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PLANT PESTS AND CHILD HEALTH: EVIDENCE FROM LOCUST INFESTATIONS IN WEST AFRICA

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Plant pests and child health: evidence from locust infestations in West Africa

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Plant pests and child health: evidence from locust infestations in West Africa

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Abstract

This thesis estimates the impact of exposure to desert locust infestations on the anthropometric status of children. Using household survey data from four West African countries combined with 30 years of locust infestation data, I exploit the variation in locust infestation exposure among children under age five, controlling for locality and mother fixed e ects. I find that increases in the yearly exposure to locust infestations decreases a child's height-for-age z-score, with the deterioration in health status being more acute among children in rural households.

Keywords: Income shocks, Child health, West Africa, Nutrition, Plant pests

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1 Introduction

High levels of income risk due to climate shocks, economic instability, illness and civil conflict is part of life for many households in developing economies. In this setting, where households have low access to formal insurance and credit markets and thus limited ability to smooth consumption, income fluctuations can lead to severe welfare e ects as households may be forced to adjust by disinvesting in health and human capital (Jensen, 2000; Alderman et al., 2006). Due to the link between early life health status and cognitive ability (Mendez and Adair, 1999; Case et al., 2005), future health (Barker, 1995; Barker et al., 1993), academic achievement (Glewwe et al., 2001) and labor market outcomes (Case and Paxson, 2008), experiencing adverse shocks in utero or during early childhood can have far-reaching consequences, both for individual welfare and economic development. Evidence from developing countries relates to this literature by showing how various types of income shocks such as rainfall and drought (Maccini and Yang, 2008; Hoddinott and Kinsey, 2001), government transfers (Duflo, 2003) and natural disasters (Hsiang and Jina, 2014) experienced during childhood have considerable impact on a child's health as well as outcomes later in life.

In this thesis, I add to the earlier evidence on temporal, adverse shocks and child health by studying the impact of desert locust infestations, a plant pest that a ects around 65 countries in Africa, South Asia and the Middle East, on the anthropometric status of children under the age of five. Desert locust infestations are characterized by large and highly mobile swarms of flying desert locusts as well as groups of marching insects, referred to as bands. During an infestation, large swarms and bands roam over vast territories and destroy crops and pasture land along their way; a single square kilometer of a swarm can consume over 120 tonnes of vegetation daily (Lecoq, 2003) - translated into reductions in food supply, this amount is enough to feed around 67.000 adults during one day[1]. Calculations like these, mostly based on entomological studies of the desert locusts as a species, have resulted in a commonly held belief that desert locust infestations pose a substantial threat to the livelihood of rural households in the a ected countries. However, reliable data on the impact of locust infestations on aggregate agricul-

[1]Based on an adult consuming 1.8 kg of food per day.

tural output as well as estimates of their e ect on household level outcomes is scarce. The available estimates on crop destruction suggest that the impact on aggregate food production is small (IMF, 2005), whereas interview studies with farmers indicate that on an individual level, being hit by a locust infestation could imply considerable income losses (Thomson and Henrietta, 2002).

The main contribution of this thesis is to provide a quantitative estimate of the household level impacts of locust infestations. I do this by exploiting the fact that the exact location and timing of locust infestations can be understood as random. The trajectory of groups of desert locusts is highly unpredictable - the locusts' movement is determined by a complex combination of weather conditions as well as the accumulation of small random alignment errors between individual locusts within the group (Yates et al., 2009). This unpredictability, combined with the large destructive capacity of groups of locusts, indicates that locust infestations can be understood as exogenous shocks to agricultural income, making them suitable for casual inference.

I match 30 years of georeferenced data on locust infestations from the Food and Agricultural Organization's (FAO) Desert Locust Information Service (DLIS) to the location of survey clusters in 13 Demographic and Health Surveys (DHS) from four West African countries; Burkina Faso, Niger, Mali and Senegal. Using the variation in experienced infestations among children within the same survey cluster as well as between siblings, I find that locust infestations experienced in utero and during childhood have a negative impact on the height-for-age among children under the age of five. A one standard deviation increase in the per-year exposure to locust infestations within 5 kilometers from the survey cluster, as measured by the number of locust infestations per square kilometer, decreases a child's height-for-age z-score with 0.084 units. These results are consistent when controlling for mother fixed e ects and robust when adding various control variables. Moreover, I find that the e ect on children in rural households, who is expected to be more dependent on agriculture for their livelihood, is economically large and statistically significant whereas the e ect on urban children is negligible. An additional finding is that the impact of locust infestations is clearly visible in alternative measures of anthropometric status, and that the e ect is especially pronounced in the weight-for-age of children.

To the best of my knowledge, this is the first study to estimate the impact of a plant pest with high relevance to agricultural production in developing countries on child health outcomes. Prior to this thesis, the e ect of plant pests on child health has only been explored in a historical context; Banerjee et al. (2010) show that a large-scale outbreak of phylloxera[2] in 19th century France had a negative impact on adult health outcomes and on the life expectancy of children. Despite locust infestations being a reoccurring issue for a large number of countries, only one previous study evaluates the welfare e ect of this particular plant pest. A study by De Vreyer et al. (2014) show that the 1987-1989 locust plague led to 2.9 percentage point decrease in school enrolment among boys in cohorts aged 0-4 during the years of the locust plague in a ected rural villages in Mali. Moreover, school attainment for girls in the same village cohorts decreased by 0.859 years compared to control cohorts. A pathway that could help explain these results runs from early life malnutrition to impaired cognitive ability, leading returns to human capital investment to decrease. The present thesis thus provides empirical supports for the findings in De Vreyer et al. (2014) by suggesting that the e ect on school enrolment and attainment is preceded by a negative impact on height-for-age.

Besides evaluating the average e ect of locust infestation exposure on anthropometric status, this thesis also links to the growing literature on gender di erentials in outcomes following adverse events experienced during early life. Prior evidence has indicated that households may respond to negative income shocks in a way that disfavour children based on their gender (Hsiang and Jina, 2014; Rose, 1999; Maccini and Yang, 2008; Duflo, 2005). However, most studies in this field explore gender di erentials in South Asia, and an important contribution of this thesis is thus to evaluate whether these results can be translated into a West-African context. By studying the e ect of locust infestations by gender, I find that it is only the nutritional status of girls that is a ected by the income shock, whereas the average estimated e ect on boys is smaller and not significant. However, these results remain inconclusive as the estimated di erence between boys and girls is not significantly di erent from zero.

[2] A plant pest that destroys the roots of vines.

This thesis also provides a deeper understanding of the human and economic costs of locust infestations as such, which is highly relevant from policy perspective; the costs for desert locust control programs (i.e. continually monitoring locust breeding and invasion areas and spraying infested areas with pesticides) are large[3](Lecoq, 2003; Brader et al., 2006) and their cost efficiency has been questioned (Jo e, 1995; Herok et al., 1995). Moreover, some experts have expressed a concern that climate change will make locust upsurges harder to forecast and potentially more frequent (Ge, 2009; FAO, 2015), although there is not yet enough evidence to draw any conclusions in this matter.

