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Eduard van der Merwe
University of Pretoria
Matthew Clance
University of Pretoria
Eleni Yitbarek
University of Pretoria
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Department of Economics
University of Pretoria
0002, Pretoria
South Africa
Tel: +27 12 420 2413

Climate Change and Child Health: A Nigerian Perspective

Eduard van der Merwe* Matthew Clance† Eleni Yitbarek‡

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Abstract

The detrimental effect of climate change on health is becoming an essential topic of economic research and policymaking. The negative impact of rising temperatures and extreme weather events on children's health outcomes and their human capital is especially concerning. This study investigates the effects of a changing climate, in terms of changes in the monthly maximum average near-surface temperature ($°C$) and total monthly precipitation (mm), on children's nutritional status in Nigeria using LSMS-ISA survey data combined with high-resolution gridded climate data. Malnutrition in children is measured in the form of stunting, underweight and wasting. Our results indicate that the changing climate is correlated with a higher probability that Nigeria's children are malnourished - even more so in rural areas. The paper's findings support the notion of the need for climate-friendly policies to mitigate the long-term effect of climate change on malnourishment; otherwise, climate change could reverse years of progress in lowering children's malnutrition.

Keywords: climate change, malnutrition, stunting, underweight, spatial analysis

JEL Classification: Q54, I12, I15

*Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa, E-mail: e.vandermerwe@tuks.co.za

†Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa, E-mail: matthew.clance@up.ac.za.

‡Corresponding author. Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa, E-mail: eleni.iytbarek@up.ac.za

1 Introduction

Achieving the sustainable development goal of zero hunger is especially important in the case of children. Good nutrition is the bedrock of child survival, health, and development. Reducing malnutrition in children will allow them to contribute to society in the future (UNICEF et al., 2020). Proper nourishment is also a key determinant in educational attainment for children. Environmental and climate factors such as rising temperatures and droughts negatively affect the welfare and nutrition of young children (Grace et al., 2015). Additionally, individuals that have experienced malnourishment in childhood have a higher probability of impaired health and productivity in adulthood (Alderman et al., 2006). The effects of malnutrition can also be intergenerational in that it can cause households to remain trapped in poverty (Pena & Bacallao, 2002).

Ahdoot et al. (2015) notes that humans are vulnerable to climate changes because of its negative effects on physical and mental health, such as increased stress and decreased air and water quality. Disease patterns, the increased probability of extreme weather events, agriculture production (productivity), and food security are all affected by climate change. Erratic temperatures and precipitation are some events that affect these key factors that influence nutrition, human capital investment, and living standards, particularly for children (Davenport et al., 2017; Lobell & Field, 2007). Children are more vulnerable to the consequences of climate change due to their dependence on caregivers and immature physiology. Furthermore, the children in households that are dependent on agriculture are most susceptible to chronic malnutrition due to climate change (Brown & Funk, 2008).

This study investigates the impact of changing temperature and precipitation on child health indicators - stunting and underweight.[1] We find evidence that supports the notion that temperature has a direct effect on child malnutrition and precipitation an indirect effect (Ahdoot et al., 2015; Cooper et al., 2019).[2] The relationship between climate change and children nutritional outcomes is complex. First, change in climate affects maturation through an agroecosystem's pathway with an adverse impact on food production; for instance, by affecting crop output, crop growth, diseases and pests (Niles et al., 2021; Reddy et al., 2019). As a result, climate change could affect food security and diet diversity by changing the availability and quality of food sources in society.

Climate change effects on food security and diet diversity could occur over the short-term (e.g. due to extreme weather events such as heatwaves and floods) and longer-term (e.g. increasing temperatures and decreasing precipitation). Second, climate change can affect nutritional outcomes indirectly through heat effects on pregnant women and their children health outcomes such as low birth weight and preterm birth (Zhang et al., 2017). Finally, climate change may reduce food security through changes in food price and market-related shocks and stressors

[1] Results for wasting are available on request.

[2] We specifically focus on the one-year lagged monthly maximum average near-surface temperature (temperature$_{t-1}$) (°C) and three-year lagged total average monthly precipitation (precipitation$_{t-3}$) (mm). For robustness, we use various measures of both determinants and the results remain relatively consistent. These results are available upon request.

(Brown et al., 2017).

We are not the first to consider the effects that temperature and/or precipitation have on children's health outcomes, but these studies use predictive changes in temperature and/or rainfall to forecast health outcomes. We instead contribute by using the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) to form a panel dataset that allows us to investigate how actual changes in temperature and precipitation impact contemporary children's health outcomes.

Our results indicate that increasing temperatures and decreasing precipitation lead to a higher probability of malnutrition among children. These effects are larger in rural areas compared to urban areas. The results suggest that climate-friendly policies the government initiates can help avert related health consequences in the population, especially among children. Improvements of public infrastructure (Bassolé et al., 2007), access to electricity (Davenport et al., 2017), as well as improved educational and social institutions (Grace et al., 2012) are some mechanisms shown to be effective against climate change and thus improve population health. For African countries that are dependent on agriculture, policies that improve climate and environmental conditions can improve human capital and the living standards of their population.

Although Black et al. (2008) found that poor children are often at considerable risk for malnutrition and stunting, in agriculture-dependent countries like Nigeria, all children are susceptible. Given Nigeria's composition, we expect urban as well as rural children to be vulnerable to changes in weather patterns since they are dependent on low-cost and locally grown foods (Davenport et al., 2017). In Nigeria, the cornerstone of the economy remains agriculture regardless of the availability of oil. Agriculture employs 36.5% of the entire labour force (World Bank, 2019) and contributes roughly a quarter of Nigeria's GDP (African Development Bank, 2019). Around 88% of farmers in Nigeria are considered small family farms (World Bank, 2019) and half of Nigeria's population is rural (FAO, 2019b). All this indicates that malnutrition will become an even more substantial concern in Nigeria with a changing climate.

The effect of climate change on child nutrition is easily observable in less developed countries. Research has shown that long-term improvement of economic development, such as higher human capital and economic growth in Africa may hinge, at least partially, on decreasing child malnutrition (Davenport et al., 2017). Chronic malnutrition leads to stunting in a third of all children under 5 years of age born in developing countries (Beegle & Christiaensen, 2019; Costello et al., 2009). Developing countries are worse off to deal with a changing climate due to a lack of resources and their dependence on agriculture (Balk et al., 2005). Sub-Saharan Africa is especially prone to malnutrition in children as it already has a history of "chronic food insecurity, poor health outcomes and, more recently, increased temperatures and decreased rainfall" (Davenport et al., 2017).

The rest of this paper is set out as follows. Section 2 introduces the data used, the methodology, and the descriptive statistics. Section 3 sets out the empirical results with regards to temperature, precipitation, as well as the combined effect. Section 4 offers discussion points and policy implications and suggestions while conclusions are drawn in Section 5.

2 Data and Methodology

Three waves of the Nigerian LSMS-ISA data are used to analyze the temperature and precipitation effects on child health for the period 2010-2011, 2012-2013, and 2015-2016. The LSMS-ISA project is a multi-topic, nationally representative household panel survey, with a focus on agriculture-related data. It is constructed in collaboration with the Nigerian National Bureau of Statistics. Multiple topics are covered and designed to improve the understanding of the links between agriculture, socioeconomic status, and non-farm income activities (Osabohien, 2018).

The LSMS-ISA data is sampled in two stages: the post-planting stage, which occurs between August and October, and the post-harvest stage, which occurs between February and April. To measure the panel-effect of climate change, we use data on children that are at in at least two consecutive waves and below the age of 5. This restriction means children in our sample are aged between 0 and 4 in wave one (2010-2011), but children that have reached age 5 by wave two (2012-2013) will not be included. This is similar between waves two and three (2015-2016).

2.1 Measures of Child Malnutrition

The analysis uses various malnutrition measures which include stunting, underweight, and wasting to understand the effects of climate change on child malnutrition. Stunting can arise due to poor nutrition in-utero and early childhood which is worse due to poor sanitation, unclean water and lack of hygiene (Grace et al., 2017). Children who suffer from stunting may never reach their full possible height, and may have suboptimal brain development that negatively affects children's cognitive development; educational attainment and economic productivity during adulthood (Beegle & Christiaensen, 2019; Feinstein, 2003; UNICEF et al., 2020). The first 1,000 days of life of a child is a critical phase of rapid physical and mental development (De Onis & Branca, 2016). Evidence from both developing and developed countries suggest that taller siblings from the same mothers perform better on cognitive tests, and have better health, economic, and educational outcomes (Case & Paxson, 2010; Glewwe & Jacoby, 1995). Stunting can also cause decades of harmful effects and can undermine the development of a country, the average per capita income penalty from stunting in developing countries is about 7% (Galasso & Wagstaff, 2019).

Wasting represents short-term life-threatening health outcomes that result from poor nutrition or disease, and children suffer from weakened immunity and have an increased risk of death when wasting is severe (UNICEF et al., 2020). The underweight measure is a composite indicator of stunting and wasting. Societies with more severe cases of conditions such as underweight and malnutrition have increased mortality rates. The effects of malnutrition vary but, it can undermine health and development, limit learning ability, diminish immune systems, reduce adult work performance and productivity, and increase the chance of giving birth to underfed babies (Jankowska et al., 2012). Grace et al. (2012) further notes that children have a lower likelihood of completing secondary school. Therefore, malnutrition has negative effects on a country's health and the development of its population, both in the short and long term.

We construct an indicator variable for each condition, stunting, underweight, and wasting, from the LSMS data following the standards of the World Health Organization (WHO) for all children under 5 years of age.[3] Children for whom we have incomplete or implausible anthropometry data are excluded from the analysis. We expect all the factors to affect the overall development of the child, but some research, namely Balk et al. (2005), have shown that stunting is a more robust indicator of chronic child malnutrition.

2.2 Measures of Climate Variability

Temperature and precipitation data are from the Climatic Research Unit (CRU-TS-4.03), University of East Anglia (Harris et al., 2014).[4] The temperature and precipitation variables measure average near-surface maximum temperature in degree Celsius and total precipitation in millimetres, respectively. We use these two variables to make the result of the study comparable to the literature (Davenport et al., 2017; Grace et al., 2015) as well as take into account the threats of increases in the daily maximum temperatures, as noted by Buis (2019).

The temperature and precipitation data are gridded monthly time-series that covers the period 1960-2018 with a spatial resolution of 2.5 minutes which is roughly $21km^2$. The households in the LSMS-ISA dataset have GPS coordinates that we associate with each grid in the climate data.[5] We use the households' GPS references to create a five-kilometre buffer around each of these points. This buffer allows us to assume, with relative certainty, that the specific household point is in that buffer zone without the zone being too big. We then used these five-kilometre buffer and georeferencing techniques to merge the climate data within the buffer with each household. Merging these two data sets at the relevant spatial and temporal scales is crucial to ensure a thorough analysis of household health and climate changes (Grace et al., 2012). Very few studies adopt this approach and, by utilizing this approach, this paper contributes to the literature. Furthermore, our method captures individual-level effects across the panel data and ensures consistency throughout.

Both the temperatures and precipitation are calculated as the monthly averages. The monthly average for each survey was taken from July (post-planting) the previous year of the survey to June (post-harvesting), the year of the survey for temperature and similarly for precipitation

[3] First, we calculate height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) z-scores. The z-scores represents the number of standard deviations by which the child's anthropometric measurements deviates from the median child growth standard of WHO (World Health Organization, 2010). Second, a z-score cut-off point of -2 is used to generate a binary indicator for stunting (a long-term child malnutrition status measure), underweight, and wasting (a short term indicator of acute malnutrition). A z-score of less than -2 identifies children who have low height-for-age or stunted children, low weight-for-age or underweight children, and low weight-for-height or wasted children (World Health Organization, 1995).

[4] The downscaled version that corrects for bias, which is produced by WorldClim (Fick & Hijmans, 2017), is used.

[5] Note that each cluster's GPS coordinates in the LSMS-ISA data are offset by up to 2km in urban areas and 5km in rural areas, randomly. Only (1%) of clusters in the rural areas are offset by around 10km.

except a 4 year and 3-year interval from July to June. These periods allow capturing the climate variability span of both the post-planting and post-harvesting stages of the LSMS-ISA dataset.

Table 1 shows how we calculated the varying values for temperature and precipitation. All the temperatures and precipitation are calculated as the monthly averages. The use of these periods is so that the climate variability span both the post-planting and post-harvesting stages of the LSMS-ISA dataset. The expectation is that the lagged values have more explanatory power in predicting the influence of climate change on the malnutrition of children (Grace et al., 2012). Furthermore, changing temperature is the main contributor to the direct consequences of climate change, such as heat stress, diseases, and air quality, on child health (Ahdoot et al., 2015). We also find a strong correlation between the monthly maximum temperature$_t$ with the different control variables. Therefore, the focus is on temperature$_{t-1}$.

Table 1: Timeline of Measures of Climate Variability

	Wave 1 (2010-2011)	Wave 2 (2012-2013)	Wave 3 (2015-2016)
Temperature$_t$ ($°C$)/Precipitation$_t$ (mm)	July 2010 - June 2011	July 2012 - June 2013	July 2015 - June 2016
Temperature$_{t-1}$ ($°C$)/Precipitation$_{t-1}$ (mm)	June 2009 - July 2010	July 2011 - June 2012	July 2014 - June 2015
Temperature$_{t-2}$ ($°C$)/Precipitation$_{t-2}$ (mm)	July 2008 - June 2009	July 2010 - June 2011	July 2013 - June 2014
Temperature$_{t-3}$ ($°C$)/Precipitation$_{t-3}$ (mm)	July 2007 - June 2008	July 2009 - June 2010	July 2012 - June 2013
Temperature$_{t-5}$ ($°C$)/Precipitation$_{t-5}$ (mm)	July 2005 - June 2006	July 2007 - June 2008	July 2010 - June 2011
Three-Year Average Temperature/Precipitation	July 2008 - June 2011	July 2010 - June 2013	July 2013 - June 2016
Five-Year Average Temperature/Precipitation	July 2006 - June 2011	July 2008 - June 2013	July 2011 - June 2016

The three and five year averages are calculated as $[(x_t+x_{t-1}+x_{t-2})/3]$ and $[(x_t+x_{t-1}+x_{t-2}+x_{t-3}+x_{t-4})/5]$, respectively, where x denotes $Temperature$ and $Precipitation$.

