Market access and child nutrition in a conflict environment

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Selected Paper prepared for presentation at the Annual Meeting of the Agricultural & Applied Economics Association (AAEA), Minneapolis, MN, July 27-29, 2014

Abstract

This paper tests uses nationally representative data from the Democratic Republic of the Congo (DRC) to test whether a household's market access, defined in terms of travel costs to the nearest town, facilitates resilience and reduces vulnerability to seasonal influences on child nutrition. The timing of a child's birth has often been found to correlate with height, weight and other health outcomes, driven by exposure to seasonal fluctuations in diets and disease during sensitive periods of physiological development. Remoteness could mediate that relationship, leaving geographically isolated households especially vulnerable to seasonal fluctuations because they cannot easily buy and sell to smooth consumption, or access medical facilities when the health environment deteriorates. To complicate matters, the presence of nearby civil insecurity may make it physically unsafe to travel significant distances. Using the 2008 DHS survey of children born between 2002 and 2007, we find that birth season is closely linked to child weights but not heights, primarily in more remote areas. This finding contrasts sharply with household wealth, which is closely linked to child heights but not weights, and only in less remote areas. Conflicts do not appear to mediate the relationship, perhaps because recorded conflicts occur primarily near towns.

Key words: child nutrition, child health, civil conflict, seasonality, market access

1. INTRODUCTION

Many influences on child health are geographical in nature, and cannot be randomly assigned in a traditional experiment. One important example is household access to markets, which could raise household incomes and also offer a variety of coping mechanisms to facilitate consumption smoothing and resilience. Conversely, isolated rural households may be more vulnerable to shocks, simply because they have fewer opportunities to smooth consumption by buying, selling, or migrating in response to changing circumstances.

In this study, we investigate the influence of market access on household resilience, using survey data on children exposed to seasonal fluctuations in diet and disease at birth in widely varying locations in the Democratic Republic of Congo (DRC). If children in households closer to markets were less vulnerable to seasonal variation, then investments in rural infrastructure and institutions to expand those markets could confer resilience and improve outcomes. Rural DRC is rich in natural resources and agricultural potential, yet nutritional indicators and standards of living are among the worst in the world and have been declining over time (Ulimwengu et al. 2012). One factor underlying this paradox could be the country's vast size, limited infrastructure, and weak institutions that leave many rural households extremely isolated and vulnerable to local fluctuations in agricultural, environmental and social conditions, including violent conflict.

Our central hypothesis is that birth season has a larger and more significant correlation with child health outcomes for more remote households, compared to those who live closer to towns and markets. That hypothesis follows from the possibility that market transactions can help a household cope with shocks and smooth consumption over time, at least to some degree. Understanding the linkages between market access and child nutrition in the challenging setting of DRC could provide a sharp illustration of how rural isolation leaves households vulnerable to shocks, and how market access can promote resilience. To conduct this study, we merged geocoded datasets for child health, household characteristics, land cover, roads, terrain, towns, and civil conflict. Spatially merging the datasets provides an unusual opportunity for integrated analysis of the linkages between climate, geography, agriculture, and nutrition, as well as contributing to the body of literature on seasonality of health outcomes for children and the consequences of geographic isolation for child health.

To obtain meaningful results, the specific methodological innovations applied here include the measurement of market access using a household's travel-cost weighted distance (the "network distance") to the nearest town, as opposed to Euclidean distance. This approach incorporates roads, land cover and terrain data, offering a key enhancement to the existing body of literature in this area. Another methodological innovation is the use of a grid, superimposed over the map of DRC to demarcate spatial units of observation, to avoid potential problems with using administrative units of observation. A third is to use all three main anthropometric indicators for children: height-for-age Z-score (HAZ), weight-for-age Z-score (WAZ), and weight-for-height Z-scores (WHZ) as outcomes of interest, so as to compare influences on both heights and weights. In the economics literature on health outcomes, most studies focus either on HAZ as an indicator of cumulative health investment, or on WHZ as an indicator of recent deprivation, but health shocks in early childhood may have long-lasting effects on future weights, and even a very recent shock may affect child height during periods of rapid growth. A fourth innovation in this study is to define seasonality in ways that are appropriate to an equatorial country, where the length and intensity of the dry season depends on distance from the equator. Finally, we use a flexible specification for age control variables which more closely matches biological evidence for how Z-scores change with age, in order to prevent bias which may arise when using an inflexible functional form. Each of these methodological innovations helps address our central policy question, which is the extent to which market access is protective against seasonal fluctuations of diet and disease in an environment of extreme rural isolation and protracted civil conflict.

2. LITERATURE REVIEW

2a. Background on the Democratic Republic of the Congo

DRC has some of the world's highest rates of child stunting (45.8%), wasting (14%), and underweight (28.2%) in the world (UNICEF 2011). Approximately 75% of the population is estimated to not consume sufficient calories for a healthy and active life (FAOSTAT 2014; Grebmer et al. 2011; WHO 2000), as the average per-capita food supply declined from 2595 kcal per person per day in 1994 to 1833 kcal per person per day in 2009 (FAOSTAT 2014). Various other nutrition indicators are also worsening over time, in contrast to encouraging trends in neighboring countries (Kandala et al. 2011; Tollens 2003), as the DRC's dire health situation is exacerbated by a protracted civil conflict.

Conflict in DRC has been endemic for decades, and has deeply shaped the food system through disruption of trade routes, looting, displacement of farmers, and land tenure insecurity (Coghlan et al. 2006; Reuveny 2007). Although the violence is typically concentrated in the Eastern provinces, it drains the already limited resources of the government, thus exacerbating food and nutrition security problems elsewhere in the country. The 2.9 million internally displaced persons (IDPs) have access to few resources or land to support themselves (FAOSTAT 2014). Violence against civilians worsens the already low agricultural productivity and stifles agricultural development.

The majority (64.6 %) of the population of DRC is rural (FAOSTAT 2014), and that rural population growth has led to sharp declines in arable land per person as well as arable land per agricultural worker (FAOSTAT 2014). The value of total agricultural production and total food production has been declining since 1997 (FAOSTAT 2014), in a setting where the major crops are produced for consumption within rural areas including cassava, maize, other roots and tubers, and plantains. The country has good conditions for agriculture, including a tropical climate with rich soils, and plentiful rainfall across much of the year. However, due to the reliance on rain-fed agriculture and poor access to storage or markets, households may be unable to effectively smooth consumption across the year.

2b. Environmental shocks and child health

There is a rich body of literature investigating the ability of households to smooth consumption across the year (Morduch 1995), and protect investments in child health (Jensen 2000). Using environmental conditions to identify children exposed to particular factors at particular times has opened countless opportunities for studying how households smooth consumption, and how this behavior affects children (Angrist et al. 2001; DiNardo 2008). The growing literature in this area uses severe environmental shocks such as a drought, famine, or war to identify exposed children (Akresh et al. 2011; Akresh et al. 2012; Almond 2006; Banerjee et al. 2007; Bundervoet et al. 2009; Chay and Greenstone 2003; Ferreira and Schady 2009; Godoy et al. 2008; Hoddinot and Kinsey 2001; Maccini and Yang 2009; Minoiu and Shemyakina 2012; Skoufias and Vinha 2012; Yamano et al. 2005; Strauss and Thomas 2008). The impact of environmental shocks on child health is especially of interest because of the potential long-term consequences affecting an individual’s risk of disease, attained height, and labor productivity (Alderman et al. 2006; Almond and Currie 2011; Barker 2008; Barker 1990; Black et al. 2008; Deaton 2007; Dewey and Begum 2011; Martorell 1999). Some studies focus on more immediate outcomes in infancy and childhood, while others extend to assess outcomes in adulthood.

Child nutrition is particularly sensitive to environmental shocks if they occur during critical developmental periods (Shrimpton et al. 2001; Victora et al. 2010; Aguero and Deolalikar 2012). In general, younger children may be more severely affected than those who are older when exposed to a nutritional insult (Aguero and Deolalikar 2012). A study of Ethiopian children found that those between 6 months and 24 months of age during a negative nutritional shock are most vulnerable (Yamano et al. 2005). A study in Zimbabwe found that children exposed between the ages of 12 months and 24 months lose 1.5-2 cm of growth after exposure to a drought at an early age (Hoddinot and Kinsey 2001). Child development is such a sensitive process, that season of birth can sometimes be used to identify exposed children even if seasonal fluctuations are not severe.

2c. Seasonality and child health

Using seasonal variation for econometric identification is weaker than using a more specific shock such as drought, in part because seasons are predictable so people will adjust their behavior to adapt, and in part because many environmental and biological factors fluctuate seasonally so it becomes difficult to distinguish between them. There may even be seasonality in the incidence of conflict (O'Loughlin et al. 2012; Hendrix and Glaser 2007). Despite these constraints, significant insight can be gained by matching the timing of exposure to the "less healthy" seasons with the timing of critical developmental periods. Birth season has been found to affect health and socioeconomic outcomes throughout life and across many diverse populations, due to the child's vulnerability at the time of conception and pregnancy, introduction of complementary foods, cessation of breastfeeding, and other developmental periods.

Households which rely on agriculture for their livelihood may be particularly susceptible to seasonal fluctuations, especially if they lack market access. For example, in Malawi, household consumption diversity was found to be positively associated with production diversity, suggesting that production fluctuations might cause consumption fluctuations (Jones et al. 2014). The less healthy period may be the rainiest, due to water-borne disease and proliferation of disease vectors. This period may also correspond to just before harvest when food supplies from the previous year dwindle, day labor may be more difficult to find, and maternal labor time and calorie expenditure increase (Buckles and Hungerman 2013; Chodick et al. 2009; Panter-Brick 1997). Similar to the random environmental shocks discussed above, seasonal variations may be especially important for health if the child's birth timing exposes them to more risk factors during critical phases of child development, such as the period of complementary feeding, or during the third trimester of pregnancy (Chodick et al. 2009).

