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Abstract

The aim of this paper is to estimate the impact of weather related income shocks on child health in rural Burkina Faso where rain fed agriculture is the dominant production system. We combine health data originating from the 2008 household survey with meteorological data to define shocks at the child level. We first estimate the marginal effect of rainfall at various ages on the child's health in order to identify the critical period during which deprivation has the most severe consequences. Then we look for a different impact of shocks on girls and boys that would reflect a gender bias in intra household resource allocation. We also assess the household ability to smooth consumption by testing for an asymmetric effect of rainfall shocks according to their size and by testing the impact of shocks according to household endowments. Results evidence a strong relationship between rainfall shocks during the prenatal period and child health. Households are not able to dampen small but negative rainfall shocks. Unexpectedly, girls are less severely affected by shocks than boys. The robustness of results is tested by using the sibling and difference-in-differences estimators as well as placebo regressions.

Keywords: Child health, rainfall shock, Burkina Faso, sibling estimator, treatment-effect model

JEL codes: I15, O15, Q54, C31

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1. Introduction

Burkina Faso is a low income and a landlocked country located in the Sahel part of West Africa and ranging among “agricultural-based countries” (World Bank, 2008). Indeed, agriculture is the major source of growth, accounting for about a third of GDP growth. Most of the poor live in rural areas (70%).

Like in many other developing countries, rural households who depend on agricultural activity for subsistence face large income fluctuations originating from weather shocks. In the absence of a formal insurance market, households can hardly protect themselves against these shocks. As evidenced by a large literature, informal risk mitigating and risk coping strategies set up by farmers only afford a partial protection against income risk (Deaton, 1992; Morduch, 1995; Townsend, 1995; Alderman and Haque 2007). Income diversification is a source of inefficiency while savings, credit and informal safety nets cannot protect against large or covariate shocks. As a consequence, income risk translates into consumption fluctuations.

Uninsured risk may have dramatic consequences on household welfare in the short and long run. Households may be forced to reduce their current consumption, including health and schooling expenditures, as well as investment in their farm. In the most severe cases, agricultural households are forced to sell productive assets such as cattle to compensate for income loss. By negatively affecting the productive capacity of the household, a temporary income shock may have a persistent impact on future income (Rosenzweig and Binswanger, 1993; Rosenzweig and Wolpin, 1993, Morduch 1995, 1999). Uninsured risk is therefore widely considered a cause of chronic poverty (Dercon and Christiaenen, 2011, Jalan and Ravallion 2001, Dercon 2004, Lokshin and Ravallion, 2000).

The empirical literature has paid a particular attention to the consequences of uninsured risk on investments in human capital. Numerous studies have shown that negative income shocks lead to lower investment in child health and education. Jacoby and Skoufias (1997) showed that income fluctuations in India have a negative impact on children’s education. Foster (1995) concludes that the impact of flooding on child’s weight in Bangladesh depends on credit market failures. Other studies drawing on Barker’s works (1998) have shown that deprivation experienced in infancy and early childhood has long-run consequences on adult future welfare. According to Barker’s “foetal origin hypothesis”, individuals who have suffered from nutritional deprivation in utero or from stunting and underweight during their first couple of years of life have poorer performance at school, a lower income level, a lower social status and a lower life expectancy (see for instance, Dercon and Hoddinott 2003, Strauss and Thomas 2008, Alderman 2011, Ferreira and Schady, 2009).

Most authors agree to recognize that young children are vulnerable to economic shocks but empirical studies diverge as to the critical period of life during which a shock has irreversible effects. This critical period can be the foetal period (Barker, 1998), the first six months of life (Dobbing 1976), the 6 to 24 months period (Martorell and Habicht, 1986 and Martorell et al. 1994) or more generally the post weaning period until age 24-36 months (e.g. Alderman et al. 2001, Hoddinott and Kinsey 2001, Alderman et al. 2006). As a general rule, nutritionists consider that stunting in the first two years of life cannot be offset later so that the size at three years is a good indicator of the size in adulthood (Martorell 1995, 1997, 1999).

To identify the impact of economic shocks occurring during childhood on adult outcomes, recent studies exploit naturally random events such as pandemics or violent conflicts (e.g. Alderman and al. 2006, Akresh et al. 2009, Akresh et al. 2010, Banerjee et al. 2007, Almond 2006, Gorgens et al. 2012). A few studies aim at assessing the impact of climate shocks on health by exploiting the spatial and temporal heterogeneity of these exogenous shocks. Among this natural experiment literature, Maccini and Yang (2009) working on Indonesia, evidenced a strong relationship between birth year rainfall and adult height, suggesting that nutrition in infancy varies with early-life rainfall. Jensen (2000) shows that households living in regions of Cote d'Ivoire that experienced an adverse weather shock invest less in children's education and health. Alderman and al. (2006) established a causal relationship between child and adult height and schooling by exploiting exogenous events such as the civil war and droughts in Zimbabwe. Gajigo and Schwab (2012) contribute to the debate on the ability of households to offset income shocks by showing how seasonal variations in child health relate to seasonal fluctuations in agricultural income and maternal nutrition in Gambia. Other authors such as Skoufias and Vinha (2012) who question the impact of the climate change, find indirect evidence of a causal relationship between climate variability, agricultural income and child height in rural Mexico.

