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The Impacts of Climate Shocks on Child Mortality in Mali

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The Impacts of Climate Shocks on Child Mortality in Mali

Abstract

The global child mortality rate has dropped significantly in the last two decades with Sub-Saharan Africa experiencing the fastest decline. However, Mali seems to be an exception, with a barely noticeable annual reduction rate of 1.8% between 1990 and 2011. We hypothesize that an increase in the number of climate shocks are partially responsible for the slow decline of child mortality in Mali. Using unique household survey panel data between 1994 and 2010 and daily climate measures from National Climate Data Center, we analyze the impact of climate shocks on child mortality in Sikasso, Mali. Applying survival analysis, we find significant effects of rain shocks on child mortality. Furthermore, higher numbers of women in the household and proximity to health facilities have a positive effect on child survival. When faced with an increased number of climate shocks, better infrastructure and healthcare facilities in the most affected regions may be able to mitigate the risk of child death in the future.

1. Introduction

According to the United Nations Children's Fund (UNICEF), the global child mortality rate has gone down significantly in recent years. Almost 6.9 million children died before reaching the age of five in 2011, compared to 12 million in 1990. Sub-Saharan Africa has seen an even faster decline in its child mortality rate, with the annual rate of reduction doubling between 1990–2000 and 2000–2011. However, child mortality in Mali actually went up in the decade from 2000-2010, a decade that saw increases in rainfall and temperatures. At the rate of 176 deaths per 1,000 live births in 2011, Mali has a child mortality rate almost twice as high as the Millennium Development Goal for 2015, with an annual decrease of barely 1.8% between 1990 and 2011 (UNICEF, 2012). Is the changing climate a key proximate cause of Mali's continued high child mortality rate?

This lack of improvement in child mortality is in spite of major improvements in agricultural production in Mali. Over the last 25 years, a quiet revolution has taken place in cereal production in the Sahel, with Mali and Burkina Faso more than doubling their per-capita production. With favorable rainfall, recent increases in cotton production and double-digit increases in cereal production raised real GDP growth from 3.2% in 2000 to an estimated 4.5% in 2010 (background note: Mali, 2012). Since there is a strong linkage between agriculture and child mortality (Pelletier et al, 1994), the fact that a rise in agricultural productivity growth has had no substantial effect on child mortality in Mali against a declining trend in Sub-Saharan Africa is both puzzling and troubling. Is there a relationship between child mortality in Mali and agricultural production?

This work investigates how climate shocks in Mali have contributed to the changes in child mortality¹ in the last twenty years operating both directly through disease vector environment and through agricultural production. The annual rainfall amount in southern Mali has been rising in the last few decades. Figure 1 illustrates the rainfall trend in Sikasso in southern Mali, from 1980 to 2010. The average annual rainfall amount increased from approximately 900mm to over 1000mm in the region, over 10% increase within the last 30 years. Figure 2 illustrates the temperature trend in Sikasso from 1980 to 2010. The average annual temperature has been rising, from approximately 25.7°C to 26.2°C. With malaria and diarrhea being among the top five causes of child mortality in Mali, we examine the effect of the changes in rainfall and temperature on the disease environment. Furthermore, households in southern Mali are heavily dependent on agriculture. While southern Mali occupies less than 15% of the total area, it is composed of approximately 50% of all arable land in Mali and represents 45% of Malian agricultural income (Deveze, 2006). Hence, household income in southern Mali is directly related to changes in the climate. We investigate the effect of household income changes due to climate change on child health care and nutrition.

We make several contributions to the growing literature on the effects of climate shocks. First, the study focuses on the household as the decision-making unit on child health investment rather than individuals. We assume that children between 1 and 5 are still under the strict care of the household adults, and that the utility maximization decisions would be made at the household level. While the public health literature reflects on some household characteristics, such as mother's education, sanitation status and income as some of the determinants of child mortality,

¹ Child mortality refers to the death of children between the ages of one and five. This differs from UNICEF and WHO definition, where child mortality is synonymous with under five mortality, referring to the death of infants and children under the age of five.

it has not adequately addressed how the effects of these household characteristics would interact with the effects of climate shocks on child mortality.

Second, this study focuses on child mortality rather than the adult or infant mortality, to which the majority of the health literature in developing countries has dedicated its attention. From the medical perspective, there is a greater urgency to resolve health issues concerning infants, as almost half of newborns in developing countries die from preventable causes before reaching the age of one. From the economic perspective, the uncertainty regarding the expected return on child health in the form of a future adult worker significantly decreases after having survived their first year. The household thus has a greater expected utility with health investments on children between 1 and 5, and so economic tradeoffs become more salient.

Third, the study parameterizes climate shocks more broadly than the previous literature has done. While the majority has looked at the relationship between the heat stress and the mortality, our research also theorizes different mechanisms through which climate shocks could affect child mortality including rainfall shocks. In addition to the heat stress, we further parameterize and empirically test the effect of the rain stress on child mortality through the changes in the disease environment and in agricultural production and how it affects household income.

Fourth, the study estimates the impact of climate shocks on child mortality through survival analysis. While popular in the health literature, a survival/duration model has not been used as much as binary dependent variable models in the economics literature. With fixed and random censoring, right-truncation, time-varying covariates and fixed termination date in our dataset, survival analysis will prove more useful in determining the effect of climate shocks on child mortality.

The remainder of this paper is divided as follows. The next section reviews the current literature regarding the determinants of child mortality, the impact of climate shocks on mortality

and economic outputs. Section 3 outlines the theoretical framework for how climate change affects child mortality within a utility maximizing household. Section 4 describes the datasets for the study in Mali. Section 5 outlines the empirical framework for the analysis. Section 6 reports the results and section 7 concludes.

2. Literature Review

The socio-economic², socio-cultural³ and proximate⁴ determinants of the infant and under-five mortality have been extensively studied in the health literature (Kandala et al 2006, Omariba et al 2007, Ssewanyana et al 2008, Barufi et al 2012). According to the UNICEF (2007), the root causes of under-five mortality in Sub-Saharan Africa are poor nutrition, lack of access to basic health and education services, low level of immunization and sanitation/living environment problems. Table 1 illustrates the leading causes of child mortality in Mali (UNICEF, 2012). These include pneumonia, malaria and diarrhea, which are the top three known causes of child death.

The current research focuses on the effects of climate shocks on child mortality in relation to these leading causes. There is an extensive public health literature review that projects a substantial increase in heat-related mortality due to the climate change (Huang et al, 2011, Jackson et al, 2010, Gosling et al, 2012, Peng et al, 2011, Diaz et al, 2004). It is well-known that heat stress on human physiology could bring about cardiovascular diseases (Pan et al 1995, Kunst 1993, Semenza 1996, Braga 2002). Furthermore, extreme rainfall situations followed by high temperature could affect the disease environment for malaria and diarrhea, which are

² Socio-economic factors include maternal education, migration status, child's birth year, household income, etc.

³ Socio-cultural factors include ethnicity, marital status, type of marriage, religion, etc.

⁴ Proximate factors include survival status of the preceding sibling, preceding birth interval, maternal age at birth of child, source of water, type of toilet facility, etc.

common in Mali and Sub-Saharan Africa in general (Curriero et al 2001, Singh et al 2001, Reiter 2001, Parham, 2010). We then apply these findings to explain the changes in child mortality. We investigate how both rainfall measures during the growing season and temperature measures during the dry season could affect child mortality.

