[The effect of childhood stunting on adult life]

Jorien Visser

S4170296

Masterstudent International Economics and Development

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Supervisor: Prof J. Smits

IN·DEI·NOMINE·FELICITER

Radboud Universiteit Nijmegen

ABSTRACT

Childhood stunting is a pervasive problem, specifically in low-income-countries. This research studies the effects of childhood stunting on wealth, reproductive health and labor market position in the adult life of Sub-Sahara African women. It adds to the literature by including more countries and years than any other study. Moreover, this study recognizes spatial clustering by including fixed effects on village level, an improvement compared to the approach taken by the WHO. This means that women are compared to women within their own environment (PSU). This research confirms the theory, with the use of data from the Global Data Lab, and finds that shorter woman in Sub-Sahara Africa, face negative consequences from their short stature, which is probably due to stunting. They live in households with lower wealth, more often live in poverty, more often work in the agricultural sector and have less children than taller women. Moreover, there is an indirect negative effect trough the level of education. This study also includes an exploratative study towards the different effect of height in rural and urban areas. The results show that the effect of height is stronger in rural than in urban areas, when it comes to the level of household wealth, living in (extreme) poverty and the position on the labor market.

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1: INTRODUCTION

Poverty is one of the most significant problems for human development (WHO, 2015, p.1). In 2015[1] almost ten percent of the world's population lived under the extreme poverty line of $1,90 a day (World bank group, 2016, p.33). Though reducing income poverty has been the aim of many development aid programs, there is still a long way to go (WHO, 2015, p. 3). In Sub-Sahara Africa, almost half of the population lives in extreme poverty, indicating a large unfinished agenda for the sustainable development goals. Globally, only 71 out of 145 countries meet the targets on income poverty, while 27 countries are predicted to be serious off target after 2030. Moreover, out of the 145 countries, only 35 meet the targets on prevalence of undernourishment, while 52 are expected to be serious off target in 2030 (World Bank group, 2016, p. 89).

Poverty and health problems often arrive together. Xala-i-Martin has named the health debacle in Africa 'the biggest problem, the largest human tragedy in the world today' (Xala-i-Martin, 2005, p. 95). Krishna (2010), in his book *one illness away,* provides evidence for health problems as the most common reason for households to fall into poverty. In his large-scale examination of the driving forces behind poverty, he explains how the negative impact of illness influences a household's income level. First, households are forced into high health-care expenses. When the treatment bought does not cure the patient, the household faces a loss of earning power and (in the sad situation of passing) high burial expenses. Second, households can often not instantly come up with the money to pay for the high health-care expenses, forcing them to take a high-interest consumption debt that becomes a burden in the following years (Krishna, 2010). Also Sene and Cisse (2015, p. 308) acknowledge that the out-of-pocket payments (the primary source for health expenditures) for medical help are financial burdens that can have serious consequences when they become too large. The negative effect on disposable income influences the living standard of the household. According to Sene, Cisse (2015) and Krishna (2010), ill-health and high out-of-pocket health-care costs have contributed to the large amount of people living in poverty.

One of the biggest health problems in Sub-Sahara Africa is childhood stunting (WHO,2015, p.1). Stunting is defined as being too short for one's age, or the failure to reach linear growth potential in the early years of life (WHO,2015, p.1). Stunting can start before birth and is associated with poor nutrition, poor food quality and frequent infections in the early days of a child's life (Berendsen, Smits, Netea and van der Ven, 2016, p. 341). These infections start a

[1] Because of production lags in household surveys, 2012 is the latest year for which information on global and regional poverty estimates is available. All 2015 numbers are statistical projections by the World Bank Group (2016).

recurrent cycle of illness, less nutrition, and lower immunity. The energy the body uses to fight recurrent diseases, cannot be used for physical growth, which causes the children to have a low-height-for-age (WHO, 2015, p.2).

Besides being short for their age, stunted children experience diminished cognitive development and permanent health problems (such as diabetes). Because there is only a small chance of catch-up growth, these effects last in adulthood (Graham-McGregor et all, 2007, p. 61, Marotell, Khan and Schroeder, 1994). When these children reach adolescence, they experience poorer educational outcomes and less productive abilities. For women, childhood stunting is associated with a lower age at the birth of the first child and a higher number of pregnancies, stillborns and children. These effects have significant economic consequences for the individual, the household they are part of and the country they live in up (Graham-McGregor et all, 2007, p.62, WHO 2010, p.1).

Because of the severity and magnitude of the effects of childhood stunting and the harmful effects of bad health on income poverty, it is important to gain more insight into stunting and its consequences. Even though there is much research on this topic, Dewey and Begun (2011, p. 7) and Coly et al. (2006, p. 2412) state that there is a lack of understanding about the effects of childhood stunting in adult life. This is partly due to the fact that most studies are of an observational nature. An example is the research of Shively and Reinbold (2011) in Bangladesh and Kenya, who found a negative relationship between stunting and household wealth levels. Moreover, previous studies focus primarily on specific locations or on the causes of stunting instead of the consequences. An example of these studies is the work of Reyes et all. (2004) in a case-control study in Alto Balsas in Mexico. They found significant differences in causes of stunting between rural and urban areas.

This research, therefore focuses on the practical implications of childhood stunting for adult life in Sub-Sahara Africa. In addition, this research pays attention to the effect of stunting in different living situations. *The aim of this study is, therefore, to determine to what extent childhood stunting influences economic and social factors in adult life, and how these effects differ between rural and urban regions*. Given that in the last decades excellent survey data on the height of African women has become available and less data is available for African men, the focus of my analyses will be on women. Moreover, stunting is more common in and heavier for boys than in girls in Sub-Sahara Africa (Wamani et all, 2007, p 17). Therefore, the results of the effects of stunting for woman are likely to be underestimations of the effects of stunting for boys.

The factors on which I will focus are the women's economic position (level of wealth), her labor market position (agricultural or non-agricultural) and her reproductive abilities (number of children). For politicians it is important to know how the effects differ between urban and rural living environments, this difference has implications for the choice of policy measure.

The WHO (2006) uses a global growth curve- the WHO Child Growth Standards median- to define stunting. This curve considers a child stunted when his/her’s height is more than two standard deviations below this curve. However, this does not take into account that “normal” heights differs globally. Already in 1980, Goldstein and Tanner indicated that separate standards need to be derived for each subgroup of the population, especially when comparing disadvantaged groups and children. Moreover, there are multiple child growth charts that all give different outcomes. An example is the child growth charts developed by the U.S. CDC (2000), who in comparison to the WHO child growth charts indicate lower results on undernutrition (De Onis, Garza, Onyango an Borghi, 2007, p.145). In addition, these growth charts do not control for populations who have natural shorter statures, such as the pygmies (Becker, Verdy, Hewlett and Pavard, 2007, p. 18).

To overcome these difficulties, this research compares individuals to individuals in their own environment. By use of fixed effects on village levels to map spatial covariance, women are only compared to women within their direct community. This is an improvement compared to the WHO measurement of stunting. Moreover, this method controls for any factors higher than community level that might influence the dependent variable. Unlike previous studies, this research does not focus on a specific region or a specific time. Instead, data comes from a large amount of countries and multiple years. To my knowledge, there is no other research that uses this fixed effects approach and combines this many countries and years.

The remainder of this research proceeds as follows. The second chapter presents background on the severity and spread of stunting worldwide. The third chapter contains a theoretical framework of literature on stunting. The fourth chapter presents the method and data used in this research and the fifth chapter publishes the results. The sixth chapter consists of a conclusion and discussion. This research ends with a list of references.

2: Background

2.1 Global development of stunting

In 2014, 159 million children around the world suffered from stunting (Unicef, 2015). This is 23.8 percent of all children worldwide. Since 1990, the global trend in stunting prevalence is decreasing. The global number of children affected declined from 255 million to 159 million between 1990 and 2014 (WHO, 2015). The percentage of stunting prevalence declined from 39.6% to 23.8% in the same time period. However, the progress in stunting reduction shows to be unequal when comparing different regions. Most progress has been made in upper/middle-income countries. Between 1990 and 2014 the number of stunted children in this part of the world declined by 77% (WHO, 2015). Low-income countries only reduced stunting by 32% in the same time period and these countries bear a disproportionate share of stunted children relative to the total population distribution. Less than 15% of all children under five years old live in low-income countries in 2014, but almost 25% of all stunted children live in low-income countries. Out of every 10 stunted children, 9 live in low- and middle-income countries (WHO,2015).

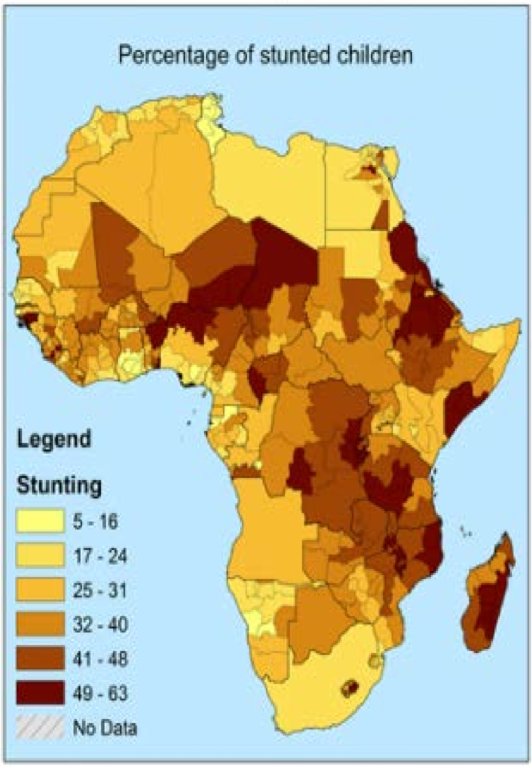


Figure 1: percentage of stunted children in Africa, sub-national level. Source: http://blogs.worldbank.org/opendata/global-data-lab-resource-subnational-development-indicators-household-surveys (26-08-2016).

In 2014, Asia and Africa hold 90% of all stunted children. Progress towards stunting reduction has been very different in both areas. The fastest decline has been in Asia where stunting has been cut almost by half. The percentage of children under 5 stunted reduced from 47.6% in 1990 to 25.1% in 2014. However, within Asia's sub-regions the progress has been imbalanced. China is responsible for most of the progress while the stunting reduction in Southern Asia is more challenging. Stunting reduction has been the slowest in Africa, between 1990 and 2014 the percentage of stunted children declined from 42.3% to 32.0% (WHO, 2015). Moreover, the absolute number of stunted children is rising in this region. UNICEF measured an increase of 23%, from 47 million to 58 million, between 1990 and 2014. Figure one present more information on the percentage of stunted children on a sub-national level in Africa. Figure two presents more information on the percentage of stunted children worldwide.

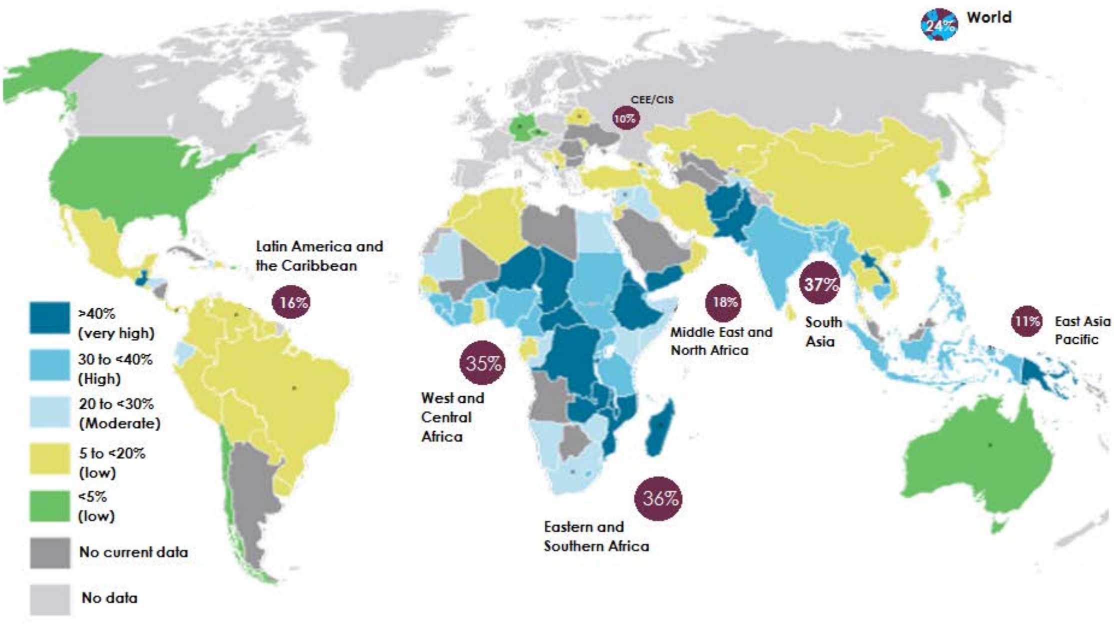
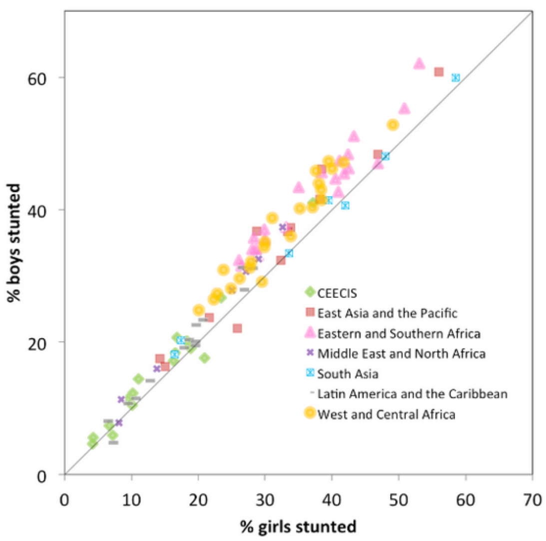


Figure 2: Percentage of stunted children worldwide. Adapted from : UNICEF, WHO, World Bank Joint Child Malnutrition dataset, May 2016 update - See more at: http://data.unicef.org/nutrition/malnutrition.html#sthash.oaBuZJk0.dpuf

The WHO (2015) aims for a 40% reduction in the number of children under five years old who are stunted, from 162 in 2012 to 100 million in 2025. If current trends continue, projections indicate that in 2025, 127 million children under five years old will be stunted. This means that the progress in stunting reduction is not going fast enough. Stunting reduction is important for the new post-2015 development agenda, particularly to the Sustainable Development Goal 2[2]: 'to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture''. The sub-goal 2.2 specifically mentions the international agreed target of reducing stunting in children under five years old by 40% in 2025 .