Drawing on this literature, the main objective of this paper is to explore the consequences of weather shocks on child's health in rural Burkina Faso. A special attention is paid to the time path of shocks which is generally not clearly taken into account in the empirical literature. Weather shocks translate into an income and nutritional shocks with a delay that depends on the crop calendar. With the high degree of precision of the survey data, we are able to characterize the nutritional conditions prevailing during the first months of the child's life. We thus carefully design the shocks calendar and conduct an in-depth analysis of households' response to weather shocks. This paper contributes to the economics of risk and insurance, health economics and gender issues by providing valuable information on households behaviour in a risky environment, the determinant of the child's heath, intra-household resource allocation, and the factors affecting resiliency.

Health data is drawn from a nationally representative survey conducted in June, 2008. Those data are combined with rainfall data produced by the meteorological office of Burkina Faso, to define rainfall shocks at the child level. We first estimate the marginal effect of rainfall at various ages on the child's health in order to identify the critical period during which deprivation has the most severe consequences. Then we look for a different impact of shocks on girls' and boys' health that would reflect a gender bias in intra household resource allocation. We also assess the household ability to smooth consumption by testing for an asymmetric effect of rainfall shocks according to their size and identify more resilient households by testing the impact of shocks depending on household endowments.

Results show the importance of weather conditions on child nutritional status. Rainfall in the prenatal period is positively correlated with height-for-age z-score of children under five while rainfall in the first and second year of life does not have any significant effect. More surprisingly, boys appear to be more vulnerable than girls to weather fluctuations. Children living in better-off households with access to safe water are less impacted by negative rainfall shocks. However, households are not able to compensate for even small but negative shocks. Results are robust to different specifications of the test equation, in particular to the introduction of maternal fixed effects that control for genetic and socioeconomic factors specific to the child. A causal relationship between rainfall shocks and child stunting can be established by exploiting the spatial variability of rainfall during the 2006 climatic year and the heterogeneity in the time of birth. Robustness tests, including placebo regressions, confirm our results.

The remainder of the paper is organised as follows. The second part provides information on the relationships between climate and nutrition in Burkina Faso. The third part provides descriptive statistics for child health and rainfall. Part 4 describes the conceptual and empirical framework. Part 5 exposes the main econometric results and part 6 details various robustness tests. Part 7 concludes.

2. The relationships between climate and nutrition in Burkina Faso

Rainfed agriculture is the dominant production system for food and cash crops with the result that food production, farm income and health environment are highly dependent on weather conditions.

Climate and agricultural cycle

The inter-tropical climate of Burkina Faso defines two seasons which determine the crop calendar and the agricultural year. The wet season runs from May to October and the dry season runs from November to May. The agricultural year runs from September to August. Planting typically takes place from May to July at the beginning of the rainy season. The main harvest occurs from September to December. A second harvest of lesser importance, the "off-season harvest", takes place from January to March (Figure 1).

In this tropical country, agricultural production is highly dependent on the rainfall level as well as on the distribution of rainfall during the rainy season. The occurrence of dry spells during the rainy season and a delayed onset of the rainy season negatively affect crop yields (Sultan et al. 2005). Precipitations being the main determinant of the agricultural production in Burkina Faso, we consider rainfall as the main indicator of weather conditions.

Rainfall is the main element determining agro-ecological zones. It explains both the agricultural land use intensity and the farming specialisation in different crops and livestock. The northern part of the country, namely the regions of Nord, Centre-Nord, and Sahel, is characterized by a shorter growing season, higher rainfall variability, and a less diversified agriculture. Millet, a low water consuming crop, is predominant in the dry north; it is also the main local food crop. Cropping systems are more diversified in the South considering the greater flexibility offered by more generous climate and soils. Cash crops are commonly cultivated in the south. Cotton, the main cash crop is mainly produced in the Hauts Bassins and the neighbouring regions, where climatic conditions are favourable. Cattle's breeding is more developed in the north.

From weather shocks to child heath

Climate shocks can lead to increased malnutrition through two main channels: the development of weather related diseases and an insufficient food intake resulting from reduced agricultural income (e.g. Skoufias and Vinha, 2012).

Weather has a direct and immediate impact on health by conditioning the development and propagation of vector and water borne diseases (e.g. McMichael et al. 2006; Githeko, 2007). The prevalence of some parasitic and infectious diseases such as malaria and cholera expands during the rainy season. By contrast, respiratory illnesses are more widespread during the dry season. As a consequence, there are seasonal fluctuations in morbidity and its causes correlated with weather conditions. In turn, infectious diseases affect the body's ability to absorb nutrients, leading to under-nutrition. In particular, repeated exposure to diarrheal infections may have dramatic consequences on the motor and cognitive development of the child.

Climate has also lagged effects on the nutritional status of children through its impact on the future harvest and the farm income. First, a rainfall shock has a direct impact on the "production-based entitlement" of households who cultivate food crops (Sen, 1981). A rainfall deficit may entail a decrease in food production and food intake of the household's members. In turn, babies whose mothers suffered from malnutrition during pregnancy or lactation period will exhibit poor growth rate and lower weight. Poor nutrition provided during early childhood has also adverse health effects on weaned children.

