989). Additionally, girls may be perceived as an investment (Cruz *et al.*, 2017), both for their labour input and for the bride price to be received upon marriage. This may result in girls receiving more care and a dietary preferential treatment, especially in rural areas where agricultural output is highest. Stunting prevalence is indeed found to be higher in rural than in urban areas (Menon *et al.*, 2000), as urban areas are usually characterized by more favourable socioeconomic conditions (Smith *et al.*, 2005). Higher socio-economic status is associated with lower sex differences in stunting (Wamani *et al.*, 2006) and thus sex differences are expected to be smaller in urban than in rural areas.

The discussion on the role of culture leads to the following core hypothesis:
Hypothesis 3: A sex difference in stunting in favour of girls exists for children growing up in cultures where a preference for girls is present.

3. Data and methodology

In this section the data and methodology are discussed. First, the data used is discussed. Next, the model used to estimate sex differences in stunting is presented. Lastly, a description of the variables used and their measurement is given.

3.1 Data

The data used in this thesis come from a combined dataset compiled from multiple Demographic Health Surveys (DHS; www.dhsprogram.com). This dataset was derived from the Global data lab (www.globaldatalab.org), following the work of Schrijner & Smits (2018). The DHS are household surveys that use a large random sample and are nationally representative, providing data on population, health and nutrition.

The combined dataset consists of data from 69 standard DHS surveys on 357,340 children aged 0-60 months living in 31 Sub Saharan countries. All data was derived from surveys held between 2000 and 2014. Using such a large database increases the discriminatory power of the study and allows for a detailed research of the role of the context. The interviews were taken from mothers aged 15-65 and thus there are no children in the sample with an absent mother. Unrealistic cases are removed from the dataset (12,592). These include parents younger than 15 years of age, mothers older than 50 and fathers older than 80. Therefore, the final dataset consists of 344,748 cases of which 171,530 female and 173,218 male.

3.2 Method

3.2.1 Methodology

The dependent variable is a dichotomous variable taking value 1 if the child is stunting and zero otherwise. Therefore, OLS assumptions on homoscedasticity and linearity are violated and logistic regression will be used.

As discussed in section 3.1, the data has a hierarchical structure, where data is nested in clusters, districts and countries. To solve the autocorrelation caused by this hierarchical structure, multilevel regression is needed. To allow for variation between clusters, districts and countries, a three level random intercept model will be used. Fixed effects dummies are included at the country level, to control for clustering and confounding at the national level.

The focus of this thesis is on variables determining the differences in stunting between boys and girls. To capture these differences, interaction analysis is used. The dummy variable ‘child sex’ will be interacted with the independent variables, to test for their possible contribution to sex differences in stunting.

For the reasons discussed above, this study will make use of a multilevel logistic regression model including interaction analysis. The following steps will be taken towards running the final model.

First, summary statistics will be presented in section 4.1. A bivariate analysis will be done to test all variables hypothesized to affect stunting. Then these variables are taken together in a multivariate model. The results will presented in section 4.2.

Second, hypotheses on sex differences in child stunting need to be tested. To do so, interaction variables will be created, whereby child sex is interacted with the other variables in the model. Each interaction term will first be added to the multivariate model independently. Next, significant interaction terms will be pooled to check if they remain significant. Then, to optimize the multivariate model with interaction terms, those interaction terms that had previously been found to be insignificant are added to the model again and tested for significance. Those that are now found to be significant will be added to the model. The aim is to create a model with all significant interactions, whereby no other interaction term would be significant when added to the model.

The models are estimated using Stata and MLwiN. Second-order penalized quasi-likleyhood (PQL2) is used as this is the recommended estimation technique for multilevel logistic regression analysis (Goldstein & Rasbash, 1996)

3.2.2 Measurement

To analyse the determinants of the likelihood of sex differences in stunting, the following variables are included in the model.

Child sex is a dummy variable taking the value 1 if the sex of the child is male and zero otherwise. Child age is measured in months and ranges between 6-60 months. Research stresses the difficulty of differentiating between foetal growth and stunting in the first six months. Therefore children below the age of six months are excluded from the analysis. To analyse the possibility of a non-linear age effect, a squared term is also added to the model. Birth size is a categorical variable taking the value 1 if very large, 2 if larger than average, 3 if average, 4 if smaller than average and 5 if very small. Birth order measures in what order a child was born into its family. Number of siblings measures how many brothers and sisters the child has.

Preceding birth interval is measured by the number of months preceding the birth of the child. Firstborn children are included as a missing variable and the missing value dummy adjustment procedure was used. Duration of breastfeeding measures the number of months a child received breastfeeding. Diarrhoea is a dummy variable taking the value 1 if the child has had diarrhoea in the two weeks prior to the survey and zero otherwise. The cases for which the diarrhoea survey response was ‘don’t know’ were treated as a missing value and the dummy variable adjustment procedure (Allison, 2001) was used to address this issue. Vitamin A is a dummy variable taking value 1 if the child has received a vitamin A dose in the first 2 months after delivery and zero otherwise. Received vaccination is a dummy variable taking the value 1 if the child has received vaccinations and the value 0 otherwise. The dummy variable adjustment procedure has been used to obtain unbiased results in case of missing values.

The International Wealth Index (IWI) is used to measure the household wealth. Previous studies either look at the household wealth index (Wamani et al. (2007), Chirande et al. (2015)) or at the type of flour (Demissie et al. (2013), Cruz et al. (2017)). However, these indices are generally not comparable across countries nor over time. Therefore, this thesis will make use of the International Wealth Index (IWI) (Smits & Steendijk, 2015).

Education of the father is measured by years of education obtained by the father. Education of the mother is measured by years of education obtained by the mother. Polygamous household is a dummy variable taking the value 1 if the household head has two or more wives and zero otherwise. Age difference between spouses is measured by age mother minus age father and is used as a proxy for female empowerment at the household level.

Maternal age is measured in years. To examine the possibility of a non-linear age effect, a squared term is also added to the model. Single motherhood is a dummy variable taking value one if the mother is the single household head and zero otherwise. Father absent is a dummy variable taking value one if the father is absent from the household, but alive, and zero otherwise. Father dead is a dummy variable taking value one if the father is deceased and zero otherwise. Grandfather present is a dummy variable taking value 1 if the grandfather is present in the household and the value 0 otherwise. Grandmother present is a dummy variable taking value 1 if the grandmother is present in the household and the value 0 otherwise.

Maternal employment is a dummy variable taking value 1 if the mother is employed and zero otherwise. Occupation of the father is measured using four dummies, taking value 1 for fathers working on the farm, at a job classified as lower non-farm, at a job classified as upper non-farm, and for fathers whose occupation is unknown/unemployed, respectively, and zero otherwise. Living in rural area is a dummy variable taking the value 1 if the child lives in a rural area and zero if it lives in an urban area.