When looking at the differences in stunting between genders, boys are more likely to be stunted than girls in most countries. Not much research has been done to explain this phenomenon, but initial review suggests that a potential reason is the fact that boys have a higher risk of being born too early. Preterm birth is linked with lower birth weight and a higher chance of being/becoming stunted (Unicef, 2015). More information is presented in figure three.

Figure 3: percentage of boys under 5 who are stunted vs percentage of girls under five who are stunted, by region. Source: UNICEF global nutrition database, 2014.

[2] http://www.un.org/sustainabledevelopment/sustainable-development-goals/. (17-10-2016)

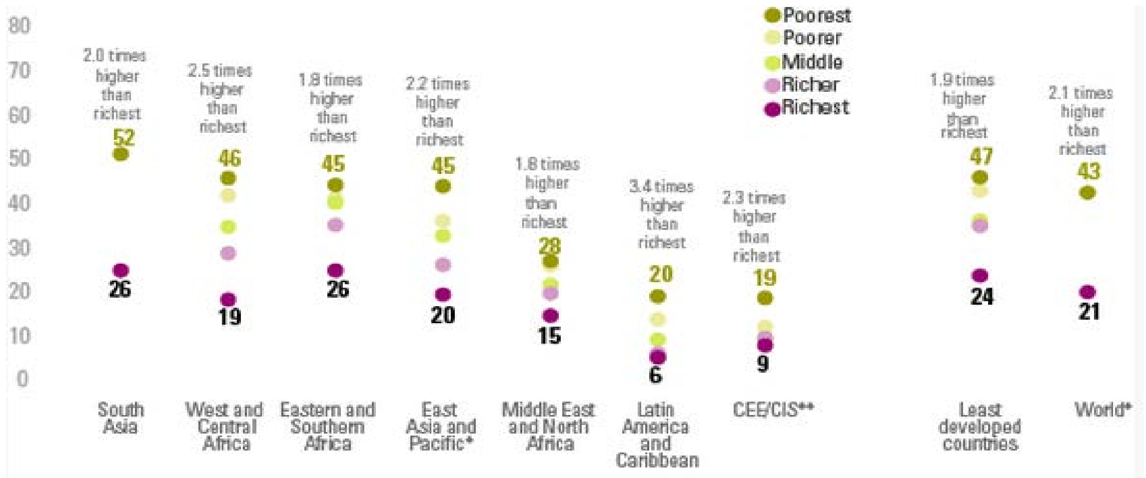


Figure 4: Percentage of children under five who are stunted, by wealth quintile and by region, 2015. Source UNICEF global database, 2015. *Excludes China **Excludes Russia

When looking at stunting rates in the different income quintiles, the stunting rate is more than double among the poorest children when compared to the richest. The absolute differences are the largest in South Asia while the relative differences are the largest in Latin America and the Caribbean (more information in figure four). In this region, the rate of stunting among the poorest 20% is almost four times higher than the rate of stunting among the richest 20% (Unicef, 2015).

2.2 Stunted children remain short as adults

This last part of the background focuses on the question whether the effect of childhood stunting on height lasts into adulthood. There is some biological evidence for potential catch-up growth, or inverse correlation between early height and subsequent growth (Cameron, Preece and Cole, 2005, p. 412). Graham-McGregor et al. (2007, p. 61) acknowledge that some children do reach a height predicted by linear growth because they make-up for the growth 'lost' in the first two years by growing more in later growth phases. However, when development is delayed there are few opportunities among children for catch-up growth, especially for those children who remain in poor environments. Graham-McGregor et al. (2007, p.61) claim that the largest part of stunted children remain stunted trough adulthood. Also Aidar and Guilkey (1997) find that there are long-term consequences of childhood stunting, including short stature in adulthood. To summarize, when people have suffered from childhood stunting, they are likely to remain stunted into adulthood and they are likely to feel the consequences of stunting for the rest of their lives. Similar results are found by: Martorell, Khan and Schroeder (1994), Sawaya, Marins, Hoffman and Roberts (2003), Coly et al. (2006), Corvalan et al (2007), Victora et al. (2008) and Dewey and Begum (2011).

3: THEORETICAL FRAMEWORK

Previous evidence indicates that stunting in childhood has an effect on health, educational and economic performance in later life. This part of the paper discusses these theories and results from different studies that have previously been done on the subject of stunting. Diagram 1 below visualizes the different theoretical effects that are discussed in this part of the research.

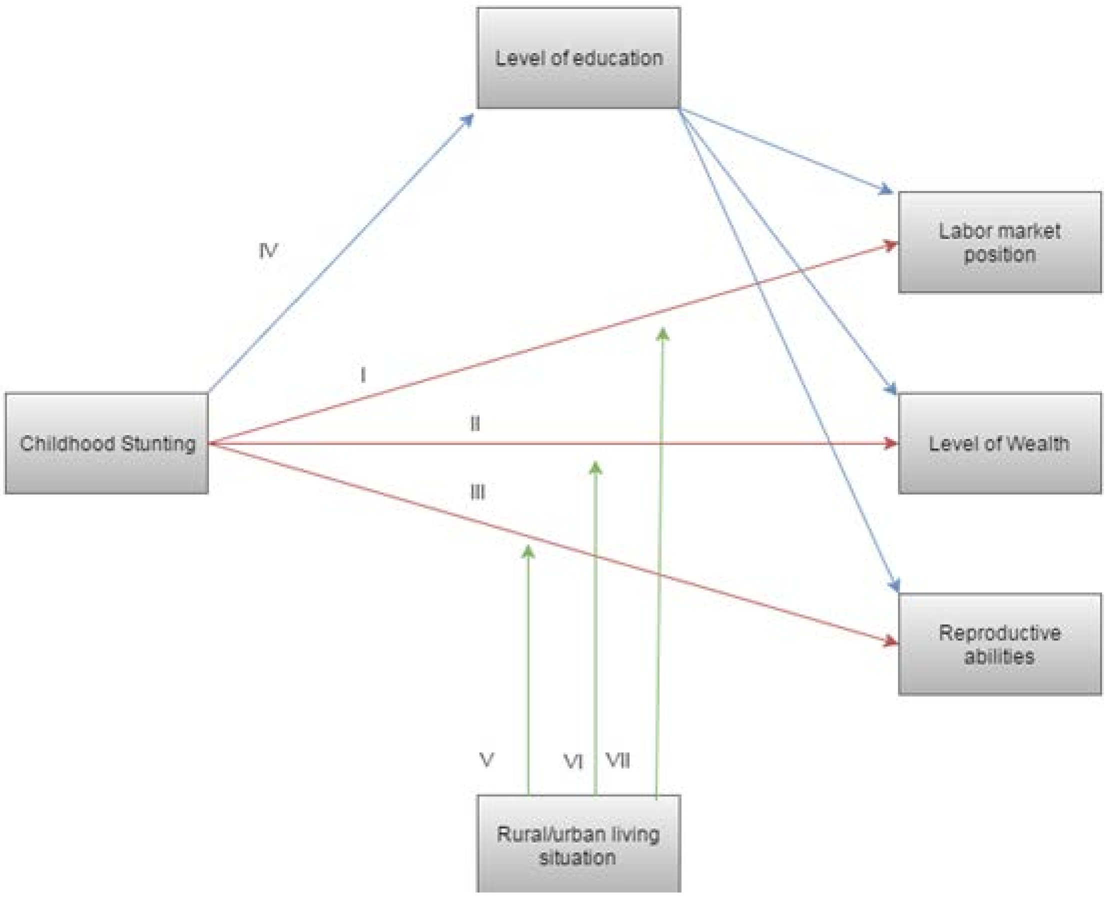


Diagram 1: framework of (in)direct effects of childhood stunting on factors in adult life: the labor market position, the level of wealth and reproductive abilities.

The red arrows numbered I, II and III indicate the direct effect of childhood stunting on the three factors of interest in adult life: labor market position, the level of wealth and reproductive abilities. In fact, there is also an indirect path. There is firm evidence for the influence of stunting on education. The blue arrows visualize this indirect effect of childhood stunting, trough the level of education, on the three factors of interest in adult life. Education is the most important control factor in this model, given its influence on all three dependent variables and the fact that additional stunting influences the level of education. The first part of the theoretic chapter discusses the effects of stunting on education and cognitive functioning. For future research, it would be recommended to find a way to include the direct effect of childhood stunting on educational and cognitive functioning outcomes. The green dotted line represents the influence of rural or urban living situation on the effect of childhood stunting. The study towards this influence is of an explorative form and no hypotheses are formulated.

3.1. The role of education

Diagram 1 shows an indirect effect of childhood stunting on the labor market position, level of wealth and reproductive abilities through education. Adults who have been stunted as children have poorer cognitive abilities, they receive on average less education and have lower school achievements (Granthman, McGregor, and Powell, 2002). Cognitive functions have a risk of being affected by stunting. This risk is especially dangerous in the first two years of life since this is an essential time for the brain to grow and develop. In these years, the brain develops rapidly through different ontogenetic events (Grantham-McGregor et al., 2007, p. 61). These events are depending on and build upon each other. Even minor instabilities can have long-term consequences for the brain's structure and its functional capacity. Moreover, brain development starts before birth. Disturbances in the uterus can also affect cognitive functioning later in life (Grantham-McGregor et al., 2007, p. 61.).

Early cognitive development is an important marker for school progress in developing countries. Pre-school cognitive ability is a predictor for children's enrolment in secondary school (Stith, Gorman, and Choudhury, 2003) and achievement scores in adolescence (Gorman and Pollit, 1996). Berkman et al (2002) find evidence of less cognitive functioning due to stunting when studying children in Peru. Chronic malnutrition, which is marked by stunting, occurred in 32% of the children in the sample. These same children scored 10 point lowers on an intelligence test at the age of 9 years. Also Granthman-McGregor and Powell (2002) find that children who were stunted between 9-24 months and had taken part in a 2-year intervention programmed of psychosocial stimulation performed worse at on cognitive test than their peers at the age of 11-12 years. Disturbances in the years that are critical to brain development, can have long-lasting consequences on long-term cognitive performance and school enrolment (Walker, Chang, Powell and Grantham McGregor, 2005). Similar results have been found by Moock and Leslie (1986), Agarwal, Upadhyhah, Triphathi and Agarwal (1987), Clarke, Grantham-McGregor and Powell (1991), Powell et all. (1995), Hutchinson et al. (1997), Fernald and Grantham-McGregor (1998), Whaley, Sigman, and Espinosa (1998), Mendez and Adair(1999), Grantham-McGregor et al. (2007), Dewey and Begun (2011).

Disturbances in the first two years are furthermore associated with poorer psychological and social functioning. Walker et al. (2007) find that people between the ages of 9-24 years in Jamaica, who have suffered from childhood stunting, reported significantly more anxiety, depressive symptoms, self-esteem, attention deficits, hyperactivity, and antisocial behavior. So besides troubles with cognitive functioning and poorer school results, stunting can lead to mental and social problems. These findings expand the range of consequences associated with stunting. Similar results can be found in Rutter, Tizard, Yule, Graham and Whitmore (1976), Maughan et al. (1996) and McGee et al. (1996).