Second, a rainfall shock translates into an income shock which in turns affects the living standards of the household. However, the relationship between rainfall and income may be ambiguous. Farmers' income is generally assumed to be positively related to the rainfall level. This is the case when the crop affected by the rainfall shock is a tradable good which price is given by the international market. In Burkina Faso, a negative (positive) rainfall shock will generate a decrease (increase) in the income of cotton and rice producers the main exported and imported crops.

Conversely, the correlation between rainfall and income may be weak for non tradable goods. A rainfall shock may result in an inverse variation of the price of local goods that dampens the impact of the shock on farmers' income. Millet and sorghum which are the main staple diet of rural populations are not traded on international markets. Their prices fluctuate according to domestic supply and demand conditions. In case of a negative rainfall shock, net sellers of grains may therefore benefit from the price increase if it compensates for their production loss. Conversely, a positive rainfall shock will have a limited positive impact on farmers' income due to the price effect.

Most studies have shown that grain markets within the sub-region are spatially integrated (Araujo *et al*. 2012). Trade flows should therefore prevent large local price variations in response to local production shocks. As a consequence, the compensating effect of price variations on income should be of little importance when rainfall shocks are spatially limited. In case of a widespread drought, surplus farmers benefiting from the price increase should be very few. The income of the vast majority of farmers is expected to be negatively affected by the rainfall deficit and consumers negatively affected by the price increase. We thus consider in this paper that a rainfall deficit has a negative impact on households' income which in turn undermines access to food and health care.

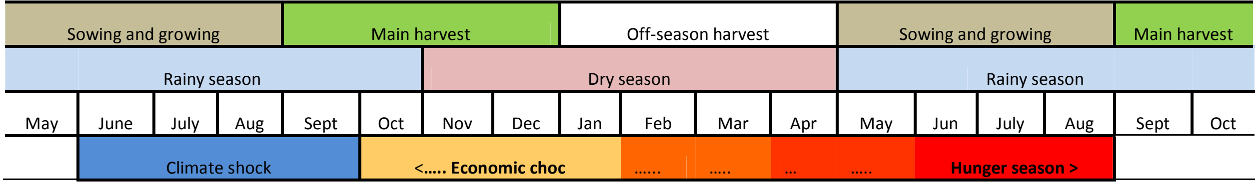
The time path of climate shocks

While the impact of a climate shock on the prevalence of diseases may be immediate, its impact on food availability, income and nutrition occurs with a delay and last over several months in relation with the agricultural calendar.

Generally, farmers sell part of their grain at the time of the harvest (i.e. during September to December) to meet their financial needs. The rest of the harvest, intended for family consumption and seed production, is stored on the farm until the next harvest or beyond.

The amount of grain stored depends directly on the production level which itself is conditioned by the rainfall distribution during the rainy season. Insufficient precipitations result in a poor harvest, low stocks and a food shortage during the period preceding the next harvest, which occurs 12 months later. The situation is most critical during the lean season[1] i.e. the period which precedes the new harvest and during which farmers' stocks are depleted (Araujo *et al*. 2012). The length of the lean season varies across years, regions and households according to the importance of households' stocks as well as their non-agricultural income but generally runs from June to August (see Figure 1).

Figure 1. The crop calendar



Sowing and growing				Main harvest				Off-season harvest				Sowing and growing				Main harvest	
Rainy season						Dry season						Rainy season					
May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct
	Climate shock				**<..... Economic choc**				......	.....	...	.....	**Hunger season >**				

Source: The authors

In this paper, we consider that a rainfall shock translates into an income and nutrition shock with a delay varying from 1 to 12 months. Therefore, a rainfall shock not only affect children alive during the shock but also children born during the following year. In the case of a deficit rainy season, children are at risk of under nutrition during the following twelve months. For instance, a rainfall deficit occurring during the 2004 rainy season – June to September 2004 – will affect the nutritional status of children alive during the shock period as well as the children born during the following crop year running from September 2004 to August 2005.

It is very important to take this delay into account in order to measure with precision the impact of a climate shock on child health and to identify the critical period of life during which children are more vulnerable to deprivations.

3. Data

Child heath

Data on children's nutritional status are drawn from the ENIAM survey conducted in June and July 2008. This survey covers the whole country and is representative at the regional level. Anthropometric data - weight, height and arm circumference - were collected on 15.669 children below 60 months. We restrict our analysis to children living in rural areas as the main impact of rainfall shocks is likely to be felt by households involved in rural activities. Our sample is made up with 12.571 children living in 273 municipalities located in 45 provinces (see on map 3 the location of the 273 municipalities represented by black dots).

To measure child health, we focus on the height-for-age indicator that measures long-term nutritional status. The height-for-age indicator is preferred to the weight-for-age indicator which mainly reflects short-term scarcities or illness episodes experienced by children shortly before the survey. In contrast, height-for-age is associated with chronic malnutrition also referred to as stunting. This is a stock variable reflecting current and past health investments (Linnemayr et al. 2008, Martorell and Habicht, 1986).