To study the role of the context, some variables are aggregated to the level of local communities (cluster) or sub national region (district).Level of development (district) measures the average level of development (IWI score) at the district level. Relative position women (district) measures the average level of age differences between spouses at the district level, as a proxy for female empowerment. The age difference is measured as age mother minus age father. Educational level (cluster) is the average amount of years of education the parents of the child in a local community obtained. Polygamy (district) is an interval variable measuring the percentage of polygamous households in the region.

4. Results

This section will present and discuss the findings of the analysis. Section 4.1 shows descriptive statistics. Section 4.2 presents the baseline bivariate and multivariate multilevel logistic regression to test the determinants of stunting, and the main model with multivariate multilevel logistic regression and interaction analysis to examine sex differences in stunting.

Results are marked significant at the 5 percent, 1 percent and 0.1 percent significance level. For each multilevel logistic regression, fixed effects dummies are used at the country level, but will only be presented for the main model and be shown in Appendix A.

4.1 Descriptive statistics

In table 4.1 the summary statistics are presented. The table presents the mean, standard deviation and minimum and maximum values of a variable. For dummy variables, the mean can be read as the percentage of the sample for which the dummy variable is one. For example, 42 percent of children in the sample are stunted, which is consistent with other estimates of stunting in Sub Saharan Africa (UNICEF, 2016).

Table 4.1: Summary statistics (n=344,748)

	Mean	S.D.	Min	Max
Stunting	0.420	0.494	0	1
Child sex	0.502	0.500	0	1
Age child (months)	31.225	15.632	6	59
Birth size (1= very large, 5= very small)	2.732	0.962	1	5
Birth order	3.737	2.443	1	18
Number of siblings	3.382	2.690	0	20
Preceding birth interval	29.583	27.591	-9	327
Duration of breastfeeding (months)	16.786	6.284	0	58
Diarrhoea	0.161	0.367	0	1
Received vaccination	0.799	0.264	0	1
Received vitamin A	0.393	0.392	0	1
Household factors				
IWI	25.752	21.812	0	100
Education father (years)	4.782	4.209	0	16
Education mother (years)	3.767	4.202	0	16
Polygamous household	0.272	0.417	0	1
Age difference spouses (mother-father)	-8.689	6.564	-59	30
Age mother (years)	29.212	6.903	15	50
Single motherhood	0.158	0.365	0	1
Father absent	0.193	0.395	0	1
Father dead	0.020	0.140	0	1
Grandmother present	0.140	0.347	0	1
Grandfather present	0.068	0.251	0	1
Mother employed	0.629	0.483	0	1
Occupation father:				
Farm (reference category)	0.295	0.405	0	1
Lower non-farm	0.165	0.329	0	1
Upper non-farm	0.041	0.177	0	1
Unknown/unemployed	0.475	0.446	0	1
Context factors				
Living in rural area	0.720	0.449	0	1
Level of development (district)	27.220	16.851	0.988	80.489
Educational level (cluster)	3.041	1.416	0	10.752
Polygamy (district)	0.279	0.176	0	1
Position women by age gap spouses (district)	-8.952	2.551	-16.695	-1.930
Year	2008	4	2000	2014

4.2 Analysis

4.2.1 Bivariate and multivariate multilevel logistic regression

Table 4.2.1 shows the results of a bivariate and a multivariate multilevel logistic regression analysis. The regression output will be interpreted as log odds and be transformed to odds ratio's by taking the exponential for ease of interpretation. Hence, independent variables should be interpreted as influencing the odds that a child is stunted. The pooled results of the bivariate multilevel logistic regression models show how every independent variable affects stunting separately. Thus, the effects presented in the table represent the effect of the independent variable on the dependent variable, without any other control factors. These results may thus be biased due to omitted variable bias, but are indicative of the relation they have with child stunting. The outcomes of the multivariate multilevel logistic regression show how the independent variable affects stunting, controlling for all other independent variables. Results are discussed below.

Table 4.2.1 Bivariate and multivariate multilevel logistic regression analysis of stunting of children aged 6-60 months (n=344,748)

	Bivariate			Multivariate		
Variable	Logodds	S.E.	Odds ratio	Logodds	S.E.	Odds ratio
Intercept				25.667**	7.733	
Child sex (boy = 1)	0.228***	0.008	1.256	0.261***	0.008	1.298
Age child (months)	0.104***	0.002	1.110	0.091***	0.002	1.095
Age child (squared)	-0.001***	0.000	0.999	-0.001***	0.000	0.999
Birth size (1=very large, 5=very small)	0.162***	0.005	1.176	0.174***	0.006	1.190
Birth order	0.009***	0.002	1.009	0.021***	0.003	1.021
Number of siblings	0.014***	0.002	1.014	0.021***	0.002	1.021
Preceding birth interval	-0.007***	0.000	0.993	-0.005***	0.000	0.995
Duration of breastfeeding (months)	0.048***	0.001	1.049	0.023***	0.001	1.023
Diarrhoea	0.097***	0.011	1.102	0.173***	0.011	1.189
Received vaccination	-0.042*	0.020	0.959	-0.042*	0.019	0.959
Received vitamin A	-0.062***	0.012	0.940	-0.001	0.012	0.999
Household factors						
IWI	-0.017***	0.000	0.983	-0.013***	0.000	0.987
Education father (years)	-0.039***	0.002	0.962	-0.008***	0.002	0.992
Education mother (years)	-0.060***	0.002	0.942	-0.029***	0.002	0.971
Polygamous household	0.106***	0.011	1.112	0.084***	0.011	1.088
Age difference spouses (mother-father)	-0.002	0.001	0.998	0.003**	0.001	1.003
Age mother (years)	-0.014**	0.005	0.986	-0.036***	0.005	0.965
Age mother (squared)	0.000*	0.000	1.000	0.0003***	0.000	1.000
Single motherhood	0.039**	0.011	1.040	-0.061**	0.021	0.941
Father absent	0.040**	0.011	1.041	0.079***	0.020	1.082
Father dead	0.081**	0.029	1.084	0.038	0.036	1.039
Grandmother present	-0.027	0.019	0.973	-0.010	0.016	0.990
Grandfather present	-0.040	0.027	0.961	-0.031	0.023	0.969
Mother employed	-0.026**	0.009	0.974	-0.028**	0.010	0.972
Occupation father (ref: farm)						
Lower non-farm	-0.154***	0.016	0.857	-0.041*	0.016	0.960
Upper non-farm	-0.426***	0.028	0.653	-0.061*	0.027	0.941
Unkown/unemployed	-0.076***	0.013	0.927	-0.002	0.014	0.998
Context factors						
Living in rural area	0.571***	0.025	1.770	0.114*	0.044	1.121
Level of development (district)	-0.022***	0.001	0.978	-0.001	0.002	0.999
Educational level (cluster)	-0.096***	0.007	0.908	-0.014*	0.006	0.986
Polygamy (district)	1.921***	0.144	6.828	0.065	0.152	1.067
Position of women by age gap spouses (district)	-0.067***	0.011	0.935	0.022*	0.010	1.022
Year	-0.033***	0.004	0.968	-0.013**	0.004	0.987

Random Part						
Level: District						
Cons/cons				0.086***	0.006	1.090
Level: cluster						
Cons/cons				0.198***	0.007	1.219

****P<0.001 **p<0.01 *p<0.05*
Note: Fixed effect dummies are used at country level, but not presented

The results show that the effects of the independent variable on the dependent variable are very similar for both kinds of analysis, mostly only small differences are present. Larger differences are reported in the discussion below.