The remainder of this thesis is structured as follows. Section 2 provides a background on desert locust infestations and discusses earlier evidence related to the impact of income shocks on child health and gender di erentials in outcomes. Section 3 discusses the identification strategy and specifications. Section 4 describes the data, section 5 presents results and section 6 concludes.

2 Background

2.1 Desert Locust infestations

Schistocerca gregaria, or the desert locust, is a plant pest that has been threatening agricultural production in African, Middle Eastern, and Southwestern Asian countries since ancient times. The desert locust is known for its ability to change its behaviour from solitary to gregarious in response to locust population density. During recession periods, small populations of solitary locust dwell in remote, non-cultivated areas of the Sahel Desert, laying their eggs in the desert soil. Following a period of above-average rainfall, the soil becomes moist enough for mass hatching and breeding to occur. As the number of solitarious locusts increases in a given area, gregarization takes place; the locusts transition from disordered movement to highly aligned behaviour and motion within the group. The gregarious locusts appear first in bands of marching, wingless hoppers. If there is enough vegetation to support the population during this phase, the hoppers fledge and become adult

[3]During the 2003–2005 desert locust plague, the costs for control operations amounted to 400 million USD.

desert locusts. If this process, referred to as a locust upsurge, is not stopped either by control measures or a break in favourable breeding conditions, it can develop into a locust plague. Locust plagues are defined as two or more regions being infested simultaneously, with widespread infestation of locust swarms and bands. For locust plagues to occur, several months of favourable breeding conditions are required, with gregarious behavior consolidating over generations. As vegetation becomes scarce in recession areas, the locusts move into the invasion areas where they can cause substantial harm to pasture lands and crops. (Symmons and Cressman, 2001; Uvarov et al., 1977)

In general, swarms travel with the wind at a speed of 16-19 km/h. The distances travelled in a day vary between 5 to more than 200 km. A single swarm of adult locust can spread over 1,200 square kilometers and contain 40-80 million individuals per square kilometer. An adult desert locust can consume around 2 grams of plants per day (Symmons and Cressman, 2001). A locust swarm of one square kilometers containing 60 million individual insects thus has the capacity to consume 120 tonnes of vegetation per day. The desert locust consumes all types of vegetation, with no apparent preference as regards cultivated crops. (Lecoq, 2003).

While the general seasonal migratory patterns of locust swarms are well known, the exact trajectory is generally determined by factors that are difficult to predict such as the strength and direction of winds (which carry the locusts from one feeding area to the next) and other weather conditions (Symmons and Cressman, 2001; Ro ey and Magor, 2003). Moreover, gregarious locusts may also change direction in a sudden and seemingly arbitrary way. Mathematical modelling of desert locust behaviour shows that these sudden changes in direction of groups of desert locust occur after an accumulation of small, random alignment errors between neighboring individual locusts within the swarm or the band (Buhl et al., 2006; Yates et al., 2009). This implies that it is virtually impossible to precisely predict where and when a locust swarm or band will choose to land and feed. Presumably, this should indicate that it is not the case that certain locations are always a ected by locusts during infestations years, confounding locust occurrence with other characteristics of those localities. This is confirmed by studying the distribution of locust observations over time (see figure 2), where it is clear that the exposure to locust infestation varies spatially and over time. To predict upsurges and movements of the desert locusts, the Desert Locust Information Service (DLIS) of FAO produces monthly locust forecasts which are based on temperature and rainfall forecasts as well as the Normalized Di erence Vegetation Index. However, due to the lack of periodicity that the species exhibit, the uncertainty of weather forecast as well as a number of other factors[4], predictions are far from perfect. For the purpose of this thesis, it is important to note that forecasts do not include predictions on the exact trajectories of swarms or bands. Rather, they are an overall assessment of the risk for upsurges and the general, seasonal movements of groups of locusts.

There is little evidence on the social and economic consequences of desert locust infestations, partly because of the lack of reliable data. FAO does not collect data on crop destruction caused by locust infestations as it is impossible to separate damage caused by locusts from other types of pests, and available studies focus mainly on the aggregate outcomes. These studies suggest that the macroeconomic impact of locust infestation may be mitigated by the fact that large locust swarms are more likely to appear during years of above-average rainfall levels: during the locust plague in 2004, cereal production in the Sahel region was 11.4 million tons, which is below the production in 2003 of 14 million tons, but within the five-year average (IMF, 2005). Nevertheless, the destruction of crops and pasture land can be complete at the local level (Lecoq, 2003), leading the food security for already vulnerable households who depend on high risk climate agriculture to deteriorate even further (Barrett, 2010; Baro and Deubel, 2006). An interview study with farmers in a ected localities in Mauritania and Eritrea suggests that locust swarms are perceived as large negative shocks to income, described by farmers with terms similar to those used for droughts (Thomson and Henrietta, 2002). Taken together, this indicates that the damage of infestations are local in their nature, and may work as negative shocks to income on the household level.

Locust plagues are prevented by close monitoring of recessions areas and breeding conditions and, in the case of upsurges, controlled by the use of pesticides.

[4]for more information on forecasts, see: http://www.fao.org/ag/locusts/

When control measures are efficient, upsurges can be stopped before developing into a regional plague. Even if control technology has improved over the years, the locust control infrastructure has had the tendency to deteriorate quickly in many countries during recession years, enabling large upsurges to reoccur (US Congress, 1990).

2.2 Household responses to income shocks

There are several thinkable ways through which locust infestations could a ect child health outcomes via income losses. First of all, locust infestations can directly a ect the household's access to food by reducing crop yield that the household would otherwise have sold or consumed. In addition, the value of livestock that households keep for their milk and meat, as input in agricultural production or as a bu er stock against income shocks can decrease if pasture land is infested. As mentioned above, locust infestations do not seem to have a large impact on aggregate output and consequently, the e ect on national prices should also be small. However, if markets are highly local a decrease in supply could also a ect households who do not primarily depend on agricultural income via local price increases. Moreover, if households decrease agricultural inputs as a response to an increased risk for locust infestations, this may lead to lower overall output.

If households have limited ability to smooth income, income shocks can lead to detrimental outcomes, as households may instead be forced to adjust by decreasing investments in human capital (Jensen, 2000), expenditures on high nutrient food (Jensen and Miller, 2007; Hsiang and Jina, 2014) or by liquidating assets or exhausting savings for the future (Kazianga and Udry, 2006; Fafchamps et al., 1998). Strategies to mitigate these outcomes include formal insurance and informal risk sharing networks (Townsend, 1994; Fafchamps and Lund, 2003), entering the credit market (Udry, 1990; Eswaran and Kotwal, 1989), accumulating precautionary savings (Loayza et al., 2000), as well as ex-post adjustments in labor supply (Kochar, 1999). During common shocks, it is considerably harder to employ these strategies since risks cannot be shared across households that are a ected simultaneously (Fafchamps and Lund, 2003). Most of the of the studies in this field indicate that the strategies available to the poor rarely allow for perfect consumption smoothing, with disinvestments in child health[5] as a potential consequence.