<u>3.2. Stunting and the level of household wealth (arrow I in diagram 1)</u>

Childhood stunting may influence production abilities and the household wealth level of women in adult life in two ways. There is a direct loss due to poor physical status and less productive abilities. There is an indirect loss in productivity due to poor cognitive development, worse school results, increased health-care costs and less success on the marriage market. Dewey and Begun (2011) conducted a treatment study in Guatemala and found that men, who had not suffered from childhood stunting, benefited by having a higher wage earned in adulthood . For women, there was no such positive effect on wage. The income effect for women in adulthood did not exist, mostly due to the fact that 70% of the women were not active in a paying job. Hodinott et al. (2008) found that adults in Guatemala earn 46% more when they have had more nutrition in their childhood. They ,therefore, qualify improving nutrition in early childhood in developing countries (and consequently decreasing stunting rates) as a 'long-term economic investment'. Similar results can be found in Aidar and Guilkey (1997). The World Bank (2006, p.1) claims that height is unequivocally related to productivity and final height is in a large part determined by nutrition in the first two years from conception. They estimated that a 1% loss in adult height as a result of childhood stunting is associated with a 1.4% loss in productivity. Grantham et al. (2007, p.67) have estimated that stunted children earn around 20% less as adults, compared to individuals who have not been stunted in their childhood. Similar results have been found by Hunt (2005) and Hadad and Bouis (1991).

Besides direct results of childhood stunting on a woman's productivity, there is an indirect effect on the household wealth level trough the marriage market. Shorter women are less successful on the marriage market (Smits and Monden, 2012). Because taller women are healthier and have fewer difficulties with giving birth, these women have more marital success. The height of a woman has positive effects on marital outcomes, taller women are more likely to get married, have higher educated husbands with better jobs and are less likely to marry at a younger age or to lose a husband due to divorce or premature death.

The following hypotheses are deducted from the above-mentioned literature and evidence:

HYPOTHESIS 1A: WOMEN WHO HAVE EXPERIENCED STUNTING AS CHILDREN LIVE IN POORER HOUSEHOLDS, COMPARED TO WOMEN WHO HAVE NOT EXPERIENCED STUNTING IN THEIR CHILDHOOD.

HYPOTHESIS 1B: WOMEN WHO HAVE EXPERIENCED STUNTING AS CHILDREN HAVE A HIGHER CHANCE OF LIVING IN (EXTREME) POVERTY, COMPARED TO WOMEN WHO HAVE NOT EXPERIENCED STUNTING IN THEIR CHILDHOOD.

3.3. Stunting and the labor market position (arrow II in diagram 1)

The effects of stunting on a person's level of education and health can have an indirect effect on the individual's labor market position. Less education means that individuals are less qualified for high-paying jobs demanding relatively more human skills (Blundell, Dearden, Meghir and Sianesi, 1999). Besides having an effect on the household's income, a better position on the labor market increases female empowerment. Empowerment can be defined as the ability to make choices. Since poverty often takes away alternatives to choose differently, poverty generally causes disempowerment (Kabeer, 2005, p. 14). Access to paid work can better women's perception of herself, increase their control of shared household income and benefit their position in discussions about household decision making. Studies in different countries have shown that women who work in the non-agricultural sector have more economic independence, have more power to escape abusive marriages and have widened social networks (Dolan and Sorby, 2003). The effects are greater for women who work in non-agricultural sectors because such employment is associated with migration and an escape from rural areas with patriarchal controls of kinship and community (Kabeer, 2005, p.19). Wage employment in the non-agricultural sector is part of the second sustainable development goal.[3]

The following hypothesis is deducted from the above-mentioned literature and evidence.

HYPOTHESIS 2: WOMEN WHO HAVE EXPERIENCED STUNTING AS CHILDREN MORE OFTEN WORK IN THE AGRICULTURAL SECTOR, COMPARED TO WOMEN WHO HAVE NOT EXPERIENCED STUNTING IN THEIR CHILDHOOD.

[3] http://www.un.org/sustainabledevelopment/sustainable-development-goals/. (17-10-2016)

3.4. Stunting and reproductive health (arrow III in diagram 1)

Women who have experienced stunting in their childhood, have more troubles with giving birth and have a higher chance of their child dying during or shortly after birth. Dewey and begum (2011) find that women who have experienced stunting in their childhood have a narrower pelvis (birth cannel), which can result in obstructed labor and perinatal mortality (stillbirths and deaths during the first 7 days after birth). In a hospital-based study in Nigeria, obstructed labor accounted for 53% of perinatial mortality (Omole-Ohonsi and Ashimi, 2007). Perinatal mortality due to physical problems with delivering the baby is largely the result of birth asphyxia (lack of oxygen to a baby during the birth process) and mothers with a height shorter than 145cm are more likely to have an infant with birth asphyxia. Children who survive birth asphyxia often live with chronic neurodevelopmental disorders, mental retardation and learning disabilities (Lee et al, 2008, p. 2). In a 2005 DHS analysis (World Bank, 2005, p. 186) children who were born to the shortest mothers had a 40% increased risk of mortality. This increased risk effect is comparable to the increased risk of mortality due to having no education or living in the poorest 20% of households (WHO, 2005, p.186). In addition the mother is affected by the obstructed labor. Injuries to the birth passage, rupture of the uterus, fistulas, incontinence and infertility are often consequences of the difficult birth. Similar results are found by Merchant, Villar and Kestler (2001), Black et al. (2008) and, Lawn et al. (2009).

There is furthermore evidence for an intergenerational effect of stunting (Victora, 2008, p. 346). Women who are stunted often give birth to children who are also stunted, passing on the burden and creating this intergenerational effect. There is a small association between the height of the mother and the birth weight of her grandchildren. However, evidence for this intergenerational transmission effect is scarce (Victora, 2008, p.346).

The following hypothesis is deducted from the above-mentioned literature and evidence.

HYPOTHESIS 3: WOMEN WHO HAVE EXPERIENCED STUNTING AS CHILDREN HAVE LESS CHILDREN COMPARED TO WOMEN WHO HAVE NOT EXPERIENCED STUNTING IN THEIR CHILDHOOD.

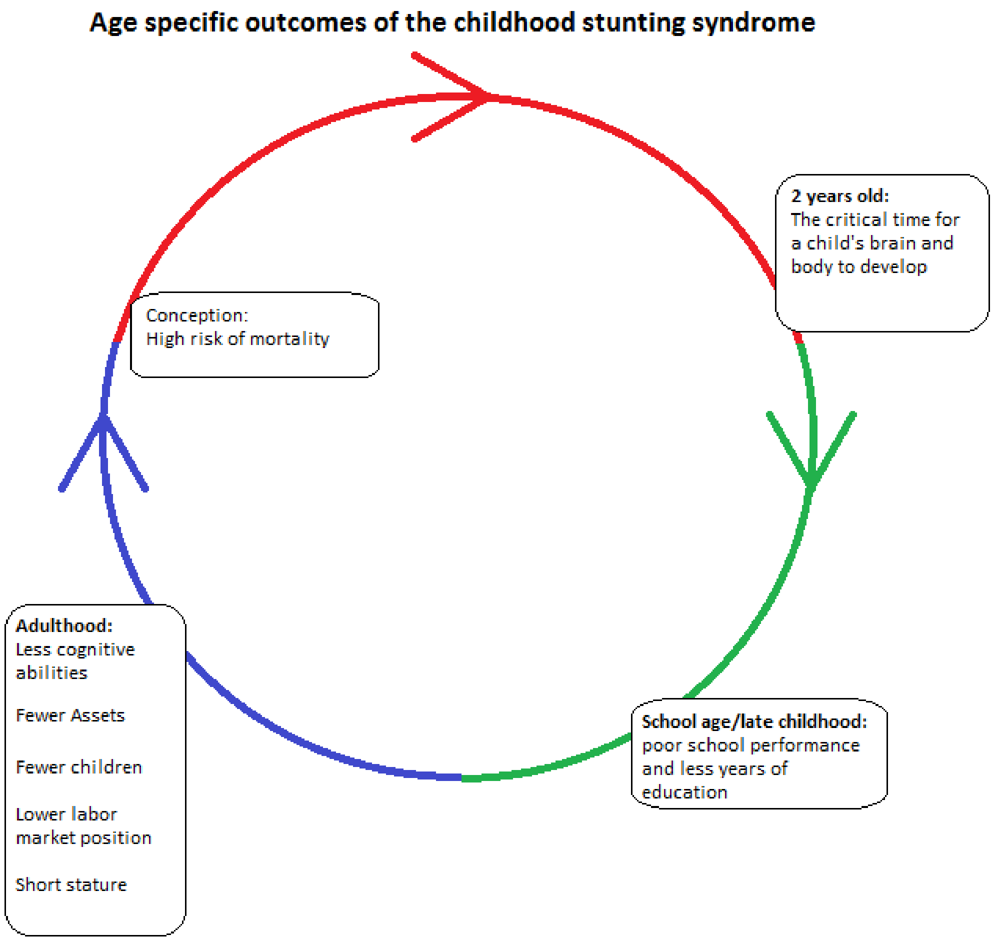


Figure 5: Inspired by Prendergast and Humphrey (2014, p.251). The red pathway denotes the period between conception and the first two years. In these years childhood stunting can create negative consequences that last a lifetime because critical developments in the brain take place in these months. The green pathway denotes the times when the child should be going to school. Due to less cognitive abilities, stunted children have poorer school performance and receive fewer years of education. The blue pathway denotes the time of adulthood. Less cognitive abilities, fewer assets, fewer children, a lower labor market position, antisocial behavior and a shorter stature are factors of adult life that can be attributed to childhood stunting.

Figure two, inspired by the research of Prendergast and Humphrey (2014, p.251), summarizes some results. They find that stunting is created in the time between conception and the first two years of life (red pathway). Stunted children have fewer years of schooling and poor school performance (green pathway). Moreover, these effects last in adulthood (blue pathway), when adults have shorter statures, less cognitive abilities, fewer assets, fewer children, a lower labor market position and anti-social behavior.

3.5. The differences between living in rural and urban areas

The influence of living in a rural or in an urban area is considered in this research because the discussed factors differ in rural and urban areas, and because there is reason to define different policy measures for different areas. First, stunting rates differ. In urban areas malnutrition rates are lower due to more favorable socioeconomic circumstances, leading to better caring practices (Smits, Ruel, Ndiaye, 2005). Fotso (2006) acknowledges these different circumstances and states that rural and urban areas each need specific policy measures to improve health and malnutrition problems. Second, the there is evidence for significant differences between rural and urban areas for the dependent variables considered in this study. Njoh (2003) found development and income differences between rural and urban areas in Sub-Sahara Africa. Kulu (2013) shows that fertility levels are lower in urban areas and large cities. People in rural areas tend to have more children than their urban peers. These differences give reason to believe that there could be variation between rural and urban areas considering the effect of childhood stunting on factors in adult life, since there is variation in the dependent factors between rural and urban areas. Since there is no evidence on the subject yet, this study about the differences of the effect of height between urban and rural areas is explorative.

4: DATA AND METHOD

4.1. Data source

The data is originated from the Global Data Lab (GDL)[4]. This lab creates databases and develops instruments for measuring and analyzing developing countries. At the heart of the GDL is the Database Developing World (DDW), an open data infrastructure in which datasets of hundreds of household surveys are connected and harmonized so numbers can be compared. It contains information on over 20 million individuals and 110 countries. Both national and sub-national data is available for almost all the countries in the developing world. This research uses DHS data on 35 countries from sub-Sahara Africa between the years of 2000 and 2016. Combining different years and countries there are 73 individual data files containing almost 600.000 individual respondents who fit the criteria of age (between 14 and 65, due to data restrictions) and sex (only women). A list of countries and years is presented in appendix A.

4.2. Fixed effects model

The analyses in this research are performed using a fixed effects model on village level. To identify villages, primary sampling units (PSUs) are used. Lawson (2015, p.13828), states that health is spatially clustered on village level, meaning that health factors and health levels differ per village. Using this approach, individuals are only compared to individuals within their direct environment and the characteristics unique to every community are controlled for. This method combines the methodological advantages of both small-scale (anthropological) studies and large-scale demographic studies. Small-scale studies acknowledge the ecological and individual determinants of different dependent variables while large-scale studies are useful in directly contrasting results from different regions (Lawson, 2015, p.13831). Comparing people to people within their direct environment, thus within their community, combines the strengths of both research methods (Lawson 2015) and simultaneously overcomes the difficulties of the WHO measurement method as mentioned in the introduction.

Kravdal (2006) has concluded that bias from using clusters averages as proxies for the rest of the population is fairly small when using DHS data. Since the analysis focuses on comparing people within communities, macro determinants of the dependent variables are already controlled for. Therefore, there is no need for these determinants to be included. Only control factors at the household level are included in the equations.

[4] Information on the global data lab from http://globaldatalab.org/ (consulted at 22-08-2016, 15:25).

Because of the large amount of clusters, the fixed effects regressions are performed by demeaning. The mean of the cluster of all variables is subtracted from the original regression. A transformation called 'within transformation', however, these variables are not time-demeaned but cluster-demeaned. This means that the standard errors are calculated with too many degrees of freedom. The standard errors in the tables presenting the results are therefore adjusted using the following formula:

$$Adjusted\ standard\ error = standard\ error * (\frac{NT-K}{N(T-1)-K})^{1/2}$$

With N representing the number of cases, T the number of clusters and K the number of independent variables in the model.