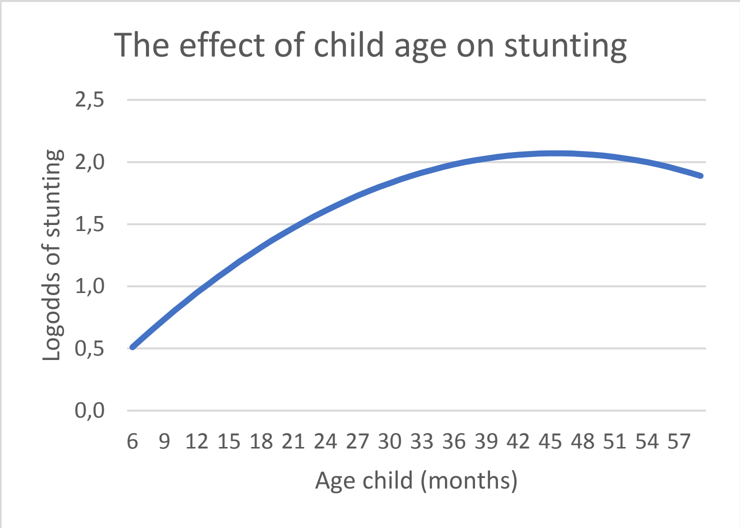

Figure 1: The effect tof child age on the logodds of stunting as predicted from the multivariate model

The odds ratio of child sex is larger than one in both models, implying that the likelihood that boys are stunted is higher than that of girls. The effect of child sex on stunting is slightly larger in the multivariate compared to the bivariate model. The results are in line with findings in previous literature (e.g. Bukusuba *et al.* (2014), Schrijner and Smits (2018), Chirande *et al.*, (2015)) and with the expectation that boys are more likely to be stunted than girls.

The age of the child in months has a non-linear, upward sloping effect on the likelihood of stunting. Hence, older children are more likely to be stunted than very young children, but this effect diminishes over time. The effect is represented in Figure 1 which shows how the odds of stunting become larger over time at a diminishing rate.

The odds ratios for birth size are larger than one which means that children with smaller birth size have higher odds of stunting. This is evidence in favour of previous literature claiming that stunting starts *in utero* (Christain *et al.*, 2013). The odds increase more in the multivariate than in the bivariate model. The results are in line with theory suggesting that worse *in utero* conditions, as measured amongst others with birth size, increase the likelihood of stunting (Christian *et al.*, 2013).

The odds ratios for the number of siblings are larger than one and significant. When a child has more siblings, the odds of stunting increase. The results also show that birth order has a positive effect on the odds of stunting, meaning that older (later born) children are more likely to be stunted. These results are in line with what can be expected from the resource dilution hypothesis (Blake, (1981) (1989), Heer (1985)).

The odds ratios for preceding birth interval are smaller than one and significant. When the preceding birth interval is larger, the odds of stunting decrease. This is in line with earlier research (Chirande *et al.*, 2015) and with theory suggesting maternal nutrient reserves may deplete when birth intervals are too short (Dewey *et al.*, 2007). The analysis implies that when children are breastfed longer, their likelihood of stunting increases. This effect is smaller in the multivariate analysis, compared to the bivariate analysis. Increasing odds of stunting may occur because after the first six months, complementary food is recommended to be added to the diet, but this is often poor in low income countries and may therefore be detrimental to child nutritional status (Marriot *et al.*, 2013). Furthermore, there may be that children which are smaller may receive breastfeeding for a longer time (Marquis, 1997).

A child which had an episode of diarrhoea in the two weeks prior to the survey is found to have higher odds of stunting than a child that did not. This is in accordance with previous findings (Bukusuba *et al.*,2017). The effect is larger in the multivariate model. As expected, children who have received vaccinations, have lower odds of stunting than children that do not. This result is only significant at the 5 percent significance level for both models. The odds ratio of vitamin A is only significant at the bivariate model. It is smaller than one, thus when children receive a vitamin A shot in the first two months after delivery, their expected odds of stunting are lower compared to children who have not received a vitamin A dose. The results of receiving vaccination and receiving vitamin A are in the same direction as reported by Berendsen *et al.* (2016). However, the findings of the multivariate model imply that no statistically significant effect of receiving vitamin A on child stunting is present.

Household factors

The effect of household wealth, as measured by IWI, is significant and implies that higher household wealth leads to lower odds of stunting among children. This is in line with theory suggesting that households with larger income, as proxied by household wealth, have more economic resources to spend on child nutrition and thus lowers the stunting prevalence. Variables measuring parental years of education are significant and show that higher education leads to lower odds of stunting. This effect is slightly stronger for maternal education, which may be because mothers are usually the ones rearing children and thus the influence of their knowledge may be larger. The odds ratios for parental education are smaller for the bivariate than for the multivariate model, implying that the effect is stronger in the first model.

The odds ratios for polygamous households are larger than one and significant. Children growing up in polygamous families have higher odds of being stunted. This is in line with theory suggesting that in polygamous relations uncertainty over genetic relatedness may increase, which can lead to conflicts and increased competition for resources (Schrijner & Smits, (2018), Strassmann (2011)). The age difference between spouses is only significant in the multivariate model. It is slightly larger than one, meaning that larger age gaps to the disadvantage of the wife, as measured by paternal age minus maternal age, lead to higher odds of stunting. As the age difference is a proxy for the position of women, this implies that worse female empowerment increases the odds of child stunting. Hence, female empowerment may decrease the likelihood of child stunting.