The height-for-age indicator is expressed as z-scores (*haz*). Z-score is given by the difference between the child's height-for-age and the median height-for-age for the same aged reference population divided by the standard deviation of the reference population. The z-scores have

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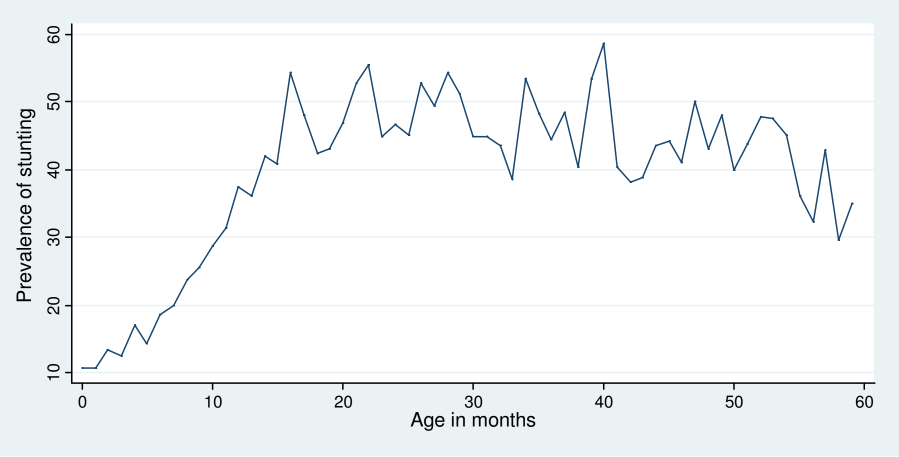
[1] also referred to as the hunger season.

been calculated using the ANTHRO 2005 software program and the 2005 World Health Organization reference.

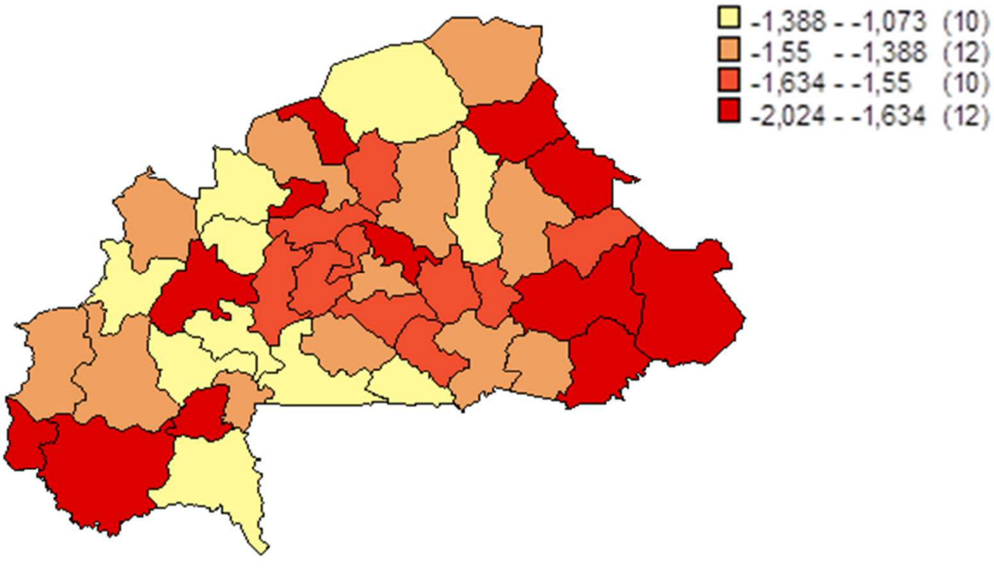
Figure 2. Prevalence of moderate stunting (*haz* < -2) by age in months



Source: The authors based on the ENIAM database

Burkina Faso experiences high rates of malnutrition chronically. The average height for age z-score is 1.53 (see table A2 in the appendix). 39% of children can be considered stunted (with a *haz* below - 2), and 16.3% of children are severely stunted (with a *haz* below - 3).

Map 2. Average height-for-age z-scores by province and quartiles



Source: The authors' calculation based on the ENIAM database

Chronic malnutrition increases rapidly during the first year of life (Figure 2). The prevalence of moderate stunting is on average 14% in the first 6 months. It increases to 28% between 6 to 12 months and reaches approximately 40% after 12 months of life. Prevalence of moderate stunting remains at a high level, between 30 to 60%, until 5 years old. Malnutrition exhibits great regional heterogeneity (Map 2). Chronic malnutrition appears to be more severe in the East and the South West parts of Burkina Faso. The regions with the highest rate of moderate stunting are the Cascades (46.5%) and the East (42.5%) whereas the rate of chronic malnutrition is about 31% in the Centre.

Rainfall data

Our data set includes decadal rainfall data originating from 138 weather stations distributed throughout Burkina Faso and covers the 1995-2008 period. We follow a four-step methodology developed by Maccini and Yang (2009) to calculate a rainfall variable at the child level.

First, we calculate a decadal rainfall index for each municipality represented in the household survey. For each decade, each municipality is matched to the closest weather station. In case of missing data, the rainfall data of the second closest station are used. As a consequence, the rainfall index for a given municipality may come from varying weather stations. On average the distance between the municipality centroid and the closest informed weather station is 15.6 km[2]. Only 5% of the municipalities in the sample are distant of more than 40 km. The median of the mean distance is 12.7 km (see Table 1).

For 40.5 % of the municipalities, the rainfall indicator has been computed using data from only one station; for 48.5% of the municipalities, data come from two stations and for 10.1% of the municipalities data come from three stations. Only one municipality (Bagré) uses rainfall data originating from five different stations[3]. On average, slightly less than two weather stations (1.92) are used to compute the municipality rainfall indicator. Therefore, we can confidently say that the municipality rainfall index mostly reflects the precipitation level measured at the closest weather station.