The variable indicating whether a woman lives in a rural or urban area is not present in the fixed effects regressions because it is impossible to include a demeaned variable for which every person in the cluster has the same score. The demeaned variable would always have the score of zero and is therefore omitted from the fixed effects regressions.

4.3. Regressions and dependent variables

The first hypothesis considers the effect of stunting on the wealth level of the household the woman is living in, and the contribution of that women to the living situation of the household. The wealth level of the household is measured by the International Wealth Index (IWI) (Smits and Steendijk, 2015). This index is an instrument developed by the GDL. Income is often not fitted for measuring the economic position of household in poor countries because there is a sufficient risk of reporting errors and income is often unstable. Consumption is also less fitted to measure the wealth or income level of households because there are comparability issues and reporting errors. A good alternative is an asset-based wealth index in which households are ranked by asset ownership. This index indicates the longer-term socio-economic position, living standard, or welfare of households. Asset wealth indexes are often used, easily computed and have an intuitive appeal. The IWI has the unique property, not like other asset-based wealth indexes, that the results can be compared across countries and years. It can be used for all low and middle-income countries and is based on the data derived from the DDW. The index is constructed of 2.1 million households in 165 DHS surveys held between 1996 and 2011 in 97 developing countries. There are 12 assets measured by 20 indicators and the final IWI is computed using principal component analysis. The IWI runs from 0 to 100, with 0 being the poorest and 100 being the richest households. The final number does not depend on a specific asset, time or region. The complete construction of the IWI is available in appendix B (Smits and Steendijk, 2015).

The IWI is used as the dependent variable in both the analyses concerning hypothesis 1a and 1b. Hypothesis 1a concerns the effect of stunting on the level of wealth in the household the woman is part of. This analysis takes the IWI as it is presented in the data, as an indicator of the wealth of a household. The second analysis, concerning hypothesis 1b, adjusts the IWI by dividing the sample into two by using poverty lines. This analysis focuses on the chance of a household living in (extreme) poverty. A cut-off line is used to determine whether or not a respondent lives in a household that can be considered as (extreme) poor. There are two cut-off lines as advised by Smits and Steendijk (2015). The first one is the 35 score in the IWI and the second the 50 score on the IWI. These cut-offs are chosen because they have a high correlation with more well-known poverty lines. The 35 score on the IWI has a high correlation with the $1,90 a day poverty line, people living below this level are categorized as the 'extreme poor'. The second cut-off line is the 50 score on the IWI, which has a high correlation with the $3,10 a day poverty line (Smits and Steendijk, 2015). People living with less than $3,10 a day are categorized as 'poor'. These analyses use a dummy as dependent variables and so require a logit analysis, where the log(odds) are a linear function of the set of independent variables. For determining significance and direction of the effects the logit coefficients are used.

The second hypothesis regards a woman's productive abilities. This is measured by the labor market position. This variable is divided into two mutually exclusive categories, inspired by the categories in Smits and Gündüz-Hoşgör (2008) and Spierings, Smits and Verloo (2008): (1) not working/housewife or unpaid/paid farm worker and (2) non-agricultural employment. The first category contains both not working/housewife and paid/unpaid farm worker because it is impossible to make a distinction between these occupations in developing countries. Moreover, as mentioned in the third chapter, there are major empowerment and wage differences between women who are employed in the agricultural sector and who are employed in the non-agricultural sector.

The third hypothesis is used to study the effect of stunting on the reproductive health of women. Reproductive health is measured by the number of children the woman has given birth to. The theory predicts that women who have suffered from stunting in their childhood have fewer children than women who have not suffered from stunting. Since this analysis is based on count data this regression is a Poisson regression.

<u>4.4. Independent variables</u>

The effect of childhood stunting on the dependent variables in adult life is studied by using adult height as the independent variable of interest. Height has effectively been used as an instrument in indicating living standards (both health and income) in developing country research (Deaton, 2007, p. 13232). Deaton also recognizes that health is mostly determined by net nutrition in early childhood, with net nutrition being the difference between calorie intake and losses due to activities and diseases. Height is a sensitive indicator of socioeconomic environment and health (Coly et al, 2006, p. 2412). Since stunted children are expected to remain stunted for the rest of their lives (Cameron, Preece, and Cole, 2005, p. 412, Graham-McGregor et al, 2007), height is a fitted marker to measure childhood stunting. Moreover, other anthropometric measurements are not stable over time but can fluctuate significantly in rather short periods. These measurements are also less informative about past malnutrition and chronic deprivation. Height can be considered as a measure of long-term well-being and as reflecting past events (Coly et al, 2006, p. 2412). Also Deaton (2007, p. 13232) states that adult height is an indicator of the economic and disease environment in childhood. Moreover, height has the advantage of being individually collected and is particularly useful in picking up elements of an individual's history (Mckay and Lawson (2003, p. 436). The direction of height is expected to be positive in all analysis except for the (extreme) poverty indicators. These variables are recoded to run from not poor to poor and so the sign of height is expected to be negative. Besides height, there are more control variables added to each equation.

The years of education the woman has received is added as a control variable in all four regression analyses. The level of education influences all kinds of demographic behavior, including productiveness and use of contraception (Jejeebhoy, 1995). Moreover, schooling empowers women, even though the personal advantages that women connect to education differ per region, culture and level of development. More empowered women experience more independence to make their own decisions. This results in fewer children for more educated women (Jejeebhoy, 1995). Emmons and Noeth (2015) have found a strong positive association between educational attainment and a family's level of wealth. Moreover, Blundell, Dearden, Meghir and Sianesi (1999) have found that more education leads to a higher level of human capital and eventually to a better position in the labor market. However, Wydick (2007) puts forth that in poor communities, where the overall educational level is low, more schooling can actually result in a lower income/wealth level and does not benefit a person's position on the labor market. Because the average person is low educated, it pays off to be a jack-off-al-trades. Being higher educated and specialized in a specific subject does not pay off in these situations. Labor specialization is only favorable when there are other specialized people to trade with.

The wealth level of a household (IWI) is added as a control variable in the analysis concerning the effect of height on a woman's reproductive health. Schoumaker(2004) estimated that women living in poverty have a larger number of children, marry younger and use fewer contraceptive methods. These effects persist after controlling for education and place of residence. Reasons for people living in poverty to have more children are old-age security, the benefits of work of children, a lower education level, and a higher mortality rate among the poor, creating a replacement mechanism.

The number of children a woman has is added as a control variable in the analyses concerning the effect of height on a household's wealth level and the effect of height on a woman's position in the labor market. A woman's behavior in the labor market depends among others on the needs of the household. Different kinds of needs can conflict with each other. Economic and care needs do not always align. Economic needs are related to the basic needs of each person: food, clothing, and housing. Care needs may prevent a woman from entering the labor market and depend on the number of people in the household that need care, such as children and elderly (Spierings, Smits, and Verloo, 2008, p.14).

The occupation of the woman is added as a control variable in the analysis concerning the effect of height on the household wealth level. Women who work outside of the agricultural sector bring a larger income to the household and accumulate more wealth than women who work in the agricultural sector (Kabeer, 2005, p.14).

The age at which a woman gives birth to her first child is added in the equation concerning the first hypothesis. Women who start having children earlier in their lives have significantly more children than women who wait with childbearing (Card and Wise, 1978). Moreover, this variable is added to the equation to control for the effect of the age on height. Women who have their first child at a young age have a lower height when reaching adolescence because the body puts all energy in the pregnancy and not in physical growth (Monden and Smits, 2009, p. 305).

The analysis concerning the effect of height on the household wealth level has a dependent variable that is not a characteristic of the woman, but a characteristic of the household she lives in. To control for the partner's influence in the position of the household, two characteristics of the partner are added to the equation as independent variables. These characteristics aim to cancel out the husband's influence on the score on the asset-based wealth index. These independent variables are: the labor market position of the partner (with the same characteristics as the variable measuring a woman's labor market position) and the years of education of the partner. The occupation of the partner is added to the analysis concerning the effect of height on the woman's labor market position since a partner's employment position influences the economic needs of the household and the decision of the woman to participate in the labor market (Spierings, Smits, and Verloo, 2008). When the partner of a woman has a job there might be no need for the woman to work herself. This implies a negative relationship between the occupation of the woman and the occupation of the husband. However, women may stop working when their labor market position is higher than that of their husband to prevent tension in the marriage. This is called a ‘ceiling effect’ (Spierings, Smits, and Verloo, 2010, p. 1396). In this situation, when a partner has a higher labor market position, there is more room for the woman to have a high labor market position herself. There is also a possible positive relationship between the occupation of the partner and the occupation of the woman when the woman benefits from the network that the partner has built in a higher position. These two theories predict a positive relation between the partner’s labor market position and the labor market position of the women. Moreover, people who are married have significant higher wealth than people who are not (continuously) married (Wilmoth and Koso, 2002). Giving a reason to include a woman’s marital status in the model.

The descriptive statistics off all the dependent and independent variables are presented in table 1. Before the regressions, several variables are transformed to fit the requirements. The variables indicating the labor market position for a woman and for the woman’s partner are transformed into dummies, with a (0) for working in the agricultural sector and a (1) for working the non-agricultural sector. The variable identifying the marital status of a woman is recoded into a dummy with two categories. The original variable consisted of multiple categories indicating whether the woman had ever been married, was widowed or divorced and other situations. The created dummy indicates if the woman is married at the point in time the DH survey was taken or if she was not, with a (0) for not being married and a (1) for being married. Every situation in which a household contains both a woman and her partner is classified as ‘married’, this includes for example cohabitation. The interaction term between height and rural is computed using centralization for easier interpretation, as is the square of height. The IWI variables are transformed for the analysis about poverty and extreme poverty. For both variables, the (0) indicates living above the poverty line and the (1) indicates living below the poverty line. The dummy variable indicating a rural or urban living situation has a (0) for living in an urban environment and a (1) for living in a rural environment. Each cluster with less than five women responding has been removed from the analyses, because sparsely and unbalanced clusters can lead to overestimation of the fixed effects models (Lawson, 2015).

Table 1: Descriptive Statistics	N	Minimum	Maximum	Mean	Std. Deviation
Height	576331	137,50	176,40	158,17	6,49
Years of education	574012	0,00	26,00	4,69	4,49
IWI	575707	,00	100,00	30,33	24,84
Age at birth of first child	422539	6	48	19,07	3,78
Urban/rural living environment 0=urban 1=rural	576331	0	1	0.64	,48
Labor market position 0=agri 1=non-agri	561442	0,00	1,00	,32	,46
Labor market position partner 0=agri 1=Non-agri	421966	0,00	1,00	,48	,50
Years of education partner	319886	0,00	25,00	4,90	4,92
Maritial status 0= unmarried 1= married	574414	0,00	1,00	,66	,47
Number of children	576331	0	18	2,93	2,85

A first look at the data shows that the mean of IWI is situated below the poverty line of $1,25 a day, indicating extreme poverty. The mean of the urban or rural living environment indicates that more people live in the rural areas than in urban areas. A mean of 0.32 for the labor market position variable indicates that more woman work in the agricultural sector than in the non-agricultural sector. The same goes for the woman's partner, however, the mean of the partner's labor market position is closer to 0.5 than for the women. Indicating that there are more women than man active in the agricultural sector. Women also have on average fewer years of education than men. The mean of marital status indicates that more women are married than unmarried.

The correlations between the different independent variables of each dependent variable are presented in table 2, 3 and 4.