Cooper et al. (2019) finds that precipitation's effect on child stunting takes even longer to affect the health of a child. They use a Standardized Precipitation–Evapotranspiration Index (SPEI) and find that using a twenty-four-month lag, has the most notable effect on child nutrition. They also note that these effects are indirect in most cases and that changing temperature lead to changing precipitation. As Myers and Bernstein (2011) notes, indirect effects such as water scarcity, displacement, uncertainty, and food security is a substantial threat and can cause long-lasting damage. Therefore, we investigate the consequences of precipitation$_{t-3}$'s impact on child health outcomes.[6]

2.3 Control Variables

The variables included in the regressions were selected based on related literature.[7] These variables control for geographical information (such as distance to water, cities, and markets), family characteristics (such as the number of meals to children, access to electricity, household head education), child characteristics (such as age and gender), household wealth (such as asset ownership and consumption), agriculture characteristics (aggregate plot size, soil quality (Fischer et al., 2008), tropical livestock unit), and household assistance (such as agri-extension services and access to credit or loans).

[6]The effect of precipitation$_{t-1}$ is also checked and available on request. We find small positive effects for precipitation$_{t-1}$ which support the results found by Skoufias and Vinha (2012) and mentioned in Phalkey et al. (2015a). Comparing the results of precipitation$_{t-1}$ and precipitation$_{t-3}$ support research that precipitation has an indirect effect on child nutrition.

[7]A full list and explanation of control variables are available in section A.4 of Appendix A.

More specifically, household size, educational attainment and gender of household head are used to control taste, preference, and income-related heterogeneity between children. The distance to freshwater data is from two sources, namely the Global Lakes and Wetlands Database (Lehner & Döll, 2004) and AQUAMAPS (FAO, 2019a). We consider freshwater as water in the form of lakes, reservoirs, rivers, freshwater marshes, floodplains, and intermittent wetlands or lakes.[8]

2.4 Estimation Strategy

Let the m variable be an indicator for childhood malnutrition where superscripts $s, w,$ and u represent an indicator that is specific to stunting, wasting, or underweight, respectively. Let X be a vector of the control variables defined in Section 2.3. Then we have the following models,

$$m_{it}^{s,w,u} = \alpha + \delta_1 Temperature_{t-1} + \beta X_{it} + \gamma \bar{X}_i + r_i + \varepsilon_{it} \tag{1}$$

$$m_{it}^{s,w,u} = \alpha + \delta_2 Precipitation_{t-3} + \beta X_{it} + \gamma \bar{X}_i + r_i + \varepsilon_{it}. \tag{2}$$

We estimate equations 1 and 2 using a correlated random effects (CRE) logit model with panel techniques where $\bar{X}_i$ is the time-average variable for i. We use the CRE logit because we are interested in the marginal effects with respect to temperature and precipitation as well as the heterogeneous impact across urban and rural communities. We could estimate the model using the conditional logit fixed effect model instead but it does not estimate the individual effects, r_i. Thus, the marginal effects based on this model would assume the individual effects are equal to 0 which would bias our estimated the marginal (partial) effect of the variable of interest (Wooldridge, 2012). Unlike the conditional logit model, using the CRE logit, we at least get can approximation of the unobserved time-invariant effects.[9]

2.5 Summary Statistics

The different climate zones across Nigeria are presented in Figure 1. The northern portion is typically dryer, experiencing less precipitation, and has higher average temperatures than the South. The south-most point is the concentration point of precipitation.[10]

Across the different waves, there is variation in the overall temperatures and precipitation.[11] We see an increase in the average maximum temperatures as well as a decrease in the average total precipitation across waves. These patterns seen in our sample are similar to the climate changes of Nigeria noted by the World Bank (2020).

In our sample, 37.7%, 19.1%, and 30.5% of children are stunted in the first, second, and third

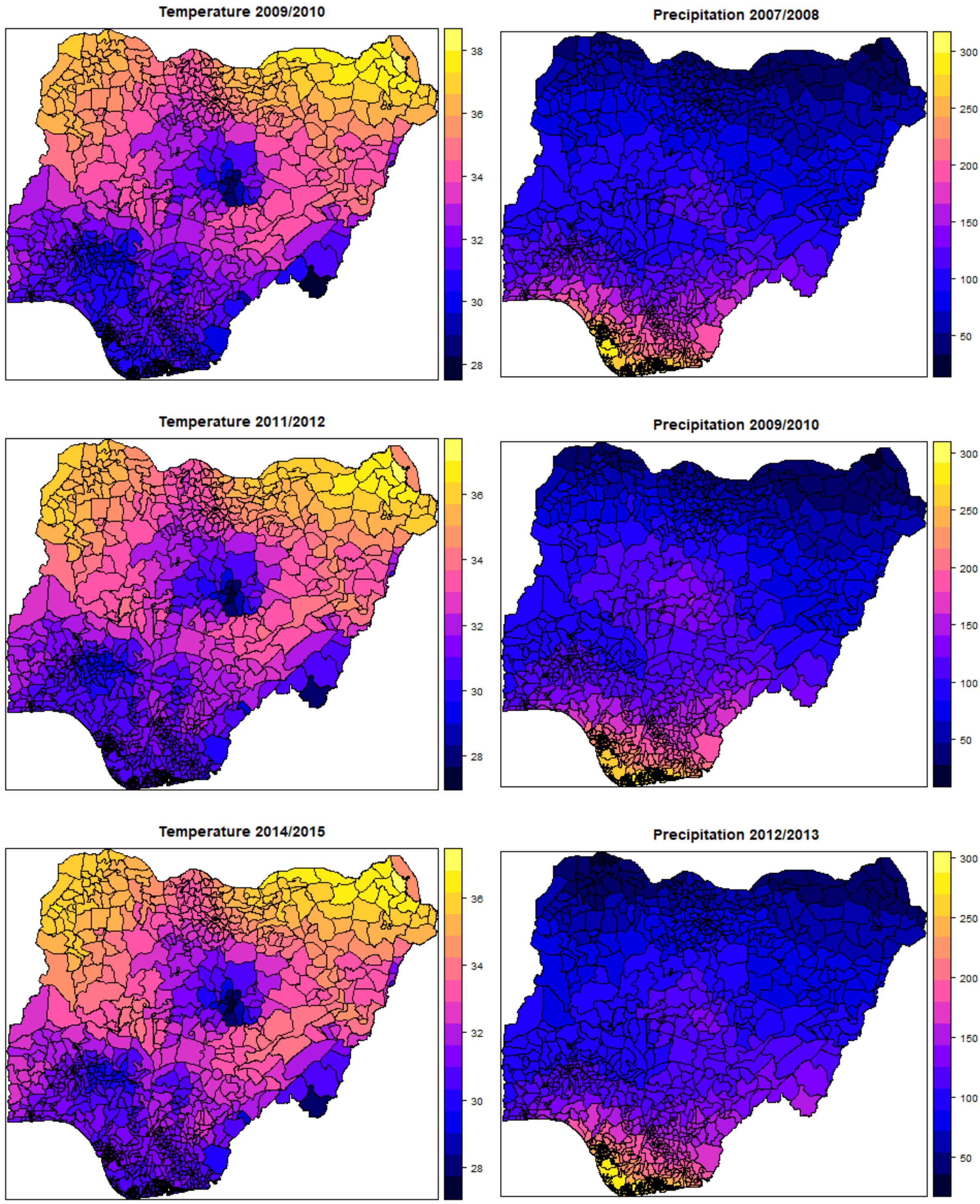
[8]More information on data sources and merging are available in Appendix A.

[9]To check the robustness of our estimates, we also used a Linear Probability Model (LPM) and the conclusions remain unchanged. Results are available from authors.

[10]Table B4 in Appendix B shows climate variables by zone.

[11]See Table B1 in Appendix B. We also investigated differences across urban and rural households. Even with the dispersion in the location of urban and rural households, one can still see differences across these two areas. See Tables B2 and B3 in Appendix B. The rural areas appear to experience warmer temperatures compared to urban areas. On average, urban households experience more precipitation.

Figure 1: Maps of Temperature and Precipitation



Note: Temperature$_{t-1}$ and precipitation$_{t-3}$ used in the analysis are shown for each wave.

waves, respectively.[12] We note a decline in the rate of stunting between the first and second wave but a deterioration between the second and third wave. Although the prevalence of underweight children in the sample is less than stunting, the pattern is similar. It is important

[12]See Table B6 in Appendix B.

to note that the decline in the prevalence of stunting and underweight could be partly data-driven. The analysis relies on children under the age of 5 that stayed in our sample for two consecutive waves, which might underestimate the prevalence of stunting and underweight in the second wave. Although our identification strategy could underestimate the prevalence of child malnutrition, we note that the full sample of children under 5 follows a similar pattern in prevalence of stunting and underweight with 39%, 19.3%, and 33.9% and 27.1%, 10.5%, and 18.2%, respectively. The fall in the prevalence of stunting and underweight in wave 2 appears to be due to an increase in the sample in the same wave, but the total number of stunted and underweight children remained almost unchanged.

Nigeria has made some progress reducing child malnutrition over the last decades (Nwosu & Ataguba, 2020). However, stunting prevalence is increasing in some parts of Nigeria; for instance, in North West, stunting in children aged 24–59 months increased from 52.6% in 2008 to 54.9% in 2013 to 56.9% in 2018 (Ezeh et al., 2021). It is worth mentioning that the decrease in the prevalence of malnutrition in the second wave coincides with colder temperatures and more precipitation in 2012/2013 (survey year of the second wave) and the year preceding it. Overall, malnutrition of children improves in our sample, but the persistent nature of stunting is alarming.

3 Empirical Results

We present the results in three stages. First, we present the effects of temperature on stunting and underweight for all children under 5 years of age. Second, we discuss the effects of precipitation on stunting and underweight. Lastly, for robustness measures, we present the results for the interaction effect of temperature and precipitation on child nutrition. For brevity, we present and discuss the marginal effects at the means of the standard logit estimation, in Tables 2, 3, and 4 for temperature, precipitation, and their interaction, respectively.[13] To measure the difference in impact on rural and urban areas, the marginal effects at the means by these areas of residence, are calculated as well.

3.1 Temperature

Table 2 displays the marginal effects of the average monthly maximum lagged temperature on child malnutrition, with stunting in Panel A and underweight in Panel C. [14] The first column only includes temperature$_{t-1}$ and CRE techniques. Then columns 2-7 gradually add additional regional and location controls as well as household demographics.[15] In Panels A and C of Table 2, temperature has a positive effect on both stunting and underweight outcomes in children

[13] The full tables are found in Appendix C Tables C1 and C2 for stunting and underweight, respectively. The increasing or decreasing effect can be discerned from the coefficient signs, but the marginal effects are more informative, the marginal effects are at the mean values of all the control variables. Calculations of the average marginal effects lead to similar results.

[14] Tables C1 and C2 in Appendix C present the full logit results on stunting and underweight for all children under 5 years of age.

[15] Controlling for the education level of the household head does not have a significant impact on the coefficients or marginal effects. Therefore, we only display the marginal effects of the first six columns of the full regression tables found in Appendix C.

and the results are robust to adding household demographics and regional characteristics.[16]

In Panel A, a one-unit ($°C$) increase in temperature$_{t-1}$ will increase the probability of a child suffering from stunting by between 16.1% and 23.2%. Increases in temperature over Nigeria has been approximately 0.3$°C$ per decade from 1981 - 2021 (NOAA National Centers for Environmental Information, 2021). This is an average change of 0.03$°C$ per year. Focusing on Column 7, this amounts to an increase in the probability of a child suffering from stunting by approximately 0.642% per year.[17] This positive correlation implies that the increase in temperature has a detrimental effect on human capital accumulation in Nigeria. Of policy concern, low human development of children that can be manifested in the form of stunting at an early age can result in a poverty trap when remediation of child stunting is partly or mostly irreversible (Barrett et al., 2016; Beegle & Christiaensen, 2019).

Focusing on Panel C in Table 2, the probability of a child being underweight increases by between 8% and 15.7% with a a one unit ($°C$) increase in temperature$_{t-1}$. Once again, with an average change of 0.03$°C$ per year, the probability of a child being underweight increases by 0.471% per year, from Column 7. Although this effect is smaller in magnitude than stunting, underweight children are less productive and have higher mortality rates.

Following the same argument as above, from Panel B Column 6 the probability of a child being stunted increases by 0.528% and 0.678% per year in urban and rural areas, respectively. The probability of a child being underweight increases by 0.396% and 0.498% in urban and rural areas, respectively.[18] From these results, it is clear that children in rural areas are more susceptible to higher temperatures. In column 7, for a one-unit change in temperature$_{t-1}$, the effect on stunting in rural areas is approximately 5 percentage points higher than in urban areas. For underweight, this difference decreases to 3.4 percentage points.

[16]Movement of households across areas (internal migration) may affect the results. However, in our sample, only 72 children (88 observations) had different GPS coordinates across waves which indicates that there is little internal migration in the data.

[17]0.03 is 3 hundredths of 1$°C$. Therefore, 3 hundredths of 21.4% is 0.642%. Over a decade, the probability of a child suffering from stunting increases by 6.42%.

[18]These marginal effects are calculated over the means of households in urban and rural areas.