Table 1. Distance between the municipality centroid and reference weather stations (km)

	1st Station	2nd station	3rd station	4th station	5th station	Total Mean	Min	Max
mean	14.3	33.4	37.1	37.8	41.39	15.6	0.4	60.1
max	59.1	96.2	64.1	37.8	41.39	35.2	0.5	96.2
min	0	1.5	21.9	37.8	41.39	13.4	0	59.8

Second, an annual rainfall index is calculated by municipality. This index is set equal to the cumulated rainfall level during the crop growing season that runs from June 1st to September 30th. Map 3 shows the mean rainfall index aggregated at the province level calculated over the period 2003-2008[4]. This map illustrates the important discrepancies in the average rainfall that ranges from 400mm in the North to 1200mm in the south of Comoé. The annual rainfall level is higher in the South West region. The North-East provinces (Oudalan, Seno, Yagha) feature a low level and a large variability of precipitations, two phenomena that are common to Sahelian areas.

Third, annual rainfall shocks are calculated as the cumulated rainfall deviation from the norm of the municipality which is calculated annually. Norm at year *t* is given by the mean rainfall over the 1995-2008 period excluding year *t*. Shocks are expressed in terms of percentage of the norm[5].

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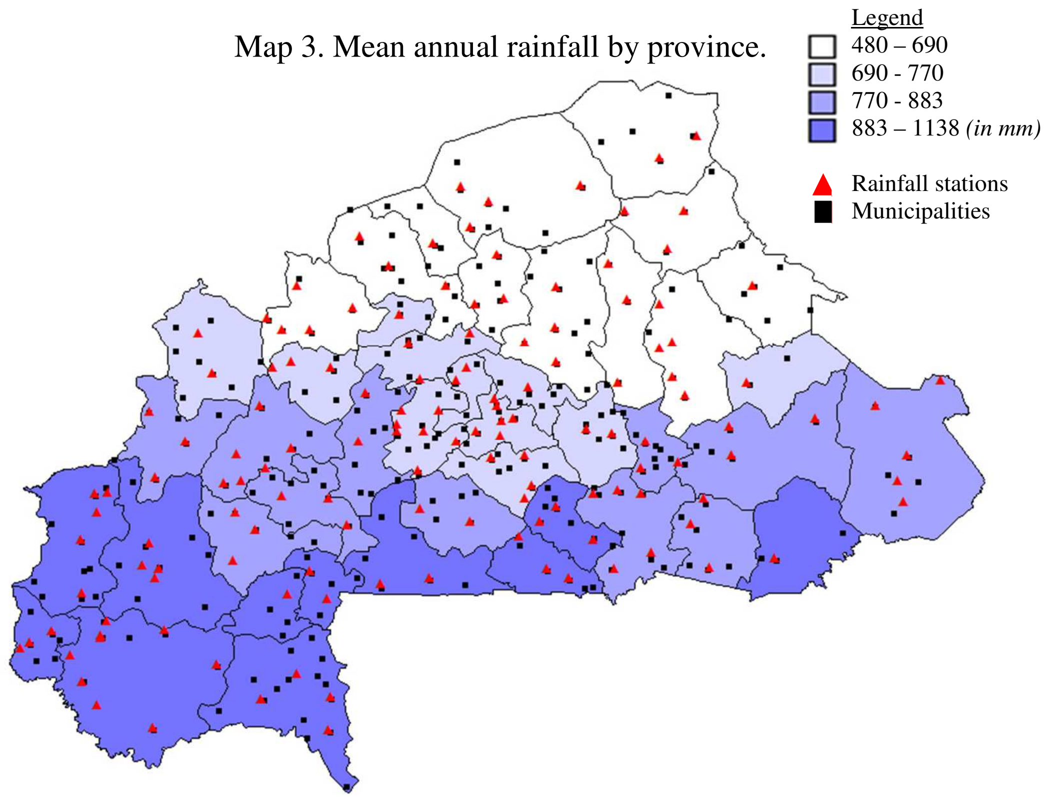
[2] Two municipalities whose distance to the closest informed weather station was greater than 100 km have been dropped from the sample

[3] The 4th and 5th stations are respectively 37.8 and 41km away from this municipality. Estimations have been conducted with and without the Bagre municipality which includes only 37 children. Results are not significantly affected.

[4] This period corresponds to the date of birth of the children in the sample.

[5] Rainfall shock at year *t* is given by: $S_t = \frac{R_{t-\bar{R}}}{\bar{R}}$ with $\bar{R} = \frac{1}{n-1}\sum_{i=1}^{n} R_t$ for i ≠ t