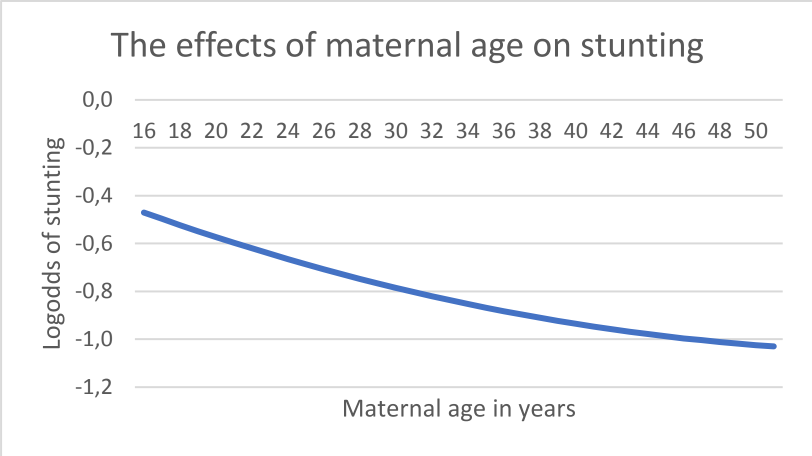

Figure 2: the effect of maternal age on the logodds of stunting. Relationship predicted from the multivariate model.

The analysis shows that maternal age has a downward sloping, nonlinear effect on the odds of stunting in both models. The odds of stunting decrease with increasing maternal age, but at a diminishing rate. The effect of maternal age on child stunting is stronger in the multivariate model. The results imply that older women are less likely to have stunted offspring than young mothers. This occurs at a decreasing rate, as can be seen from Figure 2. This has also been found by Schrijner & Smits (2018), whose study focussed on the same area.

Single motherhood has an odds ratio larger than one and is significant in the bivariate model. This implies that children of single mothers have higher odds of being stunted than children who do not have a single mother. This finding is in accordance with previous literature (Finlay *et al.*, (2016), Monasch & Boerma (2004)) and with the reasoning that single mothers have fewer time and money to invest in their children (Bronte-Tinkew & DeJong, 2004). However, in the multivariate model single motherhood is associated with significant lower odds of stunting which is not in line with earlier research just discussed.

The variable father absent yields an odds ratio larger than one and this is significant, implying that the odds of stunting are higher for those children for whom the father is absent. This effect is much stronger in the multivariate model compared to the bivariate model. The effect found is in line with the expectation. The bivariate model also shows a significant and similar effect for children with a father who is deceased, though the effect is a little stronger than for father absent. The variable for father deceased is not significant in the multivariate model. The variables indicating the presence of a grandmother or grandfather are insignificant. Hence, no effect was found for the effect of the presence of grandparents on child stunting.

The variable indicating that the mother is employed or not, has an odds ratio lower than one and is significant at the 1 percent level for both models. This indicates that working mothers are less likely to have stunted children. Hence, it may be that the positive effect of an increased income from work is larger than the negative effect of mothers having less time to care for children (LaMontagne *et al.*, (1998), Smith *et al.*,(2005)). With respect to paternal occupation, the farm category is used as the reference category for both models. Hence, all other categories are interpreted in reference to this category. Both dummies for paternal employment in the non-farming sector have significant results with odds ratio's smaller than one. This implies that, compared to fathers working on a farm, fathers having an occupation in the non-farm sector are less likely to have stunted offspring. The odds ratio for fathers working in the upper non-farm sector is smaller than that of fathers working in the lower non-farm sector. This implies that for the latter, the likelihood of stunting is slightly larger than for the former. In the bivariate model, fathers whose occupational status is unknown/unemployed have lower odds of having stunted offspring compared to fathers working on a farm. However, this variable is insignificant in the multivariate model and thus no effect of this variable on child stunting was found.

Context factors

The odds ratio for children living in a rural area is larger than one and significant in both models. The effect is much larger for the bivariate than for the multivariate model. The outcomes imply that children living in rural areas have a much larger likelihood of being stunted than children living in urban areas. This is in line with earlier findings (Menon *et al.*, 2000). The bivariate analysis show that an increase in the level of development leads to a decrease in the odds of stunting. This is in line with the expectation. For the multivariate model, no effect of the level of development of a district on stunting was found, as the coefficient for this variable is not significant. Children growing up in local communities with higher educational level are less likely to be stunted than children growing up in local communities where the educational level is low, as was also found in earlier research (Schrijner and Smits, 2018). This effect is much stronger in the bivariate model.

According to the bivariate model, the prevalence of polygamy in a district heavily increases the likelihood of stunting. No effect of the prevalence of polygamy in a district on the likelihood of child stunting was found in the multivariate model. The bivariate model shows that a larger average age gap in a district leads to lower odds of stunting. This is not in line with the expectation. The multivariate model on the other hand, shows that a larger average age gap in a district is associate with higher odds of stunting. When the position of women in a district is worse, the odds of stunting increase. This is in line with earlier findings (Schrijner and Smits, 2018).

The results indicate a time trend, where over the years the odds of stunting have decreased. The results on the random part are highly significant and suggest variation between clusters and districts.

4.2.2 Multivariate multilevel logistic regression with interaction analysis

Table 4.2.1 showed how various factors influenced the odds of stunting. To investigate how these determinants influence sex differences in stunting, interaction analysis is used. The table below presents the results for a multivariate multilevel logistic regression with all significant interactions with child sex. For variables with which an interaction with child sex was found, coefficients for boys and girls are presented separately. The column "girl" shows the coefficient for female children, the column "boy" shows the coefficient for male children. The column "all" presents the outcomes for which no significant interaction effect was found and thus the coefficient is equal for boys and girls. Results are almost completely similar to the multivariate multilevel logistic regression model presented in section 4.2.1 for variables without interaction effects presented in the "all" column. When significant interaction effects are found, the multivariate multilevel logistic regression model of section 4.2.1 presents coefficients that are in the middle of the coefficients for boys and girls presented in Table 4.2.2. Significant interaction effects and those coefficients deviating from the effects found in the Table 4.2.1 are discussed below.