Table 2
Correlations of hypothesis 1: the effect of height on the number of children

	Height	Years of education	IWI	Age at birth of first child	Urban/rural living environment
Height	1	,081	,147	,050	-,092
Years of education	,081	1	,494	,207	-,353
IWI	,147	,494	1	,159	-,588
Age at birth of first child.	,050	,207	,159	1	-,095
Urban/ rural living environment	-,092	-,353	-,588	-,095	1

Table 3
Correlations of hypothesis 2: the effect of height on the IWI

	Height	Years of education	Labor Market position	Labor market position partner	Years of education partner	Maritial status	Urban/rural living environment
Height	1	,081	,089	,072	,044	,061	-,092
Years of education	,081	1	,170	,355	,700	-,270	-,353
Labor Market position	,089	,170	1	,335	,214	,031	-,251
Labor market position partner	,072	,355	,335	1	,392	-,060	-,430
Years of education partner	,044	,700	,214	,392	1	-,011	-,356
Marital status	,061	-,270	,031	-,060	-,011	1	,154
Urban/ rural living environment	-,092	-,353	-,251	-,430	-,356	,154	1

Table 4
Correlations of hypothesis 3: the effect of height on the Labor market position

	Height	Years of education	Number of children	Labor market position partner	Maritial status	Urban/rural living environment	Years of education partner
Height	1	,081	,065	,072	,061	-,092	,044
Years of education	,081	1	-,323	,355	-,270	-,353	,700
Number of children	,065	-,323	1	-,151	,454	,177	-,189
Labor market position partner	,072	,355	-,151	1	-,060	-,430	,392
Marital status	,061	-,270	,454	-,060	1	,154	-,011
Urban/ rural living environment	-,092	-,353	,177	-,430	,154	1	-,356
Years of education partner	,044	,700	-,189	,392	-,011	-,356	1

By combining all the information and variables above, the following fixed effects equations are produced.

$$(1)\ NC_i = \beta_0 + \beta_1 Height_i\ + \beta_2 EDYR_i + \beta_3 IWI_i + \beta_4 ABFC_i + \varepsilon_i + \vartheta_i$$

$$(2)\ IWI_i = \beta_0 + \beta_1 Height_i\ + \beta_2 EDYR_i + \beta_3 NC_i + \beta_4 OCW_i + \beta_5 OCWP_i + \beta_6 EDYRP_i + \beta_7 MARSTAT_i + \varepsilon_i + \vartheta_i$$

$$(3)\ OCW_{it} = \beta_0 + \beta_1 Height_i\ + \beta_2 EDYR_i + \beta_3 NC_i + \beta_4 IWI_i + \beta_5 OCWP_i + \beta_6 MARSTAT_i + \varepsilon_i + \vartheta_i$$

Where EDYR is the number of years of education, NC is the number of children, ABFC is the age at the birth of the first child, OCW is the labor market position, OCWP is the labor market position of the partner, EDYRP is the number of years of education of the partner and MARSTAT is the marital status. The demeaning process on cluster level is as follows:

$$(4)\ (NC_{it} - \overline{NC_c}) = \beta_1(Height_{it} - \overline{Height_c}) + \beta_2(EDYR_{it} - \overline{EDYR_c}) + \beta_3(IWI_{it} - \overline{IWI_c}) + \beta_4(ABFC_{it} - \overline{ABFC_c}) + (\varepsilon_{it} - \overline{\varepsilon_c})$$

$$(5)\ (IWI_{it} - \overline{IWI_c}) = \beta_1(Height_{it} - \overline{Height_c}) + \beta_2(EDYR_{it} - \overline{EDYR_c}) + \beta_3(NC_{it} - \overline{NC_c}) + \beta_4(OCW_{it} - \overline{OCW_c}) + \beta_5(OCWp_{it} - \overline{OCWp_c}) + \beta_6(EDYRP_{it} - \overline{EDYRP_c}) + \beta_7(Marstat_{it} - \overline{Marstat_c}) + (\varepsilon_{it} - \overline{\varepsilon_c})$$

$$(6)\ (OCW_{it} - \overline{OCW_c}) = \beta_1(Height_{it} - \overline{Height_c}) + \beta_2(EDYR_{it} - \overline{EDYR_c}) + \beta_3(NC_{it} - \overline{NC_c}) + \beta_4(IWI_{it} - \overline{IWI_c}) + \beta_5(OCWp_{it} - \overline{OCWp_c}) + \beta_6(Marstat_{it} - \overline{Marstat_c}) + (\varepsilon_{it} - \overline{\varepsilon_c})$$

To shorten the notation the above equations are simplified as:

$$(7)\ \ddot{NC}_{it} = \beta_1 \ddot{Height}_{it}\ + \beta_2 \ddot{EDYR}_{it} + \beta_3 \ddot{IWI}_{it} + \beta_4 \ddot{ABFC}_{it} + \ddot{\varepsilon}_{it}$$

Where $\ddot{NC}_{it} = NC_{it} - \overline{NC_c}$ and so on.

$$(8)\ \ddot{IWI}_{it} = \beta_1 \ddot{Height}_{it}\ + \beta_2 \ddot{EDYR}_{it} + \beta_3 \ddot{NC}_{it} + \beta_4 \ddot{OCW}_{it} + \beta_5 \ddot{OCWp}_{it} + \beta_6 \ddot{EDYRP}_{it} + \beta_7 \ddot{Marstat}_{it} + \ddot{\varepsilon}_{it}$$

$$(9)\ \ddot{OCW}_{it} = \beta_1 \ddot{Height}_{it}\ + \beta_2 \ddot{EDYR}_{it} + \beta_3 \ddot{NC}_{it} + \beta_4 \ddot{IWI}_{it} + \beta_5 \ddot{OCWp}_{it} + \beta_6 \ddot{Marstat}_{it} + \ddot{\varepsilon}_{it}$$

5. RESULTS

5.1. Regressions without fixed effects

Table 5, 6, 7, 8, and 9 present the results of regressions without fixed effect. The first regression of each dependent variable (the numbers 1, 4, 7, 10 and 13) only have the independent variable of interest included. The second regression of each dependent variable (the numbers 2, 5, 8, 11 and 14) includes the square of height to control for nonlinearity. The third regression of each dependent variable (the numbers 3, 6, 9, 12 and 15) includes all the relevant control variables. The regressions without fixed effects do not control for fixed effects on the level of villages and are similar to the approach of the WHO, everybody is compared to everybody (WHO, 2006). This means there is a bias in the data since there is no control for spatial clustering. Moreover, there is no control for influences on a community level and higher.

5.1.1 The effect of height

The coefficients of height are significant at the one percent level in each regression. Overall, the theory accurately predicts the effect of height on the dependent variables. The results show a positive relationship between height and the number of children. For an average living situation, women who are taller have more children. The same goes for the effect of height on a household's level of wealth. For an average living situation, women who are taller live in a household with a higher wealth level and have a lower chance of living in (extreme) poverty. Moreover, the effect of height on a woman's occupation is also positive. Taller woman have a higher chance of being employed in the non-agricultural sector. The squares of height are significant in each regression variable indicating a non-linear relationship. However, due to the disadvantages associated with not using fixed effects, as mentioned above, these result cannot give accurate estimates. The implications regarding non-linearity are extensively discussed in the section presenting the results of the fixed effects analyses.

5.1.2 The effect of living in urban or rural environments

The results of the interaction term show, that there is no significant difference between rural and urban areas for the effect of height on the number of children. However, the interaction term between height and rural is significant for the regressions regarding the different wealth indicators and the labor market position. The results show, that the effect of height on the wealth indicator and the labor market position, is less positive for women from rural areas than for women from urban areas. An additional centimeter of height is more valuable for the level of wealth in urban areas than in rural areas. For the poverty indicators, the effect of height is less negative for rural areas than for urban areas. Because the interaction term is standardized the coefficients of height and urban or rural living environment represent the situation in which the other variable is equal to the mean.

For a person with average height, living in a rural area decreases the chance of having a job in the agricultural sector. The results considering the effect of the urban or rural living environment on the different wealth indicators also confirm the theory. People who live in rural areas have a higher chance of living below both poverty lines and have a lower score on the IWI overall. Moreover, people in rural areas have significantly more children than people who live in urban areas.

5.1.3 The effect of education

The relation between years of education and the wealth indicator is positive, as predicted by theory. The wealth level of a household increases with the number of years of education of the woman. Moreover, also the effects of education on the chance of living in poverty and extreme poverty confirm the forecasts of the theory. The chance of living above the wealth level of the poverty lines increases with years of education. This effect is lower for the poverty line of $1.90 a day than the poverty line of $3.10 a day. The results also confirm the predictions of the theory on the relationship between the years of education and the number of children and the years of education and the labor market position. Women who are more educated, are more empowered which results in fewer children. Moreover, more educated woman have a higher chance of having a job outside of the agricultural sector. This contradicts the theory of Wydick (2007), who claims that more education and specialization do not get a person a better job because specialization is not beneficial in societies with a low overall level of education.

5.1.4 The effects of the other control variables

The relationships of the other control variables are generally as predicted by theory. Worth mentioning are the results on the relationship between the occupation of the partner and the occupation of the woman. A partner that is active in the non-agricultural sector gives a woman a higher chance of having a job in the non-agricultural sector herself, this can be interpreted as a proof of the ceiling effect or as a proof that the woman benefits from the network of the partner.

The results on a woman's marital status are not confirmed by theory, being married has a negative influence on a household's wealth level, married woman have a higher chance of living below the poverty lines and a lower chance of having a job in the non-agricultural sector.

The effect of household wealth on the number of children is in line with expectations, an increased level of household wealth increases the number of children. However, the measurements of the level of household wealth and the number of children are highly correlated. Since these variables are measured at one specific point in time, there is evidence that the measured effect is an underestimation of the 'real' effect.

To summarize, what does this mean for women who have suffered from stunting in their childhoods? Since these women are shorter, they have less reproductive health, live in less wealthy households with a higher chance of living below the poverty lines, and they have fewer children. Moreover, they have a smaller chance to work outside of the agricultural sector and become more empowered. Because women who have suffered from stunting in their childhood often have cognitive impairments there is also a stunting component present in the years of education variable. Women who have less education live in poorer households and have less chance of a job outside of the agricultural sector. However, as has been warned before, the regressions without fixed effects are biased and do not control for spatial clustering.

Table 5: Results of regressions without fixed effects. Dependent variable: number of children

* significant at 10% level ** significant at 5% level *** significant at 1% level	(1) Number of children	(2) Number of children	(3) Number of children
Constant	0.947***	0.931***	-1.008***
Height in centimeters	0.003***	0.003***	0.006***
Height squared		-0.0002***	-0.0002***
Years of education			-0.037***
International Wealth Index			0.0002**
Age at birth of first child			-0.031***
Urban or rural living environment 0= Urban 1= Rural			0.101***
Interaction height and urban or rural living environment			n.s.
R^2	Not available for count data		

Table 6 : Results of regressions without fixed effects
Dependent variable: International Wealth index

* significant at 10% level ** significant at 5% level *** significant at 1% level	(4) International Wealth Index	(5) International Wealth Index	(6) International Wealth Index
Constant	-58.430 (-66.378)***	-158.603 (-66.539)***	-2.588 (-2.804)**
Height in centimeters	0.544 (98.056)***	0.546 (98.230)***	0.310 (64.282)***
Height squared		-0.004 (-5.785)***	-0.001 (-2.630)**
Years of education			1.011 (100.460)***
Urban or rural living environment 0= Urban 1= Rural			-15.832 (-202.839)***
Labor market position 0= Agricultural 1= Non-agricultural			6.567 (94.385)***
Labor market position partner 0= Agricultural 1= Non-agricultural			6.801 (91.999)***
Marital status 0= Not married 1= Married			-5.011 (-10.343)***
Year of education partner			0.771 (86.865)***
Interaction height and urban or rural living environment			-0.255 (-24.392)***
R^2	0.22	0.22	0.499

Table 7: Results of regressions without fixed effects
Dependent variable: Extreme poverty

* significant at 10% level ** significant at 5% level *** significant at 1% level	(7) Extreme poverty	(8) Extreme poverty	(9) Extreme poverty
Constant	7.121*** 1237.964	7.929*** 2775.947	5.079*** 160.648
Height in centimeters	-0.041*** 0.960	-0.045*** 0.956	-0.035*** 0.966
Height squared		0.001*** 1.001	0.0005*** 1.001
Years of education			-0.093*** 0.911
Urban or rural living environment 0= Urban 1= Rural			1.571*** 4.814
Labor market position 0= Agricultural 1=Non-agricultural			-0.773*** 0.461
Labor market position partner 0= Agricultural 1=Non-agricultural			-0.944*** 0.389
Marital status 0= Not Married 1=Married			0.530*** 1.699
Years of education partner			-0.087* 0.917
Interaction height and urban or rural living environment			0.004*** 1.004
R^2 (Nagelkerke)	0.021	0.022	0.498

Table 8: Results of regressions without fixed effects Dependent variable: Extreme poverty

* significant at 10% level ** significant at 5% level *** significant at 1% level	(10) Poverty	(11) Poverty	(12) Poverty
Constant	8.396*** 4429.709	23.695*** 1953	6.948*** 1040.843
Height in centimeters	-0.049*** 0.956	-0.052*** 10.949	-.040*** 0.816
Height squared		0.0001*** 1.0001	0.001*** 1.0001
Years of education			-0.112*** 0.894
Urban or rural living environment 0= Urban 1= Rural			1.732*** 5.651
Labor market position 0= Agricultural 1=Non-agricultural			-0.623*** 0.536
Labor market position partner 0= Agricultural 1=Non-agricultural			-1.057*** 0.348
Marital status 0= Not Married 1=Married			0.516*** 1.675
Years of education partner			-0.098*** 0.907
Interaction height and urban or rural living environment			n.s.
R^2 (Nagelkerke)	0.022	0.022	0.505

Table 9: Results of regressions without fixed effects Dependent variable: Labor Market Position

* significant at 10% level ** significant at 5% level *** significant at 1% level	(13) Labor market Position	(14) Labor market Position	(15) Labor market Position
Constant	-5.507*** 1.030	-4.008*** 0.00	-3.447*** 0.032
Height in centimeters	0.028*** 1.029	0.029*** 1.213	0.019*** 1.020
Height squared		-0.001*** 0.999	-0.0004*** 1.00
Years of education			0.046*** 1.047
Urban or rural living environment 0= Urban 1= Rural			-0.647*** 0.524
Labor market position partner 0= Agricultural 1=Non-agricultural			1.074*** 2.926
Marital status Marital status 0= Not Married 1=Married			-0.215*** 0.806
Years of education partner			0.008*** 1.008
Number of children			0.055*** 1.056
Interaction height and urban or rural living environment			n.s.
R^2 (Nagelkerke)	0.011	0.011	0.189

5.2. Regressions with fixed effects on cluster level

Table 10, 11, 12, 13 and 14 show the results of the fixed effects regressions. These regressions compare women to women within their own environment (PSU). Unlike the regressions without fixed effects, these results are not biased since there is control for spatial clustering. Moreover, the influence of factors on a community level or higher have been accounted for. For regressions in which the interaction term between height and rural or urban living environment is significant, the effect of height on the dependent variable has been presented separately for rural and urban areas.