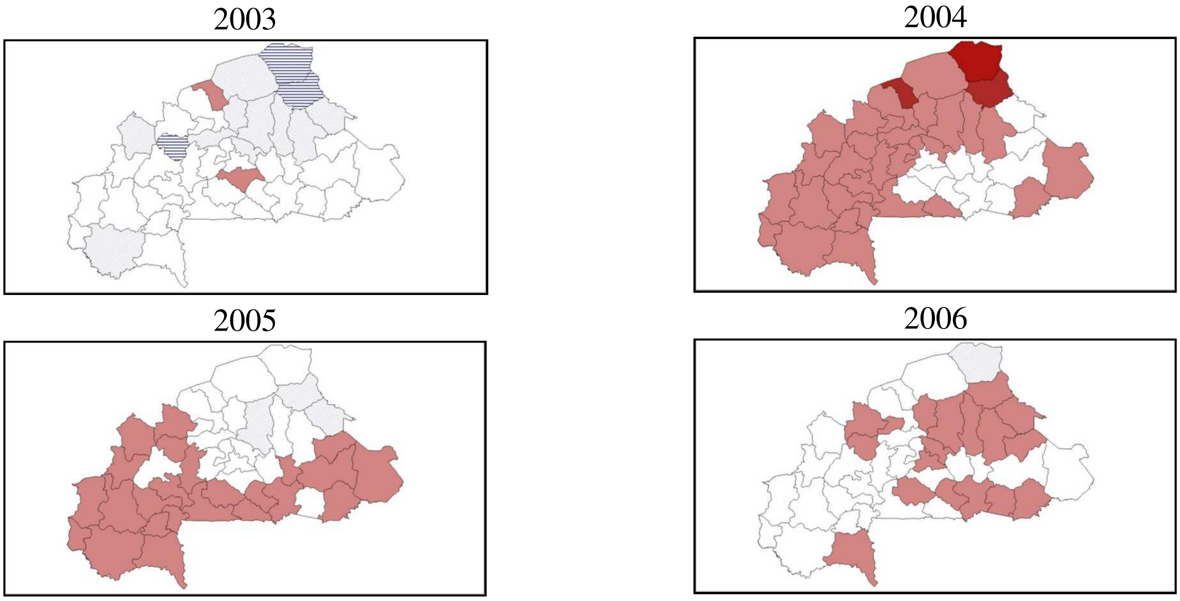
Map 3. Mean annual rainfall by province.



Source: The authors

Map 4 displays the rainfall shocks aggregated at the province level. Blue areas correspond to positive shocks (positive rainfall deviation over the long term mean), while red areas represent negative shocks. 2003 was a good year in terms of rainfall while 2004 marked the most severe drought in the period.

Map 4. Rainfall Shocks by province and year[6]



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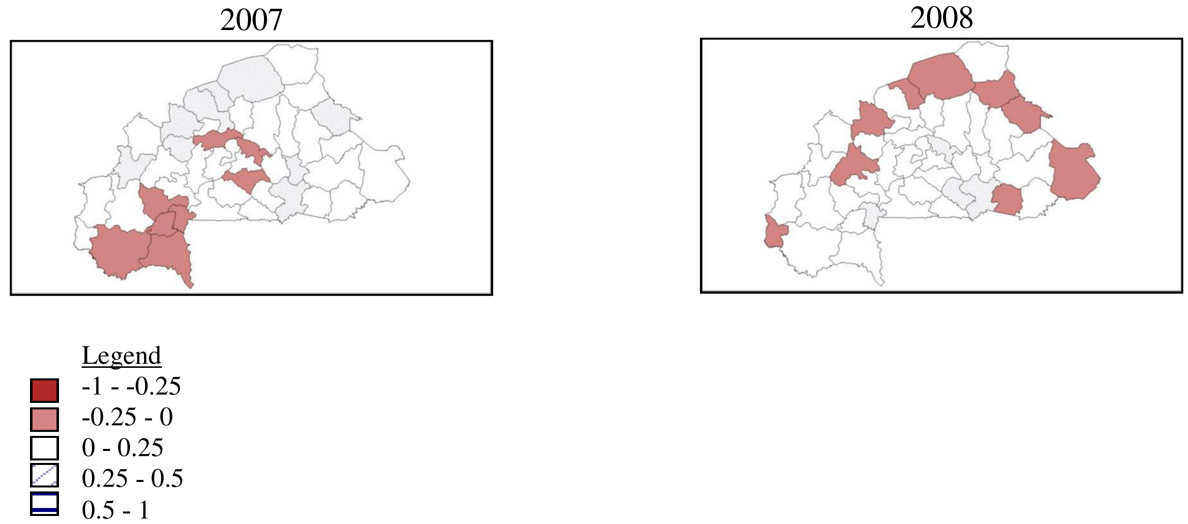
[6] Data by province are calculated as the average value of the municipality shocks.



Source: The authors

Fourth, we use the date and place of birth reported in the database, to define a rainfall shock variable at the child level. Shocks are calculated at different ages. We focus on rainfall shocks in prenatal period which are given by the rainfall shock registered in the rainy season of year $_t$ in the municipality of birth of a child born after the shock, between September $_t$ and August $_{t+1}$. This variable is calculated for each child born between January 2003 and July 2008. It captures the child's exposure to a nutritional deficiency while in utero and during her first months of life.

4. Conceptual and empirical framework

The conceptual framework for the empirical approach is a static model for child health demand originating to Becker's work on time allocation within the household (Becker 1965, 1981). Following a well-established literature (see for instance Sahn and Alderman 1997; Hoddinott and Kinsey, 2001; Behrman and Skoufias, 2004; Linnemayr et al. 2008), we consider that household utility depends on child health H, consumption of goods C, leisure L, and is affected by household characteristics X_h. The utility function of households can be written as:

$$U = U(H, L, C; X_h) \qquad (1)$$

Households are assumed to maximise utility under two constraints namely the health production function and the budget constraint.