Table 4.2.2: Multivariate multilevel logistic regression with the significant interactions between child sex (boy=1) and other independent variables of stunting for children aged 6-60 months (n=344,748)

	Logodds						Odds ratio		
Variable	Girl	S.E.	All	S.E.	Boy	S.E.	Girl	All	Boy
Intercept	25.480**	7.748			25.899**	7.749			
Child sex (boy =1)			0.418***	0.026				1.519	
Age child (months)	0.095***	0.002			0.087***	0.002	1.100		1.091
Age child (squared)			-0.001***	0.000				0.999	
Birth size			0.175***	0.006				1.191	
Birth order			0.021***	0.003				1.021	
Number of siblings			0.021***	0.002				1.021	
Preceding birth interval			-0.005***	0.000				0.995	
Duration of breastfeeding (months)	0.021***	0.001			0.025***	0.001	1.021		1.025
Diarrhoea	0.146***	0.015			0.196***	0.015	1.157		1.217
Received vaccination			-0.041*	0.019				0.960	
Received vitaminA			-0.002	0.012				0.998	
Household factors									
IWI			-0.013***	0.000				0.987	
Education father (years)			-0.008***	0.002				0.992	
Education mother (years)	-0.034***	0.002			-0.025***	0.002	0.967		0.975
Polygamous household	0.063***	0.014			0.104***	0.014	1.065		1.110
Age difference spouses (mother-father)			0.003**	0.001				1.003	
Age mother (years)			-0.037***	0.005				0.964	
Age mother (squared)			0.000***	0.000				1.000	
Single motherhood			-0.060**	0.021				0.942	
Father absent			0.079***	0.020				1.082	
Father dead			0.037	0.036				1.038	
Grandmother present			-0.010	0.016				0.990	
Grandfather present			-0.032	0.023				0.969	
Mother employed			-0.028**	0.010				0.972	
Occupation father (ref: farm)									
Lower non-farm			-0.041*	0.016				0.960	
Upper non-farm			-0.061*	0.027				0.941	
Unkown/unemployed			-0.001	0.014				0.999	
Context factors									
Living in rural area			0.114*	0.044				1.121	
Level of development (district)			-0.001	0.002				0.999	
Educational level (cluster)			-0.014*	0.006				0.986	
Polygamy (district)			0.065	0.152				1.067	
Position of women by age gap spouses (district)			0.022*	0.010				1.022	
Year			-0.013**	0.004				0.987	
Interactions with child sex (boy=1)									
Duration of breastfeeding (months)			0.004***	0.001				1.004	
Education mother (years)			0.009***	0.002				1.009	
Diarrhoea			0.051*	0.021				1.052	
Age child (months)			-0.009***	0.001				0.991	
Polygamous household			0.041*	0.017				1.042	
Random Part									
Level: District									
cons/cons			0.086***	0.006				1.089	
Level: Cluster									
cons/cons			0.198***	0.007				1.218	

****p<0.001 **p<0.01 *p<0.05*

Note: Fixed effect dummies on country level are presented separately in Appendix A

Child sex has an odds ratio that is larger than one and thus, the odds that boys are stunted is larger than the odds that girls are stunted. Compared to the multivariate multilevel logistic regression performed in section 4.2.1, child sex now has an even stronger effect on the odds of stunting, meaning that sex differences are more prominent.

When children are breastfed longer, their odds of stunting increase. A longer period of breastfeeding is associated with higher odds of stunting, because breastmilk may be used as a substitute for complementary feeding. This leads to children missing out on important nutrients and lowers child nutritional status (Girma et al., (2002), Teshome et al. (2009), Marriot *et al.*,2012)). Another explanation could be that small children are breastfed longer (Marquis, 1997). Not only does a longer period of breastfeeding increase the likelihood of child stunting, but the interaction results also suggest that boys are affected more than girls. The coefficient is 1.025 for boys and 1.021 for girls and hence, the sexes experience a difference of 0.04 in the effect of breastfeeding on child stunting. Thus, boys seem to perform worse under bad nutritional conditions, which is in line with the hypothesis that boys are more vulnerable than girls.

Parental education has the expected effect on the odds of stunting. Both fathers and mothers with more years of education are less likely to have stunted offspring. This effect is slightly stronger for mothers than it is for fathers. For maternal education, the model also shows significant, different odds for boys and girls. When the mother has had more years of education, this is more to the benefit of girls, increasing the sex difference in stunting. This is at odds with the prediction of the Trivers Willard hypothesis from which it was expected that sex differences decrease with maternal education.

Boys seem to suffer more from episodes of diarrhoea than girls. Not only does an episode of diarrhoea increase the odds of child stunting, it does so even more for male children. Male children suffering an episode of diarrhoea see their odds of stunting increase by 1.217, whereas girls see their odds of stunting increase by 1.157, a significant difference of 0.050. The large difference may be explained by theory suggesting that boys are more vulnerable to morbidity and thus, when health conditions are bad they suffer more. The results are in accordance with the expectation and with earlier findings (Elsmen *et al,* (2004), Killbride *et al.,* 1997). Hypothesis 1 posed that sex differences are larger for children growing up in harsh conditions, at the detriment of boys. An episode of diarrhoea can be seen as a condition severely detrimental to child health and the finding that boys suffer more from it is in line with this key hypothesis.

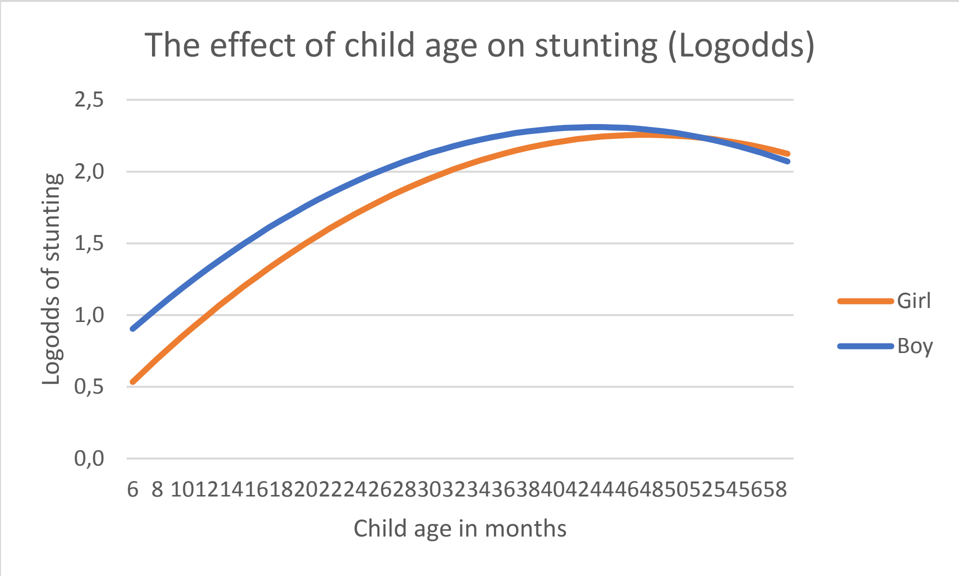

Figure 3: The effects of child age on the logodds stunting, predicted from the results of 'child sex', 'child age (months)' and 'child age (squared)' from Table 4.2.2

Figure 3 visually presents the sex difference in the effect of age on the logodds of child stunting. The intercept is higher for boys, but as the slope is steeper for girls the sex difference becomes smaller over time. The results from Table 4.2.2 also suggest that the effect of child age on child stunting is stronger for female than for male children. The effect is equal for the squared term. This result is in line with findings suggesting young boys to be more vulnerable than girls (Elsmén *et al.*, (2004), Killbride *et al.*, (1997)), but according to our results this difference in vulnerability decreases when children become older. This implies that although boys are found to be more vulnerable to external shocks to their health and living conditions, this difference seems to decrease with age.