While these shocks affect the human body directly, we also assume that the children under five are still in the care of the household adults. An extensive literature on factors that determine intra-household resource allocation suggests that a child's age, gender, birth order, mother's education, mother's bargaining power and household wealth influence how much resources are allocated to the children (Becker and Lewis 1973, Strauss and Thomas 1995, Thomas et al 2002). The health-seeking behavior of women in the household can decrease child mortality as they can help relieve some of the stresses indirectly through physical caring (Uchudi, 2001). Furthermore, different child characteristics could differentially affect child mortality. In weather-related disaster settings, Anttila-Hughes and Hsiang (2012) have found that the female infants face a higher mortality rate in the households with greater number of older siblings, especially older brothers. Therefore, climate shocks directly affect child mortality, but the impact could be mitigated or exacerbated by the household and child characteristics. We extend previous findings and investigate the effects of climate shocks in non-disaster settings. We analyze how household and child characteristics influence a child's survival even in non-extreme weather conditions.

Another body of literature illustrates how climate shocks affect the household's ability to provide adequate nutritional intake and health-improving goods for their children, indirectly affecting child mortality. Dell et al (2009) examined the impact of temperature and precipitation on national economies during the last half century and found that higher temperatures substantially reduce economic growth in poor countries. Several studies have

shown that agriculture would be negatively affected by climate change in developing countries, due to yield declines for the most important crops such as maize, sorghum and millet (Nelson 2009, Schlenker and Lobell 2010).

However, the magnitude of the projected impacts of climate change on agricultural production in Sub-Saharan Africa varies widely among different studies (Kurukulasuriya et al 2006, Challinor et al 2007). Due to the varying sensitivity of crops requiring different climate requirements, climate change can either enhance or diminish agricultural production of a given country. In the case of Mali, the changes in the crop yields due to climate changes are expected to negatively affect the malnourished population in the absence of any mitigating mechanism by 2030 (Butt et al, 2005). Burgess et al (2011) analyzed Indian climate data in the past fifty years and estimated that a greater number of hot days during the growing season increases mortality but in rural area only, suggesting a differential effect on population. Extreme weather conditions would affect agricultural productivity directly, whereas they may have smaller effect on income in more urban areas. Rural areas in developing countries are especially vulnerable and lack the necessary coping and adaptive mechanism to deal with extreme temperature shocks (IPCC, 2001). In our research, we extend these findings by investigating the effects of rainfall shocks during the growing season and focusing our analysis on Sikasso, the most agriculturally productive region in Mali. By affecting the household's ability to provide adequate food and health-improving goods, climate shocks would negatively influence child mortality in the household.

3. Theoretical Framework

In this section, we discuss two potential mechanisms through which climate changes could affect child mortality in rural regions of developing countries. We develop a conceptual

framework in which households experience climate changes directly affecting human physiology and indirectly affecting health-related decision-making process, following Browning and Chiappori (1994), Becker (2007) and Burgess et al (2011). In the model developed by Burgess et al (2011), each individual faces heat stress directly and chooses to spend a portion of their income on health-improving goods to enhance the probability of survival in extreme temperature conditions. We expand this model by considering household utility maximization rather than an individual one, precipitation stress on human physiology and on household income spending rather than heat stress only, and the mitigating effects of specific household characteristics on child survival.

First, we develop a collective household consumption allocation model following Browning and Chiappori (1994). Assuming that behavior in the household is Pareto efficient, the household maximizes the weighted sum of each member's utility, subject to its budget constraint. Each individual i receives utility u_i from consuming goods \mathbf{x}_i . Then, individual's utility is weighted by his/her importance in the household, $\tau(\theta_i)$, where θ_i denotes the individual characteristics, which determine the individual's level of importance in the household and τ is a culturally determined importance function which maps individual characteristics into importance levels. Key individual characteristics could include gender, age, and in the case of children, their birth order and mother's education. We assume that the household can save or borrow at a fixed rate r , and faces a constant price p for their output, producing a budget constraint in which total expenditure equals total household income with wage w and labor hours l . Then, the household has the following maximization problem:

$$\max U = \sum_i \tau(\theta_i) u_i(x_i) \text{ subject to } \sum_i p x_i = \sum_i w_i l_i . \quad (1)$$

Next, we expand the collective household allocation model to account for the demand for health and survival for each individual, following Becker (2007). Without loss of generality, we use a two-period model for illustration. In this two-period utility function, each individual's utility u_i depends on the current utility u_{it} and the future utility u_{it+1} , discounted by a discount factor B and survival rate $S(h_t, T)$, where $S()$ is defined as the probability of surviving to the next period, and h_i denotes any health-improving goods consumed by individual i . T denotes weather shocks experienced by all household members. Then, each individual i has the following two-period utility function:

$$u_i = u_{it}(x_{it}) + BS_{t+1}(h_{it}, T)u_{it+1}(x_{it+1}) . \quad (2)$$

Following Becker (2007) and Yarnoff (2011), we assume that the survival function is multiplicatively separable and can be decomposed into the effect of the weather shocks on survival through the changes in the disease environment, $d_T(T)$, and the effect of other health inputs on survival through the changes in agricultural productivity, $d_h(h_i)$:

$$S(h_i, T) = d_h(h_i)d_T(T) . \quad (3)$$

Considering a representative household consisting of two people, a parent and a child ($i=p, c$) in two time periods ($t=0,1$), one can write their two-period utility functions respectively as:

$$\begin{aligned} U_p &= u_{p0}(x_{p0}) + \beta S_1(h_{p0}, T)u_{p1}(x_{p1}) \\ U_c &= u_{c0}(x_{c0}) + \beta S_1(h_{c0}, T)u_{c1}(x_{c1}) \end{aligned} \quad (4)$$

The household will maximize the weighted sum of the utilities in equation (4), subject to the household budget constraint:

$$\max U = \tau(\theta_p)U_p + \tau(\theta_c)U_c \quad (5)$$

subject to

$$\begin{aligned}
& x_{p0} + \frac{S_1(h_{p0}, T)x_{p1}}{1+r} + g(h_{p1}) + x_{c0} + \frac{S_1(h_{c0}, T)x_{c1}}{1+r} + g(h_{c0}) \\
& = w_{p0}l_{p0} + \frac{S_1(h_{p0}, T)w_{p1}l_{p1}}{1+r} + \frac{S_1(h_{c0}, T)w_{c1}l_{c1}}{1+r}
\end{aligned} \tag{6}$$

In equation (6), $g(h_i)$ denotes the cost function for health inputs and we assume that the child is capable of earning wages w_c in the next period. Taking first order conditions and assuming an interior solution, the child health input, h_c^* , which maximize household utility will be described by the solution of equation (7) below:

$$\tau(\theta_c) \frac{\partial d_h(h_{c0}^*)}{\partial h_{c0}} d_T(T) \beta u_{c1} = \frac{\partial g(h_{c0}^*)}{\partial h_{c0}} + \frac{1}{1+r} \frac{\partial S_1(h_{c0}^*, T)}{\partial h_{c0}} (x_{c1} - w_{c1}l_{c1}) \tag{7}$$

Equation (7) shows the marginal benefits of child health care on the left-hand side equalized with the marginal cost on the right-side. It illustrates that the amount of the child health input purchased by the household is dependent on the importance factor of the child, the probability of surviving from the weather shocks and the increased probability of surviving due to child health input. This leads to a testable hypothesis:

Hypothesis 1: As child's importance factor ($\tau(\theta_c)$) increases, the survival probability of a child increases.