The production function of child health is given by:

$$H = F(N, X_c, X_h, X_v, \mu) \qquad (2)$$

N are health inputs including nutrient intake, health care practices and time spent by parents taking care of children, among others; X_c are child characteristics such as age and gender; X_v refers to environmental factors that are assumed to influence health, and μ captures unobserved characteristics of the child, parents, household and the community that affect the child's health.

The household faces a full income constraint given by:

$$P_cC + wL + P_nN = FI \quad (3)$$

P_c, w, and P_n are the price vectors of consumption goods, leisure and health inputs. The full income, *FI*, is given by the value of the time endowment of the household and non-labour income.

Maximisation of (1) subject to (2) and (3) yields the reduced form demand equation for child health that takes the form:

$$H = \Phi(P_c, P_n, w, FI, X_c, X_h, X_v, \mu) \quad (4)$$

Full income is an exogenous variable that does not depend on the allocation of time by the household members, while the wage rate is given in the labour market. Consequently, reduced form demand equation (4) can be estimated by OLS (Kassouf and Senauer 1996).

For agricultural households, the full income includes the farm profit (π), the value of the time endowment (*E*) of the household and non-labour income (*Tr*):

$$FI = \pi + wE + Tr \quad (5)$$

Unfortunately, our data set does not include income or expenditure data. So we cannot directly test the impact of income fluctuations of child health. Following Jensen (2000), we introduce rainfall shocks in the health demand equations assuming that rainfall shocks act through an income variation.

The estimated health demand equation is given by (6):

$$H = \gamma T + \boldsymbol{\beta}_C^{'}.X_C + \boldsymbol{\beta}^{'}_M.X_M + \boldsymbol{\beta}^{'}_H.X_H + \boldsymbol{\beta}^{'}_V.X_V + \varepsilon \quad (6)$$

H is the height-for-age z-score (*haz*).
T is the rainfall shock variable. We consider successively rainfall shocks in the prenatal period (T_0), in the first year (T_1) and in the second year of life (T_2). Children are aged [in utero – 12 months], [2 to 24 months] and [14 to 36 months] during the economic shock that follows a rainfall shock in the prenatal period, in the first year and in the second year of life, respectively.

X_C is a vector of child characteristics including: age in months, sex and being a twin.
X_M is a vector of maternal characteristics including: age, education, mother's body mass index.
X_H is a vector of household characteristics including: the household size, a household wealth index, the age and education level of the head of household.
X_v is a vector of municipality dummies.
ε is a stochastic term including unobserved characteristics of the child ε_C, her mother ε_M, the household ε_H and unobserved random shocks ν.

$\boldsymbol{\beta}_C$, $\boldsymbol{\beta}_M$, $\boldsymbol{\beta}_H$, $\boldsymbol{\beta}_V$ are vectors of parameters to be estimated along with the parameter γ.

γ measures the impact of a rainfall shock in the considered year (*t*, *t*+1 or *t*+2) on the nutritional status of birth cohorts [Sept_t 1^{st} – Oct_{t+1} 31^{th}].

5. Main results

We first estimate the impact of a rainfall shock in the prenatal period and first years of life. In a second stage, we look for gender and asymmetric effects of shocks according to their sign and size. Lastly, we test for the ability of households to cope with shocks by introducing cross variables in the test equation.

Impact of rainfall shocks in prenatal period

Table 2 reports the estimation results of equation (6). They show the positive impact of a rainfall shock in the rainy season preceding the child birth on her nutritional status. The height for age z-score of children under five increases by 0.442 when rainfall in the prenatal period is one percent higher than normal. These children are aged [in utero – 12 months] during the economic shock period that follows the rainfall shock.

Results also give several interesting insights on the determinants of malnutrition. Boys are systematically more stunted than girls; this finding is consistent with other studies conducted in Africa (e.g. Wamani and al 2007; Marcoux, 2002; Svedberg, 1990). The child's standardized height deteriorates with age; it is a common finding that chronic malnutrition increases rapidly during the first years of life. Twins have a higher risk of being stunted while children with older mother have a lower risk. The Body Mass Index (BMI) of the mother which offers a simple measure of short-run health appears to be a significant determinant of children's nutritional status. Finally, the education (both primary and secondary) of the mother has a positive impact on child nutritional status. In contrast, only secondary schooling of the household head (98.7% of the head of households are male) is positively and significantly associated with height-for-age. The age of the household head does not appear to be a significant determinant of children's nutritional status. Regarding the households characteristics, the household size is negatively correlated with height-for-age z-scores but non-significant. The wealth index (based on a principal component analysis) enters positively and significantly.

Table 2. Estimation results with child, mother and household's characteristics

Dependent variable : Children's Height for age z-score	
Rainfall shock in birth year	0.442*** (0.090)
Sexe (1 = male)	-0.264*** (0.028)
Age (in months)	-0.024*** (0.001)
Household size	-0.003 (0.003)
Twin	-0.510*** (0.125)
Mother's age	0.040*** (0.013)
Mother's age²	-0.0005** (0.000)
Body Mass Index of the mother	0.042*** (0.007)
Mother's literacy	0.084 (0.060)
Mother's primary education	0.163** (0.071)
Mother's secondary/higher education	0.274* (0.146)
Mother's other education	0.239 (0.213)
Age of the household head	0.002 (0.001)
Household head literacy	0.036 (0.055)
Household head primary education	0.018 (0.055)
Household head secondary/higher education	0.186* (0.097)
Household head other education	-0.113 (0.094)
Wealth index	0.038* (0.019)
Observations	12,572
R-squared	0.124

Notes: Absolute value of standard errors in parentheses. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence. The estimation includes municipality dummies. The standard errors are corrected for clustering at the municipality level.