When a household is polygamous, this increases the odds of child stunting, and this effect is stronger for boys than for girls. This evidence suggests that there is a cultural preference for girls, which is stronger amongst polygamous households. Girls can be seen as an investment (Cruz *et al.*, 2017) for their bridal price (Svedberg, 1990), valuable labour in agriculture and the improved status they will provide a man who marries them (Boserup. 1970). This is in line with the hypothesis that in polygamous households, there is a preference for female offspring. Also, the results are in favour of Hypothesis three, which states that sex differences are larger in cultures where a preference for girls is present.

The significant results on the random part indicate that there is indeed variation between clusters and districts.

The coefficients for the country level fixed effects dummies for the multivariate multilevel logistic regression model with interactions are presented in Appendix A. To test the robustness of the results, the multivariate multilevel regression model was performed for boys and girls separately. The results are presented and briefly discussed in Appendix B.

5. Discussion

This section will discuss the main findings of the study with respect to hypotheses posed in the theoretical framework. Special attention is paid to the three main hypotheses of this thesis and their relation to the results.

5.1 The determinants of stunting

The effects of the variables in the model on child stunting are as expected. The results imply that health factors as measured by diarrhoea prevalence, birth size, birth interval, vaccinations and vitamin A shot received affect the odds of stunting as predicted. Better child health is related to lower odds of stunting, according to the findings. Furthermore, a longer period of breastfeeding is associated with higher odds of stunting. This is in accordance with literature claiming that longer breastfeeding is used as a substitute for complementary feeding usually introduced after the first six months of life. As a consequence, children are missing out on important nutrients (Girma *et al.,* (2002), Teshome *et al.*, (2009)). It is also in line with theory suggesting that weaker children are breastfed longer (Marquis, 1997).

Variables measuring the effect of socio economic status on child stunting have the expected effect. Maternal employment, more years of both maternal and paternal education, and a higher score on the International Wealth Index are all associated with lower odds of stunting. When aggregating wealth and education to district and cluster level, the results also indicate lower odds in regions with higher socio-economic status. The results on paternal employment show that, in relation to employment as a farmer, the odds of stunting decrease when the father works in the non-farm sector. This implies that fathers working in sectors associated with higher socio-economic status are less likely to have stunted offspring, which is line with the expectation.

The theoretical framework discussed the demographic factors affecting the likelihood of child stunting. The effects of child age and maternal age on child stunting are non-linear as predicted. The odds of stunting increase with child age and decrease with maternal age, but both effects diminish over time. Children that have more siblings or children that are younger (born into the family later) are more likely to be stunted which is in line with the resource dilution hypothesis (Blake, (1981)(1989), Heer (1985). This hypothesis states that for any given amount of economic resources, less can be given to each child the more children the household consists of. The structure of caregivers in the family is also of importance. In accordance with the literature, children that live with both parents are found to be better off than children with a missing father. No effect of grandparental residence on child stunting was found, as the coefficients for these variables show up insignificant in all models used in this study. The likelihood of stunting is larger in polygamous households as opposed to households where the male has only one wife. Children growing up in regions in which polygamy is prevalent are also more likely to be stunted. This is in line with theory suggesting that polygamy leads to conflicts caused by uncertainty over genetic relatedness. However it is not in line with theory suggesting that only rich men can pay for more wives and hence polygamous households have more resources to be spent on child nutrition.

The results on the effect of single motherhood are not in line with previous findings from Finlay *et al.,* (2016) and Monasch & Boerma (2004), whose results associated single motherhood with higher odds of child stunting. A possible explanation for this may be the asymmetric parental altruism hypothesis, which predicts mothers to provide a higher share of parental care than fathers. A recent study indeed found mothers to be more altruistic towards their children than fathers when having to make the decision alone (Vyrastekova *et al.,* 2014). Other studies have found asymmetric parental investment in children too (Hoddinott and Haddad (1995), Pellenberg *et al.,* 2014). Furthermore, the data consist of a large share of unemployed fathers, who may take up a share of the resources which could be invested in the children had they not been a part of the family.

It has been discussed that cultural and societal beliefs influence child nutrition. One aspect is female empowerment. It has been argued that more female empowerment affects the odds of stunting (Malepit *et al.* (2015), Cunningham *et al.* (2015)), but that the direction of the effect depends on how female empowerment is conceptualised and measured. This study measured female empowerment as the age of the mother minus the age of the father, where a larger age gap between spouses is associated with lower female empowerment. The results suggest that higher age gaps increase the odds of stunting in both households and sub national regions. Thus, lower female empowerment is associated with higher odds of child stunting.

Children living in rural areas are more likely to be stunted than children in urban areas according to the results of this study and previous literature (Menon *et al.,* 2000).

5.2 Sex differences caused by a difference in vulnerability

In section 2 it was hypothesized that boys are biologically more vulnerable than girls and therefore if they have to grow up in more harsh conditions they will be more likely to be stunted. The outcomes of the variables testing this hypothesis will be discussed in more detail below.

To capture the effects of child nutrition on stunting, the duration of breastfeeding was measured. The results show that children which are breastfed longer are more likely to be stunted. The interaction analysis also shows that the increase in the odds of stunting is larger for boys than for girls. It was argued that extended breastfeeding may be used as a substitute when complementary food is not available, which leads to children not receiving optimal nutrition (Girma et al., (2002), Teshome et al. (2009)). It may be that boys suffer more from this because they are found to be more vulnerable than girls (Elsmén *et al.,* (2004), Killbride *et al.,* (1997)). Furthermore, it was argued that weaker children receive breastfeeding for a longer period. This may be more detrimental to boys, because they are more vulnerable. The results are in line with Hypothesis 1, which states that girls outperform boys when conditions to grow up in are difficult.

Previous literature suggests that infants which experience an episode of diarrhoea are more likely to be stunted than infants which do not, because diarrhoea decreases absorption of key nutrients (Bukusuba *et al.,* (2017) Checkley *et al.,* (2008)). Additionally, it was argued that boys may be more adversely affected from bad health conditions such as diarrhoea than girls, because they are more vulnerable (Elsmén *et al.,* (2004), Killbride *et al.,* (1997)). Indeed, the results of the interaction analysis suggest that the odds of stunting increase more for boys than for girls experiencing an episode of diarrhoea. This implies that girls may outperform boys when facing bad health conditions and therefore the findings are in favour of Hypothesis 1.