Table 2: Marginal Effects - Temperature$_{t-1}$

Panel A: Stunting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($^{\circ}C$)	0.041	0.025	0.047	0.185***	0.179***	0.190***	0.214***
	(0.043)	(0.043)	(0.043)	(0.053)	(0.054)	(0.053)	(0.059)
Observations	3511	3511	3511	3212	3212	3212	2662

Panel B: Marginal Effect of Temperature$_{t-1}$ ($^{\circ}C$) on Stunting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban	0.040	0.024	0.040	0.165***	0.162***	0.158***	0.176***
	(0.042)	(0.042)	(0.037)	(0.048)	(0.049)	(0.051)	(0.049)
Rural	0.042	0.025	0.049	0.191***	0.185***	0.200***	0.226***
	(0.043)	(0.043)	(0.045)	(0.055)	(0.055)	(0.056)	(0.062)
Observations	3511	3511	3511	3212	3212	3212	2662

Panel C: Underweight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$	0.080**	0.054	0.081**	0.140***	0.128***	0.141***	0.157***
	(0.034)	(0.034)	(0.034)	(0.039)	(0.040)	(0.039)	(0.044)
Observations	3886	3886	3886	3565	3565	3565	2936

Panel D: Marginal Effect of Temperature$_{t-1}$ ($^{\circ}C$) on Underweight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban	0.077**	0.053	0.068**	0.118***	0.115***	0.115***	0.132***
	(0.032)	(0.033)	(0.029)	(0.034)	(0.036)	(0.033)	(0.038)
Rural	0.081**	0.054	0.085**	0.147***	0.132***	0.150***	0.166***
	(0.034)	(0.034)	(0.036)	(0.041)	(0.041)	(0.042)	(0.046)
Observations	3886	3886	3886	3565	3565	3565	2936
Geographical Information	No	No	No	Yes	Yes	Yes	Yes
Family Characteristics	No	No	No	Yes	Yes	Yes	Yes
Child Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Wealth	No	No	No	Yes	Yes	Yes	Yes
Agriculture Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Assistance	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Controls	No	Yes	No	No	Yes	No	No
Urban/Rural Controls	No	No	Yes	No	No	Yes	Yes
Survey Year Indicator	Yes	Yes	Yes	Yes	Yes	Yes	Yes

We calculate the average marginal effect and use the delta-method for standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. Controls for geographical information include the following: (1) distance to the closest freshwater source (km); (2) distance to the closest (km) market; (3) distance to closest city (km); and (4) whether there is a market in the community or not. Family characteristics include: (1) size of household; (2) number of meals to children; (3) number of times adults restrict meals so children can eat; (4) number of production shocks; (5) number of market shocks; (6) gender of household head; (7) whether a household has access to electricity; and (8) whether a household has a non-farm enterprise. Controls for child characteristics include: (1) their age (in months) and (2) the gender of the child. Household wealth controls include: (1) log of education expenditure; (2) an asset index; and (3) log of household consumption per capita. Controls for agriculture characteristics include: (1) tropical livestock units; (2) log of aggregate plot size; (3) soil workability (mean); and (4) soil nutrient availability (mean). Controls for household assistance include the following: (1) borrowing from a microfinance institute/credit association/bank; (2) borrow from friends/relatives/money lenders; (3) borrow food, or rely on friend/relative; (4) government assistance (food/ cash/otherwise); and (5) agri-extension services (government or private). Additional dummy variables include regional (Regions), urban (Sector), and survey wave (Year FE) indicator variables.

3.2 Precipitation

Table 3 reports the marginal effects of precipitation$_{t-3}$ on malnutrition with Panel A displaying stunting and Panel C underweight. The marginal effects are relatively small compared to the results in Table 2. Table 3 Column 1 presents the regression result with only precipitation$_{t-3}$ and the relative CRE techniques while Columns 2-7 add additional regional, location, and household demographics controls.[19] The results indicate that increasing precipitation$_{t-3}$ has a positive effect on child stunting and decreases the probability of a child suffering from stunting. This effect remains robust to the different model specifications. Table 3 Panel C shows that the impact of changing precipitation$_{t-3}$ is not significant on predicting underweight children.

From Panel A in Table 3, results indicate that a one-unit ($1mm$) decrease in the precipitation$_{t-3}$, increases the probability of children suffering from stunting by between 0.3% and 0.4%. According to World Bank (2020), average precipitation per year has decreased significantly in Nigeria by approximately $3.5mm$ per month per decade between 1960-2006. This is a decrease in precipitation of $0.35mm$ per year. Therefore, focusing on Column 7, a decrease in precipitation$_{t-3}$ of $0.35mm$ will increase the probability of a child suffering from stunting by 0.105% per year.[20]

Our findings support the notion that precipitation has an indirect effect on child nutrition and corroborate with the empirical evidence documented by Skoufias and Vinha (2012). As noted by Phalkey et al. (2015b), the effect of precipitation works through many demographic and economic variables. The indirect effect of precipitation implies that changing patterns of rain, drizzle, or any other forms of precipitation take time to affect the nutritional status of children. More specifically, water availability from dams or nearby water sources causes the impact of dry seasons to take time to influence crop production and food security.

Regardless of the small magnitude, we again note heterogeneous effects between urban and rural areas (Panel B of Table 3). Rural areas are affected more severely than urban areas; a one-unit (mm) decrease in precipitation$_{t-3}$ leads to an increase in the probability of child stunting by 0.3% and 0.4% in urban and rural areas, respectively, when focusing on Column 7. More relevant, a decrease in precipitation$_{t-3}$ of $0.35mm$ will increase the probability of a child suffering from stunting by 0.105% in urban areas and 0.14% in rural areas per year.

[19]Tables C1 and C2 in Appendix C present the full logit results for precipitation$_{t-3}$ on stunting and underweight for all children under 5 years of age. The results for precipitation$_{t-1}$ is available on request and provides support for the results found by Skoufias and Vinha (2012) and mentioned in Phalkey et al. (2015a). Comparison of the results of precipitation$_{t-1}$ and precipitation$_{t-3}$ support research that precipitation has an indirect effect on child nutrition.

[20]0.35 hundredths of 0.3% is 0.105%. Furthermore, over a decade, a decrease in precipitation$_{t-3}$ of $3.5mm$ will increase the probability of a child suffering from stunting by 1.05%.

Table 3: Marginal Effects - Precipitation$_{t-3}$

Panel A: Stunting							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Precipitation$_{t-3}$ (mm)	-0.002*	-0.002*	-0.003*	-0.003**	-0.003**	-0.004**	-0.003*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	3511	3511	3511	3212	3212	3212	2662

Panel B: Marginal Effect of Precipitation$_{t-3}$ (mm) on Stunting							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban	-0.002*	-0.002*	-0.002*	-0.003**	-0.003**	-0.003*	-0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Rural	-0.002*	-0.002*	-0.003*	-0.004**	-0.004**	-0.004**	-0.003*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	3511	3511	3511	3212	3212	3212	2662

Panel C: Underweight							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Precipitation$_{t-3}$ (mm)	0.001	0.001	0.001	0.000	0.000	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	3886	3886	3886	3565	3565	3565	2936

Panel D: Marginal Effect of Precipitation$_{t-3}$ (mm) on Underweight							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban	0.001	0.001	0.001	0.000	0.000	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Rural	0.001	0.001	0.001	0.000	0.000	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	3886	3886	3886	3565	3565	3565	2936
Geographical Information	No	No	No	Yes	Yes	Yes	Yes
Family Characteristics	No	No	No	Yes	Yes	Yes	Yes
Child Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Wealth	No	No	No	Yes	Yes	Yes	Yes
Agriculture Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Assistance	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Controls	No	Yes	No	No	Yes	No	No
Urban/Rural Controls	No	No	Yes	No	No	Yes	Yes
Survey Year Indicator	Yes	Yes	Yes	Yes	Yes	Yes	Yes

We calculate the average marginal effect and use the delta-method for standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. Controls for geographical information include the following: (1) distance to the closest freshwater source (km); (2) distance to the closest (km) market; (3) distance to closest city (km); and (4) whether there is a market in the community or not. Family characteristics include: (1) size of household; (2) number of meals to children; (3) number of times adults restrict meals so children can eat; (4) number of production shocks; (5) number of market shocks; (6) gender of household head; (7) whether a household has access to electricity; and (8) whether a household has a non-farm enterprise. Controls for child characteristics include: (1) their age (in months) and (2) the gender of the child. Household wealth controls include: (1) log of education expenditure; (2) an asset index; and (3) log of household consumption per capita. Controls for agriculture characteristics include: (1) tropical livestock units; (2) log of aggregate plot size; (3) soil workability (mean); and (4) soil nutrient availability (mean). Controls for household assistance include the following: (1) borrowing from a microfinance institute/credit association/bank; (2) borrow from friends/relatives/money lenders; (3) borrow food, or rely on friend/relative; (4) government assistance (food/ cash/otherwise); and (5) agri-extension services (government or private). Additional dummy variables include regional (Regions), urban (Sector), and survey wave (Year FE) indicator variables.

3.3 Climate

It is noted in the literature that temperature and precipitation work in tandem to influence child nutrition (Davenport et al., 2017; Grace et al., 2012). For robustness, we estimate

$$\begin{aligned} m_{it}^{s,w,u} &= \alpha + \delta_3 Temperature_{t-1} + \delta_4 Precipitation_{t-3} \\ &+ \theta(Temperature_{t-1} \times Precipitation_{t-3}) + \beta X_{it} + \gamma \bar{X}_i + r_i + \varepsilon_{it} \end{aligned} \tag{3}$$

where we have interacted temperature$_{t-1}$ and precipitation$_{t-3}$.[21] Table 4 presents the marginal effects of the interaction model and it is clear from all of the different panels that the effect of temperature$_{t-1}$ dominates in the case of stunting and underweight.[22]

The precipitation$_{t-3}$ does not significantly affect the probability of a child being stunted or underweight in this model specification. However, these two variables work in tandem as higher temperatures, as well as less precipitation, increases the probability of children being stunted or underweight.

Comparing this combined effect with temperature alone, the marginal effects of temperature on underweight are larger by roughly 3% and the marginal effects on stunting have fallen by roughly 3%. From Panel A and C in Table 4, we get that a one-unit ($°C$) increase in temperature increases the probability of a child being stunted by 17.7% and being underweight by 18.9%. Following the same logic as in Section 3.1, with an average change of $0.03°C$ in temperature$_{t-1}$ per year, the probability of a child suffering from stunting increases by 0.531% per year and the probability of a child being underweight increases by 0.567% per year, from Column 7. We do not find any significance of precipitation$_{t-3}$ on stunting but we do find a small positive effect on underweight that is marginally significant depending on control variables included in the regression.

As documented in the earlier analysis, where we investigate the separate effect of temperature and precipitation, there still exists a difference between the impact in rural and urban areas. Children in rural areas are more susceptible to increases in temperatures as the probability that these children are either stunted or underweight is approximately, on average, 4-5 percentage points higher with a one-unit ($°C$) increase in temperature$_{t-1}$ than those children in urban areas. More relevant and focusing on Column 7, a $0.03°C$ increase in temperature$_{t-1}$, increases the probability of a child suffering from stunting by 0.429% per year in urban areas and by 0.564% in rural areas. For underweight, these probabilities are 0.474% and 0.597% per year, respectively.

[21] In the case of including the interaction between temperature$_{t-1}$ and precipitation$_{t-1}$, the results for stunting remain similar. That is, the lagged temperature still dominates the effect of children suffering from stunting. Notwithstanding, the impact on children suffering from underweight is different when looking solely at the regression tables. The precipitation$_{t-1}$ is negative and significant, while temperature$_{t-1}$ is positive but insignificant. The picture changes, though, when looking at the marginal effects at the means. Then once again, an increase in temperature$_{t-1}$ leads to a significant change in the probability of a child being underweight. A change in precipitation$_{t-1}$ does not significantly affect the probability that a child suffers from being underweight.

[22] Tables C5 and C6 in Appendix C present the full logit results for the model specified in Equation 3 on stunting and underweight for all children under 5 years of age.

Table 4: Marginal Effect - Climate Variables

Panel A: Stunted							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($°C$)	-0.014	-0.022	-0.010	0.144**	0.138**	0.149**	0.177***
	(0.047)	(0.047)	(0.047)	(0.059)	(0.059)	(0.059)	(0.065)
Precipitation$_{t-3}$ (mm)	-0.003*	-0.003*	-0.003*	-0.002	-0.002	-0.002	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	3511	3511	3511	3212	3212	3212	2662
Panel B: Marginal Effects of Climate Variables on Stunting							
Urban (Temperature$_{t-1}$ ($°C$)	-0.015	-0.023	-0.010	0.128**	0.122**	0.123**	0.143***
	(0.046)	(0.046)	(0.041)	(0.053)	(0.053)	(0.049)	(0.053)
Rural (Temperature$_{t-1}$ ($°C$)	-0.013	-0.021	-0.010	0.150**	0.144**	0.158**	0.188***
	(0.047)	(0.048)	(0.049)	(0.061)	(0.061)	(0.062)	(0.069)
Urban (Precipitation$_{t-3}$ (mm)	-0.002	-0.002	-0.002*	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
Rural (Precipitation$_{t-3}$ (mm)	-0.003*	-0.003*	-0.003*	-0.002	-0.002	-0.002	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	3511	3511	3511	3212	3212	3212	2662
Panel C: Underweight							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($°C$)	0.096**	0.086**	0.098***	0.166***	0.161***	0.169***	0.189***
	(0.038)	(0.038)	(0.038)	(0.045)	(0.045)	(0.045)	(0.049)
Precipitation$_{t-3}$ (mm)	0.002*	0.002	0.002*	0.002*	0.002	0.002*	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	3886	3886	3886	3565	3565	3565	2936
Panel D: Marginal Effects of Climate Variables on Underweight							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban (Temperature$_{t-1}$ ($°C$)	0.093**	0.086**	0.083***	0.145***	0.146***	0.138***	0.158***
	(0.036)	(0.038)	(0.032)	(0.039)	(0.041)	(0.037)	(0.042)
Rural (Temperature$_{t-1}$ ($°C$)	0.097**	0.086**	0.103***	0.173***	0.167***	0.179***	0.199***
	(0.038)	(0.038)	(0.040)	(0.046)	(0.046)	(0.047)	(0.052)
Urban (Precipitation$_{t-3}$ (mm)	0.002*	0.002	0.002*	0.002*	0.002	0.002*	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Rural (Precipitation$_{t-3}$ (mm)	0.002*	0.002	0.002*	0.002*	0.002*	0.002*	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Observations	3886	3886	3886	3565	3565	3565	2936
Geographical Information	No	No	No	Yes	Yes	Yes	Yes
Family Characteristics	No	No	No	Yes	Yes	Yes	Yes
Child Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Wealth	No	No	No	Yes	Yes	Yes	Yes
Agriculture Characteristics	No	No	No	Yes	Yes	Yes	Yes
Household Assistance	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Controls	No	Yes	No	No	Yes	No	No
Urban/Rural Controls	No	No	Yes	No	No	Yes	Yes
Survey Year Indicator	Yes	Yes	Yes	Yes	Yes	Yes	Yes

We calculate the average marginal effect and use the delta-method for standard errors in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. Controls for geographical information include the following: (1) distance to the closest freshwater source (km); (2) distance to the closest (km) market; (3) distance to closest city (km); and (4) whether there is a market in the community or not. Family characteristics include: (1) size of household; (2) number of meals to children; (3) number of times adults restrict meals so children can eat; (4) number of production shocks; (5) number of market shocks; (6) gender of household head; (7) whether a household has access to electricity; and (8) whether a household has a non-farm enterprise. Controls for child characteristics include: (1) their age (in months) and (2) the gender of the child. Household wealth controls include: (1) log of education expenditure; (2) an asset index; and (3) log of household consumption per capita. Controls for agriculture characteristics include: (1) tropical livestock units; (2) log of aggregate plot size; (3) soil workability (mean); and (4) soil nutrient availability (mean). Controls for household assistance include the following: (1) borrowing from a microfinance institute/credit association/bank; (2) borrow from friends/relatives/money lenders; (3) borrow food, or rely on friend/relative; (4) government assistance (food/ cash/otherwise); and (5) agri-extension services (government or private). Additional dummy variables include regional (Regions), urban (Sector), and survey wave (Year FE) indicator variables.