For example, in Gambia, children born during the dry season have systematically lower weight-for-age and height-for-age than children born during the rainy season (Gajigo and Schwab 2012), and birth outcomes may also be affected by season (Rayco-Solon et al. 2005). Another study of Gambian individuals demonstrated the increased risk of mortality for young adults who were born during the less healthy season (Moore et al. 2004). Child health outcomes can be affected not only by extreme changes discussed above, but also by typical variation in weather patterns, and these impacts may differ by gender or age (Maccini and Yang 2009; Tetens et al. 2003). Birth outcomes may be influenced by seasonal variations in maternal dietary patterns (Watson and McDonald 2007). Even after controlling for within-mother characteristics by comparing siblings, seasonal patterns are still seen in health outcomes (Gajigo and Schwab 2012; Currie and Schwandt 2013).

Seasonal shocks influence both diets and disease, in ways that vary widely by location. In urban areas of Bangladesh, for example, both food security and child weight-for-age vary between the monsoon season and the dry season (Hillbruner and Egan 2008). In some settings, positive rainfall shocks can worsen the health environment but improve agricultural conditions, with opposing effects on child health (Skoufias and Vinha 2012). More uniform and consistent rains may enable a lengthening of the growing season. However, the lack of a dry season may allow disease vectors such as the malarial mosquito to keep reproducing throughout the whole year (WHO 2013). Therefore, exposure to environmental dryness may have different effects on child health, depending on whether the household is urban or rural.

2d. Seasonality and market access

Recent evidence suggests that seasonality matters more for isolated households than for households in more densely populated areas (Pomeroy et al. 2014). However, being isolated in the DRC may actually be a benefit to households and children, as isolation and rugged terrain may protect them from violence which may concentrate in populated or wealthy areas (Nunn and Puga 2012; Le Billon 2001), or may give them access to enough land to meet nutritional needs. It’s also possible that the geographic remoteness of a household or their exposure to conflict affects the level of assistance they receive from humanitarian organizations. A variety of papers address these differences between remotely located and non-remotely located children, often by focusing only on a specific region.

For example, the authors of a study examining the impact of weather shocks on child health in Nigeria exclude urban children because they expect rainfall variability to affect rural children more strongly (Rabassa et al. 2012). A study which performed the analysis for both urban and rural groups in Peru found significant birth month associations for various anthropometric measurements for rural children but not for urban children (Pomeroy et al. 2014). A study of Gambian children found that households which were not as reliant on agriculture didn’t have seasonality in their nutrition outcomes (Gajigo and Schwab 2012). A study of the expansion of railroads in India found that reducing transportation costs had a protective effect for maintaining real incomes, and reduced the sensitivity of mortality rates to environmental shocks (Burgess and Donaldson 2010). In conjunction, these findings lend support to the hypothesis that proximity to markets may provide protection against seasonal fluctuations in food availability. Excluding groups of children based on geography may generally be useful for analysis, but testing the hypothesis that market access provides protection against seasonal fluctuations in environmental conditions calls for data spanning a wide range of household locations.

3. RESEARCH METHODS

3a. Measuring exposure to the dry season

We exploited the quasi-randomness of birth month to identify children exposed to the dry season in DRC in various degrees. To accurately capture seasonality in DRC, we used the absolute value of latitude of each DHS cluster's location as a proxy for rainfall and temperature, and dummy variables indicating which half of the year the child was born during to capture the timing of the dry season in each hemisphere. DRC lies between approximately 6 degrees North and 14 degrees South of the Equator. Locations closer to the equator have more uniform temperature and rainfall throughout the year, with dry seasons becoming more pronounced the further you get from the equator (World Bank CRU 2014). This pattern can be seen across the country from west to east, making the absolute value of latitude a simple indicator of how pronounced the dry season is at a particular location. Using latitude as a proxy for the degree of seasonality, as opposed to using a climate model, is appealing because of the dearth of weather stations in DRC and the limited empirical basis for estimating actual rainfall or temperature at any given place.

In the areas of DRC located in northern hemisphere (approximately 1/3 of the country's area), the dry season may last from approximately December- February, depending on the distance from the equator. In the areas of DRC located in the Southern hemisphere (approximately 2/3 of the country's area), the timing of the dry season is reversed, and lasts from June-August, again depending on distance from the equator (World Bank CRU 2014). We did not categorize months as "dry" and "rainy", but instead took an empirical approach to identify which birth months are associated with better or worse future health outcomes. There is too much variation in climate across the country to be able to characterize each month for each location ex ante. To capture the timing of the dry season across the whole country, *RainMonths* are defined as the calendar months in the Southern hemisphere, and defined as the calendar month shifted 6 months forward in the Northern hemisphere. *RainMonths* are then aggregated into *RainHalf*, which enters as a "half-year of birth" explanatory dummy variable in the regression models. The interaction term between *RainHalf* and the absolute value of latitude is included in the regressions, because we expect the birth season effect to be less pronounced the closer a household is to the equator. Statistically significant estimated coefficients on the *RainHalf* variable indicate that children are vulnerable to a seasonal fluctuation in their nutritional outcomes.

3b. Measuring nutritional outcomes

The main outcomes of interest are height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ) and weight-for-height Z-scores (WHZ) for children under the age of 5 years. Weight-for-height is likely more sensitive to seasonal variation across the year than height-for-age. But, the DHS dataset is cross-sectional, and so one might wonder where we expect to find seasonal variation in WHZ when the data were collected over a relatively short period of time. A nutritional insult which occurred at a time to disrupt normal immune system development may lead to persistent wasting (low WHZ), due to recurring or persistent morbidities (Raqib et al. 2007). The potential causal pathway between season of birth and future risk of wasting may originate from the characteristics of the health environment at birth, or the mother's nutritional status during the preconception period or during fetal development (Fernandez et al. 2002). Even a short-lived period of undernutrition may affect the microbiome of the intestines such that it increases risk of infectious diseases throughout the lifespan (Gordon et al. 2012; Kau et al. 2011).

There is mounting evidence that stunting and wasting share common causes (Martorell and Young 2012). Yet, height-for-age is typically in used just as an indicator of cumulative health investment over time, whereas weight-for-height is used just as an indicator of current nutrition status. In fact, stunting (low HAZ) can be the result of an acute nutritional insult if it occurs during a key developmental period and is severe enough, and wasting (low WHZ) can be a persistent result of past nutritional insults. Characterizing WHZ as solely an indicator of current nutritional status and HAZ as solely an indicator of cumulative health investment may fail to recognize important epigenetic, disease, and immune factors involved in determining child health, and focus too narrowly on food availability as the sole explanation for poor anthropometric outcomes. Food availability alone cannot explain variation in anthropometric indicators (Raqib et al. 2007). Due to the uncertainties surrounding human growth in different and complex environments, we prefer to take a broader view of the causes and the subsequent anthropometric manifestation of undernutrition. To this end, we allow for the potential of seasonal variation at birth to affect HAZ and WHZ, as well as WAZ because weight-for-age is the combined indicator for height and weight.

3c. Data

To conduct this study, we constructed a dataset for DRC which spatially and temporally merged child health information, household characteristics, roads, terrain, land cover, towns, and civil conflict incidents. We superimposed a 1 degree by 1 degree grid over DRC to demarcate the spatial units of observation, in order to avoid endogeneity problems that can arise from using administrative boundaries as spatial units of observation (Harari and La Ferarra 2013). Each grid-cell is approximately 69 square miles in size.

For child health data and household characteristics, we utilized the DRC's Demographic and Health Survey (DHS), a nationally representative survey conducted among 8,886 households with a subsample of 3,782 children between the ages of 0-59 months of age surveyed for the anthropometry questionnaire in 2007 (Measure DHS 2008). The children in the subsample were born between 2002 and 2007, and they were each surveyed in one of 300 geocoded DHS clusters. Observations where the families had moved in the previous 6 years were dropped (n=293), to ensure that household market access and child exposure to conflict were measured as accurately as possible, including during the mother's pregnancy with the child. Observations flagged by DHS for biologically implausible measurements (where the absolute value of calculated HAZ or WHZ was greater than six) were also dropped (n=397). Observations where the child was not present, or where the parent refused measurement, or the child was not measured for some other reason were also dropped (n=286). This left 2,806 children with biologically plausible measurements in the anthropometry sub-sample to conduct our study.

The conflict data are from the Armed Conflict Location and Event Dataset (ACLED), which details specific incidents of civil insecurity between 1997 and the present day for DRC and other countries (Raleigh et al. 2010). Events which occurred between 2001 and 2007 were retained for this project to correspond with children who were between the ages of -9 months and 59 months old when surveyed for the anthropometry sub-sample during the 2007 DHS round. The ACLED data are geocoded daily incident reports. Therefore, each day that an incident (such as a battle) continues will be counted as an additional event. We aggregated the incident reports into fatalities and number of events by month in each 1-degree square grid-cell. Each incident is categorized as one of eight different types of conflict events, including violent and non-violent activities (Raleigh et al. 2010). The dataset is designed to provide an accurate picture of overall conflict activity in a country, but it does consist of incident reports and therefore may omit events which aren't reported. Events in non-remote areas may be more likely to be observed than events in remote areas, which could bias the spatial pattern of violence reports.

Euclidean distance is a useful but incomplete proxy for travel time in the DRC context, because road quality, terrain, infrastructure, and land cover may greatly impact a person's ability to travel to market. To develop the travel cost-weighted distance measures, we utilized geocoded data on 160 major towns, roads, and land cover (including bodies of water) from the Multipurpose Africover Database on Environmental Resources (FAO MADE 2014). The DHS data were spatially merged with these layers. To obtain the distances to town, first the Euclidean distances from the centers of each DHS grid-cell to the "major town" point locations were calculated using ArcGIS 10.0 (ESRI 2013). Then, cost values for different land covers were assigned based on a modified Beaufort scale (Lindau 1995). With this scale, cells with roads and open land take on lower travel costs than cells with thick forest and open water, for example. Details on the values assigned to different land cover classes are included in the Appendix.

Data on terrain from the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model: Version 2 (ASTER-GDEM) was merged with the land cover data to assign the total travel-cost values for each cell (NASA LP DAAC 2014). Cells with steeply sloped terrain have higher assigned travel costs. The resolution of the final travel cost grid is 100 meters square, and it is the sum of the terrain travel-cost and the land cover travel-cost of the cell. The full travel cost grid was then superimposed on the existing merged dataset used to generate the network distances (the travel-cost weighted distances) from the center of each DHS grid-cell to the nearest major town. If a travel-cost weighted distance was found to be less than the Euclidean distance, the network distance is set equal to the Euclidean distance. ‘Proximity’ enters the regressions as an explanatory variable, and is defined as the inverse of network distance to the nearest town in kilometers.