Differences in morbidity may also exist *in utero*, which may lead to different outcomes in stunting (Prendergast and Humphrey, 2014). To capture *in utero* conditions, a child's birth size was measured. It has been found that children with a very small birth size are far more likely to be stunted than children with a very large birth size. No significant interaction effect was found and thus the study did not find evidence indicating that boys suffer more from bad *in utero* conditions than girls.

The results suggest that child age also influences sex differences in stunting. Boys are more likely to be stunted than girls at age six months. When they grow older the gap in the odds of stunting decreases, as an increase in age increases the odds of stunting more for girls than for boys. The results therefore seem to suggest that boys may be more vulnerable at young age, in line with previous literature (Elsmén et al., (2004), Killbride et al., (1997)). However, when children grow older, the sex difference in stunting decreases, which suggests the difference in vulnerability decreases too.

Results on child characteristics seem to indicate that sex differences may partially be explained by differences in vulnerability. Other variables testing Hypothesis 1, being birth order, number of siblings, preceding birth interval, received vaccinations, and received vitamin A, show no relation with sex differences in stunting.

5.3 The role of socio-economic status

Section 2.2 gave an in-depth discussion of the Trivers Willard hypothesis, which suggested that girls should be better off at the lower end of the socio economic strata and boys be better off at the higher end of the socio economic strata. Earlier research suggested that indeed sex differences in stunting in Sub Saharan Africa were larger among households with low asset index scores, at the detriment of boys (Wamani *et al.*,2007).

One of the measures of socio economic status is maternal education. Mothers with more years of education are found to be less likely to have stunted offspring. A result also found in previous literature (Wamani *et al.,* (2004) (2006), Chirande *et al.,* (2015)). The Trivers Willard hypothesis suggests that boys may be more likely to be stunted than girls when mothers have few years of education and that this gap decreases when maternal education increases. Hence, it was expected that boys profit more from an increase in maternal education than girls. However, the results suggest that girls profit more from an increase in maternal education. The results are thus not in line with the expectation from the Trivers Willard hypothesis and do not provide evidence in favour of Hypothesis 2. This result may be explained, however, by findings suggesting that girls are less vulnerable than boys and they may thus be better able to profit from improved living conditions.

No significant interaction results have been found for paternal education, parental employment and the International Wealth Index. The results from the models separating boys and girls (Appendix A) also show no significant relationship between these variables and sex differences. Furthermore, the results in Appendix A suggest there is no significant difference in the odds of stunting between boys and girls for maternal education. This makes the finding of a significant interaction less robust.

In sum, the results on the effect of maternal education contradict Hypothesis 2 and the other measures of socio-economic status show no evidence in favour of Hypothesis 2. The results thus imply a rejection of Hypothesis 2.

5.4 The role of culture

Section 2.2.3 discussed the role of culture in sex differences in stunting and the theory presented suggested that a cultural preference for girls may exist, leading to them receiving a preferential treatment. This preferential treatment was hypothesized to be stronger among polygamous households and regions in which polygamy was common practice, and among children growing up in rural areas as opposed to those growing up in urban areas.

It was hypothesized that a man's status could be improved by adding wives. This creates a certain value to women, especially in a region where a bride price is to be paid upon a woman's wedding. A large share of female agricultural output implies that they are the scarce resource, which also increases their value. Thus, marrying multiple women increases status of the male and household labour supply. This enables women to marry, increasing their reproductive success at the detriment of men with lower socio-economic status who cannot find a woman to marry. It was hypothesized that the subsequent cultural preference for girls would lead to larger sex differences in polygamous households and regions where polygamy was prevalent. The results indeed show that the odds of stunting in polygamous households increases more for boys than it does for girls. Specifically, the odds that boys in a polygamous household are stunted are 0.045 higher than the odds that girls are stunted. No sex difference can be found when measuring polygamy prevalence on sub national level.

Previous literature suggests that the valuable female labour in agricultural output may lead to parental favouritism (Cronk, 1989) and a situation where the girl is seen as an investment (Cruz *et al.*, 2017). It was therefore hypothesized that sex differences are larger in rural areas. However no significant interaction effect with living in a rural area was found and thus this hypothesis is rejected.

In sum, the study has found evidence confirming and rejecting Hypothesis 3. The results for the variable polygamous household seem to indicate a cultural preference for girls and are thus in favour of Hypothesis 3. However, the evidence is not in favour of the hypothesis that sex differences are larger in rural areas at the detriment of boys. Therefore, mixed results have been found for Hypothesis 3.

6. Conclusion

This section will discuss the limitations of the study, give recommendations for future research and draw a conclusion of the study.

6.1 Limitations and recommendations for future research

First, the study used pooled cross-sectional data and although the results indicate that sex differences in stunting exist and may be affected by certain variables, no causal relations could be inferred. Future research should focus on further examining the sex differences in stunting and longitudinal data may be used in the future to infer causal relations.

Second, data was collected from mothers, which has led to all children in the database having a mother and the effects of a missing mother could not be tested.

Third, this study has solely focused on stunted versus non-stunted children using a dummy variable. However, in doing so much variation gets lost. It would be interesting to be able to look at child nutritional status by using the entire range of HAZ-scores. However, this was not possible in this study due to data constraints. Another method to create slightly more variation is to perform the analysis using a dummy for children that are moderately stunted or a dummy for children that are severely stunted as the dependent variable and compare the results with the analysis performed in this study.

Fourth, the study used duration of breastfeeding as a measure of child nutrition and found this to be a determinant of sex differences in child stunting. It was argued that this may be caused by differences in vulnerability. However, this is an imperfect measure of child nutrition. It would have been better to complement the data with information on child feeding practices, however no such data was available in the current database used. Future research may want to include a measure of child feeding practices to better investigate the relation between nutrition and sex differences in stunting.

Fifth, it was argued that there may be a relation between sex differences in stunting and culture. The results on polygamy indeed suggested that girls may receive a preferential treatment. However, quantitative analysis may not be the most suitable for researching this relation. To further investigate the presence of a possible cultural preference for girls, a qualitative study could give valuable insights.

Sixth, this study used the age difference between spouses as a proxy for female empowerment. However, as the literature already noted, outcomes on female empowerment may differ for various proxies for female empowerment. For example, in Bangladesh ‘control over resources’ is found to be the most important determinant of female empowerment associated with child nutritional status, but in Nepal this is ‘control over income’ (Cunningham *et al.*, (2015), Malapit *et al.*, (2015)). Thus, the results on female empowerment in this study may be different if other proxies are used and future research may focus more on this aspect.