In order to evaluate the effects of climate change on child mortality, we identify two separate mechanisms: a direct effect of climate change on child mortality and an indirect effect of climate change on the purchase of health inputs on child mortality. We substitute the optimal amount of child care input into the survival equation. First, we rewrite the survival equation (3) to include the results of equation (7) at the optimal level as follows:

$$S_1[h_{c0}^*(\tau(\theta_c), T), T] = d_h[h_{c0}^*(\tau(\theta_c), T)] * d_T(T) \tag{8}$$

Then, differentiating with respect to climate change, T , demonstrates both the direct and indirect effects of climate change on survival:

$$\frac{dS_1[h_{c0}^*(\tau_c(\theta), T), T]}{dT} = \frac{\partial d_T(T)}{\partial T} d_h[h_{c0}^*(\tau(\theta_c), T), T] + d_T(T) \frac{\partial d_h[h_{c0}^*(\tau(\theta_c), T), T]}{\partial h_{c0}^*} \frac{\partial h_{c0}^*(\tau(\theta_c), T)}{\partial T} \quad (9)$$

Equation (9) leads to the following testable hypotheses:

Hypothesis 2: As climate shocks increase, the survival probability of a child decreases.

The second term on the right-hand side of equation (9) shows that $(\frac{\partial d_T(T)}{\partial T})$ has a direct effect on a child's survival. Since $d_T(T)$ is decreasing in T , the survival probability decreases as T increases.

Hypothesis 3: For given climate shocks, the survival probability of a child increases as the importance factor of that child increases.

The second term on the right-hand side of equation (9) shows that the importance factor of the child $(\tau_c(\theta))$ within the household influences the indirect effect of climate shocks on child mortality through the purchase of health inputs $(\frac{\partial h_{c0}^*(\tau(\theta_c), T)}{\partial T})$. In addition, the importance factor of the child will directly influence the direct effect of climate shocks on child mortality $(\frac{\partial d_T(T)}{\partial T})$ in the first right-hand side term. This suggests that the household importance factor assigned to the child can potentially either mitigate or magnify the effect of climate shocks on child mortality.

4. Data

In order to test our hypotheses regarding the impact of climate shocks on child mortality, we utilize the following datasets for household specific characteristics and climate changes between 1994 and 2010.

4.1 Suivi-Evaluation Permanent (SEP), Mali

We use a household-level panel dataset collected by Mali's Institut d'Economie Rurale (IER), the research branch of the Malian Ministry of Agriculture, between 1994 and 2010. This Suivi-Evaluation Permanent (SEP) panel data set contains detailed information about household characteristics and agricultural production, including household member information, input usage, yields, land owned, animals owned and tools owned by each household. The IER surveyed 112 farm households in three *cercles*⁵ of Sikasso region: Koutiala, Bougouni and Kadiolo. Each cercle contains three villages, each with 8-12 participating households. The households were selected randomly and were interviewed by IER extension worker per each survey site.

Table 2 summarizes the child mortality rate by cercle and by gender during the study period. There were 112 households with children between ages one and five, almost evenly distributed among three cercles: 45 in Koutiala, 32 in Kadiolo and 35 in Bougouni. The overall child mortality rate in Sikasso was 13% in our sample population, which is similar to national figures for Mali. Consistent with UNICEF (2012), male child mortality rate was higher at 14.4%, compared to female at 11.4%, all three cercles in our dataset had higher child mortality rate for male than female. Among the three cercles, Kadiolo had the lowest child mortality rate at 9.73%, and Bougouni had the highest male child mortality rate at 18.56%.

Table 3 summarizes the household characteristics used in our study. We analyze the following household characteristics: age, gender, number of women over 45 in the household, number of children between ages 1 and 5 in the household, women's education in the household, distance to the nearest market area, and household wealth. Consistent with Malian culture, a household is defined more broadly in our dataset than is typical in studies in most other parts of the world. All of the grown-up sons and their families are counted as one household under a

⁵ Republic of Mali is divided into 8 regions and 1 district, where regions are sub-divided into 49 cercles total.

single head of the household, unless explicit property division occurs. The average age of a household member in Sikasso was 19.3, with more male members than female members composing a household in all three cercles. The number of children between ages 1 and 5 in a household was 3.5 in Sikasso, with more male children than female children in all three cercles. The number of children in a household was the lowest in Bougouni, reflecting the lowest birth rate shown in Table 2. The proportion of educated women in a household was very low overall. Less than 10% of all women in an average household were literate in all three cercles. Koutiala had the lowest proportion of literate women in an average household, although it scored the highest average household wealth.

As we do not know the wealth level of a household directly, we measure two values correlated with wealth: household food security and tropical livestock unit⁶ (TLU) per capita. Both measures are in terms of the household size calculated in adult equivalence⁷. Household food security measures⁸ reflect the fact that many households are food self-sufficient. This is not surprising, considering that Sikasso is considered the bread-basket of Mali. Koutiala has the highest overall food self-security level among three cercles in Sikasso. An average household in Koutiala also had the highest TLU per capita with 0.75, owning more than a twice of the livestock wealth than an average household in Bougouni. By this standard, Koutiala stands as having the highest average wealth among the three cercles, which is consistent with Koutiala being the first area to concentrate on cotton growing during the French colonial period and thereby building a more vibrant and dynamic agricultural economy (Roberts, 1996).

⁶ The tropical livestock unit is commonly taken to be an animal of 250 kg liveweight. Various animals are converted into TLU using conversion factors (FAO factors are used here), but once consistently used, TLU represents the small farmholder's wealth level in rural developing countries.

⁷ Adult equivalence and significance of using it for the household size are explained in the Appendix section A.1. and A.2.

⁸ Household Food Self-Security is explained in the Appendix section A.1.

4.2. National Climate Data Center (NCDC)

For our study, we obtain daily Mali climate data between 1994 and 2010 from National Climate Data Center (NCDC). From this, we extract and then interpolate daily precipitation (mm) amount and temperature (average, min/max °C) at the cercle level. The SEP has some daily rainfall data for some but not all of the years between 1994-2010, which when checked against the NCDC data show similar patterns and variations.

Figure 1 and Figure 2 illustrate the average rainfall (mm) during the growing season and the average temperature (°C) in the Sikasso region between 1980 and 2010, respectively. We have included pre-1994 measures to better display the climate change trends in Southern Mali. Both figures show that average rainfall amount and temperature are increasing in this region. The average annual rainfall has increased by 100mm between 1980 and 2010, whereas average temperature has risen by about 0.5 °C during the same time period. Figure 3 illustrates the cercle-level variations in the average rainfall. While the average rainfall amount is increasing in Koutiala and Kadiolo, average rainfall amount seems invariant in Bougouni in western Sikasso. As shown in Figure 4, the average temperatures are rising in all three cercles, with Koutiala showing the most inter-annual variation.