3d. Hypothesis tests

Due to the timing of the DHS survey implementation, children born in the later months of the year are systematically younger, and therefore height-for-age Z-scores are systematically higher, as HAZ declines with age in low income contexts. This “timing artifact,” as described by Cummins (2013), prevents unbiased and consistent parameter estimation when identification relies on season (Cummins 2013). To control for age appropriately, we use a linear spline regression in each model. The age variable is piecewise linear with two knots placed at 6 months of age and 22 months of age when HAZ is the dependent variable, and one knot placed at 12 months of age when WAZ and WHZ are the dependent variables. Therefore, there are three age splines which enter as controls when HAZ is the dependent variable, and two age splines which enter as controls when WAZ and WHZ are the dependent variables. The knot placement is based on the observed nonparametric relationships between child age and each of the indicators in the DRC-DHS data.

We used kernel-weighted local polynomial smoothing and ordinary least squares (OLS) regression to conduct the analysis. There are three dependent variables of interest, one for each of the major child anthropometric indicators as dependent variables: height-for-age Z-score (HAZ), weight-for-age Z-score (WAZ), and weight-for-height Z-score (WHZ). Age in months enters with a piecewise linear functional form and knot placement depending on the dependent variable. Child sex enters as a dummy variable. Birth season (as *RainHalf*) enters as a dummy variable. The absolute value of latitude in degrees enters linearly, and also as a component of interaction terms to characterize the severity of the dry season at the household’s location. Household proximity to nearby markets, weighted by the travel cost, enters linearly and as a component of interaction terms. Household wealth enters as a categorical variable indicating wealth quintiles. Conflict enters as a continuous variable measured as the number of conflict incidents recorded for the grid-cell of the child’s residence between 2001 and 2007. This time frame captures potential exposure for the children in the sample, including time during their mother’s pregnancy.

The econometric model development is outlined below in Equations 1-3. The subscript *i* indexes children, *k* indexes the linear age splines, and *j* indexes DHS clusters (household locations). *Age* enters as a piecewise linear term with knots in the function placed depending on the anthropometric outcome in question. *Sex* is a dummy variable indicating the child is male. *H* is a vector of household characteristics, including household wealth and proximity to nearby markets. *E* is a vector of environmental characteristics, including the absolute value of latitude and exposure to conflict. *RH* indicates *RainHalf*, which is a dummy variable indicating whether the child was born during the first half of the year. If the child was born in the Southern hemisphere of the country, *RH* equals 1 for January through June. If the child was born in the Northern hemisphere of the country, *RH* equals 1 for July-December. The two- and three-way interaction terms between the *RH* dummy variable, proximity, and the absolute value of latitude are indicated by *Int*. In Equation 3, *H* represents household wealth and *Int* represents the two-way interaction terms between the absolute value of latitude and the birth season variable, as the estimation is stratified by household remoteness in this specification. ε_i is an error term with the usual properties.

The first model, Equation 1, is a diagnostic regression with all terms entering linearly and no interaction terms included. The second model, Equation 2, incorporates the full set of two- and three-way interaction terms between birth *RainHalf*, proximity, and latitude. The third model, Equation 3, stratifies the estimation by household remoteness. Areas are classified as remote if the network distance to travel to the nearest major town is greater than 45km. This cutoff was chosen based on the median of estimated distance to the nearest town which was 44.8km. Other terms remain the same once the model is stratified for estimation, and the *proximity* term is dropped. All three models are estimated by Ordinary Least Squares (OLS) regression, and standard errors are clustered by grid-cell to account for correlations among respondents who reside in the same areas. Analysis was performed in StataMP 12 (StataCorp 2011).

$$Z - score_i = \alpha + \sum_{k=1}^{n} \beta_k Age_k + \beta_{n+1} Sex_i + \delta \vec{H}_j + \gamma \vec{E}_j + \lambda RH_i + \varepsilon_i \qquad (1)$$

$$Z - score_i = \alpha + \sum_{k=1}^{n} \beta_k Age_k + \beta_{n+1} Sex_i + \delta \vec{H}_j + \gamma \vec{E}_j + \lambda RH_i + \sum_{q=1}^{10} \rho_q Int_j + \varepsilon_i \qquad (2)$$

$$Z - score_i = \alpha + \sum_{k=1}^{n} \beta_k Age_k + \beta_{n+1} Sex_i + + \delta H_j + \lambda E_j + \lambda RH_i + \sum_{q=1}^{3} \rho_q Int_j + \varepsilon_i \qquad (3)$$

3f. Limitations

Time variant factors which are not controlled for could impact results. We found no evidence of seasonality in the timing of conception or the incidence of civil insecurity, but several other sources of bias could intervene, such as systematic differences in fetal or child survival. The econometric models do not yet account for the endogeneity of household wealth in determining child nutrition, nor the spatial correlations between conflict, wealth, and population. Also, the conflict data are incident reports and therefore may be biased towards increased reporting in areas that are easier to observe, such as non-remote areas.

4. RESULTS

Descriptive statistics are presented in Table 1. The mean and standard deviations for selected variables are given for the whole sample, and then split into the sub-samples used in our hypothesis tests. To make the cut-off for "remote" households, we rounded up from the median network distance to the nearest major town, which is 44.8 km. There are 1375 children who live in households located more than 45km from a major town, and 1431 children who live in households less than 45km from a major town. Children were identified as being born during the "less healthy season" if they were born during the first *RainHalf* " which is January to June in the Southern hemisphere and July to December in the Northern hemisphere. The "less healthy" and "healthier" classifications are based on the regression analysis outlined below, and were not decided upon ex ante. There are 1553 children in the sample who were born during the "less healthy" season, and 1253 children born during the "healthier" season. Whether these key variables differ significantly across groups was first assessed with preliminary t-tests.

The results of the exploratory t-tests are presented in Table 2, split by gender, household remoteness, and birth season. Boy children (N=1386) have consistently lower HAZ, WAZ, and WHZ than girl children (N=1420) across the age spectrum (p=0.031, p=0.001, and p=0.003, respectively). This difference in means is statistically significant and it increases in rural areas compared with urban areas. Mean HAZ and mean WAZ are lower in remote areas compared with non-remote areas (p=0.012 and p=0.014, respectively). There is not a statistically significant difference between mean WHZ in remote areas and mean WHZ in non-remote areas. Mean HAZ and mean WAZ are lower for children born during the less healthy season (p=0.095 and p=0.039, respectively) compared with children born during the healthier season.

Figures 1-3 show the kernel-weighted (Epanechnikov kernel) local polynomial smoothing for each of the anthropometric indicators against child age in months, and separated between remote and non-remote households. There is a steep decline in HAZ before 24 months of age, and then the slope becomes less steep afterwards but is still negative. Children living in remote households have consistently lower HAZ than children living in non-remote households, but this difference is not very large in magnitude. There is a similar pattern for WAZ, except that weights appear to more closely match-up between remote and non-remote households until 12 months of age, when children in remote households become consistently worse off. As indicated by the exploratory t-tests, there are not consistent differences in the relationship of WHZ to age between children in remote and non-remote households. Both group experience a steep decline in WHZ until about 12 months of age, when a slow catch-up begins.

Figures 4-6 show the kernel-weighted (Epanechnikov kernel) local polynomial smoothing for each of the anthropometric indicators against child "rain-month" of birth. *Rain-months* are defined as the calendar months for locations in the Southern hemisphere and defined as the calendar months shifted forward 6 months for locations in the Northern hemisphere. Rain-months are defined in this way so that the timing of the dry season can be identified across the whole country using one variable. Figure 4 shows that there is no relationship between rain-month of birth and HAZ for remote households, and that children in non-remote households born in the second half of the year appear to achieve higher HAZ scores. Figure 5 shows that, except for rain-months 7-10, WAZ is consistently higher for children in the non-remote households. Figure 6 shows that WHZ is higher for children born in non-remote locations during the first half of the year, and higher for children born in remote locations in the second half of the year.

Table 3 presents the results of an exploratory Ordinary Least Squares (OLS) regression. In this model, child anthropometric Z-scores are estimated as a function of age, sex, conflict exposure, household wealth, proximity to the nearest major town, and rain-month of birth. The reference group for birth half dummy variables is the second half of the year, which is July-December in the Southern hemisphere and January-June in the Northern hemisphere. HAZ, WAZ, and WHZ decline with age, although for HAZ the decline is not seen until 6 months of age. WHZ recovers slightly for children over 12 months of age. Male children have consistently lower Z-scores, ranging from a penalty of about 11% of one standard deviation for WAZ to 8% of one standard deviation for WHZ. Conflict incidents in the grid-cell of residence have statistically significant associations with nutritional outcomes: a negative association with HAZ and a positive association with WHZ, but these associations are quite small in magnitude. Household wealth is positively associated with HAZ and WAZ, but not WHZ. In this model, distance from the equator and proximity to nearby markets do not have statistically significant associations with child Z-scores. Being born during the first half of the year (the less healthy season) has a negative association with WAZ. The estimated coefficient on the birth season variable is statistically significant, indicating that there is seasonality present in determining WAZ.

Table 4 incorporates interaction terms into the econometric model. The full set of two- and three-way interaction terms between the birth *RainHalf* dummy variable and latitude and proximity are included. The relationships between child age and Z-scores is the same as with the diagnostic model, with declines seen in the first two years of age, followed by a slow recovery for WHZ after 12 months of age. Male children are consistently worse off for all three indicators. The number of conflict incidents in the grid-cell of residence is negatively associated with HAZ and positively associated with WHZ, and both estimated coefficients are statistically significant. Household wealth has a statistically significant and positive association with HAZ and with WAZ. In this regression, increasing distance from the equator (increasing dryness) and proximity to markets are negatively associated with WAZ and WHZ, but the overall marginal effects for these variables (Table 4a) are not statistically significant. The estimated marginal effects also show that being born during the less healthy season is negatively associated with WAZ, just as seen in the diagnostic regression model.