4 Discussion and Policy Implications

Over the past decades, several positive steps have been taken to reduce childhood malnutrition. Ensuring food and nutrition security in rural Nigeria is an important policy goal since households are vulnerable to food shortages, unbalanced diets, poor quality of food, and insufficient amounts of food (Akinyele, 2009). From the turn of the millennium, several programs and policies have effectively reduced the prevalence of stunting and underweight in children in the country. Some of these programs include the Food and Nutrition Policy (FNPN), the National Plan of Action for Food and Nutrition, Accelerated Child Survival and Development, The Agriculture Nutrition Advantage (TANA) (Awoyemi et al., 2012). These community and country-level programs and policies were introduced to combat the malnutrition levels in Nigeria. Furthermore, they are in place to mitigate risk, address the causes of malnutrition, achieve zero hunger, and contribute to sustainable national food security.

The results set out in Section 3 highlight the potential dangers of climate change that can overturn decades of progress made to reduce child malnutrition in Nigeria. As climate change models project increasing temperature and decrease in precipitation in Nigeria, child malnutrition could worsen in the absence of interventions that reduce the effect of climate change through multiple pathways, especially in rural areas. As a result, children in rural areas are more likely to suffer from climate-changing conditions, which will lead to a decrease in their ability to improve their living standards as adults since malnutrition and low human capital accumulation can lead to a vicious cycle of the human development trap (Hoddinott et al., 2013; Yitbarek & Beegle, 2019).

From a policy perspective, results point out the demand for climate-friendly policies that can avert the effect of climate change on malnutrition among children. Improvements of public infrastructure (Bassolé et al., 2007), access to electricity (Davenport et al., 2017), as well as improved educational and social institutions (Grace et al., 2012) are some mechanisms shown to be effective against climate change and thus improve population health. For countries like Nigeria, where most of the population depends on subsistence agriculture, promoting climate-smart agricultural practice can reduce child malnutrition and increase human capital accumulation (Tesfaye & Tirivayi, 2018, 2020).

5 Conclusion

Achieving the goal of all children being free of malnutrition (UNICEF et al., 2020) and the sustainable development goal of zero hunger is difficult given the range of factors that influence child nutrition. In this paper, we provide empirical evidence showing a need to address climate change.

We use the LSMS-ISA panel data to investigate the effect of actual changes in temperature and precipitation patterns on children's malnutrition. The study provides a shred of empirical evidence that an increase in the monthly average maximum temperature increases the probability of stunting and underweight in Nigeria. In contrast, an increase in the average monthly precipitation decreases the probability of a child being malnourished. The study also illustrates that an increase in temperature has a more immediate and direct impact on the prevalence of stunting and underweight than changes in precipitation. Changes in precipitation mainly occur through indirect effects. This can be due to the rich water sources in Nigeria. Lastly, the effects of climate change are more pronounced in rural areas than in urban areas.

Overall, results indicate that leaps and bounds made to combat malnutrition can be lost if the effects of changing temperature and precipitation are not addressed. The first step to mitigating the effect of climate change on the malnutrition rate in children is to ensure that child-orientated policies are in place (Lawler & Patel, 2012). These policies will set the course for children in many years to come. Such policies will also improve the response to climate change and ensure a sustainable future for the next generations.

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A Technical Appendix

A.1 Climate Data

Temperature and precipitation data are from the Climatic Research Unit (CRU-TS-4.03), University of East Anglia (Harris et al., 2014).[23] This version is a gridded time-series dataset that covers the period 1960-2018. The spatial resolution is 2.5 minutes which is roughly $21km^2$. The variables available are average near-surface minimum temperature ($°C$), average near-surface maximum temperature ($°C$) and total precipitation (mm). For this paper, we focus on the effects that changes in the average monthly maximum near-surface temperature ($°C$) and the average monthly total precipitation (mm) has on child nutrition.

A.2 Agriculture and Geographical Factors

Soil quality data is from the Harmonized World Soil Database version 1.2. This dataset is a 30 arc-second (about $1km^2$) raster database with over 15 000 different soil mapping units that combine existing regional and national updates of soil information worldwide with the information contained within the 1 : 5000000 scale FAO-UNESCO Soil Map of the World (Fischer et al., 2008). The variables used to measure the soil quality is the "Nutrient availability", "Nutrient retention capacity", "Rooting conditions", "Oxygen availability to roots", "Excess salts", "Toxicity", and "Workability (constraining field management)" of the soil. These vary on a scale from 0-7 where 0 - Ocean, 1 - No or slight limitations, 2 - Moderate limitations, 3 - Severe limitations, 4 - Very severe limitations, 5 - Mainly non-soil, 6 - Permafrost area, and 7 - Waterbodies.

The first source of freshwater data is from the Global Lakes and Wetlands Database (Lehner & Döll, 2004). This database draws on a variety of existing data to create a global scale of large lakes, reservoirs, waterbodies, and wetlands. This paper utilizes freshwater in the form of lakes, reservoirs, rivers, freshwater marshes, floodplains, and intermittent wetlands or lakes. A second source used for freshwater data is AQUAMAPS. AQUAMAPS is a global spatial database on water and agriculture which is produced by the Food and Agriculture Organization of the United Nations (FOA). From this database, freshwater sources include water bodies, rivers, and dams in Africa (FAO, 2019a).

A.3 Combining the Demographic and Climate Data

The households in the LSMS-ISA dataset have GPS references which are offset by two kilometres in urban areas, five kilometres in rural areas and in extreme rural cases (1%) are offset by ten kilometres. We used the households' GPS references to create a five-kilometre buffer around each of these points. This buffer allows us to assume, with relative certainty, that the specific household point is in that buffer zone without the zone being too big. We then used these five-kilometre buffer and georeferencing techniques to merge the climate data in this buffer with each specific household.

[23] The downscaled version that corrects for bias, which is produced by WorldClim (Fick & Hijmans, 2017), is used.

Merging these two data sets at the relevant spatial and temporal scales is crucial to ensure a thorough analysis of household health and climate changes (Grace et al., 2012). Very few studies adopt this approach and, by utilizing this approach, this paper contributes to the literature. Furthermore, this method of combination ensures we capture the individual-level effects across our panel data and ensures consistency throughout.

Given that the spatial resolution of the climate data is $21km^2$, households are combined with their GPS locations to the specific climate conditions ascribed by the resolution. Since the maximum distance a household is offset by is ten kilometres, we can assign these households climate conditions with relative confidence that those will be the climate conditions the household experience. Although households close to each other can experience different climate conditions, this barely happens and depends on the breakdown of the grid that contains the climate data.

A.4 Control Variables

Controls for geographical information include the following: (1) distance to the closest freshwater source (km); (2) distance to the closest (km) market; (3) distance to closest city (km) - with a population of twenty thousand or more people; and (4) whether there is a market in the community or not. Access to freshwater, markets, and cities are shown to be determinants of child malnutrition. The expectation is that access to these sources reduces malnutrition rates.

Controls for family characteristics include the following: (1) number of people in the household; (2) number of meals to children; (3) number of times adults restrict meals so children can eat; (4) number of production shocks; (5) number of market shocks; (6) gender of household head; (7) whether a household has access to electricity; and (8) whether a household has a non-farm enterprise. Columns 7-9 also controls for the household head's education. Given the importance of the parent's education, we expect the household head to influence the level of malnutrition of the children due to the prominent role of the household head. The education level is in four categories: no education, completed primary education, completed secondary education, and completed tertiary or higher education. Since the expectation is that mothers are more nurturing than their male counterparts, there is a control for the gender of the household head. Furthermore, electricity can be a proxy for different social infrastructures and is important to control for.

Controls for child characteristics include (1) their age (in months); and (2) the gender of the child. Household wealth controls include: (1) log of education expenditure; (2) an asset index; and (3) log of household consumption per capita. A household's asset index compromise of whether they have a bicycle, motorcycle, car/other vehicles (vans), tractor, computer, telephone, cellular, radio, television, refrigerator, and stove. Therefore, this asset index ranges from zero to eleven, where eleven indicates a household that owns all of the assets. A control for education expenditure is necessary, as the literature expect more education reduces the chance of malnutrition.

Controls for agriculture characteristics include the following: (1) tropical livestock units; (2)

log of aggregate plot size; (3) soil workability (mean); and (4) soil nutrient availability (mean). The livestock of households determines the tropical livestock unit for each household (Otte & Chilonda, 2002). Calculations of this unit of measurement are for the beginning of the period (post-planting stage), and the end of the year (post-harvesting stage). Due to the correlation, we only use the TLU at the end of the survey period. Since the plot size of a household influences agriculture production, a control for the aggregate plot size of each household is necessary. We use the log form of plot size and assign a value of zero ($log(1)$) to those households who do not have a plot.

Furthermore, agriculture productivity depends on soil quality. Hence, it is beneficial to control for the mean of soil workability and nutrient availability of the soil. Each household has a five-kilometre buffer while the soil quality is approximately on a $1km^2$ grid. Therefore, the mean of these indications of soil quality in the five-kilometre buffer is the closest approximation to the household's actual level of soil quality. A high mean value of these soil quality indicators implies better soil quality, as previously discussed.

Controls for household assistance include the following: (1) borrowing from a microfinance institute/credit association/bank; (2) borrow from friends/relatives/money lenders; (3) borrow food, or rely on friend/relative; (4) government assistance (food/ cash/otherwise); and (5) agri-extension services (government or private). The financial status or assistance a household receive can influence the nutritional status of children.

Lastly, the columns alternate between no regional or sectoral dummies, regional dummies, and sectoral dummies. The use of dummies for the regions of Nigeria controls for regional fixed effects. The motivation being the dispersion seen in Figure B1. These regions are North-Central, North-West, North-East, South-South, South-East, and South-West. The sectoral dummy consists of whether the household is classified as urban or rural. Since we investigate the effects of climate change across these areas, it is important to account for different urban and rural fixed effects.

B Descriptive Statistics

This section present the descriptive statistics for the sample.

Table B1: Temperature and Precipitation Across Waves

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	1528 (30.5)	2391 (47.8)	1088 (21.7)
{Temperature}			
Temperature$_t$ ($°C$), mean (sd)	32.78 (1.80)	32.67 (1.76)	32.65 (1.59)
Temperature$_{t-1}$ ($°C$), mean (sd)	33.20 (1.97)	32.59 (1.73)	32.76 (1.65)
Temperature$_{t-2}$ ($°C$), mean (sd)	32.90 (1.93)	32.79 (1.76)	32.84 (1.64)
Temperature$_{t-3}$ ($°C$), mean (sd)	32.40 (1.71)	33.22 (1.94)	32.71 (1.73)
Temperature$_{t-5}$ ($°C$), mean (sd)	32.97 (1.90)	32.79 (1.76)	32.82 (1.73)
Three Year Average Monthly Maximum Temperature (°C), mean (sd)	32.96 (1.90)	32.68 (1.75)	32.75 (1.63)
Five Year Average Monthly Maximum Temperature (°C), mean (sd)	32.74 (1.81)	32.84 (1.81)	32.72 (1.66)
Average Temperature in the Wettest Quarter (°C), mean (sd)	25.23 (1.09)	25.22 (1.08)	25.20 (1.11)
{Precipitation}			
Precipitation$_t$ (mm), mean (sd)	113.61 (52.50)	110.54 (45.73)	107.91 (45.60)
Precipitation$_{t-1}$ (mm), mean (sd)	110.50 (48.70)	110.18 (52.67)	101.21 (50.52)
Precipitation$_{t-2}$ (mm), mean (sd)	117.55 (53.93)	112.39 (51.18)	99.01 (47.32)
Precipitation$_{t-3}$ (mm), mean (sd)	112.19 (51.02)	109.32 (47.94)	106.83 (43.13)
Precipitation$_{t-5}$ (mm), mean (sd)	107.32 (51.10)	110.73 (50.23)	108.38 (47.51)
Three Year Average Monthly Precipitation (mm), mean (sd)	113.89 (51.46)	111.04 (49.65)	102.71 (47.37)
Five Year Average Monthly Precipitation (mm), mean (sd)	113.95 (51.64)	111.70 (49.81)	104.20 (46.77)
Monthly Precipitation in the Wettest Quarter (mm), mean (sd)	234.00 (65.09)	232.07 (63.71)	227.18 (59.49)
Monthly Rainfall in the Wettest Quarter (mm), mean (sd)	217.61 (49.03)	215.01 (45.80)	206.11 (42.62)