5. Empirical Framework

The empirical analysis is carried out as follows. We estimate the impact of climate shocks on child mortality at the household level during the 16 year period in Sikasso, Mali. We limit the observations for households with children between 1 and 5 years old between 1994 and 2010. We analyze the impact of climate changes, represented by the changes in climate shock measures, during this time period.

We measure the impact of climate shocks on child mortality by estimating equation (8). We use parametric survival-time models with censored data estimated by maximum likelihood. We estimate the probability that a child will live to a certain age (5 in our case) or that s/he will die in a particular year. The risk of death in childhood is measured as the duration time of survival since age 1. The main advantages of survival-time models over OLS or binary dependent variable models such as logit or probit are that they account for the issues of fixed censoring at the time of survey, right truncation at age 5, and entries of new observations of children turning 1 throughout the survey period.

A correctly chosen parametric survival-time model generally results in more precise parameter estimates than semi-parametric and nonparametric survival-time models whose underlying time-dependency is unspecified. Parametric survival-time models differ by the distributional assumptions they make about the shape of the hazard rate and whether they are in the proportional hazard (PH) or accelerated failure time (AFT) forms. Different distributional assumptions characterize how the hazard rate varies with time in each model. The PH form assumes that the hazard rates for different levels of covariates maintain the same proportionality for all values of survival time period, whereas the AFT form assumes that the survival can either be accelerated or decelerated by a linear function of the covariates at different survival time period. Therefore, we empirically determine the most suitable shape for the hazard rate to our survival data among the three parametric models, which feature negative duration dependence: the accelerated failure time (AFT) forms of the Weibull, lognormal and the loglogistic. Our assumption of negative duration dependence is tested empirically. We compare these models using the Akaike Information Criteria (AIC) and select the model with the lowest AIC value. In order to test hypotheses presented in Section 3, we estimate the following AFT model:

$$\ln(t_i) = \beta T_{j_i} + \alpha Z_{i_i} + \gamma T_{j_i} * Z_{i_i} + \delta X_h + \zeta X_z + \sigma u \quad (10)$$

with i denoting each individual child, j each household cluster, t survival time, σ a scale factor related to the shape parameter of the hazard rate, and u an error term. We use T as the main control variables for climate shocks. For other explanatory variables, we use the determinants of child's importance factor and health care Z , the interaction effects between climate shocks and the determinants of child's importance factor ($T*Z$), household characteristic variables X_h , and zone fixed effects X_z .

We parameterize equation (10) based on our theoretical model and other variables suggested by the previous literature on climate, agriculture and infant mortality. For climate shocks, we use two measures, one for rainfall shocks and another for temperature shocks. First, a rainfall shock is measured using the total number of days with daily rainfall amount of over 10mm (Figure 5). Continuous days with daily rainfall over 10mm have been shown to increasingly and negatively affect the disease environment, drinking water and sanitation status. Second, a temperature shock is measured using the number of continuous days above 32 °C as a measure of a "heat wave" (Figure 6). As discussed in Section 2, continuous hot days are correlated with increased occurrences of cardiovascular diseases, circulatory shocks and drought. Then, we control for average annual rainfall amount, average annual temperature, and rainfall amount deviations from the mean.

For the determinants of a child's importance factor, we consider the following measures: age, gender, women's education, and number of siblings under 5. As a child grows, his potential to contribute to the household well-being would increase. He can assist with small household chores and even babysit smaller siblings, relieving adults to handle more economically productive work. Thus, an older child would have a higher importance factor in the household.

In male-dominated societies like Mali, male children would have higher importance than female children. Biologically, however, male infants and toddlers are more susceptible to childhood diseases than female ones. Child mortality statistics from the UNICEF (2012) suggest that a male child under 5 has a higher mortality rate than a female child in most developing countries, including Mali. This reflects that although a higher importance factor associated with male children would suggest more health inputs diverted for their survival, it may not be enough to reverse the effects of the biological factors, especially when compounded by high rainfall shocks. Furthermore, the literature suggests (Caldwell and McDonald 1982, Cleland and Van Ginneken 1988, Das Gupta 1990) that as a mother becomes more educated, her healthcare knowledge and her bargaining power in caring for a child increase. Since we do not have data on specific mother to child relationship in a household, however, we use the percentage of literate women in the household as a proxy. In addition, each household can afford only a limited quantity of health inputs for its children. Therefore, as the number of children under 5 in a household increases, each child would compete with the others diluting a child's importance factor. This would reduce the amount of health care each child can potentially receive, thus decreasing a child's survival probability.

For the household's ability to provide health care for a child, we use measures of household wealth and access to health care. First, we use a dummy variable for the household food security to indicate whether the household is capable of providing sufficient calories and nutrients in the short-term. As the household becomes more food secure, it should be able to provide better nutrition for its children. Second, in order to measure more permanent household wealth, household's ownership of livestock is used. In order to aggregate the wealth represented by cows, oxen, donkey, poultry and pigs, we use tropical livestock unit (TLU) per capita as a proxy. Third, we use the number of women over 45 in the household as a proxy for how well a

household is able to care for their children under five, since culturally women are typically in charge of child care. As the women draw near the end of the childbearing age, they are more capable of health care for other children than their own. Thus, we expect that as the number of women over 45 increases, more health care for the children is supplied by the household. Finally, healthcare provision for children could increase if a healthcare facility is easily accessible. Since we do not have data on the locations of health care facilities in the region, we use the distance to the nearest large market as a proxy for more inexpensive access to health care. Based on field observations, we assume that not all villages have a health care facility, and that a more market-centered village is the likely place for one. In addition, the market center is the likeliest place to find necessary medicines and to seek medical advice. Thus, we use the distance from each village to the nearest market –centered village as a proxy for accessibility to health care.

6. Empirical Results

First, we have investigated different parametric models for our data. Table 4 presents the regression results from the estimation of three parametric survival-time models without interaction effects: the Weibull (column 1), the lognormal (column 2), the loglogistic (column 3). The magnitude and significance of the shape parameters show that the hazard is eventually declining, confirming our assumption of negative duration dependence. While the AIC scores for all models are similar, we have selected the lognormal AFT model whose lowest AIC score suggests the best characterization of the underlying time-dependency in hazard rate. With a shape parameter σ less than 1, the hazard rate first rises and then falls during the survival time period.

Table 5 presents estimation results from seven lognormal AFT models of the effects of climate shocks, individual and household characteristic on child mortality. Column 1 shows the

baseline model without any interaction effects. The results illustrate significant effects of high rainfall shocks. An additional day with over 10mm rainfall could decrease a child's survival time by 0.4% and is statistically significant at 1% level. On the other hand, the effect of temperature shock measured as the duration of a heat wave above 32°C was almost zero and statistically insignificant. This could be due to the fact that temperature changes occur at a much slower rate than rainfall shocks, and our study period of 16 years may not have been enough to observe any effect. Another possibility is that the temperature shock might not have had a great deal of variation in the study areas. As illustrated in Figure 6, heat wave was almost non-existent in Bougouni, and there was not much variance in Kadiolo during our study period.