The estimated coefficients on the interaction terms in this model tell an interesting story. The effects of distance from the equator and proximity to nearby markets reinforce one another for WAZ and WHZ. The more pronounced the dry season is for a child, the more it matters how close he or she lives to the market. Similarly, the closer a child lives to the market, the more it matters how dry the environment is. The estimated coefficient on the interaction term between birth season and proximity are strongly positive and statistically significant for WAZ and WHZ, indicating that the effects of proximity to markets and birth season also reinforce one another. The effects of proximity and birth season also appear to reinforce one another in determining weights, but not in determining heights. The estimated coefficient on the three-way interaction between birth season, proximity, and the absolute value of latitude is negative and statistically significant for WHZ.

The following two tables (Table 5 and Table 5a) split the regression analysis into two groups by household remoteness. Households are classified as remote if they are located 45km or more away from a major town, measured in the travel-cost weighted distance. Table 5 shows the results for the whole model, and Table 5a shows the estimated marginal effects for the individual variables. The age to Z-score profiles remain similar after stratification. Child heights don't start to decline until the 6 to 22 month age period when there is a relatively steep decline, and they continue declining after 22 months of age at a slower rate. WAZ and WHZ declines for the first 12 months, and then WHZ recovers slightly afterwards. Boys are systematically worse off, especially in the remote areas. Being male is not negatively associated with HAZ in non-remote areas. The proximity variable is now stratifying the sample and therefore no longer enters as an explanatory variable. The estimated marginal effects show that increasing distance from the equator (increasing dryness) is negatively associated with weights in the remote groups, and positively associated with weights in the non-remote groups. These associations are statistically significant. The estimated marginal effect of household wealth is statistically significant and positive, as expected, for HAZ and WAZ in non-remote areas, and also positive for WAZ in remote areas. Wealth is not significantly associated with HAZ in remote areas, or with WHZ in remote or non-remote areas. Conflict exposure is negatively associated with HAZ in non-remote areas, negatively associated with WAZ in remote areas, and positively associated with WAZ and WHZ in non-remote areas.

There are statistically significant, negative birth season effects for WAZ and WHZ in remote areas, as shown in the marginal effects Table 5a. In remote areas, being born during the first half of the year is associated with a penalty of 11% of one standard deviation of WAZ and a penalty of about 17% of one standard deviation of WHZ. Birth season is positively associated with WHZ in non-remote areas, albeit with a shallower slope. The estimated coefficients on the interaction terms between birth season and the absolute value of latitude are negative in non-remote areas for WAZ and WHZ. This indicates that the effects of being born during the less healthy season are counteracted by the effects of environmental dryness. Season is a significant determinant of WAZ and WHZ in remote areas, and of WHZ in non-remote areas. Season is not a significant determinant of HAZ in either remote or non-remote areas.

In summary, child nutritional status in DRC varies by birth season, geographic isolation, and conflict exposure. The Z-score-age profiles seen here follow expected patterns that are well established in the literature. In general, boy children have lower Z-scores in DRC, especially in remote areas. Birth season does not appear to be a determinant of child heights in the DRC. Birth season is a significant determinant of child weights in remote areas. A more prolonged and intense dry season is negatively associated with WAZ and WHZ, but only in remote areas. In contrast, a more prolonged and intense dry season is positively associated with WHZ in non-remote areas. Conflict incidents are positively associated with child WAZ and WHZ in non-remote areas, and negatively associated with HAZ in non-remote areas, but these effects are small.

5. ROBUSTNESS CHECKS

Results do not change whether including or excluding households which have lived in their interview location for fewer than 6 years at the time of the interview (N=293). Results also do not change when including or excluding respondents who took a trip lasting more than 1 month during the 12 months preceding the interview date, which could include households that were internally displaced for a time due to conflict (N=307). These observations were originally excluded to ensure that exposure to conflict and remoteness was accurately measured. With the large number of internally displaced persons in DRC, surveys may be skewed against this at-risk group due to measurement challenges.

Any seasonality in births, deaths or in the incidence of civil conflict could impact the results of this study. However, this does not appear to be the case. For example, we performed nonparametric tests to assess whether there is seasonality in the incidence of conflict in DRC, and found no evidence of any differences in means across the year in aggregate, or for any of the individual provinces.

6. DISCUSSION

In the DRC context, these results need to be considered in terms of the potential spatial associations between humanitarian assistance projects, civil unrest, and natural resources. As expected, child HAZ and WAZ are generally lower in more remote households, as seen in the nonparametric graphs. The econometric analysis reveals that there is seasonality in child weights in remote areas, and that a more pronounced dry season is associated with poorer child weight outcomes, but again only in remote areas. These findings support the hypothesis that household market access is protective against seasonal fluctuations in food availability and disease transmission. The vulnerability of remote households is extreme enough to be reflected in seasonal fluctuations of their children's future weight-for-age Z-scores, relative to households with easier market access whose children's future Z-scores are not as affected by birth season.

Interestingly, while being born during the dry season in remote areas is associated with lower future child weights, being born at during that season in less remote areas is linked to higher future child weights. This contrast provides some suggestive evidence that dry seasons are healthier in more populated areas, in ways that cannot be smoothed by market access and market transactions. Children with better market access may have better protection against seasonal fluctuations in food availability, but they are not necessarily as well protected against seasonality in infectious disease cycles. Infectious diseases such as malaria may stop transmitting for periods of time if the dry season is long and intense enough, because the reproductive cycle of the malarial mosquito is halted (Trape et al. 1993). The shorter the dry season, the less of a respite the children have from mosquitoes and other disease vectors which rely on rains for their reproduction. Disease transmission may be facilitated by higher population density in non-remote areas. Sanitation could also prove to be a key factor which links season to WHZ in non-remote areas (Korpe et al. 2012). Sanitation is arguably more of a challenge in non-remote areas due to higher population density. The child health data of the DHS and other surveys should be used to investigate this hypothesis further.

These patterns between dryness at birth and future WHZ can be seen in the local polynomial smoothing of WHZ against rain-month of birth in Figure 6. In the first rain-half of the year, which is arguably the drier season across both hemispheres in DRC, child WHZ is systematically lower for remote areas, and systematically higher for non-remote areas. This pattern reverses for the wetter half of the year. These observed patterns are consistent with the hypothesis that dryness is bad for children in remote areas because of the impact on food availability, and good for children in non-remote areas because of the impact on disease prevalence. These graphs also suggest that rain-month of birth has a stronger impact overall on child WHZ in remote areas, given the larger amplitude of the cycle across the year for remotely located children compared with non-remotely located children.

The strong observed patterns between birth season and WHZ suggests that there are important environmental factors which determine future WHZ beyond present food availability. This finding contradicts the conventional wisdom that WHZ can only be used as an indicator of current health or nutritional status. Instead, it appears that the food availability at birth and then 6 months later when the complementary feeding period begins are important determinants of WHZ in the future. This could be due to chronic malabsorption issues (environmental enteropathy) developed due to recurrent episodes of undernutrition (van der Merwe et al. 2013). Low WHZ may begin as a seasonal episodic problem, but if severe enough, it may become chronic due to the reinforcing mechanisms of undernutrition and disease (Korpe et al. 2012). The health and nutritional status of the mother during the neonatal period could also be a factor determining WHZ because of sensitive immune system development during that period. The etiology of specific types of wasting should be investigated further by scrutinizing health data in the DHS and other surveys.

Conflict incidents have a negative association with heights, which is what we would expect. Children who have been exposed to more civil conflict have had reduced health investments over their lifespan, potentially leading to lower HAZ. However, conflict incidents have a positive association with weights, which is counter-intuitive. There are two potential explanations for this finding. The first potential explanation is the spatial associations between wealth and conflict. If conflict is more concentrated in wealthier, natural-resource rich areas because armed groups are fighting for control of said resources, children may be better off in those wealthier areas just because they are wealthier on average, regardless of any nearby fighting. Children who live in the natural resource poor areas will be more susceptible to seasonal fluctuations because they are poorer overall. If conflict is spatially correlated with wealth, then these results can be explained in part by wealth disparities across the country.

This hypothesis is supported by the fact that the mean household wealth index is significantly higher for conflict affected (mean=3.33) households than non-conflict affected (mean= 2.49) households (two-sample t-test $p<0.001$). We can test this hypothesis further by examining the nonparametric relationship between conflict incidence and household wealth. Figures 7 and 8 show the kernel-weighted local polynomial smoothing regressions for the total number of conflicts and for the total number of fatalities that each household experienced over 2001-2007, by household wealth quintile. These graphs show a clear positive relationship between household wealth and both the number of conflicts and the number of fatalities experienced by a household.

Another potential explanation for the positive association between conflict and child weights is the attention the conflict brings for humanitarian assistance projects. It’s possible that humanitarian assistance efforts have succeeded in part to improve child weights in conflict-affected areas. The conflict affected areas are more likely to receive attention from humanitarian organizations because it is an acute crisis that is relatively more easily observed. Given that HAZ can be used as an indicator of more long-term nutritional status, the negative association between the number of conflicts and HAZ is consistent with the hypothesis that successful humanitarian assistance is the cause of the disparity. Humanitarian assistance is more likely to be able to improve weights in the short term for acute crises, but they are not necessarily as well equipped to improve heights over the long term, or over successive generations. Children who are not exposed to conflict are not necessarily as effectively targeted for humanitarian assistance, and therefore are not protected against seasonal fluctuations in food availability like the children who are exposed to conflict. Unfortunately, this hypothesis will be difficult to test because there is no geocoded dataset which estimates the level and targeting for the many humanitarian assistance projects in DRC. Overall, the correlations between conflict and Z-scores are small in magnitude and therefore should be interpreted with caution.

7. CONCLUSIONS

This study exploits seasonal changes in children’s environment to test whether market access promotes resilience, helping households shield their children from fluctuations in food availability and disease transmission. Our methodological innovations include measuring market access in terms of travel cost based on detailed land cover and terrain data, and measuring seasonality in terms of the dry season that arises further from the equator. We also incorporate flexible age controls into each regression, to capture the influence of survey timing on children’s heights and weights. Our findings suggest that children living in more remote locations are more vulnerable to seasonal fluctuations than otherwise similar children living in less remote areas, as evidenced by the effect of birth season on future weights (but not heights). Controlling for season and other factors, household wealth is associated with child height (but not weight), and only in less remote areas. This contrast indicates systematic differences in households' ability to nourish and protect children, leaving more remote rural households more vulnerable to shocks while those closer to towns are more able to use household wealth to improve children's growth.