Another way for households to adjust to shocks is by altering the way resources are distributed among family members. Evidence shows that the welfare of girls is disproportionately sacrificed in times of scarcity; in the Philippines, the average increase in infant mortality following a typhoon can be completely attributed to an increased risk among female infants (Hsiang and Jina, 2014). In India, there is a considerable increase in the excessive mortality rate of girls relative to boys during droughts (Rose, 1999) and following a crop loss, families with many girls are more likely to reduce educational expenditures relative to families with many boys (Cameron and Worswick, 2001).

A mechanism consistent with these findings is that parents give more weight to boys when making intra-family allocation decisions due to a perceived di erence in returns to investment. This may result in resources being held back from girls when the family cannot a ord to care for all its members, leading to gender di erentials in outcomes. As regards health outcomes, gender di erences may also arise due to inherent di erences in biological resilience. Prenatal and neonatal mortality is higher among boys, reflecting a male disadvantage in disease susceptibility in utero and during infancy (Naeye et al., 1971; Sanders and Stoecker, 2011). This means that all else equal, girls are more resilient to health shocks than boys.

It is important to note that the evidence on gender bias cited above may not be valid for other developing economies. Gender preferences can di er across cultures, both in terms of their intensity and manifestations. Specifically, cultural di erences between Africa and South Asia have been suggested as an explanation for the India-Africa di erence in child health birth order gradients (Jayachandran and Pande, 2015) as well as the marital age for girls during droughts (Corno et al., 2016), and an important contribution of this thesis is to study whether a gender di erential in child health outcomes following an adverse income shock are also present in West Africa.

[5]Note that due to the link between health in early life an human capital accumulation, investments in health and human capital are not always distinguishable.

3 Empirical Strategy

3.1 Definition of treatment

To create a variable measuring a child's exposure to locust infestations, I match the DHS survey cluster location to the coordinates of locust infestations, using infestations occurring within a five kilometer radius from the DHS survey cluster centroid. There are multiple reasons for using a five kilometers radius as the basis for constructing the treatment variable. First of all, observations of locusts occurring closer to the DHS survey cluster can be expected to have a larger impact compared to observations further away, as households should depend more on agricultural and pastoral land in the immediate surroundings of their locality. Moreover, as DHS survey clusters are displaced up to five kilometers to protect the anonymity of the respondents, using a five kilometer radius guarantees some overlap between the area used for defining the treatment and the real area surrounding the survey cluster. At the same time, a relatively small radius will limit the noise that is picked when the distance is expanded as any potential effect will become more difficult to measure when using a larger area. Nevertheless, limiting the area to a small radius could introduce an upward bias if infestations further away are in fact determinants of height-for-age, due to the spatial correlation of locust infestations. In the Appendix, I show that choosing a distance of 10 or 15 kilometers does not change my main results considerably. To enable a comparison between estimates while using different areas as the basis for the construction of the treatment variable, the number of locust infestations observed within each distance is divided by the area of a circle with the corresponding radius. This results in the treatment being measured as the density of locust infestations per square kilometer. Infestations within 5 kilometers from the survey cluster centroid are defined as experienced by a child in that cluster based on their date of birth, including time in utero. As I only utilize the within DHS survey cluster variation in locust exposure, older children within a given cluster will have experienced at least as many locust events as their younger counterparts. In order to compare the exposure of children of different ages, and to obtain a measure of locust exposure which is more readily interpreted, I compute the z-scored locust density per year in life.

3.2 Fixed effects models

The identification exploits the variation in locust infestations across children of different ages within the same survey cluster, with the main assumption being that the number and timing of locust infestations within a survey cluster is exogenous. To identify the treatment effect, it is crucial that only variation in locust infestation that is randomly assigned to children is utilized. Even if the exact location of infestations is random, locust infestations are more likely to occur in the invasion region bordering the Sahel desert than further south in the tropical Savannah, resulting in some clusters having higher average locust infestation exposure than others (see figure 2.). This implies that using the cross-cluster variation locust infestation exposure would result in treatment being correlated with cross-sectional differences, as it is likely that unobservable characteristics of clusters vary systematically along the same (north-south) geographical dimension. As a consequence, I only utilize within-cluster and within-family variation in locust exposure. To do this, I specify two fixed-effects models. The key identifying assumption in fixed-effects models is that unobservable factors are fixed within the group so that within a DHS survey cluster, the error term is not simultaneously i) correlated with the measure for exposure to locust infestations and ii) containing determinants of height-for-age. Per-year locust infestation exposure should be randomly assigned to individuals within the same DHS survey cluster, meaning that innate characteristics of children are not determinants of locust exposure. If this assumption holds, the error term will be uncorrelated with the independent variable. I test the robustness of this assumption by regressing predetermined variables on locust infestation exposure.

The DHS survey-cluster fixed effect will control for time-invariant observable and unobservable characteristics within a cluster. However, selective migration remains a concern. If there is selective outward migration in response to experienced locust infestations by households whose children have higher height-for-age z-scores, any estimated effect will be confounded by the the change in group composition. To reduce the concern of migration being the underlying reason for any observed effect, I proceed by comparing children born to the same mother by estimating a mother-fixed effects model, using only within-family variation in the per-year locust exposure. This has the advantage of tightly controlling for characteristics shared by siblings born to the same mother. However, the mother fixed effects model imposes a sample restriction. Hence, the two models are used to complement each other; one providing a larger, non-restricted sample and one confirming that the results are not generated by migration. This means that it is crucial for the estimates to exhibit consistency across the two models, which I will highlight further when discussing the results.

3.3 Controls

There is a well-established non-linear relationship between age and the outcome variable; because height-for-age is a stock variable reflecting the accumulated health investments during a child's life, older children have lower height-for-age compared to younger children (Martorell and Habicht, 1986). To control for this, I include a full set of age-in-years dummies in all specifications.

Locust upsurges in breeding areas, as well as the development of an upsurge into a locust plague, is highly correlated with above-average levels of precipitation. This does not automatically imply that infested survey clusters have experienced high levels of rainfall but to the extent that regional rainfall is correlated with rainfall at a specific location in that region, children who have experienced more years of above-average precipitation are also more likely to have experienced higher exposure to locust infestations. To disentangle the effect of above-average rainfall on height-for-age from the impact of locust infestations, I control for deviations in rainfall during a child's life. I do this by expressing the rainfall level for each month in a child's life in terms of standard deviations from the pixel mean for the corresponding month and then computing the average of these monthly standard deviations.

3.4 Specifications

To estimate the e ect of locust infestations on height-for-age z-score, I regress height-for-age on the yearly number of locust infestations per square kilometer within 5 kilometers from the cluster center, controlling for cluster fixed e ects in equation (1) and mother fixed e ects in equation (2).

$$HFA_{i,c,j,s,t} = \beta LocustInfestations_{ic} + \alpha_c + \theta_j + \gamma_{st} + \psi R_{ic} + \epsilon_i \quad (1)$$

$$HFA_{i,m,j,s,t} = \beta LocustInfestations_{im} + \alpha_m + \theta_j + \gamma_{st} + \psi R_{im} + \epsilon_i \quad (2)$$

$$LocustInfestations_{i,c} = \frac{\sum_{n=1}^{N} \frac{LocustObservation_{n,i,c,(\tau-t)}}{\pi \times (5km)^2}}{age_{it}} \quad (3)$$

$$LocustObservation_{i,c,(\tau-t)} = \begin{cases} 1, & \text{if} -9 \leq \tau - t \leq age_{it} \\ 0, & \text{otherwise.} \end{cases} \quad (4)$$

$HFA_{i,c,j,s,t}$ is the height-for-age of child i of age s years surveyed in cluster c in survey j at time t. $LocustInfestations_{i,c}$ is the per-year measure of locust infestations within 5 kilometers of cluster c experienced by child i, in utero or during her lifetime. α_c is the cluster fixed-e ect. θ_j represents a set of survey-year dummies and γ_{st} represents a set of age dummies. R_{im} measures the average monthly deviation deviation from mean monthly rainfall in the DHS cluster pixel, experienced by child i. In equation (2), cluster fixed e ects is exchanged for mother fixed e ects.