Some determinants of a child's importance factor were statistically significant. In particular, a child's age significantly affected the survival probability. As a child between the ages 1 and 4 got older by one year, a child's survival time increased by 44.2%. A child's gender was also a significant factor in a child's survival. A male child had his survival time decreased by 5.3% compared to a female child. This suggests that a higher value placed on a male child in Mali was not able to overcome the biological factors influencing higher male mortality. However, while we predicted that women's education would improve a child's survival probability, we found that it had an opposite effect at statistically insignificant level. This could be due to the fact that our measure of mother's education is more basic than those used in most literature. While we used the percentage of literate women in a household as a proxy, our data did not specify the level of literacy or education attained by each woman. Furthermore, women in our study area had an extremely low literacy level, illustrated in Table 3. As women in Mali attain more education, the importance of mother's education in a child's survival may be realized in the future.

The results also show that a household's ability to provide health care significantly affects a child's survival. Growing up in a food-secure household increases a child's survival time by 2.4%, in line with our prediction.⁹ On the other hand, household's livestock wealth did not have a statistically significant effect. More permanent household wealth measured in total livestock might not be easily convertible to money in a very short-term. As a result, a sick child might not benefit from household livestock wealth in time. In addition, having more women over the childbearing age of 45 in a household significantly increases a child's survival time by 3.3%. Another significant factor in a child's survival was the distance to the nearest market. Used as a proxy for access to health care in terms of medicine and medical facility, living far from the market greatly decreased the survival time by 2.6%.

Columns 2-6 on Table 5 present the results of models where the effect of high rainfall shocks is allowed to vary by several individual and household characteristics such as household food security, household livestock wealth, distance to the nearest market, number of women over 45, and gender of a child, respectively. Column 7 presents results from a model that includes all of the factors in previous models. The results indicate that the effect of high rainfall shocks does not differ by these characteristics as there were no differential effects in all specifications. We found no significant interaction effect between high rainfall shocks and household food security level in column 2. We expected that when a household is more food secure, it can lessen the impact of the climate shocks more. It could be that since the effect of a rain shock operates directly through an increase in disease environment, whether a household is food secure or not might not matter in reducing the rain shock effect on a child's survival. We also found no significant interaction effect between high rainfall shocks and the number of women over 45 in

⁹ We also estimated using household agricultural income as a measure of a short-term wealth and found similar results.

the household in column 5. We expected that more health care provided by more women in the household could reduce the negative effect of high rainfall shocks. Column 3 presents a statistically significant effect of high rainfall shocks varied by household livestock wealth. These results demonstrate that the households with greater wealth response better to the rainfall shocks and increase a child's survival time. However, all of the differential effects investigated in this study have not presented any significant impact on child mortality.

Considering the small sample size for child deaths and limited regional focus in the household survey dataset, our method might lack the power to properly estimate such an interaction. More detailed analysis of interaction effects is required.

7. Conclusion

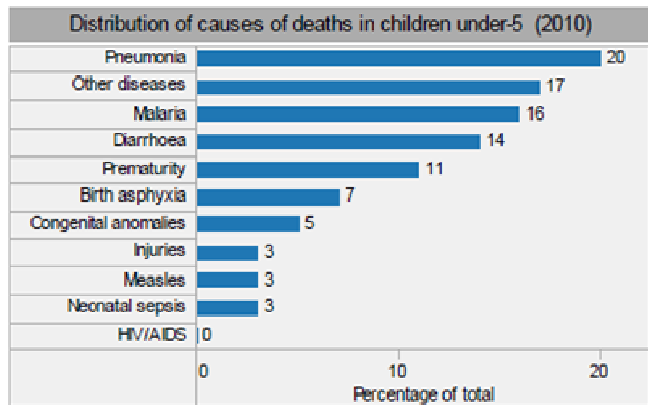
In spite of the recent increase in agricultural productivity and economic growth, Mali has not experienced any substantial decrease in child mortality compared to other developing countries in Sub-Saharan Africa. Using household survey panel data set from Sikasso in southern Mali and an NCDC dataset on daily temperature and precipitation, we tested whether our climate shock measures, a child's importance factor in a household and a household's ability to provide health care affected child mortality, and whether the effect varied by specific individual and household characteristics. We have identified two channels through which climate shocks affects child mortality: direct impacts on human physiology, and indirect impacts on household investment decisions on health-improving goods via income shocks. We have found significant effects of having additional rain days of over 10mm daily accumulation on decreasing the probability of a child's survival. A household's ability to provide health care for its children, measured as household food security and the number of women over 45, contributed significantly to a child's survival. When a household is located far from the nearest market, it resulted in a greater risk of

child death compared to being near the market, where proper medical assistance is more readily available.

The current findings have several important policy implications. We have found that the average rainfall amount and high rainfall shocks in Sikasso have increased in the last twenty years. If the trend continues, Malians will need to cope with an increase in child mortality due to worsening of the disease environment in certain regions. Identifying future climate trends in Mali and the regions affected by the climate changes will be important in strategizing prevention mechanisms. By targeting villages affected the most by the climate changes, the Malian government can invest in improving child health more efficiently.

Tables

Table 1. Leading causes of child mortality in Mali



UNICEF, 2012.

Table 2. Child Mortality Summary by cercles in Sikasso

	Full Sample			Koutiala			Kadiolo			Bougouni		
	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
Number of Households	112			45			32			35		
Number of Birth (>=1 year old)	793	417	376	352	180	172	257	140	117	184	97	87
Number of Death (<=5 years old)	103	60	43	51	28	23	25	14	11	27	18	9
Child Mortality Rate (%)	12.99%	14.39%	11.44%	14.49%	15.56%	13.37%	9.73%	10.00%	9.40%	14.67%	18.56%	10.34%

*Child Mortality Rate is calculated as the percentage of the total number of death between 1 and 5 over total number of child surviving the first year during the study period.

Table 3. Summary Statistics of households with children between ages 1 and 5, by cercles in Sikasso

	Sikasso (All)	Koutiala	Kadiolo	Bougouni
Age	19.28 (15.90)	19.03 (13.74)	19.22 (19.84)	19.65 (14.32)
Gender	0.683 (0.683)	0.643 (0.422)	0.663 (0.402)	0.754 (0.329)
Number of F children under 5	1.595 (1.424)	1.879 (1.739)	1.702 (1.264)	1.136 (0.946)
Number of M children under 5	1.899 (1.177)	2.033 (1.739)	2.103 (1.294)	1.527 (1.114)
Proportion of Literate women in HH	0.0622 (0.0925)	0.0347 (0.0784)	0.0866 (0.106)	0.0715 (0.0918)
HH Food security	1.161 (1.111)	1.654 (1.292)	0.778 (0.613)	0.938 (0.910)
HH Livestock wealth (TLU per capita)	0.593 (0.774)	0.753 (0.807)	0.672 (0.941)	0.309 (0.398)
Distance to nearest market (km)	17.21 (14.75)	21.19 (15.04)	10.69 (12.43)	18.87 (12.97)
Number of Women over 45	1.076 (0.803)	0.972 (0.779)	1.329 (0.959)	0.950 (0.643)
Number of Household	112	45	32	35

Standard errors are in parentheses

Table 4. Parametric AFT models for the effect of climate shocks on a child's survival between ages 1 and 5