In summary, we find that households' access to towns and markets is closely linked to resilience, protecting children from seasonal fluctuations in ways that differ from a household's own level of wealth. Further examination of the health, climatic and other data is needed to confirm this result, with robustness tests to address the roles of spatial correlation and coincident cycles, selective morbidity and mortality, and other confounders. However, these results suggest an important role for market integration, transportation infrastructure and rural services of all kinds as protective against health shocks, in addition to their many other influences on household well-being. Interventions to improve households' access to towns and markets could reduce vulnerability, independently of their effects on household wealth, in addition to investments that target causes of malnutrition more directly such as improved diets and health care, or reduced disease transmission and civil conflict.

8. TABLES, MAPS, FIGURES

Figure 1

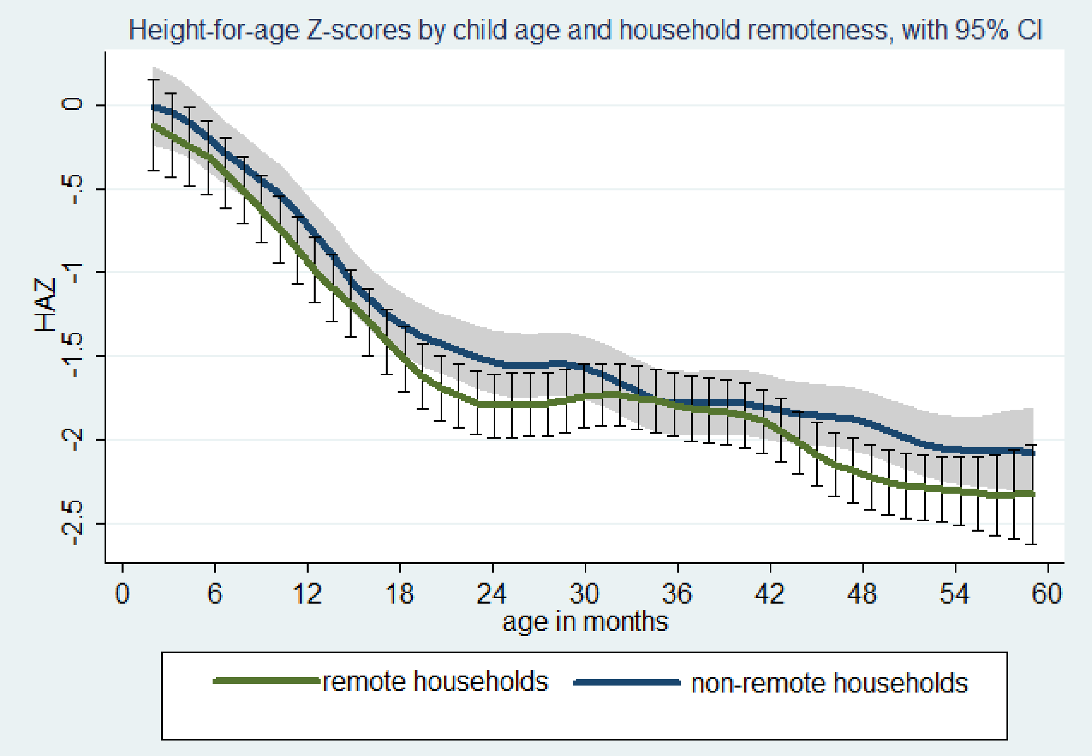

Figure 2

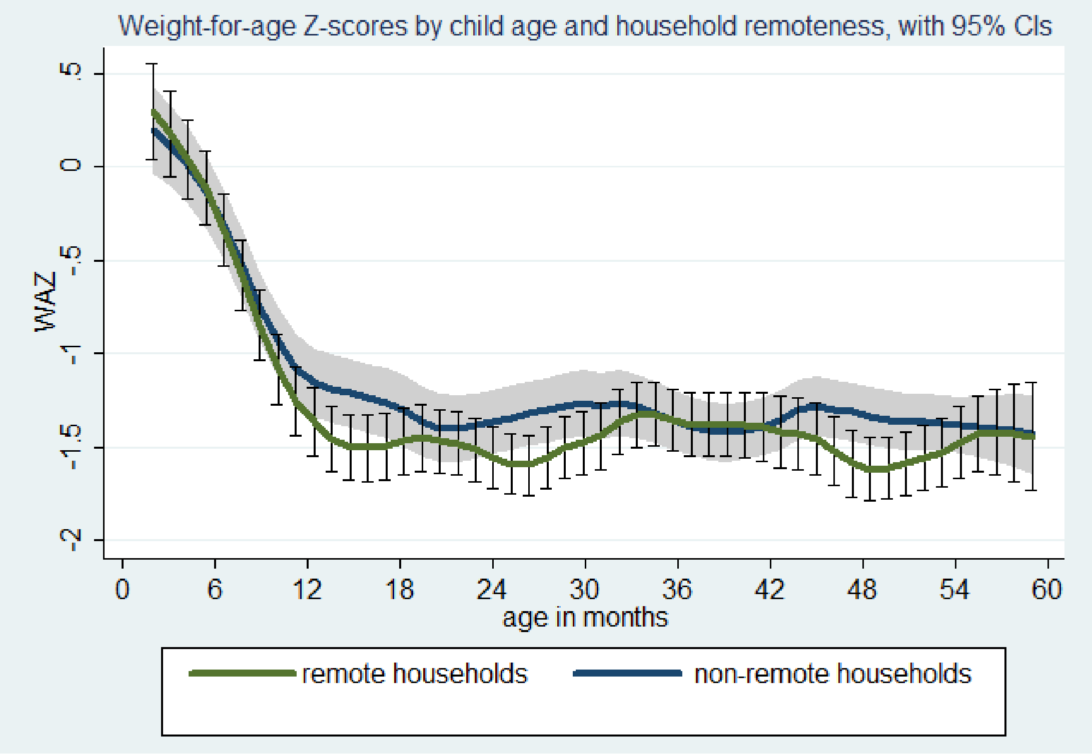

Figure 3

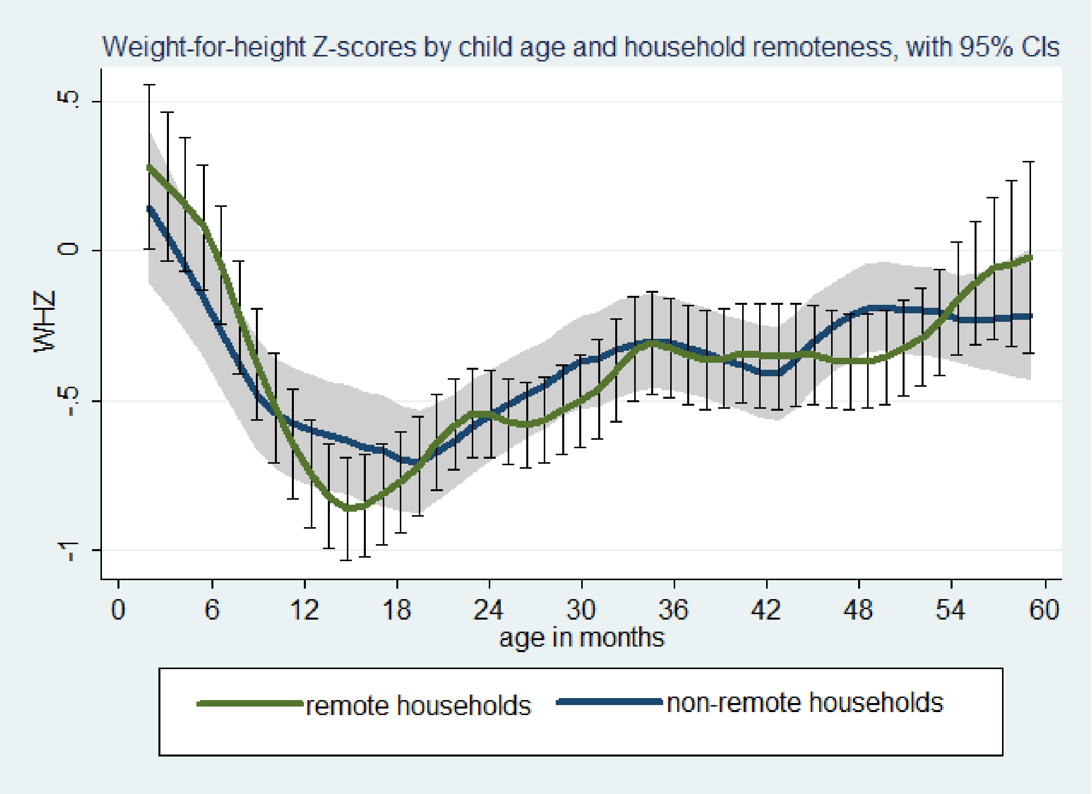

Figure 4

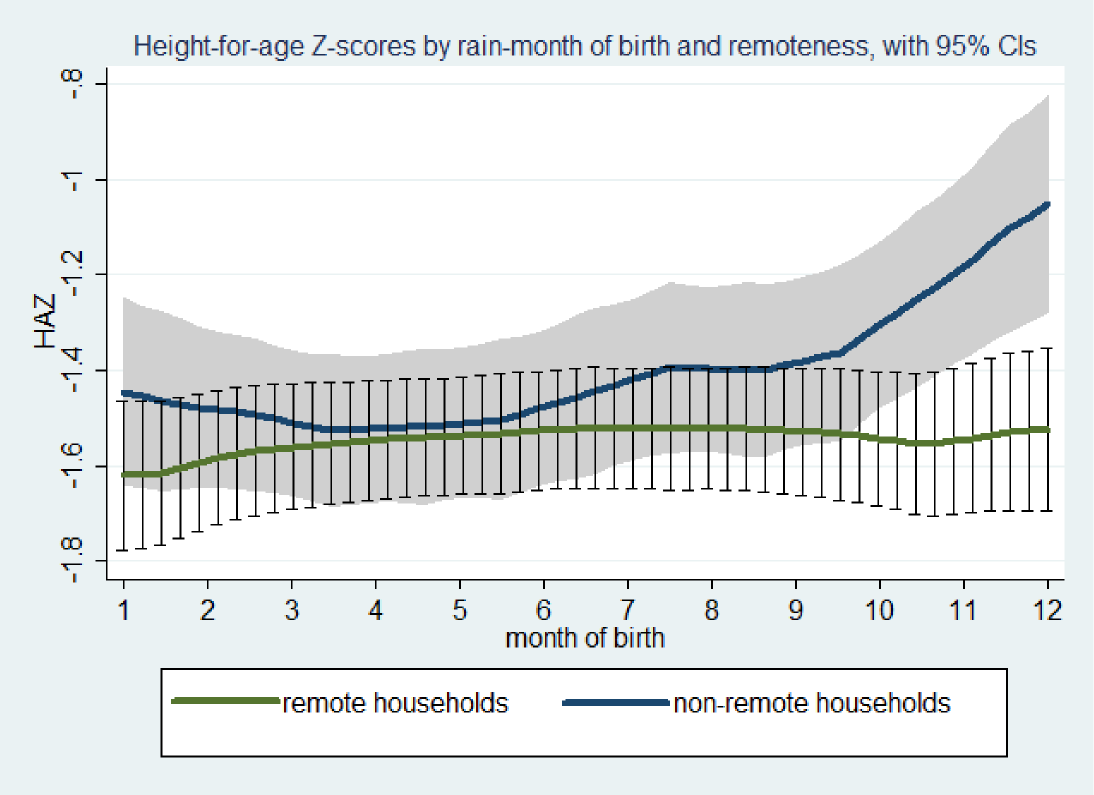

Figure 5

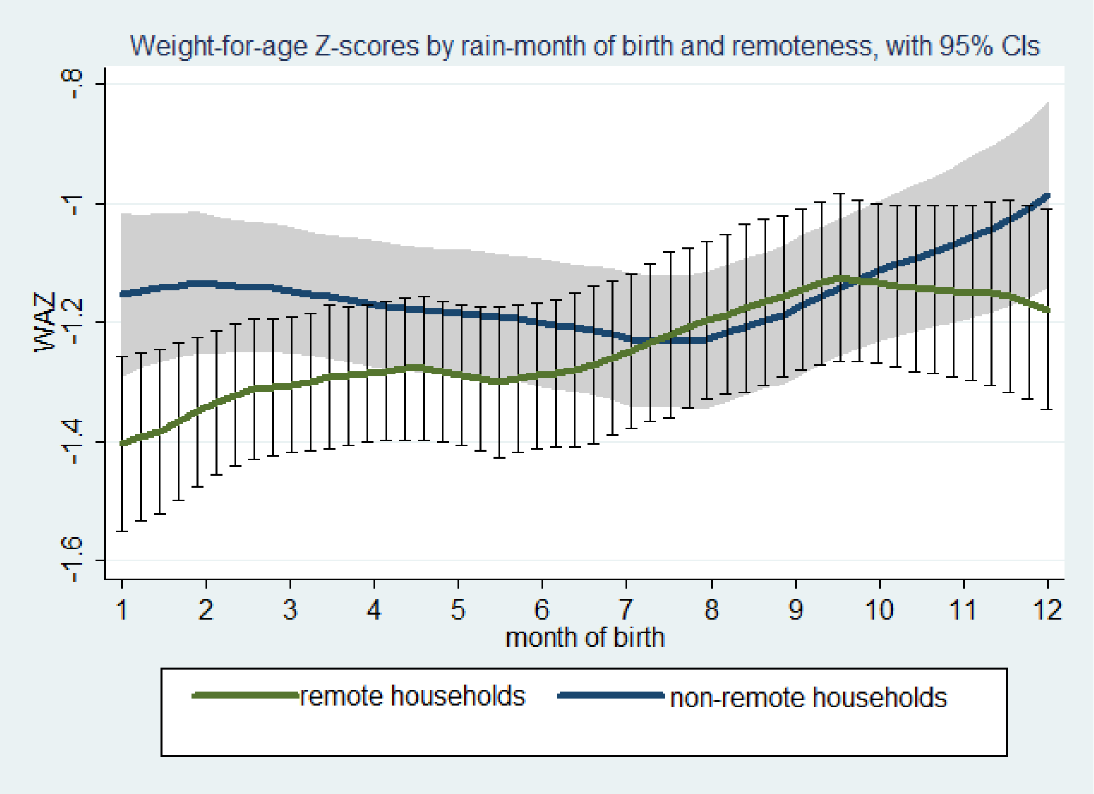

Figure 6

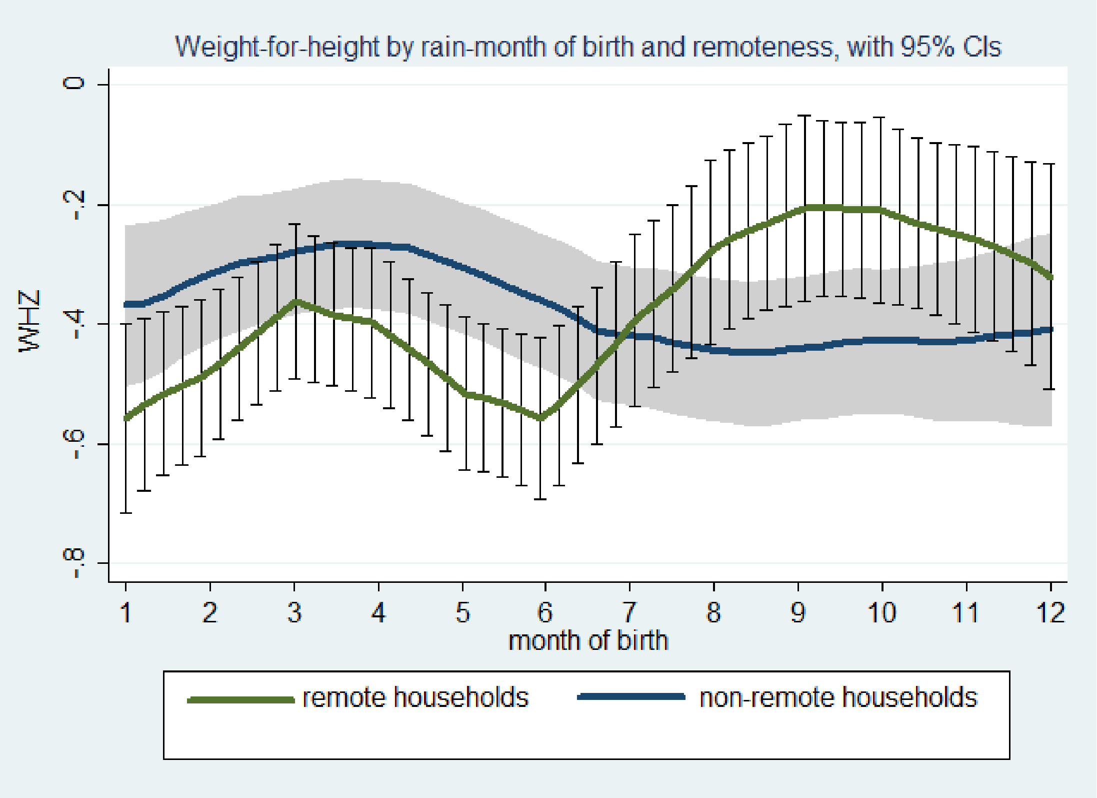

Figure 7

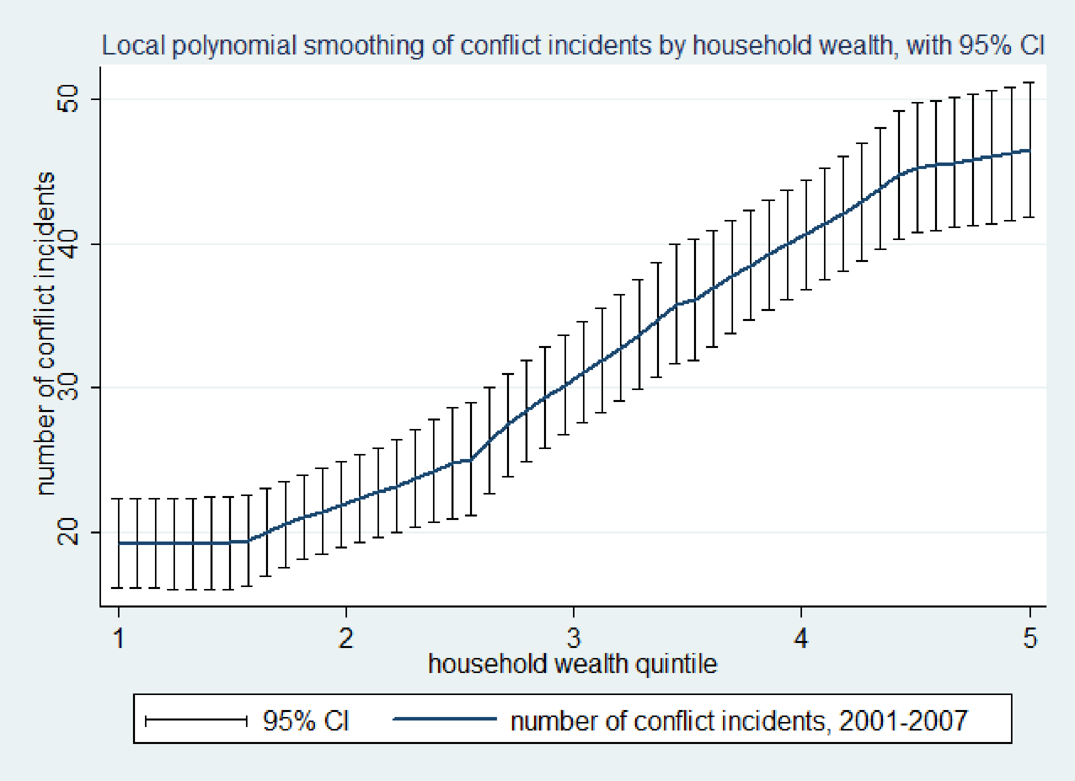

Figure 8

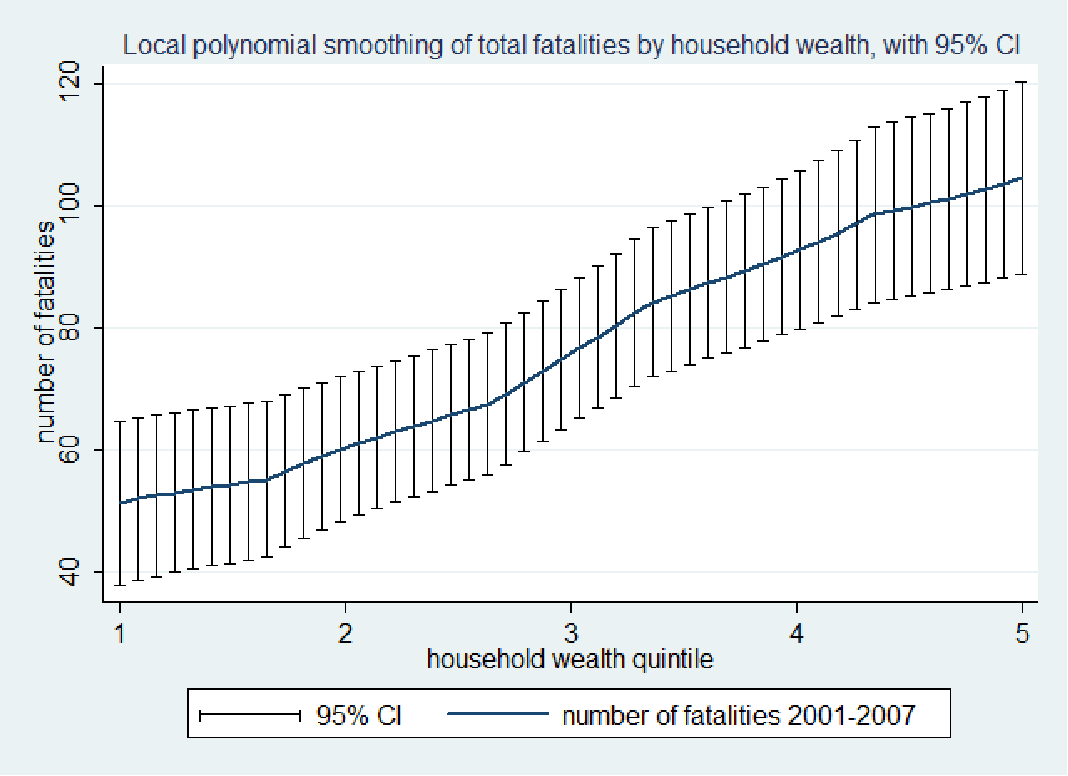

Table 1: Descriptive Statistics by birth season and household remoteness

	All Children N=2806	*Less healthy Not remote N=793*	*Healthier Not remote N=638*	*Less healthy Remote N=760*	*Healthier Remote N=615*
Child variables					
HAZ	-1.47 (*1.87*)	-1.49 (*1.85*)	-1.26 (*1.88*)	-1.52 (*1.88*)	-1.58 (*1.83*)
WAZ	-1.20 (*1.38*)	-1.17 (*1.38*)	-1.11 (*1.36*)	-1.31 (*1.35*)	-1.18 (*1.43*)
WHZ	-0.38 (*1.33*)	-0.31 (*1.32*)	-0.44 (*1.31*)	-0.49 (*1.27*)	-0.27 (*1.40*)
Age	29.16 (*16.53*)	29.01 (*16.25*)	30.19 (*17.09*)	28.27 (*16.21*)	29.39 (*16.65*)
Percentage of Boys	49.4%	48.2%	50.3%	49.8%	49.4%
Household Variables					