Average temperature in the wettest quarter, monthly precipitation in the wettest quarter, and monthly rainfall in the wettest quarter are taken from the LSMS-ISA dataset. Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B2: Temperature and Precipitation Across Waves in Urban Areas

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	411 (31.4)	634 (48.4)	264 (20.2)
{Temperature}			
Temperature$_t$ ($°C$), mean (sd)	32.40 (1.77)	32.30 (1.71)	32.31 (1.52)
Temperature$_{t-1}$ ($°C$), mean (sd)	32.74 (1.94)	32.22 (1.68)	32.42 (1.59)
Temperature$_{t-2}$ ($°C$), mean (sd)	32.45 (1.91)	32.42 (1.71)	32.51 (1.57)
Temperature$_{t-3}$ ($°C$), mean (sd)	32.04 (1.69)	32.76 (1.89)	32.31 (1.68)
Temperature$_{t-5}$ ($°C$), mean (sd)	32.52 (1.88)	32.42 (1.71)	32.42 (1.68)
Three Year Average Monthly Maximum Temperature (°C), mean (sd)	32.53 (1.87)	32.31 (1.70)	32.41 (1.56)
Five Year Average Monthly Maximum Temperature (°C), mean (sd)	32.35 (1.79)	32.43 (1.77)	32.35 (1.60)
Average Temperature in the Wettest Quarter (°C), mean (sd)	25.19 (1.10)	25.20 (1.09)	25.14 (1.10)
{Precipitation}			
Precipitation$_t$ (mm), mean (sd)	123.97 (52.65)	117.96 (45.49)	111.48 (45.82)
Precipitation$_{t-1}$ (mm), mean (sd)	116.68 (47.13)	118.10 (52.19)	114.25 (49.94)
Precipitation$_{t-2}$ (mm), mean (sd)	128.37 (54.04)	123.23 (51.45)	106.32 (47.31)
Precipitation$_{t-3}$ (mm), mean (sd)	124.29 (50.79)	116.54 (46.22)	115.51 (43.44)
Precipitation$_{t-5}$ (mm), mean (sd)	112.49 (49.95)	123.33 (50.03)	119.76 (48.24)
Three Year Average Monthly Precipitation (mm), mean (sd)	123.01 (51.00)	119.76 (49.51)	110.68 (47.16)
Five Year Average Monthly Precipitation (mm), mean (sd)	123.14 (51.02)	120.68 (49.36)	112.54 (46.71)
Monthly Precipitation in the Wettest Quarter (mm), mean (sd)	232.95 (67.64)	232.37 (65.77)	227.54 (62.60)
Monthly Rainfall in the Wettest Quarter (mm), mean (sd)	212.68 (44.40)	210.97 (39.39)	202.96 (35.24)

Average temperature in the wettest quarter, monthly precipitation in the wettest quarter, and monthly rainfall in the wettest quarter are taken from the LSMS-ISA dataset. Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B3: Temperature and Precipitation Across Waves in Rural Areas

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	1117 (30.2)	1757 (47.5)	824 (22.3)
{Temperature}			
Temperature$_t$ (°C), mean (sd)	32.92 (1.79)	32.80 (1.76)	32.76 (1.60)
Temperature$_{t-1}$ (°C), mean (sd)	33.37 (1.95)	32.73 (1.73)	32.87 (1.66)
Temperature$_{t-2}$ (°C), mean (sd)	33.07 (1.91)	32.92 (1.76)	32.95 (1.65)
Temperature$_{t-3}$ (°C), mean (sd)	32.53 (1.70)	33.38 (1.93)	32.83 (1.73)
Temperature$_{t-5}$ (°C), mean (sd)	33.13 (1.88)	32.92 (1.76)	32.95 (1.73)
Three Year Average Monthly Maximum Temperature (°C), mean (sd)	33.12 (1.88)	32.81 (1.75)	32.86 (1.63)
Five Year Average Monthly Maximum Temperature (°C), mean (sd)	32.89 (1.80)	32.98 (1.81)	32.83 (1.66)
Average Temperature in the Wettest Quarter (°C), mean (sd)	25.24 (1.09)	25.23 (1.08)	25.21 (1.11)
{Precipitation}			
Precipitation$_t$ (mm), mean (sd)	109.79 (51.95)	107.87 (45.53)	106.77 (45.50)
Precipitation$_{t-1}$ (mm), mean (sd)	108.23 (49.09)	107.32 (52.57)	97.04 (50.02)
Precipitation$_{t-2}$ (mm), mean (sd)	113.57 (53.36)	108.48 (50.53)	96.66 (47.11)
Precipitation$_{t-3}$ (mm), mean (sd)	107.74 (50.40)	106.72 (48.30)	104.05 (42.68)
Precipitation$_{t-5}$ (mm), mean (sd)	105.42 (51.41)	106.19 (49.53)	104.73 (46.72)
Three Year Average Monthly Precipitation (mm), mean (sd)	110.53 (51.25)	107.89 (49.34)	100.16 (47.19)
Five Year Average Monthly Precipitation (mm), mean (sd)	110.57 (51.48)	108.47 (49.59)	101.53 (46.50)
Monthly Precipitation in the Wettest Quarter (mm), mean (sd)	234.39 (64.15)	231.96 (62.97)	227.07 (58.49)
Monthly Rainfall in the Wettest Quarter (mm), mean (sd)	219.42 (50.53)	216.47 (47.83)	207.12 (44.70)

Average temperature in the wettest quarter, monthly precipitation in the wettest quarter, and monthly rainfall in the wettest quarter are taken from the LSMS-ISA dataset. Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B4: Temperature and Precipitation Across Zones

Columns by: zone	(1) North-Central	(2) North-East	(3) North-West	(4) South-East	(5) South-South	(6) South-West
n (%)	882 (17.6)	1134 (22.6)	1325 (26.5)	605 (12.1)	612 (12.2)	449 (9.0)
{Temperature}						
Temperature$_t$ (°C), mean (sd)	32.13 (1.46)	34.00 (1.37)	33.82 (1.44)	31.41 (0.67)	31.00 (0.46)	31.25 (0.83)
Temperature$_{t-1}$ (°C), mean (sd)	32.23 (1.48)	34.24 (1.44)	33.96 (1.49)	31.45 (0.68)	31.03 (0.47)	31.28 (0.84)
Temperature$_{t-2}$ (°C), mean (sd)	32.23 (1.46)	34.24 (1.41)	33.99 (1.45)	31.48 (0.67)	31.06 (0.45)	31.30 (0.81)
Temperature$_{t-3}$ (°C), mean (sd)	32.24 (1.50)	34.30 (1.47)	34.08 (1.51)	31.42 (0.69)	31.00 (0.48)	31.29 (0.86)
Temperature$_{t-5}$ (°C), mean (sd)	32.24 (1.47)	34.28 (1.39)	34.02 (1.46)	31.47 (0.67)	31.06 (0.45)	31.30 (0.82)
Three Year Average Monthly Maximum Temperature (°C), mean (sd)	32.20 (1.46)	34.16 (1.40)	33.92 (1.45)	31.44 (0.67)	31.03 (0.46)	31.28 (0.82)
Five Year Average Monthly Maximum Temperature (°C), mean (sd)	32.18 (1.46)	34.19 (1.38)	33.93 (1.44)	31.42 (0.67)	31.01 (0.45)	31.25 (0.82)
Average Temperature in the Wettest Quarter (°C), mean (sd)	24.88 (1.18)	25.27 (0.97)	25.46 (1.33)	25.13 (0.75)	25.21 (0.56)	25.16 (1.15)
{Precipitation}						
Precipitation$_t$ (mm), mean (sd)	106.35 (15.10)	79.56 (20.80)	75.21 (16.61)	158.53 (18.21)	198.32 (42.58)	121.08 (21.48)
Precipitation$_{t-1}$ (mm), mean (sd)	106.23 (16.63)	70.79 (18.77)	71.18 (19.84)	160.91 (19.40)	200.66 (44.21)	120.24 (16.71)
Precipitation$_{t-2}$ (mm), mean (sd)	105.45 (16.48)	72.60 (18.16)	74.74 (16.50)	162.24 (19.71)	205.90 (44.27)	128.17 (25.07)
Precipitation$_{t-3}$ (mm), mean (sd)	110.12 (13.78)	72.67 (19.17)	74.84 (18.58)	157.55 (16.87)	195.05 (40.80)	124.01 (19.84)
Precipitation$_{t-5}$ (mm), mean (sd)	106.66 (14.39)	71.05 (18.24)	72.84 (15.04)	159.77 (18.32)	199.83 (41.62)	125.98 (23.74)
Three Year Average Monthly Precipitation (mm), mean (sd)	106.01 (15.26)	74.31 (18.31)	73.71 (17.21)	160.56 (18.77)	201.62 (42.99)	123.16 (19.71)
Five Year Average Monthly Precipitation (mm), mean (sd)	107.57 (14.58)	74.54 (18.57)	74.20 (17.31)	160.90 (18.65)	202.11 (42.75)	124.33 (18.99)
Monthly Precipitation in the Wettest Quarter (mm), mean (sd)	223.79 (29.82)	196.13 (34.77)	201.16 (35.60)	281.30 (27.53)	344.35 (65.17)	205.59 (44.19)
Monthly Rainfall in the Wettest Quarter (mm), mean (sd)	210.65 (33.42)	190.87 (36.88)	190.41 (30.25)	262.24 (23.83)	275.12 (47.84)	198.83 (16.18)

Average temperature in the wettest quarter, monthly precipitation in the wettest quarter, and monthly rainfall in the wettest quarter are taken from the LSMS-ISA dataset. Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B5: Control Variables at Household Level

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	1528 (30.5)	2391 (47.8)	1088 (21.7)
{Varying Control Variables}			
Distance to Closest Water Source (km), mean (sd)	4.41 (2.99)	4.43 (3.04)	4.49 (3.07)
Distance to Closest Market(km), mean (sd)	69.81 (44.06)	70.45 (43.48)	72.32 (43.05)
Distance to Closest City (km), mean (sd)	22.93 (21.87)	19.45 (15.45)	27.55 (21.43)
Log of Education Expenditure, mean (sd)	4.83 (3.51)	5.24 (3.43)	6.18 (3.11)
Log of Consumption per Capita, mean (sd)	11.03 (0.68)	11.09 (0.62)	11.25 (0.63)
Number of People in Household, mean (sd)	7.35 (3.13)	7.86 (3.57)	8.26 (3.30)
Number of Children in HH (Less than 5 Years of age), mean (sd)	3.33 (1.18)	3.53 (1.04)	3.59 (2.19)
Number of Meals to Children, mean (sd)	3.58 (1.57)	3.71 (2.00)	3.50 (1.09)
Restricted Meals so Children can Eat, mean (sd)	0.45 (1.06)	0.50 (1.24)	0.42 (1.03)
Household Asset Index, mean (sd)	3.01 (1.84)	3.17 (1.74)	3.44 (1.55)
Number of different Production Shocks Reported, mean (sd)	0.14 (0.42)	0.15 (0.38)	0.10 (0.33)
Number of different Market Shocks Reported, mean (sd)	0.12 (0.44)	0.13 (0.41)	0.18 (0.46)
Log of Aggregate Plot Size, mean (sd)	8.58 (1.54)	8.66 (1.28)	8.69 (1.36)
Tropical Livestock Units as of the time of survey, mean (sd)	3.79 (54.24)	1.27 (5.84)	1.34 (4.80)
Soil Workability (constraining field management) (mean), mean (sd)	1.50 (0.68)	1.50 (0.70)	1.51 (0.72)
Soil Nutrient availability (mean), mean (sd)	1.82 (0.79)	1.80 (0.78)	1.77 (0.78)
{Binary Control Variables}			
Borrow Food, or Rely on Friend/Relative? (Yes), n (%)	181 (12.4)	192 (8.3)	105 (9.7)
Borrow from Microfinance/Credit Associations/Bank (Yes), n (%)	53 (3.5)	121 (5.1)	56 (5.2)
Borrow from Friends/Relatives/Money Lenders (Yes), n (%)	494 (32.4)	739 (31.2)	114 (10.5)
Borrow from Informal Institution (Yes), n (%)	284 (18.7)	431 (18.2)	33 (3.0)
Has Non-Farm Enterprise (Yes), n (%)	761 (49.8)	1461 (61.1)	666 (61.2)
Agri-extension (Government/Private Sector) (Yes), n (%)	77 (5.0)	62 (2.6)	33 (3.0)
Government Assistance (food/cash/otherwise) (Yes), n (%)	25 (1.6)	102 (4.3)	39 (3.6)
Does HH have Electricity in Dwelling? (Yes), n (%)	674 (44.2)	1122 (47.0)	483 (44.5)
Gender of Household Head, n (%)			
Female	65 (4.3)	102 (4.3)	62 (5.8)
Male	1462 (95.7)	2286 (95.7)	1013 (94.2)
sector, n (%)			
Urban	411 (26.9)	634 (26.5)	264 (24.3)
Rural	1117 (73.1)	1757 (73.5)	824 (75.7)
{Categorical Control Variables}			
Ordered Level of Household Head's Completed Education, n (%)			
None/Less than Primary	487 (37.9)	759 (39.1)	365 (42.3)
Primary School Complete	438 (34.1)	585 (30.1)	244 (28.3)
Secondary School Complete	294 (22.9)	467 (24.1)	205 (23.8)
University or Higher Education Complete	65 (5.1)	130 (6.7)	48 (5.6)
zone, n (%)			
North-Central	280 (18.3)	414 (17.3)	188 (17.3)
North-East	358 (23.4)	543 (22.7)	233 (21.4)
North-West	358 (23.4)	623 (26.1)	344 (31.6)
South-East	190 (12.4)	293 (12.3)	122 (11.2)
South-South	203 (13.3)	299 (12.5)	110 (10.1)
South-West	139 (9.1)	219 (9.2)	91 (8.4)

Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B6: Variables for Children in the Sample