	(1) Weibull	(2) Lognormal	(3) Loglogistic
<u>Climate Shock Variables</u>			
Rainfall shock (days)	-0.00504*** (0.00186)	-0.00441*** (0.00153)	-0.00431*** (0.00162)
Temp shock (days)	-7.94e-05 (0.00294)	-0.000354 (0.00249)	-0.000687 (0.00257)
<u>Child Importance Variables</u>			
Age	0.364*** (0.0238)	0.366*** (0.0188)	0.362*** (0.0222)
Gender	-0.0500 (0.0329)	-0.0544* (0.0279)	-0.0504* (0.0296)
Number of F children under 5	-0.0164 (0.0110)	-0.0138 (0.00871)	-0.0141 (0.00943)
Number of M children under 5	0.00179 (0.00867)	0.00223 (0.00704)	0.00125 (0.00767)
Percentage of literate women in HH	-0.125 (0.119)	-0.0999 (0.0953)	-0.104 (0.104)
<u>Household Care Ability Variables</u>			
HH Food security	0.0349** (0.0137)	0.0238* (0.0123)	0.0256** (0.0121)
HH Livestock wealth (TLU per capita)	0.0131 (0.0141)	0.0169 (0.0123)	0.0161 (0.0129)
In_Distance to Market (km)	-0.0296*** (0.00994)	-0.0265*** (0.00762)	-0.0273*** (0.00902)
Number of Women over 45	0.0388** (0.0194)	0.0327** (0.0160)	0.0319* (0.0172)
Shape Parameter σ	0.122*** (0.0155)	0.230*** (0.0242)	0.104*** (0.0141)
Log likelihood	-196.402	-189.793	-192.67
AIC	432.804	419.587	425.34
Observations	2,647	2,647	2,647

1. All models include controls for average annual rainfall, average annual temperature, rainfall mean deviations, cercle/zone fixed effects, and a time trend. Time ratio (percentage change) is calculated by exponentiating the coefficient.

2. Robust standard errors are in parentheses.

***Statistical significance at 1% level, **at 5% level, *at 10% level

Table 5. Effect of climate shocks on a child's survival between ages 1 and 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Climate Shock Variables							
Rainfall shock (days)	-0.00441*** (0.00153)	-0.00310 (0.00199)	-0.00544*** (0.00168)	-0.00246 (0.00192)	-0.00329* (0.00185)	-0.00437** (0.00187)	-0.000263 (0.00326)
Temp shock (days)	-0.000354 (0.00249)	-0.000500 (0.00252)	-0.000311 (0.00250)	-0.000415 (0.00253)	-9.22e-05 (0.00249)	-0.000356 (0.00249)	-0.000320 (0.00255)
Child Importance Variables							
Age	0.366*** (0.0188)	0.366*** (0.0189)	0.366*** (0.0188)	0.366*** (0.0187)	0.367*** (0.0187)	0.366*** (0.0188)	0.367*** (0.0188)
Gender	-0.0544* (0.0279)	-0.0549* (0.0280)	-0.0546* (0.0280)	-0.0537* (0.0277)	-0.0543** (0.0277)	-0.0525 (0.0786)	-0.0350 (0.0797)
Number of F children under 5	-0.0138 (0.00871)	-0.0136 (0.00865)	-0.0129 (0.00860)	-0.0139 (0.00861)	-0.0136 (0.00874)	-0.0138 (0.00871)	-0.0123 (0.00849)
Number of M children under 5	0.00223 (0.00704)	0.00228 (0.00706)	0.00207 (0.00704)	0.00151 (0.00710)	0.00176 (0.00707)	0.00223 (0.00705)	0.000852 (0.00719)
Percentage of Literate Women in HH	-0.0999 (0.0953)	-0.106 (0.0952)	-0.0989 (0.0966)	-0.116 (0.0961)	-0.0888 (0.0963)	-0.100 (0.0955)	-0.116 (0.0982)
Household Care Ability Variables							
HH Food security	0.0238* (0.0123)	0.0665* (0.0347)	0.0241** (0.0123)	0.0239** (0.0121)	0.0242** (0.0122)	0.0238* (0.0123)	0.0783** (0.0351)
HH Livestock wealth (TLU per capita)	0.0169 (0.0123)	0.0159 (0.0124)	-0.0505 (0.0318)	0.0161 (0.0124)	0.0168 (0.0123)	0.0169 (0.0123)	-0.0621* (0.0335)
In_Distance to market (km)	-0.0265*** (0.00762)	-0.0267*** (0.00762)	-0.0263*** (0.00765)	0.00266 (0.0201)	-0.0265*** (0.00761)	-0.0265*** (0.00763)	0.00400 (0.0202)
Number of Women over 45	0.0327** (0.0160)	0.0329** (0.0159)	0.0321** (0.0159)	0.0329** (0.0159)	0.0731 (0.0460)	0.0326** (0.0160)	0.0791* (0.0478)
Rain Shock/Characteristic Interaction							
Rain shock x HH Food security		-0.00116 (0.000872)					-0.00146* (0.000871)
Rain shock x HH Livestock wealth			0.00207** (0.00106)				0.00235** (0.00110)
Rain shock x In_Distance to market				-0.000818 (0.000573)			-0.000846 (0.000574)
Rain shock x Number of women over 45					-0.00114 (0.00122)		-0.00132 (0.00128)
Rain shock x Gender						-5.34e-05 (0.00208)	-0.000545 (0.00214)
Observations	2,647	2,647	2,647	2,647	2,647	2,647	2,647

1. All models include controls for average annual rainfall, average annual temperature, rainfall mean deviations, circle/zone fixed effects, and a time trend. Time ratio (percentage change) is calculated by exponentiating the coefficient.