Wealth Quintile	2.9 (*1.42*)	3.29 (*1.45*)	3.53 (1.40)	2.39 (*1.19*)	2.37 (*1.20*)
Distance to town	64.77 (*52.06*)	34.49 (*7.66*)	34.00 (*7.38*)	97.72 (57.09)	100.65 (*61.09*)
Environment Variables					
Conflicts	31.28 (*66.9*)	49.63 (*75.96*)	44.38 (*69.51*)	16.15 (*60.59*)	12.72 (*47.02*)
Abs(Latitude)	4.31 (*2.64*)	4.40 (*2.62*)	4.37 (*2.44*)	4.40 (*2.71*)	4.00 (*2.77*)

Mean (*standard deviation*). Conflicts are total number of incidents in the 2001-2007 period in the respondent's grid-cell of residence.

Table 2: Two-sample T-tests with equal variances

	HAZ	***WAZ***	***WHZ***
Gender			
Girls	-1.406	-1.126	-0.311
Boys	-1.537	-1.278	-0.449
Difference	0.131	0.152	0.138
Pr(T>t)	0.031**	0.001***	0.003***
Household Location			
Not Remote	-1.393	-1.145	-0.368
Remote	-1.552	-1.260	-0.392
Difference	0.159	0.115	0.023
Pr(T>t)	0.012**	0.014**	0.321
Birth season			
Born less healthy season	-1.513	-1.243	-0.400
Born healthier season	-1.419	-1.150	-0.353
Difference	0.093	0.092	0.047
Pr(T>t)	0.095*	0.039**	0.175

Note: Significance levels are shown by *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Diagnostic Regression

VARIABLES	Units/type	(1) HAZ	(2) WAZ	(3) WHZ
Age spline 1	Linear spline	-0.080	-0.202***	-0.122***
		(0.163)	(0.000)	(0.000)
Age spline 2	Linear spline	-0.092***	-0.002	0.013***
		(0.000)	(0.531)	(0.000)
Age spline 3	Linear spline	-0.013***		
		(0.002)		
Child is male	Dummy	-0.191**	-0.164***	-0.112**
		(0.014)	(0.003)	(0.048)
Number of conflicts	Count	-0.002***	0.000	0.002***
		(0.000)	(0.569)	(0.000)
Wealth quintile	Categorical	0.225***	0.135***	0.006
		(0.000)	(0.000)	(0.884)
Absolute value(latitude)	Degrees	-0.013	-0.009	0.003
		(0.414)	(0.589)	(0.879)
Proximity	km^{-1}	1.389	0.576	-0.336
		(0.612)	(0.780)	(0.913)
Born during half 1	Dummy	-0.113	-0.113**	-0.049
		(0.181)	(0.045)	(0.375)
Constant	Constant	-0.129	0.814***	0.718***
		(0.734)	(0.000)	(0.001)
Observations	N	2,704	2,704	2,704
Adjusted R-squared	R^2	0.163	0.155	0.049
F test	Prob>F	0.000	0.000	0.000

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Incorporating interaction terms