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	1528 (30.5)	2391 (47.8)	1088 (21.7)
{Continuous Variables}			
Age in Months, mean (sd)	17.73 (11.12)	30.30 (18.24)	38.36 (18.71)
Weight (kg), mean (sd)	9.60 (7.03)	12.02 (4.83)	15.24 (3.60)
Length (cm), mean (sd)	68.23 (26.88)	84.67 (19.63)	97.60 (10.23)
Length/height-for-age Z-score, mean (sd)	-1.05 (2.71)	-0.63 (1.88)	-0.99 (2.00)
Weight-for-age Z-score, mean (sd)	-0.77 (2.20)	-0.48 (1.42)	-0.51 (1.44)
Weight-for-Height/Length Z-score (WHO), mean (sd)	0.05 (1.86)	-0.15 (1.39)	0.03 (1.47)
{Binary Variables}			
Gender, n (%)			
Female	715 (46.8)	1132 (47.3)	509 (46.8)
Male	813 (53.2)	1259 (52.7)	579 (53.2)
Is Child Stunted?, n (%)			
No	526 (62.3)	1453 (80.9)	606 (69.5)
Yes	318 (37.7)	343 (19.1)	266 (30.5)
Is Child Wasted?, n (%)			
No	789 (86.8)	1722 (91.0)	904 (92.9)
Yes	120 (13.2)	171 (9.0)	69 (7.1)
Is Child Underweight?, n (%)			
No	807 (72.7)	1696 (89.2)	776 (88.6)
Yes	303 (27.3)	205 (10.8)	100 (11.4)
Does HH have Electricity in Dwelling?, n (%)			
No	851 (55.8)	1267 (53.0)	603 (55.5)
Yes	674 (44.2)	1122 (47.0)	483 (44.5)
Gender of Household Head, n (%)			
Female	65 (4.3)	102 (4.3)	62 (5.8)
Male	1462 (95.7)	2286 (95.7)	1013 (94.2)
{Categorical Variables}			
Ordered Level of Household Head's Completed Education, n (%)			
None/Less than Primary	487 (37.9)	759 (39.1)	365 (42.3)
Primary School Complete	438 (34.1)	585 (30.1)	244 (28.3)
Secondary School Complete	294 (22.9)	467 (24.1)	205 (23.8)
University or Higher Education Complete	65 (5.1)	130 (6.7)	48 (5.6)

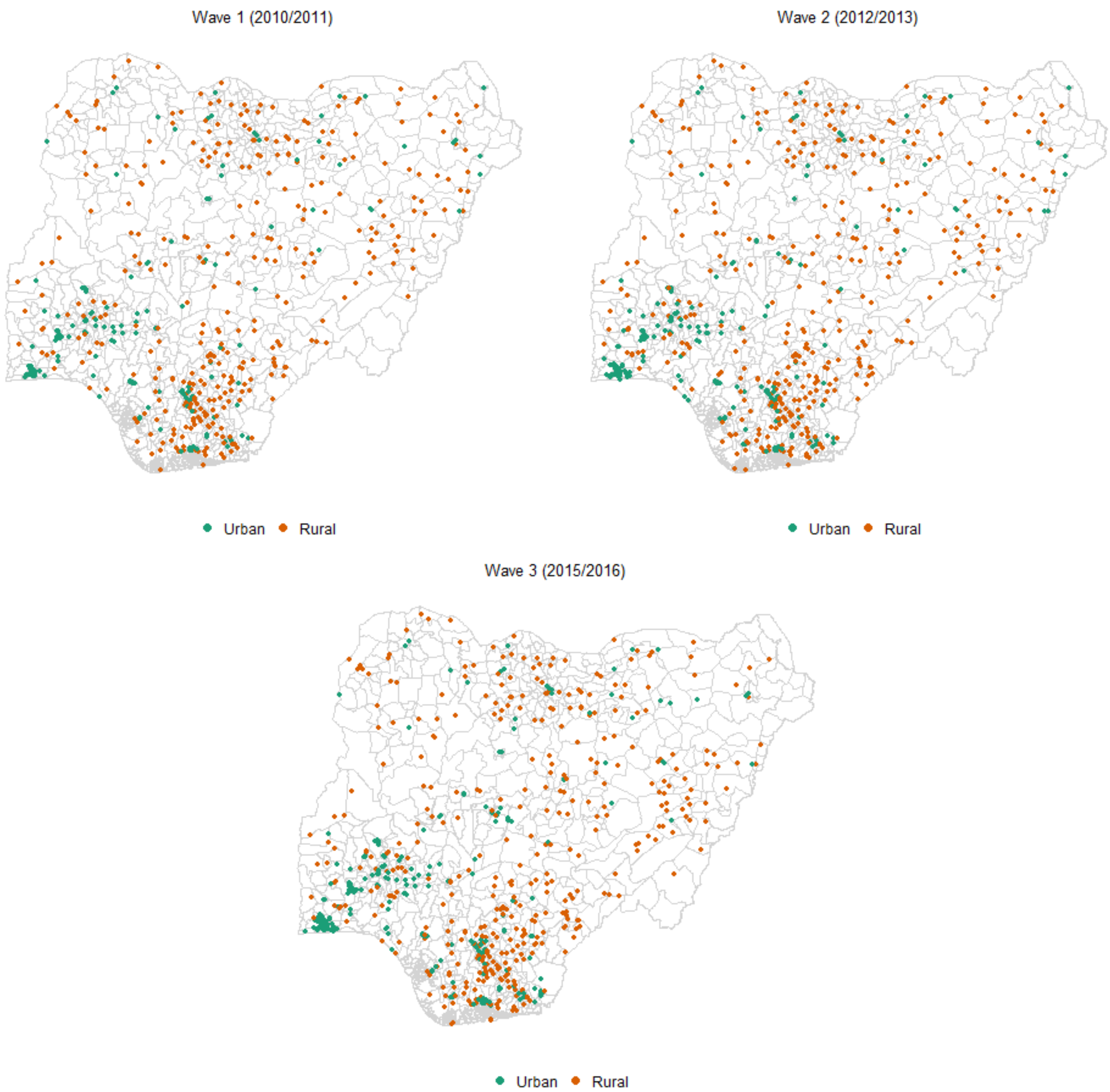
Note that sample is from children under 5 that are present in at least two consecutive surveys.

Table B7: Variables for Children in the Sample (no panel restriction)

Columns by: Year of Survey	2010/2011	2012/2013	2015/2016
n (%)	2544 (28.0)	3487 (38.4)	3053 (33.6)
{Continuous Variables}			
Age in Months, mean (sd)	26.46 (17.33)	28.98 (19.09)	26.02 (19.11)
Weight (kg), mean (sd)	10.75 (6.65)	12.09 (5.02)	12.17 (4.52)
Length (cm), mean (sd)	74.48 (34.42)	84.85 (19.89)	85.63 (16.29)
Length/height-for-age Z-score, mean (sd)	-1.20 (2.53)	-0.60 (1.92)	-1.00 (2.15)
Weight-for-age Z-score, mean (sd)	-0.88 (2.07)	-0.47 (1.42)	-0.61 (1.70)
Weight-for-Height/Length Z-score (WHO), mean (sd)	0.05 (1.80)	-0.15 (1.43)	-0.05 (1.62)
{Binary Variables}			
Gender, n (%)			
Female	1201 (47.2)	1675 (48.0)	1466 (48.0)
Male	1343 (52.8)	1811 (52.0)	1587 (52.0)
Is Child Stunted?, n (%)			
No	853 (61.0)	1985 (80.7)	1651 (66.1)
Yes	545 (39.0)	476 (19.3)	845 (33.9)
Is Child Wasted?, n (%)			
No	1289 (87.9)	2374 (90.7)	2420 (89.0)
Yes	178 (12.1)	243 (9.3)	300 (11.0)
Is Child Underweight?, n (%)			
No	1291 (72.9)	2336 (89.5)	2105 (81.8)
Yes	479 (27.1)	273 (10.5)	467 (18.2)
Does HH have Electricity in Dwelling?, n (%)			
No	1387 (54.7)	1893 (54.4)	1711 (56.3)
Yes	1149 (45.3)	1589 (45.6)	1328 (43.7)
Gender of Household Head, n (%)			
Female	124 (4.9)	167 (4.8)	190 (6.3)
Male	2416 (95.1)	3316 (95.2)	2844 (93.7)
{Categorical Variables}			
Ordered Level of Household Head's Completed Education, n (%)			
None/Less than Primary	858 (39.8)	1159 (42.1)	1053 (43.8)
Primary School Complete	702 (32.6)	814 (29.5)	671 (27.9)
Secondary School Complete	489 (22.7)	609 (22.1)	562 (23.4)
University or Higher Education Complete	106 (4.9)	173 (6.3)	116 (4.8)

Note that sample is from children under 5.

Figure B1: Maps of Urban and Rural Split



C Regression Results

C.1 Stunting and Temperature$_{t-1}$

This section presents the full CRE logit model coefficients for all covariates.

Table C1: Logit Regressions (Coefficients) - Temperature$_{t-1}$ and Stunting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($^{\circ}C$)	0.237	0.144	0.268	1.077***	1.045***	1.107***	1.288***
	(0.245)	(0.241)	(0.243)	(0.352)	(0.358)	(0.348)	(0.412)
Distance to Closest Water Source (km)				0.006	0.006	0.005	0.005
				(0.015)	(0.015)	(0.015)	(0.017)
Distance to Closest Market (km)				-0.001	-0.001	-0.002	0.010
				(0.019)	(0.019)	(0.018)	(0.025)
Distance to Closest City (km)				-0.002	-0.002	-0.002	-0.001
				(0.005)	(0.005)	(0.005)	(0.006)
Is there a Market in the Community?				-0.155	-0.184	-0.148	-0.120
				(0.166)	(0.167)	(0.166)	(0.185)
Number of People in Household				-0.063	-0.064	-0.062	-0.078
				(0.046)	(0.046)	(0.046)	(0.055)
Number of Meals to Children				0.082*	0.083*	0.081*	0.121**
				(0.043)	(0.044)	(0.043)	(0.055)
Restricted Meals so Children can Eat				0.015	0.017	0.012	0.012
				(0.065)	(0.065)	(0.065)	(0.073)
Number of Production Shocks				-0.078	-0.089	-0.073	-0.121
				(0.165)	(0.164)	(0.165)	(0.190)
Number of Market Shocks				0.293**	0.288**	0.287**	0.368**
				(0.133)	(0.133)	(0.132)	(0.150)
Gender of Household Head				-0.020	-0.081	0.006	0.086
				(0.223)	(0.225)	(0.222)	(0.242)
Does HH have Electricity in Dwelling?				-0.050	-0.049	-0.050	-0.003
				(0.251)	(0.254)	(0.250)	(0.281)
Has Non-Farm Enterprise				-0.078	-0.069	-0.085	-0.079
				(0.187)	(0.187)	(0.187)	(0.218)
Primary Education Complete							-0.145
							(0.125)
Secondary Education Complete							-0.169
							(0.148)
University/Higher Education Complete							-0.514*
							(0.310)
Age in Months				0.029***	0.029***	0.029***	0.031***
				(0.005)	(0.006)	(0.005)	(0.006)
Gender				0.146*	0.151*	0.139	0.086
				(0.088)	(0.088)	(0.088)	(0.100)
Log of Education Expenditure				-0.035	-0.035	-0.035	-0.040
				(0.024)	(0.025)	(0.024)	(0.028)
Household Asset				0.121**	0.119**	0.121**	0.088

Index				(0.059)	(0.060)	(0.059)	(0.068)
Log of				0.101	0.101	0.106	0.149
Consumption per Capita				(0.143)	(0.143)	(0.142)	(0.161)
Tropical				0.029**	0.027**	0.029**	0.022**
Livestock Units				(0.012)	(0.012)	(0.012)	(0.011)
Log of Plot Size				-0.013	-0.012	-0.015	-0.003
of All Households				(0.031)	(0.031)	(0.030)	(0.035)
Soil Workability				0.084	0.065	0.087	0.026
(mean)				(0.061)	(0.063)	(0.061)	(0.071)
Soil Nutrient				-0.079	-0.005	-0.083	-0.097
Availability (mean)				(0.065)	(0.071)	(0.065)	(0.075)
Borrow from				0.171	0.179	0.175	-0.213
Microfinance/Credit Associations/Bank				(0.329)	(0.330)	(0.329)	(0.383)
Borrow from				-0.032	-0.030	-0.038	-0.086
Friends/Relatives/Money Lenders				(0.152)	(0.153)	(0.152)	(0.172)
Borrow Food, or				-0.212	-0.218	-0.204	-0.389
Rely on Friend/Relative?				(0.234)	(0.236)	(0.234)	(0.270)
Government				-0.307	-0.334	-0.312	-0.119
Assistance (food/cash/otherwise)				(0.327)	(0.326)	(0.327)	(0.382)
Agri-extension				0.143	0.128	0.138	0.139
(Government/Private Sector)				(0.359)	(0.358)	(0.360)	(0.426)
Rural			0.395***			0.324**	0.325**
			(0.102)			(0.140)	(0.159)
2010/2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)
2012/2013	-0.868***	-0.951***	-0.854***	-0.797***	-0.820***	-0.782***	-0.729***
	(0.156)	(0.160)	(0.156)	(0.215)	(0.219)	(0.212)	(0.245)
2015/2016	-0.244*	-0.320**	-0.238*	-0.852***	-0.885***	-0.845***	-0.880***
	(0.127)	(0.129)	(0.127)	(0.199)	(0.199)	(0.199)	(0.226)
North-East		0.093			-0.016		
		(0.144)			(0.178)		
North-West		0.166			0.108		
		(0.138)			(0.165)		
South-East		-0.545***			-0.353*		
		(0.170)			(0.205)		
South-South		-0.353**			-0.452**		
		(0.175)			(0.206)		
South-West		-0.117			-0.097		
		(0.201)			(0.239)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3511	3511	3511	3212	3212	3212	2662
Rho	0.089	0.080	0.084	0.023	0.019	0.019	0.066

Panel Level sd.	0.568	0.537	0.550	0.277	0.254	0.252	0.483
Chi-Squared	139.83	155.28	148.99	205.56	209.68	207.80	165.74

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model. * $p < .10$, ** $p < .05$, *** $p < .01$.