2. Robust standard errors are in parentheses.

***Statistical significance at 1% level, **at 5% level, *at 10% level

Figures

Figure 1. Average annual rainfall (mm) in Sikasso

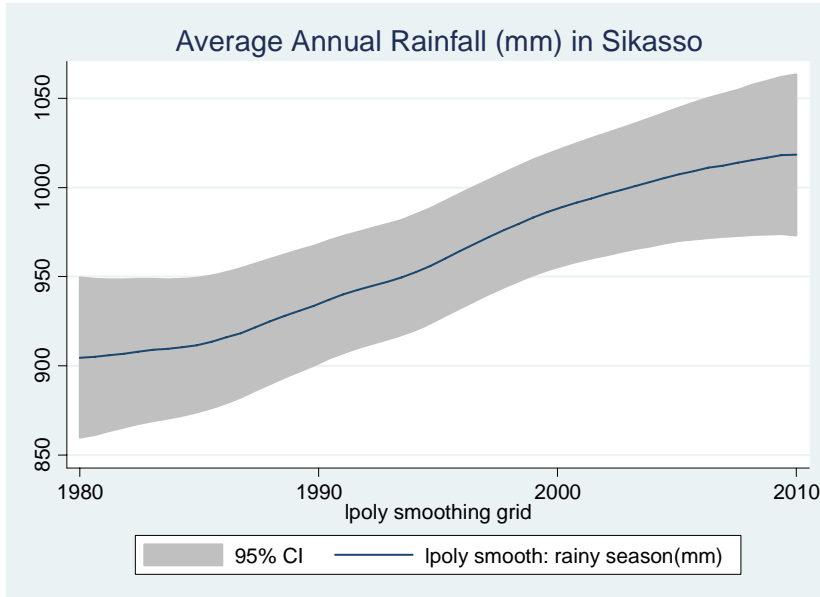


Figure 2. Average temperature(°C) in Sikasso

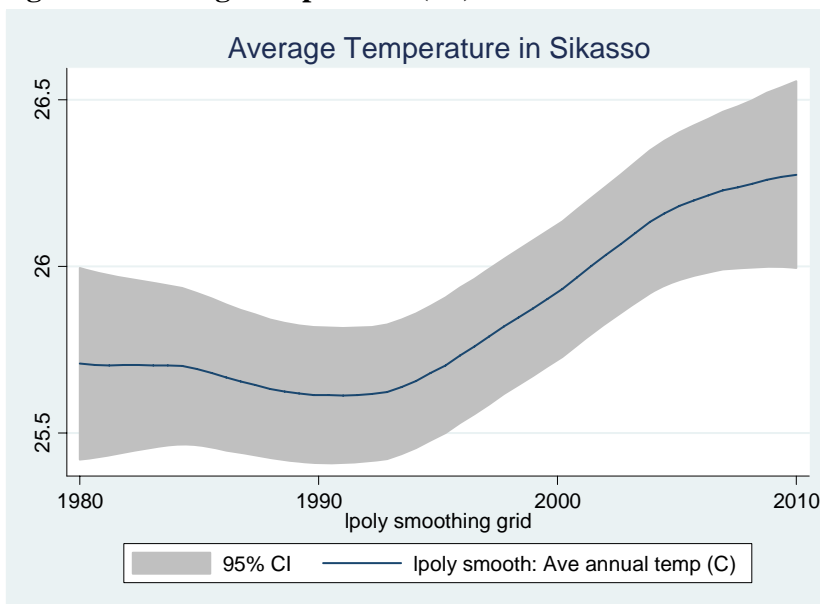


Figure 3. Average annual rainfall(mm) in cercles, Sikasso

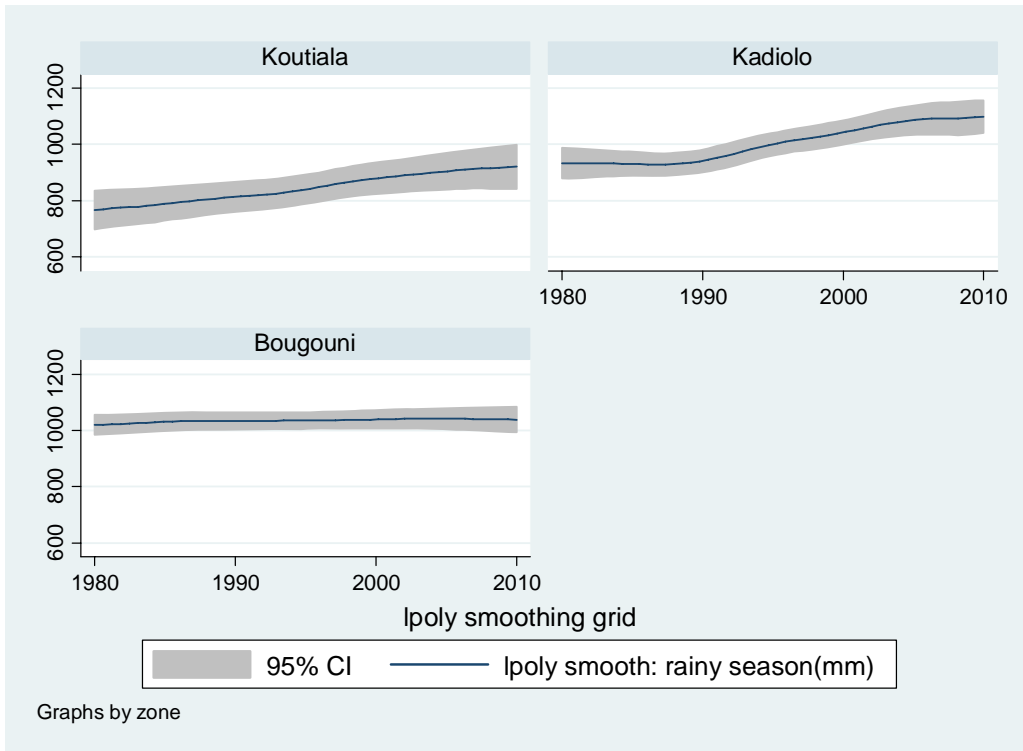


Figure 4. Average annual temperature(°C) in cercles, Sikasso

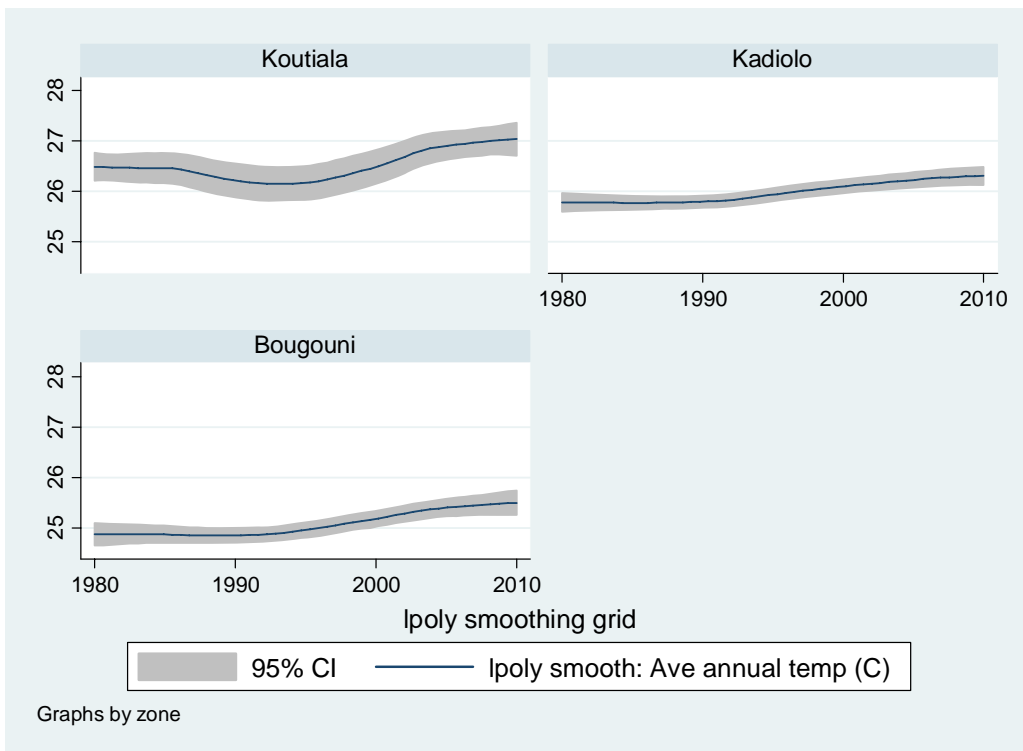


Figure 5. Rain shock (Total number of rain days above 10mm)

