Child Malnutrition and Climate Change in Sub-Saharan Africa: An analysis of recent trends in Kenya

Introduction

The United Nations Millennium Project Hunger Task Force (HTF) suggests that reducing hunger vulnerability in children requires a multi-faceted approach. Beyond household level behaviors (such as breastfeeding), the HTF encourages the development and expansion of safety-nets – strategies to identify and combat famine or food shortage *before* the population is dramatically affected; increasing economic resources and access to food (particularly for the impoverished) – including diversifying income sources beyond agricultural production and expanding the capabilities of rural communities; and, finally, the HTF highlights the importance of sustainable natural resource use – encouraging conservation and regeneration of the natural environment (Sanchez et al. 2005; Balk, Storeygard et al. 2005). While the environmental component of these strategies on food insecurity and malnutrition has been evaluated (see Balk, Storeygard et al. 2005) and is theoretically supported (see the UNICEF framework of Smith and Haddad 2000), there remains little empirical research evaluating the relationship between natural resources, namely variables related to climate, and child malnutrition. This research aims to evaluate the impacts of climate variables on child hunger in Sub-Saharan Africa using the most up-to-date climate and health data available.

Many countries within Sub-Saharan Africa – where malnutrition rates are high and the population-environment balance is delicate – face particular risks as indications of warming climates threaten current food systems (Funk and Brown 2009; Brown and Funk 2008). Among these countries Kenya ranks both among the most malnourished and shows the greatest indication of climate change (Williams and Funk 2010). Approximately 30% of Kenya's children between one and five years old are malnourished – a rate which has changed little over the last 15 years (FAO 2009). Climatologists have also determined that Kenya is, and, since the 1970s, has been, experiencing increases in average annual temperatures and decreases to the heavy rain periods (Williams and Funk 2010). The combination of these climate factors is theorized to lead to increasing strains on food resources as the land area suitable for planting and agricultural production is decreasing (Brown and Funk 2008). Through a reduction in both the quality of the food produced and the area suitable for cultivation, climate change may be exacerbating food shortages and may therefore lead to an increase in child malnutrition.

The purpose of this research is to determine if climate change variables are related to rates of child hunger in Kenya. Specifically, we will evaluate the correlation between surface temperatures, rainfall levels and variability – significant components of climate change – and their impact at the household/cluster- and regional-level on the rates of stunting (a primary indicator of child hunger) among children aged one to three. The inclusion of the climate data into this analysis serves two purposes; 1) to evaluate the correlation between climate variables and child malnutrition and 2) to determine if warming trends are linked to higher rates of malnutrition

Data

We rely on two types of data for this analysis – 1) demographic/health data and 2) climate data.

Demographic/Health Data: The demographic data come from the Demographic and Health Survey (DHS) data sets for Kenya (1989 and 2008). In addition to child-specific anthropometric measures, these datasets also contains household and parental information that has been linked to child health and food insecurity. The data collected in 2008 by Macro DHS are attributed with geographic coordinates at the household level but, because of privacy restrictions (explained in more detail below), are suitable for comparison at the sampling cluster level (approximately 4th administrative level, n>300). These data in addition to the earliest time period of DHS Kenyan data (1989) will be used to examine the relationship between climate and stunting at a micro-level.

To compare stunting over time and with respect to the warming trends in Kenya we will also extend the analysis to a regional level (the 2nd administrative level, n=8). In addition to the theoretical contribution of a macro-level analysis (discussed further in the methods section), evaluating macro-level trends in stunting allows for the use of the earliest time period available of Kenyan DHS data (1989) as geographic coordinates were not employed (making neighborhood or cluster comparisons impossible). Comparing correlates of child hunger from more than 20 years ago, before the onset of notable climate change, to 2008, as Kenya is in the midst of notable warming and drying, will help to highlight the changes in hunger levels that may be attributable to the changes in the physical environment.

The height[1] for age Z-scores (HAZ) of children under 3 years old serves as the **dependent variable** for this analysis. The HAZ is a standard measurement of child stunting used globally and is indicative of chronic malnutrition (WHO 2004, WorldBank 1995, Kwena, Terlouw et al. 2003 WorldBank 1995; Sahn and Stifel 2002; Balk, Storeygard et al. 2005)[2]. We focus on children under 3 years old because height for age at this growth period is generally assumed to be independent of racial, ethnic, and socioeconomic status (WHO 2004). Children more than two standard deviations (HAZ<=-2) from the reference height-for-age ratio for their age group are considered *stunted*. For example children with a HAZ score of less than -2 are said to suffer from chronic malnutrition and those with an HAZ score less than -3 considered to suffer from severe chronic malnutrition. These standards are based on the Multicenter Growth Reference Study (MGRS), conducted by the World Health Organization from 1997 and 2003 (WHO 2004)[3]. Stunting can occur as a result of caloric deficiency or improper nutrients (unhealthy diet) either before or after birth[4].

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[1] Length is used for children <24 months, height for children >24 months WHO (2004). The WHO Multicentre Growth Reference Study (MGRS), World Health Organization..

[2] Height for age is the preferred measure of chronic malnutrition because it less likely than other indicators to be impacted by disease or other sources of stress when the data is collected. For example Sahn and Stifel (2002) note that height for age, unlike weight, will not be impacted by temporary ailments such as diarrhea or malaria.