$LocustInfestations$ is computed by equation (3)-(4), where $LocustObservation_{i,c,(\tau-t)}$ is an observation of gregarious locust within 5 kilometers from the centroid of cluster c, occurring when the child was $\tau - t$ months old, where τ is the date when the gregarious locust was observed and t is the survey date of the child. A locust observation is a binary variable taking the value 1 if the infestation was experienced by the child, i.e. if the child's age at the time of the infestation was between -9 to age_{it}, which is the age in months of child i at the survey date t. Note that the number of locust observations per square kilometers is divided by the child's age in years, where age is defined as being in the n:th year of life in order to avoid generating missing values for children who are zero years old.

3.5 Remaining concerns

When DLIS records a locust infestation event, this is sometimes followed by treatment of the observed area by the use of chemical pesticides, which can have detrimental impacts on human health (Jepson et al., 2014). Due to the lack of consistent data on control operations, a major drawback of my identification strategy is that it cannot disentangle this impact from the e ect that locust infestations have on child health via losses in household income.

Another concern related to migration is that none of the specifications control for the time that households have lived in a DHS survey cluster. If households moved to the cluster shortly before being surveyed by DHS, I might define children who, in reality, have been exposed to infestations as non-exposed and vice versa. In Appendix 1, I show that the results are consistent when only including household who have lived in the same DHS survey cluster for more than 5 years. However, data on this variable is missing for 21 percent of the sample, making it difficult to draw any decisive conclusions on this matter.

Finally, it is important to note that any e ect of locust infestation should interpreted as estimated after the use of any ex-ante risk management strategies. If infestations are anticipated based on forecasts or reports of infestations in neighbouring areas, households may diversify labour or invest in structures to protect their crops. In addition, household may reduce agricultural inputs so as to minimize their loss in the event of an infestation. This implies that children in areas that are not actually hit can experience adverse outcomes from the mere risk of being infested. Moreover, the desert locust is edible and indeed consumed as food in a number of countries, which means that crop losses may be partly compensated by the consumption of locusts.

4 Data Desctiption

4.1 Demographic & Health Survey Data

The Demographic Health Survey (DHS) is a standardized survey of households in developing countries. DHS surveys women aged 15-49 years, and collect data on their children who are five years or younger. I pool all georeferenced DHS surveys containing data on height and weight for children under the age of five, in four West African countries that have experienced locust infestations during the time period 1985-2015. This results in 13 surveys from four countries; Senegal, Burkina Faso, Mali, and Niger[6].

In standard DHS surveys, anthropometric data is recorded for a representative subset of the total sample, and anthropometric data is available for 78 169[7] children in the pooled sample used in this thesis. To make height comparable across children of di erent genders and ages, I compute height-for-age z-scores by implementing a tool[8] developed by the World Health Organization (WHO). WHO:s normalized height-for-age variable is based on gender and age-specific growth standards for children under age five, with a reference distribution based on a population of children from six countries across five continents[9], who have received recommended nutrition and health inputs. A height-for-age z-score of zero implies having the median height for one's gender and age in months, whereas stunting is defined as being two or more standard deviations below this median (WHO Multicentre Growth Reference Study Group, 2006).

According to WHO:s guidelines, height-for-age z-scores above 6 or below -6 are likely to be caused by errors in the underlying height or age data. The sample is reduced to 76 361 when I exclude these observations[10]. The WHO tool uses a child's height, age in months and gender to compute the height-for-age z-scores (World Health Organization, 2007). I define the age in months by using the time elapsed between a child's birth date and the date that the child was measured.

[6]For a detailed list of the surveys included, see Table 10 in the Appendix.

[7]Out of 188 310 observations.

[8]http://www.who.int/childgrowth/software/en/

[9]Brazil, Ghana, India, Norway, Oman and the United States.

[10]Including these observations leads to more significant results.

The children in the sample were surveyed during 1992-2011, and live in 4242 survey clusters. In Figure 1, I show the distribution survey clusters across the countries included in this thesis. Sample characteristics are displayed in Table 1. After excluding outliers in terms of height-for-age, the average height-for-age z-score in the sample is -1.44, with a standard deviation of 1.8. The mean age in years is 2.24. 51 percent of the children in the sample are boys. On average, children in the sample have experienced 0.02 locust infestations during their life. 73 percent of children live in rural areas and for rural children, the average height-for-age z-score is -1.59, which is below the mean of -1.01 in urban areas.

DHS data is geocoded on the cluster level, which consists of one or more geographically close villages in rural areas, or by neighborhoods in urban areas. Treatment (i.e. exposure to locust infestations) is computed based on the location of these DHS clusters in relative to the location where gregarious locusts have been observed. It is important to note that the location of DHS clusters are randomly displaced to protect the confidentiality of respondents. Displacement is performed by randomly changing the coordinates of the DHS cluster, displacing it within a 5 km (in rural areas) or 2 km (in urban areas) radius circle from its real location (Perez-Heydrich et al., 2013).

4.2 Desert Locust Data

FAO:s Desert Locust Information Service (DLIS) is tasked with continually surveying recession and invasion areas and record, complete with coordinates, all observations of desert locusts. I received the complete data set via email correspondence with Keith Cressman, who is Senior Locust Forecasting Officer at FAO[11]. A monthly summary of newly collected locust data is found in the DLIS monthly bulletins[12]. It is important to note that the desert locust data is not an exhaustive record of all locust infestations that have occurred within five kilometers from a DHS survey cluster. Desert locust infestations are not detectable on satellite imagery - instead, data is collected by field officers who monitor large areas by land- and airborne vehicles in order to find upsurges or track the movements

[11] Contact: keith.cressman@fao.com

[12] http://www.fao.org/ag/locusts/en/info/info/index.html

of swarms or bands of gregarious locusts.

Moreover, it is probable that areas where there is systematic under-reporting of locust infestations di er (e.g. due to their remoteness) from areas where reporting is more accurate. However, in order for under-reporting to undermine the identification strategy of this thesis, this measurement error must vary over time in a way that also determines height-for-age of children within the cluster. An example can be used to illustrate this. During civil conflicts, surveying locust infestation areas becomes more difficult, probably leading to less events being recorded in the DLIS data set. For this to bias my estimates upwards, there must be an simultaneous increase in height-for-age during the same time period. Moreover, reporting systems has changed and improved over time as GPS technology has become cheaper and more available (Cressman, 2008). Since year of survey is positively correlated with height-for-age in my sample, any negative impact of locust infestations on height-for-age should not be a spurious result attributed to a correlation between improved reporting systems and height-for-age.