5.2.1. The effect of height

The effect of height on the dependent variables is significant and in the expected direction for all regressions. Taller woman have more children than their cluster average while shorter women have fewer children than their cluster average (Graph 1). Within a cluster, taller women live in households with higher wealth levels than their cluster mean (Graph 2) and are more often employed in the non-agricultural sector (Graph 5). The negative sign of the poverty indicators means that taller women more often live above the poverty lines than the average mean of their cluster (Graph 3 and Graph 4). The relationships are in line with the expectations and the hypotheses are confirmed.

The squared height variables are not significant for the regression considering the effect of height on the labor market position and for the regression considering the effect of height on living in (extreme) poverty (Graph 3 and Graph 4). On village level, these relationships show no evidence of nonlinearity. The regression with the number of children as a dependent variable has a negative squared height, which indicates that the effect of height decreases as height increases (Graph 1). Women who are taller than the mean of their cluster have more children than the average woman within her cluster. Women who are shorter than the average mean within a cluster have fewer children than the average women within their cluster. However, this effect flattens out as women become taller.

Graph 2 shows the effect of height on a household's wealth level. The results show a positive relationship, indicating that taller women live in households with more wealth than women who are shorter. This concave function has a peak that is well outside of the maximum value of the demeaned height variable. So for the women in this dataset, there is only a positive relationship with a declining increase as women get taller. The same goes for the effect of height on the labor market position (Graph 5).

5.2.2 The effect of living in urban or rural environments

The interaction variable between height and urbanization is not significant for the regression with the number of children as the dependent variable. For the other regressions regarding the effect of height, the interaction variable is significant and shows a stronger effect of height for women who live in rural areas than for women who live in urban areas. This is represented in the graphs by the difference between the blue and red line. Rural women have more to gain/lose by an additional/deducted centimeter in height regarding these dependent variables.

5.2.3. The effects of education

The tables show the following results for the indirect effect of education. More educated women have fewer children, a higher score on the wealth indicators and poverty indicators and they more often work in the non-agricultural sector. These results are as predicted by theory. The positive effect of education on the wealth and labor market position indicators are in the expected directions, disproving the expectations of Wydick (2007) that more education (and more specialization) is harmful for a person's economic position. However, since the marginal gains of one year of additional education are small, it could be argued that there is evidence to support this theory. More research in this area is needed, the relationship could, for instance, be nonlinear because of decreasing marginal returns to education.

5.2.4. The effect of other control variables

The tables show the following results for the effect of the other control variables. The relationships of the other control variables are generally as predicted by theory. The number of children increases with wealth, and a woman also has more children the younger she is at the birth of her first child. However, the measurement of the level of household wealth and the number of children are highly correlated. Since these variables are measured at one specific point in time, there is evidence that the measured effect is an underestimation of the 'real' effect.

A higher labor market position (in the non-agricultural sector) increases the wealth level of the household the woman lives in. The same goes for the labor market position of the woman's partner. These two factors have more influence on the wealth indicators than the woman's height.

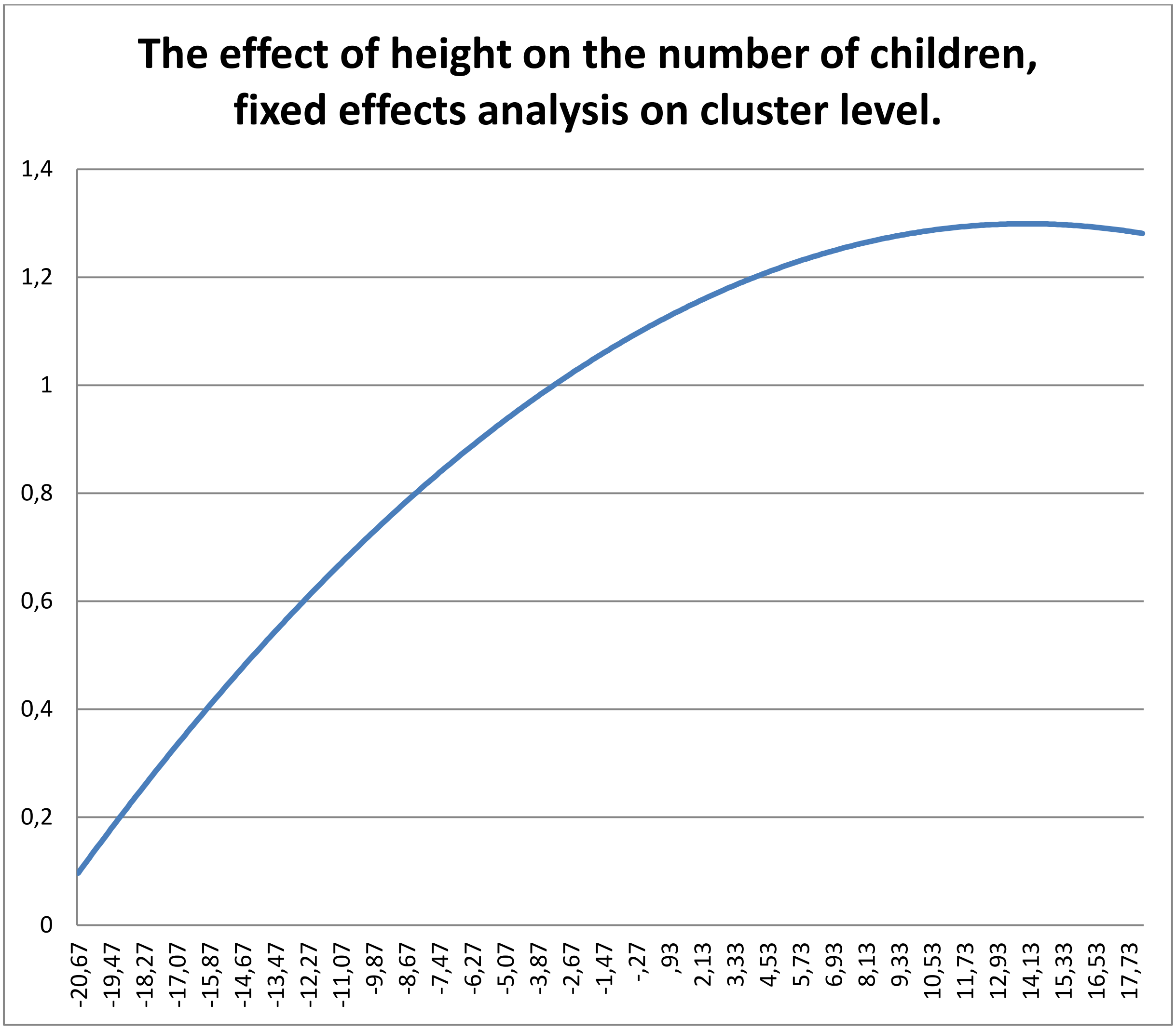
The effect of the number of children on a woman's labor market position is positive and this is not as predicted by theory. Care needs increase with the number of children, which indicates a negative relationship. These women might more often be unemployed or working on the household's own property. Again, it is striking that being married has a negative impact on a household's level of wealth, this is contrary to the predictions of the theory. This effect could be explained by the competitive resource hypothesis (Schrijner, 2014). With more people in a household, the same income needs to feed more mouths. Since all household members are net consumers, marrying and having children makes more people compete for the same resources.

The coefficients of marital status on the poverty indicators are not significantly different from zero. The results considering a woman's labor market position show that this position is mainly influenced by the position of the woman's partner. This provides evidence for both the network theory and the ceiling effect.

What do these results mean for stunted women? Since they are shorter, women who have been stunted as children have fewer children themselves. They live in poorer household with lower scores on the IWI index and often below poverty lines. Moreover, these women regularly work in the agricultural sector. Living in poverty and working in the agricultural sector un-empowers these women, making them more vulnerable for abusive marriage and giving them less power in household decision making. As has been mentioned in the previous part, education also has a stunting components since stunting results in less cognitive abilities. This indirect effect increases the negative influences that the woman experience from childhood stunting in their lives. Since the effects of height on the number of children and the score on the IWI are stronger for shorter women than for taller women, these effects are relatively worse for stunted women.

Table 10: Results of regressions with fixed effects on cluster level
Dependent variable: Number of children

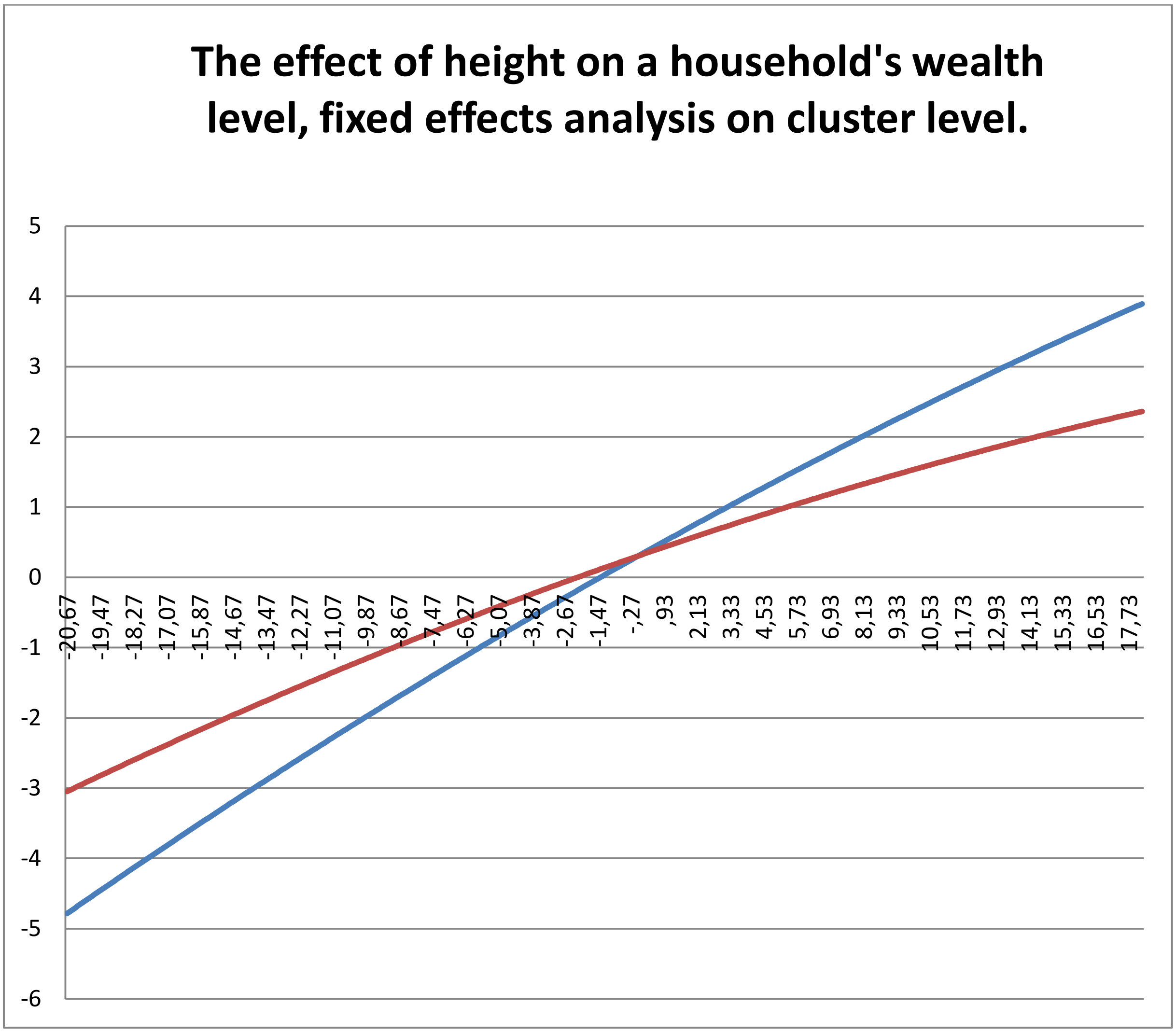
* significant at 10% level ** significant at 5% level *** significant at 1% level	(16) Number of children	(17) Number of children	(18) Number of children
Constant	0.949 (249.120)***	0.976 (206.913)***	0.920 (201.112)***
Height in centimeters	0.019 (31.615)**	0.019 (32.160)***	0.026 (12.109)***
Height squared		-0.00064 (-9.524)***	-0.001 (-9.517)***
Years of education			-0.173 (-131.955)***
International Wealth Index			0.009 (29.120)***
Age at birth of first child			-0.111 (-103.093)***
Interaction height and urban or rural living environment			n.s.
R^2	0.002	0.003	0.074
Adjusted standard errors	2.475	2.475	2.384



Graph 1: The effect of height on the number of children, fixed effects analysis on cluster level. The horizontal axis shows the cluster-demeaned height. The vertical axis shows the cluster demeaned number of children. The results show that height has a positive effect on the number of children on cluster level.