6.2 Conclusion

This study aimed to investigate sex differences in child stunting. The focus was on three factors influencing sex differences in child stunting, namely differences in vulnerability of young children, increased sex differences in favour of girls in low socio-economic strata, and a culturally determined preferential treatment towards girls. The study found broad evidence in favour of Hypothesis one, suggesting a relation between sex differences in stunting and differences in vulnerability. No evidence was found for Hypothesis 2 which states that boys are more likely to be stunted in low socio-economic strata and that this sex difference decreases in higher socio-economic strata. The results testing Hypothesis 3, which posed that a preferential treatment towards girls may exist in Sub Saharan African communities, are mixed. In sum, the study has shown that sex differences in stunting are determined by the duration of breastfeeding, maternal education, diarrhoeal prevalence, child age and polygamy at the household level.

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Appendix A – Country level fixed effects dummies

Table A: Country level fixed effects for the multilevel, multivariate logistic regression with interaction analysis presented in Table 4.2.2

Country (ref: Burundi)	Log odds	S.E.	Odds ratio
Benin	-0.453**	0.130	0.636
Burkina Faso	-0.821***	0.126	0.440
Cote d'Ivoire	-0.808***	0.125	0.446
Cameroon	-0.657***	0.121	0.518
Congo Democratic Republic	-0.269*	0.107	0.764
Congo Brazzaville	-0.899***	0.113	0.407
Ethiopia	-0.668***	0.108	0.513
Gavon	-0.988***	0.138	0.372
Ghana	-0.955***	0.116	0.385
Guinea	-0.746***	0.149	0.474
Gambia	-0.927***	0.152	0.396
Kenya	-0.910***	0.106	0.403
Liberia	-0.845***	0.109	0.430
Lesotho	-0.512**	0.182	0.599
Madagascar	-0.251*	0.122	0.778
Mali	-0.753***	0.126	0.471
Mozambique	-0.565***	0.115	0.568
Malawi	-0.325**	0.100	0.723
Namibia	-0.925***	0.117	0.397
Niger	-0.391**	0.140	0.676
Nigeria	-0.420**	0.136	0.657
Rwanda	-0.558***	0.111	0.572
Senegal	-1.407***	0.149	0.245
Sierra Leone	-0.686***	0.119	0.504
Swaziland	-0.959***	0.151	0.383
Togo	-0.961***	0.127	0.383
Tanzania	-0.525***	0.115	0.592
Uganda	-0.884***	0.121	0.413
Zambia	-0.308**	0.107	0.735
Zimbabwe	-0.433***	0.116	0.649

Table A.1 presents country level fixed effects dummies used in the multivariate multilevel logistic regression with interactions, to control for clustering and confounding at the national level.

Appendix B – Robustness check

To test the robustness of the results found in section four, the multivariate multilevel logistic regression was performed for boys and girls separately. The results are presented in table B.1 and briefly discussed below. As a rule of thumb, differences between the sexes are statistically significant when the difference between the coefficients is at least twice their standard error.

Table B.1: Multivariate multilevel logistic regression of stunting for male and female children aged 6-60 months, separately

	Male (N=173,205)			Female (N=171,543)		
Variable	Logodds	S.E.	Odds ratio	Logodds	S.E.	Odds ratio
Intercept	23.100**	8.226		28.449**	8.586	
Age child (months)	0.087***	0.003	1.091	0.094***	0.003	1.099
Age child (squared)	-0.001***	0.000	0.999	-0.001***	0.000	0.999
Birth size	0.180***	0.007	1.197	0.168***	0.007	1.183
Birth order	0.023***	0.004	1.023	0.020***	0.004	1.020
Number of siblings	0.022***	0.003	1.022	0.019***	0.003	1.019
Preceding birth interval	-0.004***	0.000	0.996	-0.005***	0.000	0.995
Duration of breastfeeding (months)	0.025***	0.001	1.025	0.022***	0.001	1.022
Diarrhoea	0.192***	0.015	1.212	0.151***	0.015	1.163
Received vaccination	-0.020	0.023	0.980	-0.061	0.025	0.941
Received vitamin A	0.009	0.016	1.009	-0.017	0.016	0.983
Household factors						
IWI	-0.013***	0.001	0.987	-0.014***	0.001	0.986
Education father (years)	-0.009***	0.002	0.991	-0.008***	0.002	0.992
Education mother (years)	-0.029***	0.002	0.971	-0.032***	0.002	0.969
Polygamous household	0.108***	0.015	1.114	0.064***	0.015	1.066
Age difference spouses (mother-father)	0.004***	0.001	1.004	0.003***	0.001	1.003
Age mother (years)	-0.037***	0.007	0.964	-0.036***	0.007	0.965
Age mother (squared)	0.000*	0.000	1.000	0.000*	0.000	1.000
Single motherhood	-0.079*	0.029	0.924	-0.046*	0.029	0.955
Father absent	0.092***	0.025	1.096	0.065***	0.027	1.067
Father dead	0.071	0.048	1.074	-0.008	0.049	0.992
Grandmother present	-0.027	0.022	0.973	0.006	0.021	1.006
Grandfather present	-0.009	0.030	0.991	-0.059	0.033	0.943
Mother employed	-0.013	0.013	0.987	-0.035	0.014	0.966
Occupation father (ref: farm)						
Lower non-farm	-0.043*	0.020	0.958	-0.042*	0.022	0.959
Upper non-farm	-0.054	0.036	0.947	-0.071	0.037	0.931
Unkown/unemployed	-0.007	0.017	0.993	0.007	0.019	1.007
Context factors						
Living in rural area	0.108*	0.048	1.114	0.103*	0.049	1.108
Level of development (district)	-0.001	0.002	0.999	-0.001	0.002	0.999
Educational level (cluster)	-0.017*	0.007	0.983	-0.008*	0.007	0.992
Polygamy (district)	0.136	0.167	1.146	0.038	0.165	1.039
Position of women (district)	0.032**	0.011	1.033	0.016**	0.011	1.016
Year	-0.012**	0.004	0.988	-0.015**	0.004	0.985

Note: Fixed effects dummies on country level were used, but are not shown

Random Part	Logodds	S.E.	Odds ratio	Logodds	S.E.	Odds ratio
Level: regyear						
cons/cons	0.081***	0.007	1.084	0.089***	0.006	1.093081
Level: clusnr						
cons/cons	0.175***	0.009	1.191	0.196***	0.009	1.216527

***p<0.001 **p<0.01 *p<0.05

The effects of the variables on the odds of stunting are in line with the previous findings of this study. Most results are also in line with the expectation that girls outperform boys. Using the rule of thumb, the effects of child age, preceding birth interval, duration of breastfeeding, diarrhoea prevalence and polygamy are statistically significantly different for boys and girls.

No statistically significant difference between the sexes has been found for the effect of maternal education on stunting. This makes the results found in the interaction analysis of section 4 less robust. Remarkable is that in this test, the difference in the coefficients of boys and girls for the variable preceding birth interval is statistically significant. This seems to indicate that girls profit more from a large birth interval than boys. This evidence is in accordance with Hypothesis 1.