I use data on both bands and swarms, as these are observations of desert locusts that exhibit gregarious behaviour and thus have the potential to cause substantial harm to crops. Locusts infestations vary in size and density, and thus in destructive ability, but since the data on the area and density of swarms and bands is not consistent, I choose to treat all infestations as having equal impact. This approach will fail to capture a number of things. Firstly, swarms and bands with a higher density have a greater capacity to destroy crops and pasture lands. Secondly, the coordinates for the observation of the locusts is treated as the midpoint of a locust infestation, and the e ect is assumed to work only within a small area from these coordinates. As swarms and bands can stretch over large areas and are able to move in and out of a locality quickly, this assumption does not perfectly describe how infestations work in reality. I acknowledge that this measure can be improved if the present data limitations were to be solved. Nevertheless, it is worth noting that if anything, the issues discussed above should lead to a downward bias on my estimates.

Figure 2 shows locust events reported by FAO field officers Mali, Niger, Senegal and Burkina Faso during 1985-2015. Most locust observations are concentrated in time to the two largest locust plagues in recent history for this region; 1987-1989 and 2003-2005. During the entire time period, 5168 observations of gregarious locusts have been recorded in this area. Summing over all events coded as experienced, a total of 2528 children have experienced 5653 locust infestations within 5 kilometers from their survey cluster centroid. Children who have been exposed to locust infestations are distributed over several years, with the bulk of these children being surveyed during 1992 or 1993 (in Senegal and Niger) as well as in 2005 and 2006 (in Mali and Senegal), i.e. shortly after the two large locust plagues in the region.

4.3 Precipitation Data

The Africa Rainfall Climatology (ARC) data set[13] is produced by the Climate Prediction Center of the National Oceanic and Atmospheric Administration. The ARC data contains daily calibrated precipitation estimates, based on both geostationary infrared data centered over Africa from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and quality controlled Global Telecommunication System (GTS) gauge observations reporting daily rainfall accumulations over Africa from 1984 to the present. The spatial resolution is 0.1×0.1 degrees. All DHS cluster locations are matched to a pixel. The pixel mean and standard deviation is computed for each month, using all available data[14]. For each child in the DHS data, the average of monthly standard deviations is calculated.

5 Results

5.1 Main results

Table 2 reports the main results. Column (1) displays the e ect of a one standard deviation increase in locust density within 5 kilometers from the DHS cluster centroid, as measured by the per-year number of locust events per square kilometer,

[13] Available at ftp://ftp.cpc.ncep.noaa.gov/fews/fewsdata/africa/arc2/

[14] 1st of January 1983 - 17th of April 2017

while controlling for cluster fixed e ects. This specification will drop children who are the only observation in a survey cluster, explaining why the number of observations di ers by 31 observations from the original sample. The e ect is negative and significant: on average, a one standard deviation increase in the per-year locust exposure within 5 kilometers from the DHS survey cluster leads to a decrease in a child's height-for-age z-score by 0.089 units. In column (2), I control for mother fixed e ects. As this specification only uses within-family variation, the sample will be restricted to the universe of siblings in the sample. The results are consistent with the findings in column (1). Column (3) and (4) introduces the rainfall control variable, and column (5) and (6) includes survey-year dummies. The results remains stable across all columns.

In Table 3, the e ect I disaggregate the e ect by gender and by whether the child lives in a rural or an urban area. In column (1), I find that on average, boys have a lower height-for-age z-score than girls. It is also worth noting that a one standard deviation increase in locust exposure among girls completely eradicates this advantage. The estimated di erence between girls and boys is positive - the point estimate for the the e ect on boys is less than half compared to the e ect on girls. However, this di erence is not significantly di erent from zero. Moreover, an F-test of the average e ect on boys cannot reject the null that the impact on locust infestations on boys height-for-age is zero. This pattern persists in column (2), which includes mother fixed e ects instead of survey cluster fixed e ects.

In column (4)-(5), I interact the variable for locust exposure with a dummy for children in urban households[15], as well as an interaction term for the treatment on urban households. The results align with the expectation that the e ect of a shock to agricultural income should be weaker among children in urban households. First of all, I find that there is a significant di erence between children in urban and rural areas as regards the average treatment e ect. Furthermore, the null of a zero average e ect on urban households cannot be rejected. Notably, the estimated average e ect on rural households is -0,280 with survey cluster fixed e ects, and -0.298 with mother fixed e ect, both which are considerably larger than the average e ects estimated in column (1)-(2) of Table 1.

[15] A household is defined as urban or rural by DHS.

In Table 4 and 5, the results from Table 4 are enhanced by estimating the regressions separately on male, female urban and rural subsamples. The results from Table 3 are clearly reflected in this analysis. In Table 4, the negative e ect is smaller for boys than for girls and the e ect for girls is significant in both column (3) and (4), whereas the e ect on boys is only significant in column (2). Comparing to the regressions in column (3)-(4) of Table 3, where I cannot reject the null of a zero e ect on urban households, I find a significant and negative e ect of locust infestations on height-for-age when analyzing the urban sample separately (Table 5, column (1)-(2). The relatively large e ect on rural households persists in column (3)-(4) of Table 5.

5.2 E ect on other health outcomes

Height-for-age is used as the main outcome due to the well-established link between height-for-age and later in life outcomes. However, I evaluate the e ect of locust infestation exposure on other measures of nutritional status as a sanity check. If nutritional status is indeed a ected by locust infestations, the impact should run in the same direction for other relevant measures. In Table 6, I regress two other measures of anthropometric status computed by the WHO tool, namely weight-for-age (WFA) z-score and BMI-for-age z-score. Again, I use the WHO guidelines to drop implausible values[16], explaining why the sample di ers compared to the main specification in Table 1. Moreover, I create a dummy variable which equals 1 if the child has a height-for-age z-score of -2 or smaller, i.e. is considered stunted by WHO:s standards.

The specification is identical to those used to estimate column (4)-(5) of Table 1 and include age-in-year dummies as well as survey-year dummies. I find that the negative impact of locust infestations on nutritional status is clearly reflected in these measures as well; a one-standard deviation increase in per-year locust exposure decreases weight-for-age z-score by 0.142 standard deviations. Again, the mother fixed e ects specification estimates a larger e ect. BMI-for-age is also negatively a ected by exposure to locust infestations, as shown in column (2)-(3).

[16] In Table 3, this excludes observations with a WFA z-score above 5 and below -6 in column (1) and (2), and observations with a BMI z-score above 5 and below -5 in column (3) and (4).

In column (5), I find that the probability of being stunted increases with 2 percent as a response to an increase in the measure for locust infestation exposure. The estimate is identical in the mother fixed e ects model, but not significant.

5.3 Sanity check: predetermined characteristics

To test the assumption that the number and timing of locust infestations are exogenous, I run the specification used in column (3)-(4) of Table 1 on predetermined mother and child characteristics. The results are displayed in Table 7, 8 and 9. As I posit that nutritional status is a ected by locust infestations via a shock to agricultural income, many of the variables available in the DHS data are potentially endogenous to the treatment. This is especially true for children, for which most variables measures health outcomes. This means that there are few variables that will truly be predetermined on the child level.