Table 11: Results of regressions with fixed effects on cluster level Dependent variable: International Wealth Index

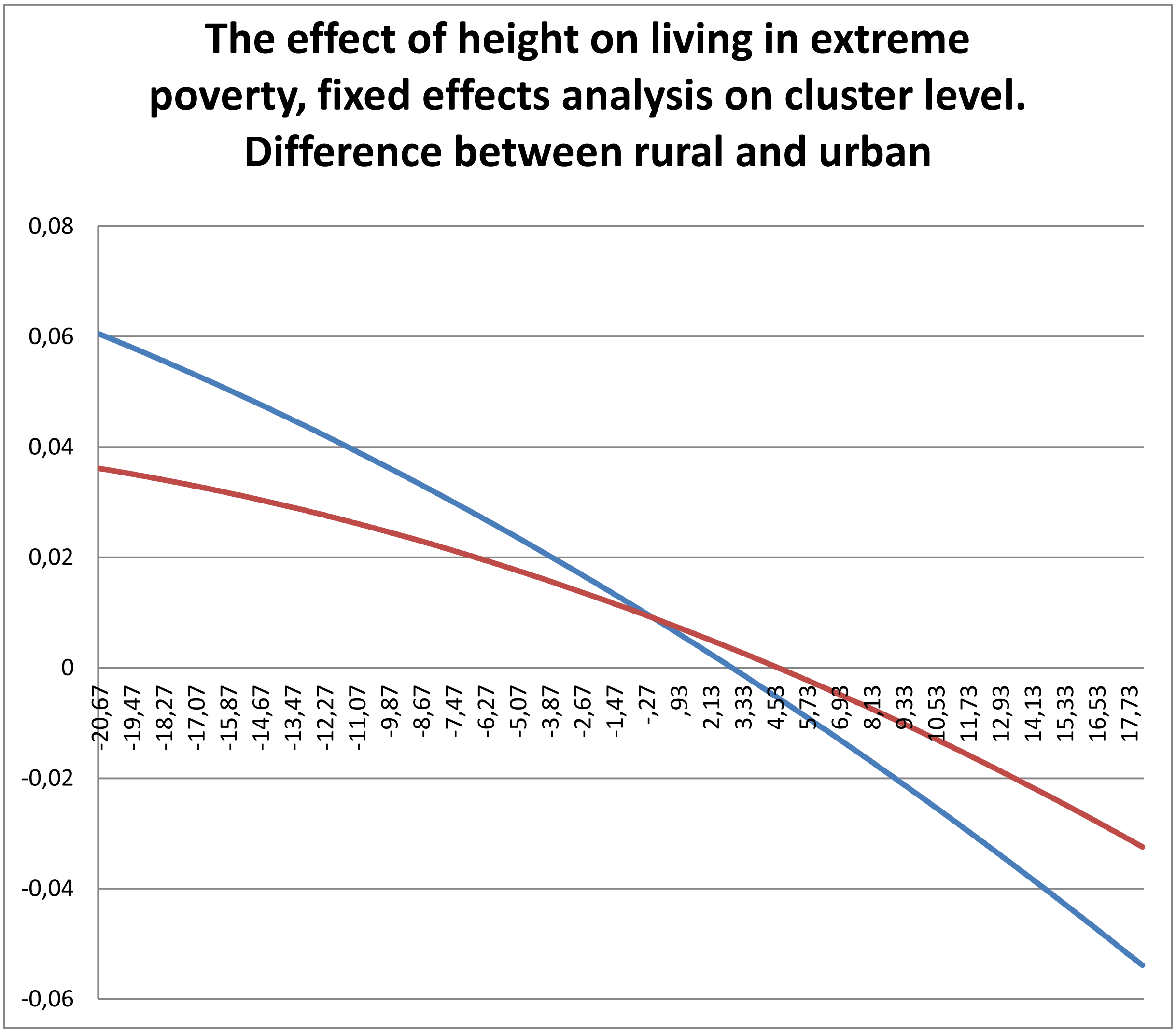
* significant at 10% level ** significant at 5% level *** significant at 1% level	(19) International Wealth index	(20) International Wealth index	(21) International Wealth index
Constant	-0.35 (-2.145)***	-0.012 (-0.574)	0.305 (7.703)****
Height in centimeters	0.93 (36.677)***	0.093 (36.649)***	
Urban			0.220 (18.291)****
Rural			0.136 (14.070)*
Height squared		-0.001 (-1.966)**	-0.001 (-3,587)***
Years of education			0.668 (86.900)***
Labor market position			1.441 (27.450)***
Labor market position partner **0= Agricultural** **1=Non-agricultural**			2.518 (44.276)***
Marital status **0= Not Married** **1=Married**			n.s.
Years of education partner			0.657 (100.113)***
Interaction height and urban or rural living environment			-0.084 (12.335)***
R^2	0.002	0.002	0.113
Adjusted standard errors	12.5074	12.5073	10.905



Graph 2: The effect of height on a household's wealth level, a fixed effects analysis on cluster level. The horizontal axis represents the demeaned height. The vertical axis represents the demeaned wealth level of a household. The red line shows the effect for urban areas and the blue line the effect for rural areas. The results show that height has a positive effect on household wealth on cluster level. The effect of height is stronger in rural areas than in urban areas.

Table 12: Results of regressions with fixed effects on cluster level Dependent variable: Extreme poverty

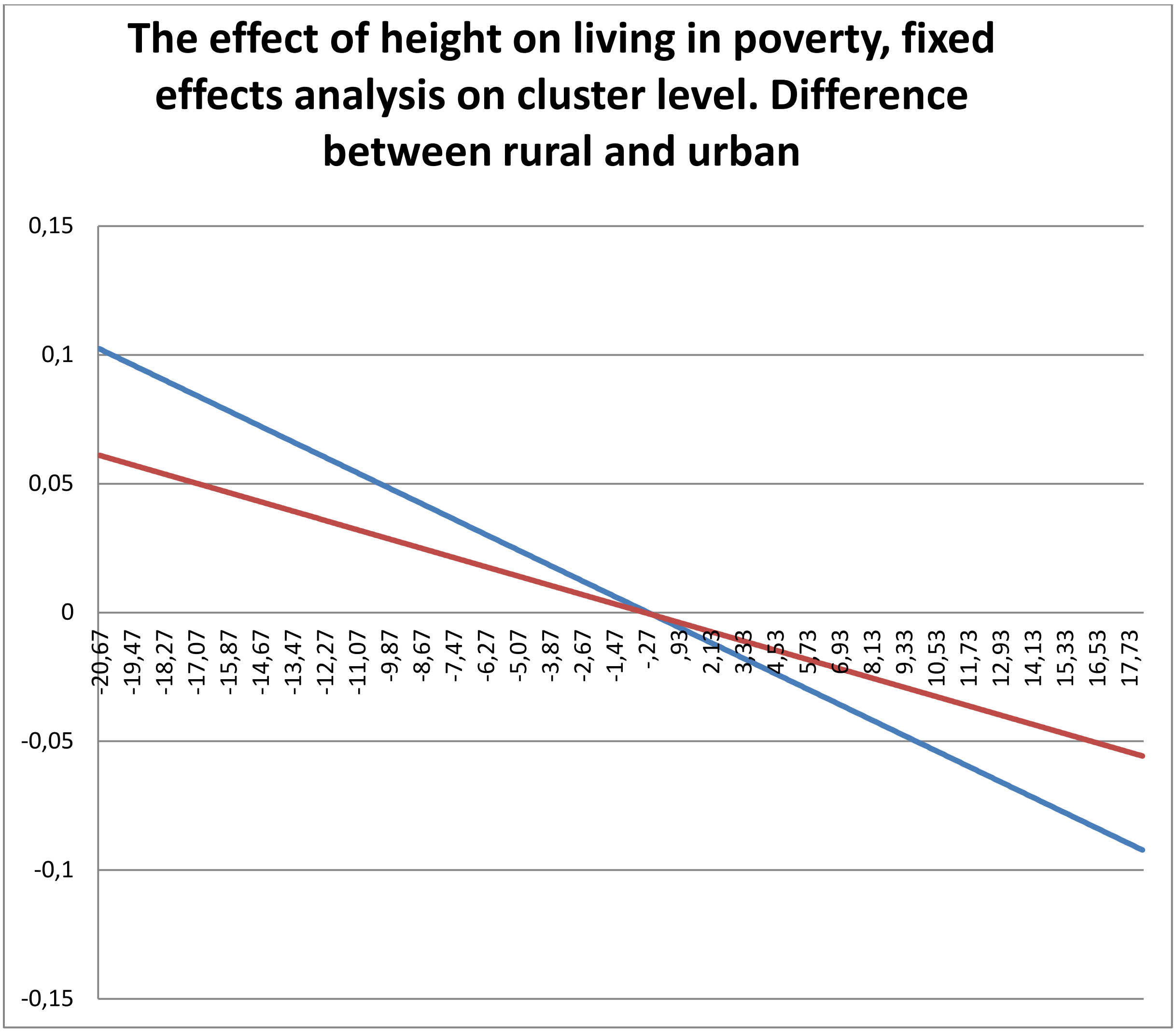
* significant at 10% level ** significant at 5% level *** significant at 1% level	(22) Extreme poverty	(23) Extreme poverty	(24) Extreme poverty
Constant	-0.006 (-14.840)***	-0.006 (-13.257)***	-0.009 (7.504)***
Height in centimeters	-0.002 (-26.037)***	-0.002 (-26.007)***	
Urban			0.003 (-9.760)***-
Rural			0.002 (-8.716)*
Height squared		0.00001457 (2.150)**	0.00002181 (2.749)**
Years of education			-0.008 (-44.403)***
Labor market position			-0.027 (-20.074)***
Labor market position partner **0= Agricultural** **1=Non-agricultural**			-0.053 (-37.128)***
Marital status **Marital status** **0= Not Married** **1=Married**			n.s.
Years of education partner			-0.011 (-68.813)***
Interaction height and urban or rural living environment			0.00117 (5.575)***
R^2	0.001	0.001	0.047
Adjusted standard errors	0.297	0.297	0.276



Graph 3: The effect of height on a living in extreme poverty, a fixed effects analysis on cluster level. The horizontal axis represents the demeaned height. The vertical axis represents the demeaned extreme poverty line. The red line shows the effect for urban areas and the blue line the effect for rural areas. The results show that height has a negative effect on living in extreme poverty on cluster level. The effect of height is stronger in rural areas than in urban areas.