C.2 Underweight and Temperature$_{t-1}$

Table C2: Logit Regressions (Coefficients) - Temperature$_{t-1}$ and Underweight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($°C$)	0.692**	0.469	0.698**	1.268***	1.172***	1.283***	1.433***
	(0.302)	(0.299)	(0.298)	(0.365)	(0.379)	(0.363)	(0.399)
Distance to				0.003	0.009	0.003	0.005
Closest Water Source (km)				(0.019)	(0.019)	(0.019)	(0.021)
Distance to				-0.040	-0.044*	-0.041*	-0.081**
Closest Market (km)				(0.025)	(0.026)	(0.024)	(0.037)
Distance to				-0.004	-0.003	-0.004	-0.007
Closest City (km)				(0.006)	(0.006)	(0.006)	(0.007)
Is there a				0.455**	0.410**	0.456**	0.427**
Market in the Community?				(0.197)	(0.196)	(0.197)	(0.217)
Number of People				-0.033	-0.024	-0.033	-0.042
in Household				(0.058)	(0.058)	(0.058)	(0.069)
Number of Meals				0.110**	0.113**	0.110**	0.098*
to Children				(0.053)	(0.055)	(0.052)	(0.057)
Restricted Meals				0.017	0.020	0.016	0.064
so Children can Eat				(0.078)	(0.077)	(0.078)	(0.082)
Number of				-0.249	-0.276	-0.247	-0.266
Production Shocks				(0.191)	(0.192)	(0.190)	(0.214)
Number of Market				0.372**	0.362**	0.372**	0.521***
Shocks				(0.165)	(0.166)	(0.164)	(0.197)
Gender of				0.149	0.061	0.157	0.210
Household Head				(0.293)	(0.295)	(0.293)	(0.311)
Does HH have				0.211	0.199	0.209	0.120
Electricity in Dwelling?				(0.288)	(0.293)	(0.288)	(0.329)
Has Non-Farm				0.328	0.339	0.329	0.386
Enterprise				(0.226)	(0.227)	(0.226)	(0.262)
Primary							-0.170
Education Complete							(0.154)
Secondary							-0.207
Education Complete							(0.180)
University/Higher							-0.393
Education Complete							(0.395)
Age in Months				0.026***	0.025***	0.026***	0.023***
				(0.007)	(0.007)	(0.007)	(0.007)
Gender				0.212**	0.224**	0.209*	0.240**
				(0.107)	(0.108)	(0.107)	(0.120)
Log of Education				-0.020	-0.024	-0.020	-0.033
Expenditure				(0.030)	(0.030)	(0.030)	(0.035)
Household Asset				0.170**	0.174**	0.170**	0.170**
Index				(0.069)	(0.070)	(0.069)	(0.076)
Log of				-0.096	-0.085	-0.092	0.056
Consumption per Capita				(0.172)	(0.174)	(0.172)	(0.184)
Tropical				-0.006	-0.006	-0.006	-0.003

Livestock Units				(0.007)	(0.007)	(0.008)	(0.005)
Log of Plot Size of All Households				-0.043 (0.036)	-0.045 (0.037)	-0.042 (0.036)	-0.045 (0.043)
Soil Workability (mean)				-0.138* (0.079)	-0.168** (0.080)	-0.137* (0.079)	-0.205** (0.089)
Soil Nutrient Availability (mean)				-0.218** (0.085)	-0.098 (0.088)	-0.221*** (0.086)	-0.243** (0.095)
Borrow from Microfinance/Credit Associations/Bank				0.235 (0.444)	0.276 (0.458)	0.235 (0.443)	0.094 (0.480)
Borrow from Friends/Relatives/Money Lenders				0.033 (0.177)	0.029 (0.179)	0.032 (0.177)	0.040 (0.196)
Borrow Food, or Rely on Friend/Relative?				-0.427 (0.262)	-0.466* (0.266)	-0.427 (0.262)	-0.697** (0.290)
Government Assistance (food/cash/otherwise)				0.153 (0.367)	0.167 (0.369)	0.155 (0.367)	0.440 (0.445)
Agri-extension (Government/Private Sector)				-0.231 (0.408)	-0.207 (0.409)	-0.231 (0.408)	-0.198 (0.482)
Rural			0.294** (0.121)			0.157 (0.172)	0.057 (0.190)
2010/2011	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
2012/2013	-0.832*** (0.184)	-0.978*** (0.193)	-0.823*** (0.182)	-1.048*** (0.238)	-1.077*** (0.247)	-1.039*** (0.237)	-0.889*** (0.252)
2015/2016	-0.921*** (0.161)	-1.026*** (0.165)	-0.917*** (0.161)	-1.447*** (0.260)	-1.453*** (0.262)	-1.440*** (0.260)	-1.403*** (0.287)
North-East		0.285 (0.176)			0.050 (0.215)		
North-West		0.359** (0.173)			0.106 (0.205)		
South-East		-0.620*** (0.230)			-0.650** (0.277)		
South-South		-0.335 (0.210)			-0.476* (0.267)		
South-West		0.359* (0.215)			0.646** (0.261)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3886	3886	3886	3565	3565	3565	2936
Rho	0.147	0.138	0.144	0.119	0.119	0.117	0.155
Panel Level sd.	0.754	0.725	0.742	0.666	0.666	0.659	0.778
Chi-Squared	155.58	170.01	160.18	210.14	224.36	210.73	165.70

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model.

C.3 Stunting and Precipitation$_{t-3}$

Table C3: Logit Regressions (Coefficients) - Precipitation$_{t-3}$ and Stunting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Precipitation$_{t-3}$ (mm)	-0.014*	-0.014*	-0.015*	-0.020**	-0.020**	-0.021**	-0.019*
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)	(0.010)
Distance to				-0.002	-0.002	-0.004	-0.002
Closest Water Source (km)				(0.014)	(0.014)	(0.014)	(0.016)
Distance to				-0.007	-0.007	-0.009	0.006
Closest Market (km)				(0.017)	(0.017)	(0.017)	(0.024)
Distance to				-0.002	-0.001	-0.002	-0.000
Closest City (km)				(0.005)	(0.005)	(0.005)	(0.006)
Is there a				-0.106	-0.118	-0.100	-0.077
Market in the Community?				(0.166)	(0.167)	(0.166)	(0.185)
Number of People				-0.071	-0.073	-0.070	-0.083
in Household				(0.046)	(0.046)	(0.045)	(0.054)
Number of Meals				0.073*	0.074*	0.071*	0.111**
to Children				(0.043)	(0.043)	(0.042)	(0.054)
Restricted Meals				0.042	0.040	0.041	0.041
so Children can Eat				(0.064)	(0.064)	(0.064)	(0.072)
Number of				-0.096	-0.103	-0.090	-0.123
Production Shocks				(0.163)	(0.163)	(0.162)	(0.187)
Number of Market				0.275**	0.273**	0.267**	0.355**
Shocks				(0.132)	(0.132)	(0.131)	(0.148)
Gender of				-0.031	-0.049	-0.006	0.069
Household Head				(0.225)	(0.226)	(0.224)	(0.242)
Does HH have				-0.041	-0.044	-0.042	-0.007
Electricity in Dwelling?				(0.252)	(0.253)	(0.251)	(0.286)
Has Non-Farm				-0.107	-0.101	-0.117	-0.118
Enterprise				(0.185)	(0.185)	(0.184)	(0.213)
Primary							-0.137
Education Complete							(0.123)
Secondary							-0.113
Education Complete							(0.146)
University/Higher							-0.504
Education Complete							(0.306)
Age in Months				0.022***	0.022***	0.022***	0.023***
				(0.005)	(0.005)	(0.005)	(0.006)
Gender				0.153*	0.156*	0.145*	0.094
				(0.087)	(0.087)	(0.087)	(0.098)
Log of Education				-0.033	-0.034	-0.033	-0.036
Expenditure				(0.024)	(0.024)	(0.024)	(0.027)
Household Asset				0.119**	0.120**	0.118**	0.083
Index				(0.059)	(0.059)	(0.059)	(0.067)
Log of				0.059	0.062	0.064	0.090
Consumption per Capita				(0.141)	(0.141)	(0.140)	(0.157)
Tropical				0.028**	0.027**	0.028**	0.022**

Livestock Units				(0.012)	(0.012)	(0.012)	(0.011)
Log of Plot Size of All Households				-0.015	-0.015	-0.017	-0.007
				(0.030)	(0.031)	(0.030)	(0.034)
Soil Workability (mean)				0.046	0.046	0.044	-0.017
				(0.061)	(0.062)	(0.060)	(0.071)
Soil Nutrient Availability (mean)				-0.004	0.017	-0.002	-0.008
				(0.068)	(0.071)	(0.068)	(0.077)
Borrow from Microfinance/Credit Associations/Bank				0.200	0.200	0.208	-0.150
				(0.326)	(0.327)	(0.325)	(0.371)
Borrow from Friends/Relatives/Money Lenders				-0.016	-0.013	-0.024	-0.064
				(0.151)	(0.152)	(0.151)	(0.169)
Borrow Food, or Rely on Friend/Relative?				-0.213	-0.210	-0.206	-0.363
				(0.233)	(0.234)	(0.233)	(0.267)
Government Assistance (food/cash/otherwise)				-0.399	-0.413	-0.409	-0.253
				(0.325)	(0.325)	(0.325)	(0.380)
Agri-extension (Government/Private Sector)				0.107	0.097	0.098	0.106
				(0.351)	(0.351)	(0.350)	(0.415)
Rural			0.401***			0.391***	0.388**
			(0.101)			(0.144)	(0.162)
2010/2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)
2012/2013	-1.046***	-1.053***	-1.044***	-1.330***	-1.335***	-1.328***	-1.328***
	(0.105)	(0.105)	(0.104)	(0.149)	(0.149)	(0.148)	(0.169)
2015/2016	-0.364***	-0.374***	-0.363***	-0.988***	-1.002***	-0.988***	-1.034***
	(0.111)	(0.111)	(0.110)	(0.196)	(0.197)	(0.195)	(0.220)
North-East		0.097			0.005		
		(0.150)			(0.182)		
North-West		0.162			0.101		
		(0.146)			(0.175)		
South-East		-0.355*			-0.262		
		(0.198)			(0.226)		
South-South		-0.017			-0.233		
		(0.237)			(0.266)		
South-West		-0.125			-0.091		
		(0.198)			(0.236)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3511	3511	3511	3212	3212	3212	2662
Rho	0.086	0.083	0.079	0.015	0.015	0.007	0.044
Panel Level sd.	0.558	0.547	0.531	0.224	0.221	0.153	0.389
Chi-Squared	147.75	155.60	157.70	207.71	208.61	211.20	170.50

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model.

C.4 Underweight and Precipitation$_{t-3}$

Table C4: Logit Regressions (Coefficients) - Precipitation$_{t-3}$ and Underweight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Precipitation$_{t-3}$ (mm)	0.007	0.006	0.007	0.002	0.001	0.002	0.007
	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
Distance to Closest Water Source (km)				-0.001	0.004	-0.002	0.003
				(0.018)	(0.018)	(0.018)	(0.020)
Distance to Closest Market (km)				-0.043**	-0.047**	-0.043**	-0.067**
				(0.020)	(0.020)	(0.019)	(0.032)
Distance to Closest City (km)				-0.003	-0.002	-0.003	-0.005
				(0.006)	(0.006)	(0.006)	(0.007)
Is there a Market in the Community?				0.507**	0.469**	0.508**	0.469**
				(0.198)	(0.196)	(0.198)	(0.217)
Number of People in Household				-0.040	-0.034	-0.040	-0.043
				(0.054)	(0.054)	(0.054)	(0.062)
Number of Meals to Children				0.103*	0.103*	0.102*	0.082
				(0.053)	(0.054)	(0.053)	(0.055)
Restricted Meals so Children can Eat				0.051	0.047	0.050	0.099
				(0.078)	(0.077)	(0.078)	(0.081)
Number of Production Shocks				-0.249	-0.267	-0.248	-0.244
				(0.188)	(0.190)	(0.188)	(0.210)
Number of Market Shocks				0.369**	0.363**	0.369**	0.523***
				(0.162)	(0.164)	(0.162)	(0.192)
Gender of Household Head				0.116	0.084	0.124	0.154
				(0.296)	(0.297)	(0.295)	(0.311)
Does HH have Electricity in Dwelling?				0.205	0.199	0.200	0.110
				(0.294)	(0.295)	(0.294)	(0.338)
Has Non-Farm Enterprise				0.279	0.290	0.280	0.322
				(0.221)	(0.223)	(0.220)	(0.256)
Primary Education Complete							-0.153
							(0.151)
Secondary Education Complete							-0.121
							(0.177)
University/Higher Education Complete							-0.400
							(0.392)
Age in Months				0.018***	0.018***	0.018***	0.015**
				(0.007)	(0.007)	(0.007)	(0.007)
Gender				0.218**	0.228**	0.213**	0.238**
				(0.107)	(0.107)	(0.107)	(0.118)
Log of Education Expenditure				-0.018	-0.022	-0.017	-0.028
				(0.030)	(0.030)	(0.030)	(0.034)
Household Asset Index				0.164**	0.168**	0.163**	0.162**
				(0.068)	(0.069)	(0.068)	(0.075)
Log of Consumption per Capita				-0.149	-0.135	-0.145	-0.006
				(0.168)	(0.171)	(0.167)	(0.180)
Tropical				-0.005	-0.005	-0.005	-0.002

Livestock Units				(0.007)	(0.007)	(0.008)	(0.005)
Log of Plot Size				-0.051	-0.053	-0.050	-0.049
of All Households				(0.036)	(0.036)	(0.035)	(0.041)
Soil Workability				-0.166**	-0.174**	-0.168**	-0.238***
(mean)				(0.078)	(0.078)	(0.078)	(0.088)
Soil Nutrient				-0.142	-0.075	-0.142	-0.142
Availability (mean)				(0.088)	(0.088)	(0.088)	(0.098)
Borrow from				0.336	0.347	0.340	0.254
Microfinance/Credit Associations/Bank				(0.445)	(0.458)	(0.444)	(0.482)
Borrow from				0.055	0.048	0.053	0.067
Friends/Relatives/Money Lenders				(0.175)	(0.177)	(0.175)	(0.194)
Borrow Food, or				-0.445*	-0.480*	-0.446*	-0.698**
Rely on Friend/Relative?				(0.262)	(0.264)	(0.261)	(0.288)
Government				0.083	0.106	0.087	0.320
Assistance (food/cash/otherwise)				(0.363)	(0.364)	(0.364)	(0.440)
Agri-extension				-0.207	-0.190	-0.207	-0.191
(Government/Private Sector)				(0.402)	(0.403)	(0.402)	(0.471)
Rural			0.287**			0.221	0.144
			(0.120)			(0.175)	(0.194)
2010/2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)
2012/2013	-1.228***	-1.241***	-1.222***	-1.662***	-1.654***	-1.658***	-1.541***
	(0.113)	(0.114)	(0.113)	(0.179)	(0.180)	(0.179)	(0.195)
2015/2016	-1.174***	-1.188***	-1.170***	-1.625***	-1.614***	-1.620***	-1.572***
	(0.143)	(0.143)	(0.143)	(0.256)	(0.258)	(0.255)	(0.281)
North-East		0.313*			0.071		
		(0.179)			(0.219)		
North-West		0.386**			0.118		
		(0.177)			(0.217)		
South-East		-0.555**			-0.598**		
		(0.261)			(0.300)		
South-South		-0.201			-0.328		
		(0.288)			(0.356)		
South-West		0.334			0.633**		
		(0.216)			(0.262)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3886	3886	3886	3565	3565	3565	2936
Rho	0.141	0.135	0.135	0.104	0.108	0.100	0.128
Panel Level sd.	0.735	0.718	0.718	0.617	0.632	0.604	0.696
Chi-Squared	154.61	163.84	158.34	207.36	216.79	208.51	166.65

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model.