I test two time-invariant outcomes for children; child's gender and birth order. I construct birth order as 5 binary outcome variables, including all children who are of birth order five or higher in one category. Generally, the estimates are insignificant, small and of varying sign across all columns. In column (2), the result indicates that a one standard deviation increase in locust exposure increases the probability that the child is a boy by 2,7 percent. This estimate is small, but it does indicate that when comparing siblings, there is some gender imbalance between those who have experienced relatively more infestations and those who have experienced relatively less.

I further expand the sanity check by running the same regressions on predetermined variables of the mother: literacy, age, age at marriage and religion. I find that locust exposure cannot explain any of these predetermined characteristics of the mother. Again, the estimates are small and of varying sign across all columns. It is worth noting that there should be zero variation in mother predetermined characteristics between siblings. Whereas this is true for most outcomes, in column (6) of Table 8 there is a positive variance for age at marriage, which is probably due to errors in the data.

6 Concluding remarks

This thesis shows that the health of children is negatively a ected in the presence of locust infestations, with deteriorated anthropometric status as a result. I estimate these e ects by exploiting within-locality and within-family variation in locust infestation exposure. As expected, the impact is larger for rural households while among urban children, I find no significant e ect. I find some indications that the impact is larger among girls, perhaps suggesting the presence of gender bias influencing the allocation of resources within the households; the average e ect on girls is relatively large and significant, whereas the null of a zero e ect on boys cannot be rejected. However, the results are inconclusive as the estimated di erence between boys and girls is not statistically significant.

A few limitations are worth highlighting. Due to large inconsistencies in the data on the density and spread of the observed locust infestation, and the potentially large number of unreported events of locust infestations, the estimates presented in this thesis should not be interpreted as exact responses in height-for-age to an increase in the per-year number of locust infestations per square kilometer. Rather, the treatment variable should be understood as the relative intensity at which locust infestations have been experienced by a child. Another major limitations is that the data does not allow me to disentangle the e ect of treatment on height-for-age from that of chemical pesticides.

In the empirical strategy used in this thesis, I do not di erentiate the e ect in terms of the age at survey as the number of a ected children in each age group is very small. With more observations this would be a useful exercise, as it is plausible that there are heterogeneous e ects in terms of age. Ideally, one would also allow the e ect to di er based on during which year in a child's life that an infestation was experienced. Moreover, this e ect should be allowed to vary across di erent ages at the time of the DHS survey, separating two e ects: i) being at a certain age when experiencing an infestation ii) being at a certain age when experiencing an infestations interacted with the time passed since this experience. This analysis would also provide more insight to the considerable e ect of locust infestations on weight-for-age estimated in Table 6; weight-for-age, generally thought of as a flow measure of health investments which reflects the current nutritional status of a child, should be more a ected for children surveyed shortly after an infestation.

Despite the limitations in data and the room for further analysis mentioned above, this thesis provides rigorous and economically important estimates on the impact of a plant pest a ecting a large number of countries, but for which there is almost a complete absence of any empirical evidence on the microeconomic consequences. Moreover, the identification strategy used in this thesis suggests that the estimates can be given a casual interpretation. By using a measure of child health which is highly relevant in predicting human capital accumulation, my results do not only imply that locust infestations have instantaneous e ects on nutritional status, but that the long-run costs of locust infestations might be larger than what is evident immediately after the event has taken place. From a policy perspective, this is an important result as it suggests that there are both short- and long-run gains to be made from insuring households against the risk of being infested. As this shock can be seen as idiosyncratic on a national level, there is a case to be made for reallocating resources to those who have been a ected by an infestation.

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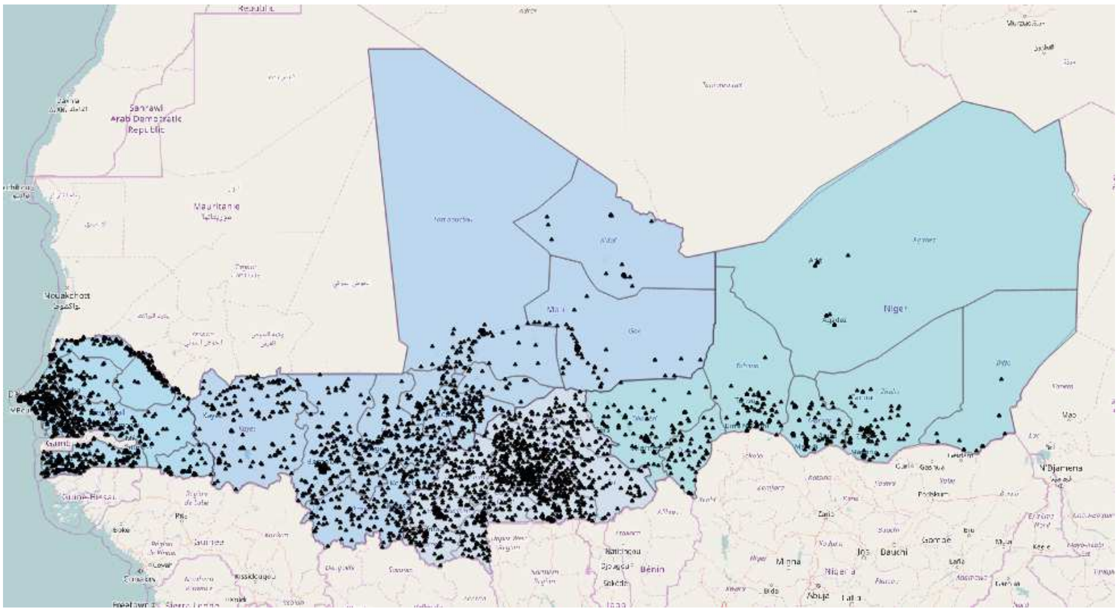