[3] For general information on the MGRS, see: http://www.who.int/childgrowth/mgrs/en/

[4] Children age 0-3 with high height for age ratios (>2) are generally considered healthy which, after controlling for parental genetics, is the result of a well-balanced and nutritious diet (ie. not too little food,

Independent variables are selected to control for biological determinants of malnutrition as well as household and parental characteristics that are linked to child stunting. In particular we will include in the model child age, breastfeeding experience, urban/rural dwelling, birth order, and sex as well as parental characteristics (namely age, education level, age at first birth, marital status, maternal height-to-weight ratio) (Balk, Storeygard et al. 2005, Bloss et al. 2004, etc.).

Climate Data: The climate data come from several different sources. Climate data are interpolated from a combination of ground based meteorological stations, remotely sensed data, and *a priori* knowledge of climatic patterns within that region. The resulting data set covers approximately 40 years – from early 1970s until the current period – and provides an interpolated surface of climate information. This data represents the most up-to-date and quantitatively advanced climate information and has never been used in an analysis of this type (please see Funk et al. (forthcoming) for more information on how the data was collected and interpolated).

In the cases where we have DHS geo-referenced households the climate data are linked to households based on the location of the DHS sampling cluster (clusters contain approximately 10 households) where the child resides. DHS records the geographic location of the center of all clusters where surveys were administered. To protect the privacy of respondents, urban clusters are randomly shifted by 2km, rural clusters by 5km, and 5% of all clusters shifted by 10km. We account for the location shift by aggregating climate data both in and around the community cluster location. Specifically we attribute households with climate data for an approximate 900 square kilometer grid cell - including where the cluster lies, and all grid cells congruent to the cluster grid cell. Attributing the cluster grid cell with the climate information of itself and its neighbors accounts both for the location shift and the fact that rainfall and temperature outside of a household's immediate area may still influence that household's ability to meet the caloric and nutritional requirements of its members. In the cases where we do not have geo-referenced DHS data (the earlier survey years) we attribute regions with region-level aggregate climate attributes.

Precipitation data are used to capture a household's dependence on rainfed crops. We only include precipitation that occurs during the critical wet months for a period covering the life and estimated gestation period of the child (age in months + 9). We include both the variables the average and the variance of rainfall during this period. We also will include a count of the total number of wet days (rainfall > 5mm). Variance is included to account for volatility in rainfall and its impact on crop development (REF). Similarly we will also include the average and standard deviations of temperature. Precipitation, temperature and their corresponding derivatives are key indicators of climate change (Williams and Funk 2010). These variables have been used in other studies to highlight warming trends in Kenya (Williams and Funk 2010). In addition to the climate related variables of precipitation mean and standard deviation and temperature and standard deviation, slope, elevation and land use type (e.g. crop type) will be incorporated into the

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not too much food, and a proper diet). However there is some research that shows that children who grow exceptionally fast between age 0-3 might exhibit a propensity for obesity later in life Baird, J., D. Fisher, et al. (2005). "Being big or growing fast: systematic review of size and growth in infancy and later obesity." BMJ **331**(7522): 929-..

model. This information comes from the data archives of the Famine Early Warning System (FEWS http://www.fews.net) which archives and processes data gathered from governmental sources. As this type of geophysical information is linked to planting ease and agricultural production it may interact with the climate variables and impact food availability (Husak et al. 2008).

Methods/Analysis

To evaluate the relationship between climate change and child hunger we will construct both macro- and micro-level models. The macro-level (regional level) model reflects the level at which policy decisions are more frequently made and provides information about the context of child malnutrition. The micro-level models (cluster level) will highlight the factors that shape a child's early experiences with hunger at (nearly) an individual level. Constructing both types of models and interpreting the results with respect to each level of analysis will help to provide more detailed insight into the complexities of child malnutrition in the context of climate change.

We use linear regression to model the relationship among climate variables and child malnutrition at both levels of analysis. At the macro-level we model the proportion of stunted children under age 3 as the response variable with aggregate values of the demographic/health variables and the climate/geophysical variables. We will construct a model for two time periods (1989 and 2008) and compare the significance and coefficient values to determine the impact of climate change over time on child stunting. We will also construct a model based primarily on the 2008 data but incorporate the change over time in temperature, rainfall and related growing area at a regional-level to determine if regions that have experienced notable changes to their climates are characterized by increased child stunting.

We will also construct a micro-level (sampling cluster-level) model using the georeferenced data from the DHS in combination with the high resolution climate and geophysical data. In the micro-level models we will model child stunting at the household level using the 2008 Kenyan DHS data and climate data for the relevant time periods for each child (a time series of data from conception year through current year). The goal of this model will be to determine if child stunting at the micro-level is linked to climate variables. We anticipate that observations within the same sample cluster are correlated and since correlations within groups (commonly referred to as 'clustering') can lead to downward bias in standard error estimates (Moulton 1986) we will adjust for this correlation through a boot-strap technique designed to adjust our standard error estimates (see Cameron, Gelbach et al. 2008). This method (*wild-t* bootstrap) out-performs other measures under a variety of conditions including the two most relevant to our study: 1) small (<30) cluster sizes and 2) within group heteroskedasticity. The results of this micro-level model will be interpreted both on its own and within the context of the macro-level model results.

Expected Contribution

The goal of this research is to evaluate the relationship between climate variables and child malnutrition. Climate change could be particularly dire in impoverished, food insecure countries in Africa where poor people depend on locally grown, easily available and affordable food. A reduction in arable land could contribute to greater stress on natural resources and could perhaps eventually inhibit or even reverse positive strides in health and development. By incorporating climate variables into an analysis of child hunger we are able to more thoroughly evaluate the potential impacts of climate change on child hunger. The results of this research will motivate further investigations into the ramifications of a warming planet as well as provide insight for policy makers concerned with HTF goals.

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