Table 13: Results of regressions with fixed effects on cluster level Dependent variable: Poverty

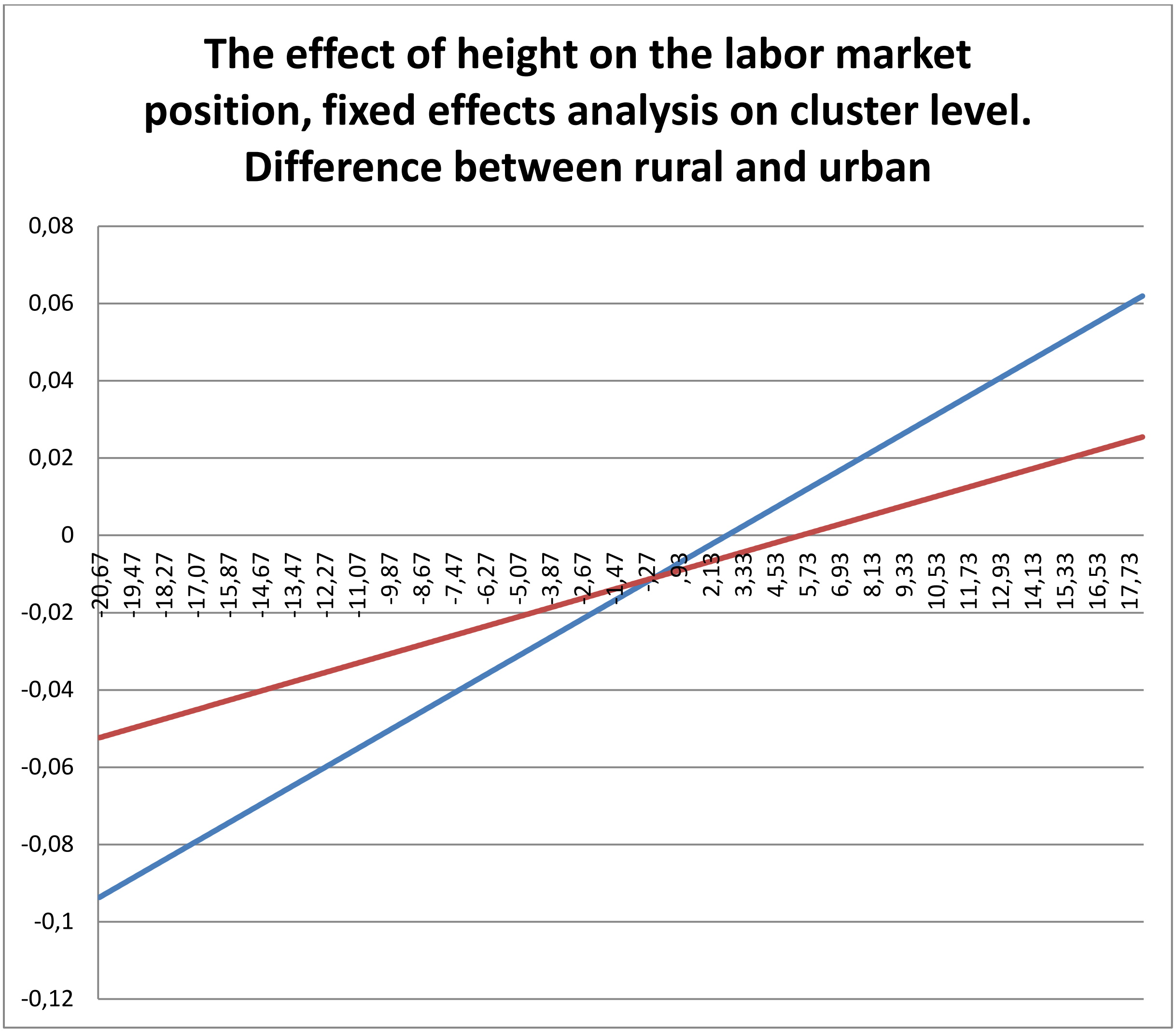
* significant at 10% level ** significant at 5% level *** significant at 1% level	(25) Poverty	(26) Poverty	(27) Poverty
Constant	-0.004 (-12.032)***	-0.004 (-9.452)***	-0.011 (11.303)***
Height in centimeters	-0.001 (-24.530)***	-0.001 (-24.534)***	
Urban			-0.005 (-18.191)*
Rural			-0.003 (-4.307)*
Height squared		n.s.	
Years of education			-0.009 (-59.380)***
Labor market position			-0.020 (-17.853)***
Labor market position partner **0= Agricultural** **1=Non-agricultural**			-0.024 (-19.019)***
Marital status **Marital status** **0= Not Married** **1=Married**			0.004 (1.901)*
Years of education partner			-0.010 (-73.342)***
Interaction height and urban or rural living environment			0.002 (14.250)***
R^2	0.001	0.001	0.053
Adjusted standard errors	0.2695	0.2695	0.2384



Graph 4: The effect of height on a living in poverty, a fixed effects analysis on cluster level. The horizontal axis represents the demeaned height. The vertical axis represents the demeaned poverty line. The red line shows the effect for urban areas and the blue line the effect for rural areas. The results show that height has a negative effect on living in poverty on cluster level. The effect of height is stronger in rural areas than in urban areas.

Table 14: Results of regressions with fixed effects on cluster level Dependent variable: Labor Market Position

* significant at 10% level ** significant at 5% level *** significant at 1% level	(28) Labor market position	(29) Labor market position	(30) Labor market position
Constant	-0.001 (-1.314)	-0.0003 (-0.468)	-0.009 (-5.720)***
Height	0.003 (32.344)***	0.003 (32.323)*	
Height squared		n.s.	
Urban			0.004 (10.771)***
Rural			0.002 (9.564)*
Years of education			0.011 (47.004)***
International Wealth Index			0.002 (24.774)***
Labor market position partner 0= Agricultural 1=Non-agricultural			0.108 (55.470)***
Marital status Marital status 0= Not Married 1=Married			0.028 (8.523)***
Years of education partner			0.001 (5.887)***
Number of children			0.011 (40.498)***
Interaction Height and urban or rural living environment			-0.002 (-7.016)***
R^2	0.002	0.002	0.032
Adjusted standard errors	0.3973	0.3973	0.3744



Graph 5: The effect of height on a women's position on the labor market, a fixed effects analysis on cluster level. The horizontal axis represents the demeaned height. The vertical axis represents the demeaned position on the labor market. The red line shows the effect for urban areas and the blue line the effect for rural areas. The results show that height has a positive effect on the woman's labor market position on cluster level. The effect of height is stronger in rural areas than in urban areas.

6. Conclusion and discussion

This research studies the effects of childhood stunting on different factors in the adult life of Sub-Sahara African women. It adds to the literature by including more countries and years than in any other study. Moreover, this study recognizes spatial clustering by including fixed effects on a village level, an improvement compared to the approach taken by the WHO. The results on cluster level confirm the theory and make clear that women who are shorter, which is probably due to childhood stunting, face serious negative consequences from their short stature. These women do not reach their full potential.

There are four hypotheses tested in this study. The first hypothesis concerns the effect of height on wealth. Part A of this hypothesis predicts that women who have suffered from childhood stunting live in households with lower wealth levels, part B of this hypothesis predicts that women who have suffered from childhood stunting more often live in (extreme) poverty. The second hypothesis in this study predicts that women who are shorter, which is probably due to childhood stunting, more often work in the agricultural sector. The third hypothesis in this study, predicts that women who are shorter, which is probably due to childhood stunting, have fewer children than women who are taller.

This study finds evidence for a positive relationship between height and wealth on a cluster level. A shorter stature is associated with lower wealth levels. Women who are shorter live in households with less wealth and more often live in (extreme) poverty than tall women, who have probably not suffered from childhood stunting. These results confirms both hypothesis 1a and 1b. This study also finds support for the theory about the effect of height on a woman's labor market position. There is evidence that woman who are taller more often work in the non-agricultural sector. Since working in the non-agricultural sector has a positive effect on female empowerment, this is another area in which shorter women feel negative consequences. This result confirms the second hypothesis. With respect to the results on the relationship between height and reproductive health, this study finds evidence on cluster level that height has a positive effect on the number of children a woman has. Shorter women have significantly less children than taller women, due to smaller birth channels leading to stillbirths. This result confirms the third hypothesis.

This research, in addition, includes a study towards the indirect effect of height on the dependent variables trough education. There is ample evidence that childhood stunting has negative effects on cognitive development, leading to fewer years of education and worse school results. Furthermore, education is an important control variable for all four dependent variables. This study finds evidence that education benefits a woman when it comes to gaining a better labor market position and wealth accumulation, indicating an indirect negative effect for stunted women. Moreover, there is evidence that education has a negative effect on the number of children a woman has. Since stunted women receive fewer years of education, there is an indirect effect that has a positive influence on the number of children they have.

This study as well includes an exploratative study towards the different effect of height in rural and urban areas. This is an explorative study since there is no former research to build upon. Regarding this difference the results are mixed. The results show that there is no significant difference of the effect of height between rural and urban women when it comes to their number of children. However, there is a significant difference of the effect of height for women from rural and urban areas, when it comes to the level of household wealth, living in (extreme) poverty and the position on the labor market. The effect of height on these dependent variables is stronger in rural than in urban areas. Rural women have more to gain/lose by an additional/deducted centimeter in height than women from urban areas.

The results also provide evidence for a 'ceiling effect' or 'network effect' between the labor market position of the woman and the position of her partner. The results on the effect of education on wealth and the labor market position do provide evidence for a positive relationship. However, there might be decreasing marginal returns to education. Further research into this discussion is needed.

Poverty and health problems often come together, and form a significant problem for human development. Stunting is a widespread problem, specifically in low-income-countries. The effect of stunting in childhood last in adult life and stunted women experience negative influences from past malnutrition in the areas of reproductive abilities, labor market position and wealth accumulation. These negative influences are not only felt by the women themselves, they influence the household they are part of and the country they live in. Giving all the more reasons to regard stunting as an important obstacle to poverty alleviation and human development.

Some caution is needed towards these results. First, when measuring the labor market position of women, the category 'not working\housewife or unpaid/paid farm worker' is used. In this ordinal interval variable, this category is regarded as the lowest rank. It is assumed that woman is 'more successful' when she is in one of the higher categories. However, there are examples of communities that consider a wife that is active on the labor market as worse, than a woman being a housewife. This has to do with different social norms (Verick, 2014, p1). In this situation, a man earns enough for his wife to stay at home. This is a symbol of stature. Even though these women might be well educated and enough skilled to find a job in the labor market, they stay at home because this gives the family (and the husband) more stature. These practices do not coincide with the model developed in this research. Moreover, there underreporting is widespread, so the data does not perfectly reflect women's work (Verick, 2014, p1).

Second, the theory about the effect of height on the level of income indicates that it is easier to measure this relationship for men than for women since there are more reporting difficulties when measuring the income of women. It might be argued that this gives a reason to include men in the regression regarding this effect, men are, obviously, also vulnerable for stunting. Unfortunately, there is a lack of data on the height of men.

Third, this research does not provide strictly causal evidence because this is not a controlled experiment. However, due to the time lag between the measurement of the factors of interest in the adult life, and the influence on the level of these factors of interest in childhood, there is no space for reverse causality. Because of the time-horizon, this is simply not possible. It would have been of great added value if multiple height measurements for each person were available, however, there is no database which contains this information on such a scale. Overall, the results have identified important relationships and there are strong indications that stunting and height play an important role in determining different factors in adult life. More research with better data is of extreme importance given the large number of children still affected by childhood stunting.

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8. APPENDIX A: COUNTRIES AND YEARS

	Country/Years			
1.	**Benin**	2006	2011	
2.	**Burkina Faso**	2003	2010	
3.	**Burundi**	2010		
4.	**Cameroon**	2004	2011	
5.	**Chad**	2004		
6.	**Comoros**	2012		
7.	**CongoBrazzaville**	2005	2011	
8.	**CongoDR**	2007	2013	
9.	**Cote d'Ivoire**	2005	2011	
10.	**Eritrea**	2002		
11.	**Ethiopia**	2000	2005	2011
12.	**Gabon**	2000	2012	2013
13.	**Gambia**	2013		
14.	**Ghana**	2003	2008	2014
15.	**Guinea**	2005	2012	
16.	**Kenya**	2003	2008	2014
17.	**Lesotho**	2004	2010	
18.	**Madagascar**	2004	2009	
19.	**Malawi**	2000	2004	2010
20.	**Mali**	2001	2006	2013
21.	**Mauritania**	2001		
22.	**Mozambique**	2003	2011	
23.	**Namibia**	2000	2006	2013
24.	**Niger**	2006	2012	
25.	**Nigeria**	2003	2008	2013
26.	**Rwanda**	2000	2005	2010
27.	**SaoTome**	2009		
28.	**Senegal**	2005	2011	2012
29.	**Sierra Leone**	2008	2013	
30.	**Swaziland**	2006		
31.	**Tanzania**	2004	2010	
32.	**Togo**	2014		
33.	**Uganda**	2001	2006	2011
34.	**Zambia**	2002	2007	2014
35.	**Zimbabwe**	2006	2011	

9. Appendix B: the International Wealth Index Composition

Source: Global database website. How to compute IWI - Global Data Lab. (n.d.). Retrieved August 13, 2016, from http://globaldatalab.org/iwi/using/

Consumer Durable	**Weight**
Television	8.612657
Refrigerator	8.429076
Phone	7.127699
Car	4.651382
Bike	1.84686
Cheap Utensils	4.118394
Housing Characteristics	
Floor Material	
Low Quality	-7.558471
Medium Quality	1.227531
High Quality	6.107428
Toilet Facility	
Low Quality	-7.439841
Medium Quality	-1.090393
High Quality	8.140637
Number of Rooms	
Zero or One	-3.699681
Two	0.38405
Three or More	3.445009
Public Utilities	
Acces to Electricity	8.056664
Water Source	
Low Quality	-6.306477
Medium Quality	-2.302023
High quality	7.952443
Constant	25.00447

Water supply:

- high quality is bottled water or water piped into dwelling or premises;
- middle quality is public tap or protected well;
- low quality is unprotected well, spring or surface water.

Toilet facility:

- high quality is flush toilet;
- middle quality is public toilet, improved pit latrine etc.;
- low quality is traditional pit latrine or no toilet facility.

Floor quality:

- high quality is finished floor with parquet, carpet, tiles, linoleum, ceramic etc.;

- middle quality is cement, concrete, wood, etc.;
- low quality is none, earth, dung etc.

For the seven consumer durables and for the access to electricity category, dummies must be created indicating whether or not the household owns the specific durable. The total number of indicators needed to compute the IWI is 20. To rank a household on the IWI scale, the following formula is used:

$$IWI = constant + \sum (W_n X_n)$$

Where X are the variable indicators and W their IWI weights. If one or more indicators is missing, the formula can be adapted by using a separate formula for each missing variable.