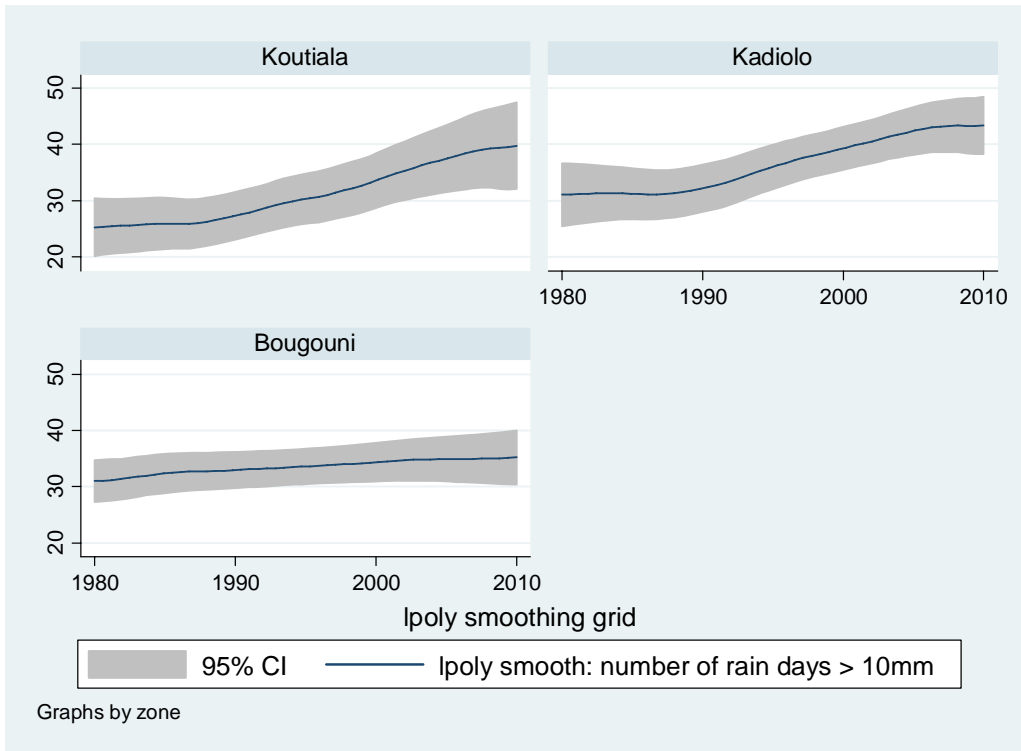
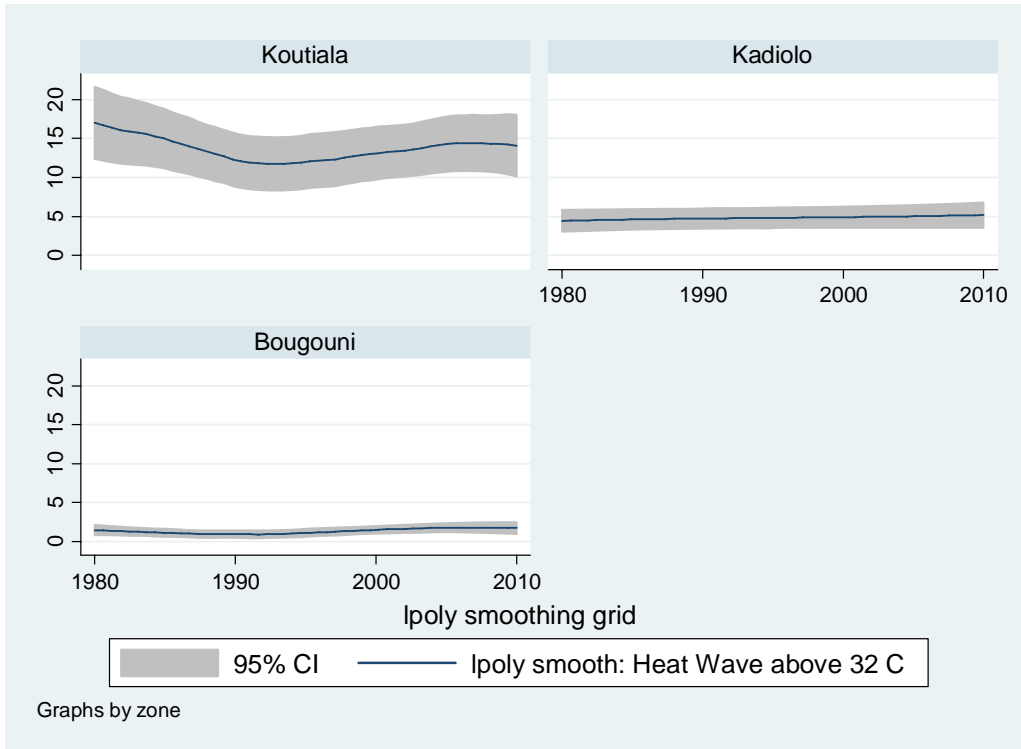


Figure 6. Temperature shock (heat wave, days continuously above 32 °C)



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Appendix A

1. Household Food Self-Security

In order to measure food self-security at the household level, we construct a food self-security index (FSSI) based on daily calorie intake and the size of household. With over 80% of the dietary energy intake in Mali coming from cereal consumption (USAID, 2008), we assume that the total amount of available calories per household come from the total cereal production per household. The cereals most commonly produced by Malian farmers are maize, sorghum, millet and rice. The energy information for each cereal is summarized in Table A.1. Then, the size of household is re-adjusted to account for gender and age of all members in the household (Falusi, 1985). Equivalent male scale weights used for readjustment are shown in Table A.2.

Table A.1. Energy information on cereal crops

Cereal Item	Energy (Kcal/kg)
Maize	3650
Rice	3600
Millet	3780
Sorghum	3390

Source: Nutrient Data Laboratory, USDA 2011.

Table A.2. Equivalent Male Adults Scale Weights

Age Category	Male	Female
Under 1 yr	0	0
1-6.9 yrs	0.4	0.3
7-14.9 yrs	0.75	0.75
15-54.9 yrs	1	0.9
55 and above	0.8	0.65

Source: Falusi, 1985.

A daily recommended level of 2250 Kcal per adult male is used as the cutoff. If the readjusted household is able to consume 2250 Kcal or above per capita per day from their own cereal production, the household is considered food self-secure. If it consumes less, the household is considered food self-insecure. FSSI is then defined as:

$$\text{Food Self Security Index (FSSI)} = \frac{\text{Daily Available Calories per Household}}{\text{Daily Required Calories per Household}}$$

$FSSI \geq 1$ indicates food self-security for the household while $FSSI < 1$ indicates household food self-insecurity. For the purpose of this paper, we convert FSSI into a binary variable. Household food self-security is one if $FSSI \geq 1$, zero otherwise.

2. Household Size

Household size commonly refers to the number of family members in the household. Here, we use a readjusted household size for adult equivalence used in FSSI measurement to reflect the gender and age of each family member. The daily energy consumption requirement is different depending on the gender and age of each person. Even for the same household size, if it mainly composed of young children, the required energy consumption can be low whereas the energy consumption can be much larger if made up of adults. By taking this account and readjusting the household size, we can measure required calorie amount per varying household structure more appropriately.