Figure 1: DHS survey clusters

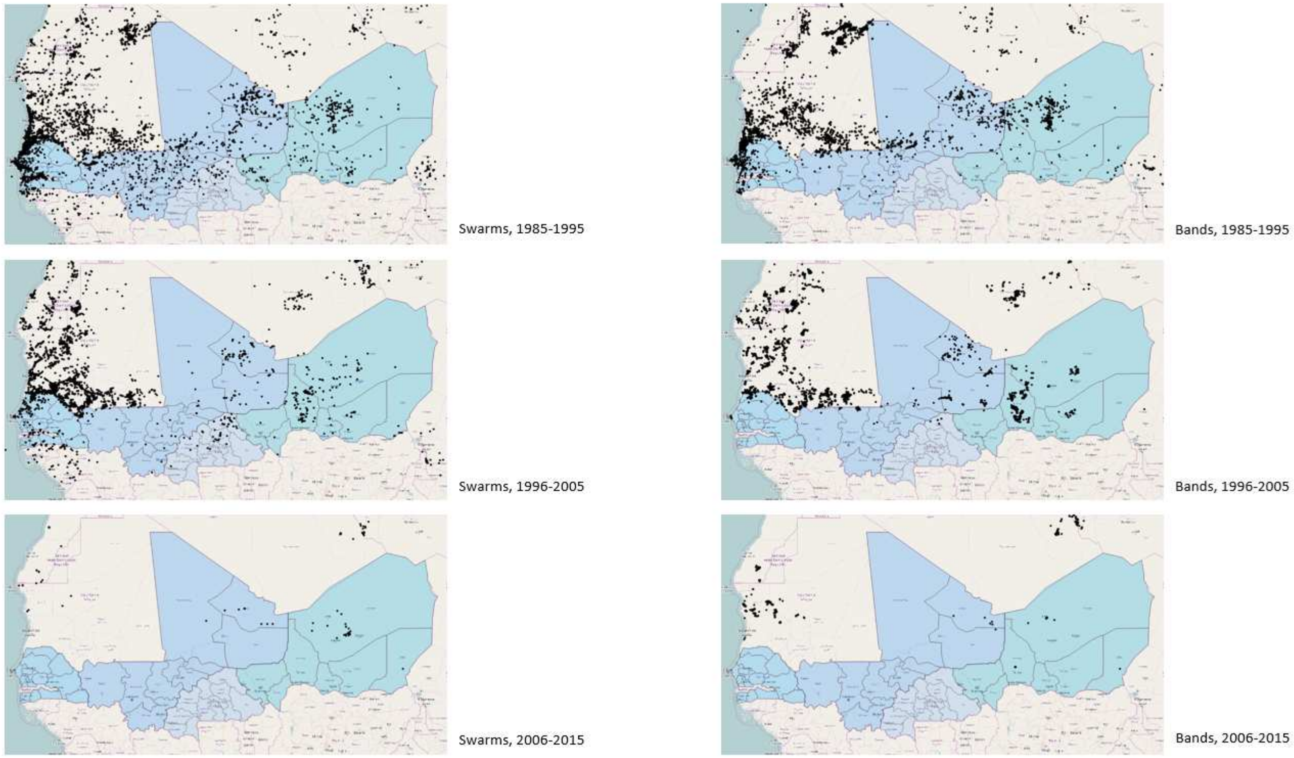

Figure 2: Locust observations by type, 1985-2015

Table 1: Descriptive Statistics

	Total sample Mean	Rural Mean	Urban Mean
Child Health Outcomes			
Child's HFA z-score	−1.44	−1.59	−1.01
	(1.80)	(1.83)	(1.65)
Child's WFA z-score	−1.33	−1.46	0.97
	(1.43)	(1.45)	(1.67)
BMI-for-age z-score	−0.52	−0.54	−0.46
	(1.47)	(1.50)	(2.12)
Other child characteristics			
Child is a boy	0.51	0.51	0.50
	(0.50)	(0.50)	(0.50)
Child's age in years	2.24	2.24	2.25
	(1.47)	(1.48)	(1.45)
Locust exposure			
Average number of events within 5 km per year in life	0.02	0.01	0.04
	(0.13)	(0.06)	(0.23)
Mother and household characteristics			
Mother's age in years	28.97	29.10	26.96
	(7.09)	(7.17)	(6.68)
Mother is literate	0.22	0.35	0.35
	(0.42)	(0.48)	(0.48)
Muslim	0.79	0.76	0.85
	(0.41)	(0.42)	(0.35)
Christian	0.11	0.11	0.11
	(0.31)	(0.31)	(0.31)
Traditional/animist religion	0.08	0.10	0.03
	(0.27)	(0.30)	(0.18)
Observations	76361	55871	20490

Notes: Standard deviation in parenthesis.

Table 2: Main results

	(1) HFA z-score	(2) HFA z-score	(3) HFA z-score	(4) HFA z-score	(5) HFA z-score	(6) HFA z-score
Z-scored density of locust per year, 5 km	-0.089**	-0.111**	-0.092**	-0.115**	-0.092**	-0.115**
	[0.037]	[0.049]	[0.038]	[0.050]	[0.038]	[0.050]
Average deviation from monthly precipitation			0.523***	0.541***	0.522***	0.541***
			[0.082]	[0.111]	[0.082]	[0.111]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	no	no	no	no	yes	yes
Observations	76332	37141	76332	37141	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 3: Disaggregated e ects by gender and by urban/rural

	(1) HFA z-score	(2) HFA z-score	(3) HFA z-score	(4) HFA z-score
Z-scored density of locust per year, 5 km	-0.122**	-0.155**	-0.280***	-0.235**
	[0.054]	[0.067]	[0.080]	[0.091]
Z-scored density of locust per year, 5 km × Child is a boy	0.075	0.095		
	[0.066]	[0.078]		
Child is a boy	-0.123***	-0.108***		
	[0.018]	[0.026]		
Z-scored density of locust per year, 5 km × Urban			0.234**	0.146
			[0.089]	[0.107]
Urban			-	-
			-	-
Average deviation from monthly precipitation	0.527***	0.544***	0.517***	0.538***
	[0.082]	[0.111]	[0.082]	[0.111]
Postestimation: linear combinations				
Z-scored density of locust per year, 5 km: E ect on boys	-0.047	-0.059		
	[0.046]	[0.059]		
Z-scored density of locust per year, 5 km: E ect on urban children			-0.046	-0.089
			[0.041]	[0.057]
Cluster FE	yes	no	yes	no
Mother FE	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes
Observations	76332	37141	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.
In column (3) and (4), the main e ect *Urban* is absorbed by the fixed e ect.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 4: Subsample analysis: Gender

	Boys		Girls	
	(1)	(2)	(3)	(4)
	HFA z-score	HFA z-score	HFA z-score	HFA z-score
Z-scored density of locust per year, 5 km	-0.074	-0.124*	-0.133**	-0.213**
	[0.050]	[0.068]	[0.050]	[0.083]
Average deviation from monthly precipitation	0.497***	0.612**	0.575***	0.648***
	[0.111]	[0.213]	[0.102]	[0.195]
Cluster FE	yes	no	yes	no
Mother FE	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes
Observations	38637	9988	37416	9453

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 5: Subsample analysis: Urban and Rural

	Urban		Rural	
	(1)	(2)	(3)	(4)
	HFA z-score	HFA z-score	HFA z-score	HFA z-score
Z-scored density of locust per year, 5 km	-0.079*	-0.108*	-0.255**	-0.221**
	[0.042]	[0.056]	[0.081]	[0.092]
Average deviation from monthly precipitation	0.123	0.269	0.556***	0.572***
	[0.184]	[0.231]	[0.090]	[0.123]
Cluster FE	yes	no	yes	no
Mother FE	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes
Observations	20469	9268	55863	27873

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 6: Other measures of anthropometric status

	(1) WFA z-score	(2) WFA z-score	(3) BMI-for-age z-score	(4) BMI-for-age z-score	(5) Child is stunted	(6) Child is stunted
Z-scored density of locust per year, 5 km	-0.127***	-0.139***	-0.091**	-0.100**	0.020*	0.020
	[0.031]	[0.034]	[0.031]	[0.033]	[0.011]	[0.013]
Average deviation from monthly precipitation	0.164**	0.168**	-0.143**	-0.134	-0.105***	-0.108***
	[0.068]	[0.084]	[0.069]	[0.098]	[0.018]	[0.028]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	77353	38185	75606	36674	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 7: Robustness check: child predetermined outcomes