VARIABLES	Type/units	(1) HAZ	(2) WAZ	(3) WHZ
Age spline 1	Linear spline	-0.084	-0.203***	-0.123***
		(0.152)	(0.000)	(0.000)
Age spline 2	Linear spline	-0.091***	-0.002	0.013***
		(0.000)	(0.553)	(0.000)
Age spline 3	Linear spline	-0.014***		
		(0.002)		
Child is male	Dummy	-0.192**	-0.167***	-0.116**
		(0.014)	(0.003)	(0.041)
Number of conflicts	Count	-0.002***	0.000	0.002***
		(0.000)	(0.493)	(0.000)
Wealth quintile	Categorical	0.218***	0.121***	-0.007
		(0.000)	(0.000)	(0.853)
Abs value(latitude)	Degrees	-0.018	-0.069*	-0.076*
		(0.757)	(0.066)	(0.084)
Proximity	km^{-1}	-4.201	-16.789***	-19.277**
		(0.659)	(0.000)	(0.038)
Born during half 1	Dummy	-0.050	-0.323*	-0.417**
		(0.867)	(0.073)	(0.036)
Abs val(lat)*Proximity	Interaction	0.942	3.770***	4.266**
		(0.654)	(0.005)	(0.015)
Born half 1 *abs val(lat)	Interaction	-0.042	0.017	0.063
		(0.590)	(0.756)	(0.117)
Born half 1*proximity	Interaction	2.232	16.336**	20.625***
		(0.845)	(0.011)	(0.001)
Born half 1*abs val(lat)*proximity	Interaction	0.671	-2.370	-3.730***
		(0.814)	(0.214)	(0.002)
Constant	Constant	-0.034	1.142***	1.111***
		(0.937)	(0.000)	(0.000)
Observations	N	2,704	2,704	2,704
Adjusted R-squared	R^2	0.163	0.160	0.054
F test	Prob>F	0.000	0.000	0.000

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4a: Incorporating interaction terms

Marginal effects

VARIABLES	Type/units	(1) HAZ	(2) WAZ	(3) WHZ
Age spline 1	Linear spline	-0.084	-0.203***	-0.123***
		(0.149)	(0.000)	(0.000)
Age spline 2	Linear spline	-0.091***	-0.002	0.013***
		(0.000)	(0.552)	(0.000)
Age spline 3	Linear spline	-0.014***		
		(0.002)		
Child is male	Dummy	-0.192**	-0.167***	-0.116**
		(0.012)	(0.002)	(0.039)
Number of conflicts	Count	-0.002***	0.000	0.002***
		(0.000)	(0.492)	(0.000)
Wealth quintile	Categorical	0.218***	0.121***	-0.007
		(0.000)	(0.000)	(0.853)
Abs value(latitude)	Degrees	-0.012	-0.004	0.008
		(0.469)	(0.741)	(0.647)
Proximity	Km^{-1}	2.695	2.674	1.391
		(0.294)	(0.233)	(0.650)
Born during half 1	Dummy	-0.115	-0.115**	-0.050
		(0.178)	(0.030)	(0.300)
Observations	N	2,704	2,704	2,704

pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Stratifying by remoteness

VARIABLES	Type/units	(1)	(2)	(3)	(4)	(5)	(6)
		HAZ	HAZ	WAZ	WAZ	WHZ	WHZ
		Remote	Not Remote	Remote	Not Remote	Remote	Not Remote
Age spline 1	Linear spline	-0.134	-0.022	-0.211***	-0.189***	-0.138***	-0.107***
		(0.180)	(0.712)	(0.000)	(0.000)	(0.000)	(0.000)
Age spline 2	Linear spline	-0.085***	-0.095***	0.000	-0.003	0.016***	0.010**
		(0.000)	(0.000)	(0.931)	(0.473)	(0.000)	(0.039)
Age spline 3	Linear spline	-0.016***	-0.010				
		(0.001)	(0.135)				
Child is male	Dummy	-0.168*	-0.203*	-0.194***	-0.169**	-0.159**	-0.117
		(0.066)	(0.082)	(0.007)	(0.043)	(0.011)	(0.212)
Abs val(latitude)	Degrees	-0.024	0.016	-0.054**	0.086***	-0.050	0.100***
		(0.576)	(0.699)	(0.016)	(0.000)	(0.108)	(0.000)
Wealth quintile	Categorical	0.096	0.298***	0.071**	0.154***	0.021	-0.023
		(0.132)	(0.000)	(0.050)	(0.000)	(0.637)	(0.645)
Number of conflicts	Count	-0.000	-0.003***	-0.001**	0.001**	-0.001	0.003***
		(0.965)	(0.000)	(0.016)	(0.047)	(0.190)	(0.000)
Born during half 1	Dummy	0.045	0.031	-0.182	0.299**	-0.307**	0.395***
		(0.829)	(0.909)	(0.140)	(0.042)	(0.043)	(0.000)
Half 1*abs(lat)	Interaction	-0.006	-0.045	0.006	-0.079***	0.020	-0.067***
		(0.902)	(0.381)	(0.854)	(0.006)	(0.518)	(0.000)
Constant	Constant	0.377	-0.741*	1.307***	0.145	1.212***	0.109
		(0.539)	(0.090)	(0.000)	(0.440)	(0.001)	(0.589)
Observations	N	1,375	1,431	1,375	1,431	1,375	1,431
Adjusted R-squared	R^2	0.135	0.180	0.160	0.157	0.065	0.057
F test	Prob>F	0.000	0.000	0.000	0.000	0.000	0.000

Robust pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5a: Stratifying by remoteness
Marginal effects

VARIABLES	Type/units	(1) HAZ Remote	(2) HAZ Not Remote	(3) WAZ Remote	(4) WAZ Not Remote	(5) WHZ Remote	(6) WHZ Not Remote
Age spline 1	Linear spline	-0.134	-0.022	-0.211***	-0.189***	-0.138***	-0.107***
		(0.176)	(0.709)	(0.000)	(0.000)	(0.000)	(0.000)
Age spline 2	Linear spline	-0.085***	-0.095***	0.000	-0.003	0.016***	0.010**
		(0.000)	(0.000)	(0.931)	(0.467)	(0.000)	(0.031)
Age spline 3	Linear spline	-0.016***	-0.010				
		(0.001)	(0.125)				
Child is male	Dummy	-0.168*	-0.203*	-0.194***	-0.169**	-0.159***	-0.117
		(0.062)	(0.072)	(0.005)	(0.035)	(0.009)	(0.203)
Abs value(latitude)	Degrees	-0.028	-0.009	-0.051***	0.042***	-0.039*	0.063***
		(0.321)	(0.680)	(0.001)	(0.003)	(0.075)	(0.007)
Wealth quintile	Categorical	0.096	0.298***	0.071**	0.154***	0.021	-0.023
		(0.128)	(0.000)	(0.046)	(0.000)	(0.636)	(0.642)
Number of conflicts	Count	-0.000	-0.003***	-0.001**	0.001**	-0.001	0.003***
		(0.965)	(0.000)	(0.014)	(0.039)	(0.186)	(0.000)
Born during half 1	Dummy	0.019	-0.169	-0.157**	-0.047	-0.225***	0.101**
		(0.839)	(0.183)	(0.024)	(0.504)	(0.003)	(0.038)
Observations		1,375	1,431	1,375	1,431	1,375	1,431

pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

9. ACKNOWLEDGEMENTS

This work was supported by a U.S. Borlaug Fellowship in Global Food Security, and the American Society for Nutrition/Mars Inc. 2014 Predoctoral Fellowship Award. The ASTER L1B data product was obtained through the online Data Pool at the NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov/data_access).

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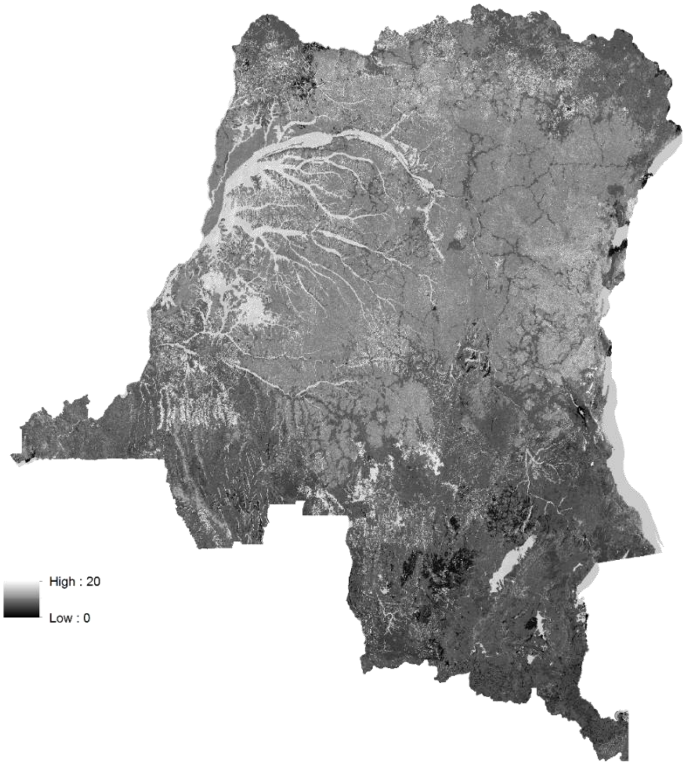
11. APPENDIX

A. Cost-surface value assignment by land-cover class

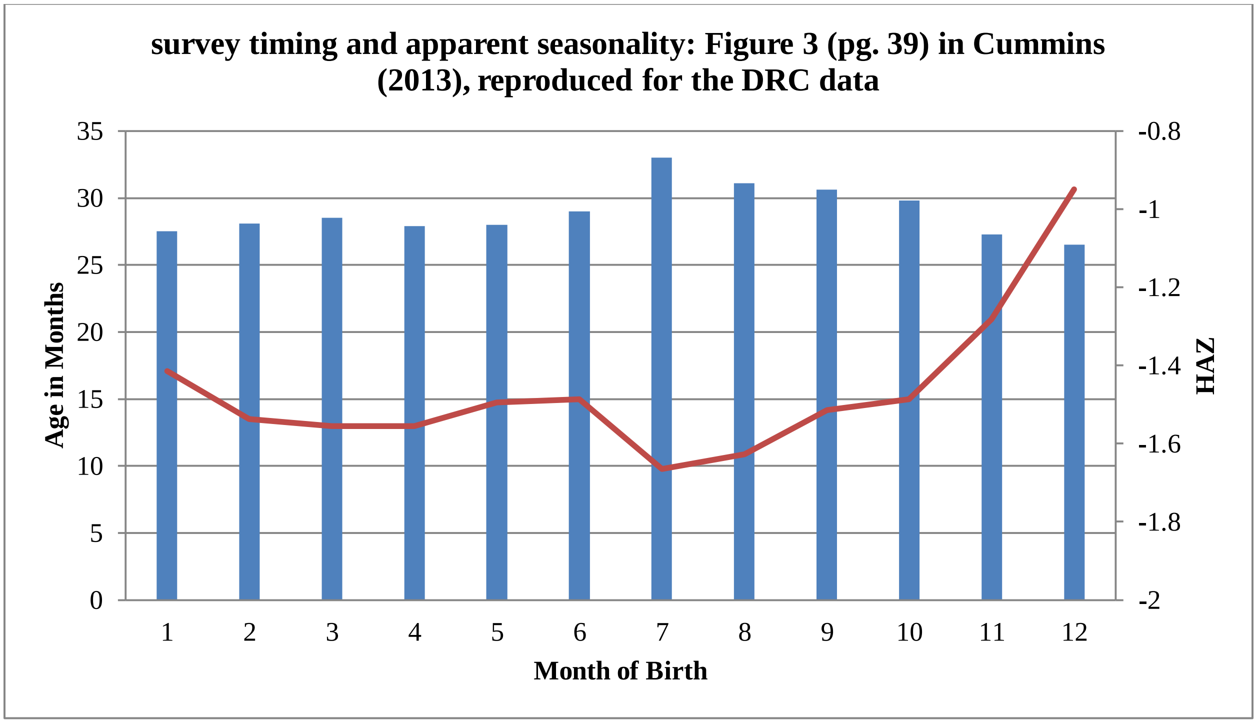
Land cover classifications
10: impassable (quarries, open water)
9: passable but not without considerable effort
8: difficult to pass through (dense forest)
7: more difficult to pass through (dense shrub)
6: moderate-difficult (medium density forest, cropland)
5: moderate difficulty
4: moderate-easy difficult (sparse shrub, open forest)
3: easy-moderate (dense urban)
2: easy but with some impedance
1: easy (open land)
0: very easy (paved open land)

B. Cost-surface map

This is a depiction of the final travel-cost weighted distance raster. Lighter shades represent higher costs of travel, and darker shades represent lower costs of travel. For example, you can see the Congo River and various tributaries in light shades in the Northwest of the country, because open water is considered "impassable," and given the highest cost value.



C. Addressing the Cummins (2013) critique: timing-artifact chart reproduced for the DRC data



We can see that the timing artifact for these data is present, but is not be as clear/extreme for DRC as in the Bangladesh data Cummins presents in his paper, for example. Higher HAZ is apparent in November and December, where children were measured at, on average, ages 27.3 and 26.5 months respectively, which are the lowest mean ages-at-measurement across all months (highest mean HAZ scores corresponds to highest mean ages-at-measurement in November and December). This is happening because children born in those months were measured at younger ages due to survey timing, and HAZ is systematically higher for younger children. Similarly, for the birth month of July, we can see that the highest mean age-in-months-at-measurement (33 months) corresponds to the lowest mean HAZ (-1.66).

D. Frequency distribution of Euclidean distances to the nearest major town