C.5 Stunting and Climate Variables

Table C5: Logit Regressions (Coefficients) - Climate Variables and Stunting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($^{\circ}C$)	0.105	0.084	0.120	1.043***	1.075***	1.052***	1.337***
	(0.268)	(0.269)	(0.265)	(0.382)	(0.386)	(0.378)	(0.444)
Precipitation$_{t-3}$ (mm)	0.042	0.050*	0.040	0.054*	0.075**	0.048	0.078**
	(0.028)	(0.030)	(0.027)	(0.030)	(0.032)	(0.030)	(0.034)
Temperature$_{t-1}$ ($^{\circ}C$) ×	-0.002**	-0.002**	-0.002**	-0.002**	-0.003***	-0.002**	-0.003**
Precipitation$_{t-3}$ (mm)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Distance to				0.000	0.002	-0.001	-0.004
Closest Water Source (km)				(0.015)	(0.015)	(0.015)	(0.017)
Distance to				-0.002	-0.003	-0.004	0.013
Closest Market (km)				(0.019)	(0.019)	(0.018)	(0.024)
Distance to				-0.002	-0.002	-0.003	-0.002
Closest City (km)				(0.005)	(0.005)	(0.005)	(0.006)
Is there a				-0.154	-0.166	-0.150	-0.126
Market in the Community?				(0.167)	(0.167)	(0.167)	(0.185)
Number of People				-0.056	-0.057	-0.055	-0.067
in Household				(0.046)	(0.046)	(0.046)	(0.055)
Number of Meals				0.083*	0.085*	0.081*	0.123**
to Children				(0.044)	(0.044)	(0.044)	(0.055)
Restricted Meals				0.016	0.016	0.014	0.008
so Children can Eat				(0.064)	(0.065)	(0.064)	(0.073)
Number of				-0.084	-0.094	-0.079	-0.114
Production Shocks				(0.165)	(0.165)	(0.164)	(0.190)
Number of Market				0.286**	0.282**	0.279**	0.364**
Shocks				(0.133)	(0.133)	(0.133)	(0.150)
Gender of				-0.022	-0.046	-0.002	0.092
Household Head				(0.225)	(0.225)	(0.223)	(0.242)
Does HH have				-0.038	-0.044	-0.037	0.027
Electricity in Dwelling?				(0.251)	(0.252)	(0.251)	(0.282)
Has Non-Farm				-0.089	-0.077	-0.098	-0.088
Enterprise				(0.186)	(0.187)	(0.186)	(0.215)
Primary							-0.161
Education Complete							(0.124)
Secondary							-0.151
Education Complete							(0.148)
University/Higher							-0.525*
Education Complete							(0.309)
Age in Months				0.028***	0.028***	0.028***	0.030***
				(0.006)	(0.006)	(0.005)	(0.006)
Gender				0.144	0.144	0.137	0.082
				(0.088)	(0.088)	(0.088)	(0.099)
Log of Education				-0.035	-0.035	-0.034	-0.040
Expenditure				(0.024)	(0.024)	(0.024)	(0.028)
Household Asset				0.117**	0.118**	0.116*	0.081

Index				(0.059)	(0.059)	(0.060)	(0.068)
Log of				0.113	0.113	0.118	0.177
Consumption per Capita				(0.143)	(0.143)	(0.143)	(0.161)
Tropical				0.028**	0.026**	0.028**	0.022*
Livestock Units				(0.012)	(0.012)	(0.012)	(0.011)
Log of Plot Size				-0.012	-0.011	-0.014	-0.004
of All Households				(0.030)	(0.031)	(0.030)	(0.034)
Soil Workability				0.064	0.072	0.061	-0.006
(mean)				(0.063)	(0.063)	(0.062)	(0.073)
Soil Nutrient				-0.055	-0.044	-0.047	-0.069
Availability (mean)				(0.071)	(0.072)	(0.070)	(0.081)
Borrow from				0.175	0.166	0.180	-0.206
Microfinance/Credit Associations/Bank				(0.328)	(0.327)	(0.327)	(0.379)
Borrow from				-0.035	-0.028	-0.043	-0.085
Friends/Relatives/Money Lenders				(0.152)	(0.153)	(0.152)	(0.171)
Borrow Food, or				-0.219	-0.224	-0.211	-0.384
Rely on Friend/Relative?				(0.235)	(0.236)	(0.235)	(0.270)
Government				-0.338	-0.358	-0.346	-0.163
Assistance (food/cash/otherwise)				(0.326)	(0.325)	(0.326)	(0.380)
Agri-extension				0.124	0.112	0.117	0.132
(Government/Private Sector)				(0.356)	(0.357)	(0.356)	(0.422)
Rural			0.386***			0.376***	0.378**
			(0.101)			(0.145)	(0.162)
2010/2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)
2012/2013	-1.058***	-1.095***	-1.048***	-0.909***	-0.928***	-0.896***	-0.819***
	(0.174)	(0.176)	(0.173)	(0.228)	(0.229)	(0.226)	(0.258)
2015/2016	-0.345***	-0.375***	-0.341***	-0.877***	-0.890***	-0.876***	-0.906***
	(0.131)	(0.132)	(0.130)	(0.199)	(0.200)	(0.198)	(0.225)
North-East		-0.032			-0.130		
		(0.157)			(0.193)		
North-West		0.061			0.030		
		(0.151)			(0.179)		
South-East		-0.483**			-0.332		
		(0.206)			(0.229)		
South-South		-0.305			-0.546*		
		(0.269)			(0.296)		
South-West		-0.149			-0.130		
		(0.203)			(0.240)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3511	3511	3511	3212	3212	3212	2662
Rho	0.084	0.081	0.078	0.018	0.015	0.012	0.052

Panel Level sd.	0.549	0.538	0.527	0.248	0.225	0.203	0.426
Chi-Squared	157.34	162.20	165.55	211.12	212.97	214.29	173.53

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model.

Precipitation$_{t-3}$ (mm)

C.6 Underweight and Climate Variables

Table C6: Logit Regressions (Coefficients) - Climate Variables and Underweight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature$_{t-1}$ ($°C$)	0.698**	0.582*	0.716**	1.415***	1.390***	1.425***	1.654***
	(0.328)	(0.333)	(0.326)	(0.398)	(0.411)	(0.395)	(0.439)
Precipitation$_{t-3}$ (mm)	-0.026	-0.038	-0.024	-0.013	-0.012	-0.016	0.003
	(0.033)	(0.037)	(0.033)	(0.038)	(0.041)	(0.038)	(0.041)
Temperature$_{t-1}$ ($°C$)$\times$	0.001	0.002	0.001	0.001	0.001	0.001	0.001
Precipitation$_{t-3}$ (mm)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Distance to				0.000	0.009	-0.001	0.000
Closest Water Source (km)				(0.019)	(0.019)	(0.019)	(0.021)
Distance to				-0.034	-0.038*	-0.034	-0.061*
Closest Market (km)				(0.022)	(0.023)	(0.021)	(0.034)
Distance to				-0.004	-0.003	-0.004	-0.007
Closest City (km)				(0.006)	(0.006)	(0.006)	(0.007)
Is there a				0.423**	0.388**	0.423**	0.381*
Market in the Community?				(0.198)	(0.197)	(0.198)	(0.218)
Number of People				-0.027	-0.021	-0.028	-0.031
in Household				(0.058)	(0.059)	(0.058)	(0.068)
Number of Meals				0.107**	0.110**	0.106**	0.091
to Children				(0.052)	(0.055)	(0.052)	(0.056)
Restricted Meals				0.021	0.021	0.020	0.065
so Children can Eat				(0.078)	(0.076)	(0.077)	(0.081)
Number of				-0.244	-0.263	-0.242	-0.250
Production Shocks				(0.189)	(0.191)	(0.188)	(0.211)
Number of Market				0.375**	0.372**	0.374**	0.526***
Shocks				(0.165)	(0.166)	(0.165)	(0.197)
Gender of				0.094	0.050	0.102	0.147
Household Head				(0.294)	(0.295)	(0.294)	(0.311)
Does HH have				0.213	0.213	0.209	0.136
Electricity in Dwelling?				(0.295)	(0.295)	(0.295)	(0.339)
Has Non-Farm				0.327	0.335	0.329	0.377
Enterprise				(0.226)	(0.228)	(0.226)	(0.262)
Primary							-0.162
Education Complete							(0.154)
Secondary							-0.145
Education Complete							(0.180)
University/Higher							-0.388
Education Complete							(0.395)
Age in Months				0.027***	0.026***	0.028***	0.025***
				(0.007)	(0.007)	(0.007)	(0.008)
Gender				0.221**	0.229**	0.216**	0.246**
				(0.108)	(0.108)	(0.108)	(0.120)
Log of Education				-0.018	-0.022	-0.018	-0.031
Expenditure				(0.031)	(0.030)	(0.031)	(0.035)
Household Asset				0.167**	0.172**	0.166**	0.162**

Index				(0.069)	(0.070)	(0.070)	(0.076)
Log of				-0.095	-0.086	-0.090	0.065
Consumption per Capita				(0.172)	(0.174)	(0.172)	(0.185)
Tropical				-0.007	-0.006	-0.007	-0.003
Livestock Units				(0.008)	(0.008)	(0.008)	(0.005)
Log of Plot Size				-0.041	-0.045	-0.040	-0.043
of All Households				(0.036)	(0.037)	(0.036)	(0.042)
Soil Workability				-0.177**	-0.172**	-0.181**	-0.260***
(mean)				(0.081)	(0.081)	(0.081)	(0.091)
Soil Nutrient				-0.121	-0.071	-0.118	-0.125
Availability (mean)				(0.093)	(0.092)	(0.092)	(0.104)
Borrow from				0.282	0.306	0.283	0.155
Microfinance/Credit Associations/Bank				(0.445)	(0.459)	(0.444)	(0.479)
Borrow from				0.031	0.024	0.029	0.042
Friends/Relatives/Money Lenders				(0.178)	(0.180)	(0.177)	(0.198)
Borrow Food, or				-0.433	-0.469*	-0.432	-0.698**
Rely on Friend/Relative?				(0.264)	(0.267)	(0.264)	(0.292)
Government				0.190	0.205	0.196	0.475
Assistance (food/cash/otherwise)				(0.373)	(0.373)	(0.373)	(0.455)
Agri-extension				-0.181	-0.173	-0.179	-0.130
(Government/Private Sector)				(0.408)	(0.410)	(0.409)	(0.482)
Rural			0.287**			0.260	0.176
			(0.121)			(0.178)	(0.197)
2010/2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(.)
2012/2013	-0.762***	-0.821***	-0.749***	-0.918***	-0.912***	-0.905***	-0.721***
	(0.205)	(0.213)	(0.203)	(0.252)	(0.260)	(0.251)	(0.268)
2015/2016	-0.927***	-0.965***	-0.920***	-1.456***	-1.433***	-1.448***	-1.398***
	(0.165)	(0.168)	(0.165)	(0.261)	(0.263)	(0.261)	(0.288)
North-East		0.282			0.028		
		(0.186)			(0.228)		
North-West		0.352*			0.083		
		(0.185)			(0.221)		
South-East		-0.481*			-0.568*		
		(0.271)			(0.301)		
South-South		-0.050			-0.264		
		(0.319)			(0.384)		
South-West		0.414*			0.666**		
		(0.228)			(0.268)		
Controls	No	No	No	Yes	Yes	Yes	Yes
Education	No	No	No	No	No	No	Yes
CRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	No	Yes	No	No	Yes	No	No
Urban/Rural	No	No	Yes	No	No	Yes	Yes
Number of Observations	3886	3886	3886	3565	3565	3565	2936
Rho	0.143	0.138	0.138	0.119	0.121	0.114	0.152

Panel Level sd.	0.741	0.727	0.726	0.665	0.673	0.651	0.767
Chi-Squared	162.95	173.02	166.41	214.81	225.18	216.20	172.73

Clustered standard errors at the individual level. Controls represents whether geographical information, family characteristics, child characteristics, household wealth, agricultural characteristics, and household assistance controls were included. Education represents education controls. Rho is the proportion of the total variance contributed by the panel-level variance component. CRE denotes Correlated Random Effects Model.