	(1) Child is a boy	(2) Child is a boy	(3) Birth order=1	(4) Birth order=1	(5) Birth order=2	(6) Birth order=2	(7) Birth order=3	(8) Birth order=3	(9) Birth order=4	(10) Birth order=4	(11) Birth order≥5	(12) Birth order≥5
Z-scored density of locust per year, 5 km	0.006	0.027*	-0.007	-0.007	-0.010	-0.005	0.011	0.007	0.009	0.012	-0.003	-0.008
	[0.012]	[0.016]	[0.006]	[0.007]	[0.007]	[0.013]	[0.007]	[0.011]	[0.006]	[0.008]	[0.007]	[0.005]
Average deviation from monthly precipitation	0.038**	0.016	-0.026**	-0.025	0.019	0.018	0.000	0.019	-0.018*	-0.033	0.025*	0.020
	[0.017]	[0.027]	[0.012]	[0.015]	[0.013]	[0.022]	[0.012]	[0.021]	[0.011]	[0.021]	[0.015]	[0.014]
Cluster FE	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	76332	37141	76332	37141	76332	37141	76332	37141	76332	37141	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 8: Robustness check: mother predetermined outcomes

	(1) Age	(2) Age	(3) Literacy	(4) Literacy	(5) Age at marriage	(6) Age at marriage
Z-scored density of locust per year, 5 km	0.066	0.000	0.001	0.000	-0.058	0.001
	[0.093]	[0.000]	[0.006]	[0.000]	[0.053]	[0.001]
Average deviation from monthly precipitation	0.082	0.000	0.020**	0.000	0.124	-0.002
	[0.206]	[0.000]	[0.007]	[0.000]	[0.079]	[0.005]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	76332	37141	76235	37099	75163	36967

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 9: Robustness check: mother predetermined outcomes

	(1) Muslim	(2) Muslim	(3) Christian	(4) Christian	(5) Traditional	(6) Traditional
Z-scored density of locust per year, 5 km	-0.001	0.000	0.001	-0.000	-0.000	-0.000
	[0.002]	[0.000]	[0.002]	[0.000]	[0.001]	[0.000]
Average deviation from monthly precipitation	0.001	0.000	0.005	0.000	-0.001	-0.000
	[0.007]	[0.000]	[0.007]	[0.000]	[0.006]	[0.000]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	71049	34184	71049	34184	71049	34184

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Appendix

Table 10: Demographic Health Surveys

Country	*Surveys*	*Observations with anthropometric data*
Burkina Faso	1993, 1998-99, 2003, 2010	4592, 4782, 8801, 6730
Mali	1995-96, 2001, 2006	5009, 10043, 11650
Niger	1992, 1998	4891, 4891
Senegal	1992-93, 2005, 2010-11, 2012-13	4694, 2941, 3929, 6071

Table 11: Results when using a 10 kilometer radius

	(1) HFA z-score	(2) HFA z-score	(3) HFA z-score	(4) HFA z-score	(5) HFA z-score	(6) HFA z-score
Z-scored density of locust per year, 10 km	-0.119**	-0.164**	-0.134**	-0.166**	-0.358***	-0.302**
	[0.048]	[0.057]	[0.067]	[0.072]	[0.080]	[0.093]
Z-scored density of locust per year, 15 km × Child is a boy			0.044	0.014		
			[0.082]	[0.102]		
Child is a boy			-0.128***	-0.122***		
			[0.020]	[0.029]		
Z-scored density of locust per year, 15 km × Urban					0.308**	0.174
					[0.095]	[0.113]
Urban					-	-
					-	-
Average deviation from monthly precipitation	0.521***	0.540***	0.526***	0.545***	0.516***	0.538***
	[0.082]	[0.111]	[0.082]	[0.111]	[0.082]	[0.111]
Postestimation: linear combinations						
Z-scored density of locust per year, 10 km: E ect on boys			-0.090	-0.152*		
			[0.057]	[0.081]		
Z-scored density of locust per year, 10 km: E ect on urban children					-0.050	-0.129**
					[0.050]	[0.064]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	76332	37141	76332	37141	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

In column (5) and (6), the main e ect *Urban* is absorbed by the fixed e ect.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 12: Results when using a 15 kilometer radius

	(1) HFA z-score	(2) HFA z-score	(3) HFA z-score	(4) HFA z-score	(5) HFA z-score	(6) HFA z-score
Z-scored density of locust per year, 15 km	-0.133**	-0.179**	-0.149**	-0.163**	-0.394***	-0.336**
	[0.051]	[0.059]	[0.069]	[0.068]	[0.084]	[0.102]
Z-scored density of locust per year, 15 km × Child is a boy			0.048	-0.049		
			[0.089]	[0.110]		
Child is a boy			-0.127***	-0.133***		
			[0.021]	[0.030]		
Z-scored density of locust per year, 15 km × Urban					0.342***	0.197
					[0.099]	[0.121]
Urban					-	-
					-	-
Average deviation from monthly precipitation	0.520***	0.539***	0.526***	0.545***	0.516***	0.536***
	[0.082]	[0.111]	[0.082]	[0.111]	[0.082]	[0.111]
Postestimation: linear combinations						
Z-scored density of locust per year, 15 km: Effect on boys			-0.101	-0.212**		
			[0.063]	[0.092]		
Z-scored density of locust per year, 15 km: Effect on urban children					-0.052	-0.139**
					[0.052]	[0.065]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	76332	37141	76332	37141	76332	37141

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

In column (5) and (6), the main effect *Urban* is absorbed by the fixed effect.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Table 13: Households who have lived in the DHS survey cluster for at least 5 years

	(1) HFA z-score	(2) HFA z-score	(3) HFA z-score	(4) HFA z-score	(5) HFA z-score	(6) HFA z-score
Z-scored density of locust per year, 5 km	-0.081**	-0.096*	-0.131**	-0.149*	-0.234**	-0.194**
	[0.039]	[0.055]	[0.052]	[0.077]	[0.080]	[0.090]
Z-scored density of locust per year, 5 km × Child is a boy			0.112*	0.116		
			[0.062]	[0.083]		
Child is a boy			-0.116***	-0.122***		
			[0.019]	[0.030]		
Urban					-	-
					-	-
Z-scored density of locust per year, 5 km × Urban					0.193**	0.121
					[0.091]	[0.110]
Average deviation from monthly precipitation	0.512***	0.535***	0.516***	0.538***	0.508***	0.532***
	[0.089]	[0.128]	[0.089]	[0.127]	[0.090]	[0.128]
Cluster FE	yes	no	yes	no	yes	no
Mother FE	no	yes	no	yes	no	yes
Age-in-year dummies	yes	yes	yes	yes	yes	yes
Survey-year dummies	yes	yes	yes	yes	yes	yes
Observations	59725	28081	59725	28081	59725	28081

All regressions are OLS regressions. Robust standard errors, clustered at the DHS survey cluster level, in brackets.

In column (5) and (6), the main e ect *Urban* is absorbed by the fixed e ect.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$