The positive impact of rainfall shocks in prenatal period on child health is robust to controlling for the introduction of various time trend specifications: a municipality-year of birth specific time trend as well as a municipality-month of birth specific time trend (table 3). These cross variables capture the temporal variation in the outcome variable that is specific to each municipality and date of birth.

Results are also robust to controlling for household fixed effects or for maternal fixed effects (sibling estimators). The household (maternal) fixed effect regressions control for all observable and unobservable household (maternal) characteristics that are constant across siblings such as biological and socioeconomic factors. The impact of rainfall shocks on child height for age z-score is higher (0.536 to 0.601) when using the sibling estimator. This means that children without brothers and sisters are less impacted compared to those with siblings[7]. A possible interpretation is that parents of only children invest more in their child's health.

Table 3. Impact of a rainfall shock in the child's birth year

Dependent variable : Children's Height for age z-score					
	OLS	OLS with trend	OLS with trend	Household FE	Mother FE
Rainfall shock in prenatal period (T_0) [in utero - 12 months]	0.442*** (0.0904)	0.466*** (0.088)	0.444*** (0.0876)	0.536*** (0.108)	0.601*** (0.148)
Child characteristics	Yes	Yes	Yes	Yes	Yes
Mother characteristics	Yes	Yes	Yes	Yes	No
Household characteristics	Yes	Yes	Yes	No	No
Municipality fixed effects	Yes	No	No	No	No
Year of birth - municipality trend	No	Yes	No	No	No
Month of birth-municipality trend	No	No	Yes	No	No
Observations	12,572	12,571	12,571	9,769	6 262
R-squared	0.124	0.123	0.122	0.098	0.114

The children age during the 12 months following the rainfall shock (i.e. the economic shock period) is in brackets. Robust standard errors are in parentheses. Standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence.

The critical period of life

To identify the critical period during which an economic shock has the most severe impact on the child's health, we test the impact of a rainfall shock in the first and second year of life. The children are aged [2 to 24 months] and [14 to 36 months] respectively during the economic shock period that follows the rainfall shock. Results are given in table 4. They show that rainfall shocks occurring in the first and second year of life do not have any significant impact on the child long term nutritional status.

Table 4. Impact of a rainfall shock at first and second year of life

Dependent variable **:** Height for age z-score								
	OLS	OLS with trend	OLS with trend	Mother FE	OLS	OLS with trend	OLS with trend	Mother FE
Rainfall shock in 1st year (T_1) [2 - 24 months]	0.001 (0.113)	-0.016 (0.112)	-0.024 (0.113)	0.157 (0.204)				
Rainfall shock in 2nd year (T_2) [14 - 36 months]					0.153 (0.109)	0.127 (0.110)	0.094 (0.110)	0.492 (0.356)
Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother characteristics	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Household characteristics	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Municipality fixed effects	Yes	No	No	No	Yes	No	No	No
Year of birth - municipality trend	No	Yes	No	No	No	Yes	No	No
Month of birth-municipality trend	No	No	Yes	No	No	No	Yes	No
Observations	10164	10164	10164	4,869	7370	7370	7370	3,659
R-squared	0.080	0.080	0.075	0.012	0.095	0.098	0.093	0.071

In brackets the children age during the 12 months following the rainfall shock.

Robust standard errors are in parentheses. The standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significance at 1% level of confidence.

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[7] Household (or maternal) fixed effect regressions exclude households with only one child. The sibling dataset reduces to 6,262 children when restricting the sample to children with at least one sibling under 5 years (table 3).

We thus conclude that children are more vulnerable to a weather related shock during their in utero life and the first months of their early life. During this period, the vast majority of children are breastfed (91% of the mothers in the sample declare to have breastfed their children), weaning generally occurring between 18 and 24 months.

These results are in line with a large medical and economic literature showing a strong relationship between maternal nutrition, foetal growth and after birth weight and size (see for instance Gajigo and Schwab, 2012). They confirm that the nutrition of mothers during pregnancy and breastfeeding play a critical role.

Gender effect

Table 5 shows that the impact of a rainfall shock is significantly lower for girls. Girls do not benefit as much as boys from an increase in income following a good harvest but they are less affected by a negative shock. This result supports the idea that there is no intra-household gender discrimination detrimental to girls in Burkina Faso. In contrast, boys appear to be more sensitive to the quality and quantity of nutrition during the foetal and lactation periods than girls.

Table 5. Impact of a rainfall shock in the child's birth year by gender

Dependent variable: Height for age z-score				
	(1)	(2)	(4)	(6)
Rainfall shock in prenatal period (T_0)	0.442*** (0.0902)	0.565*** (0.110)	0.583*** (0.111)	0.548*** (0.111)
T_0 * Girls		-0.256** (0.126)	-0.235* (0.130)	-0.209 (0.130)
Child characteristics	Yes	Yes	Yes	Yes
Mother characteristics	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	No	No
Year of birth - municipality trend	No	No	Yes	No
Month of birth-municipality trend	No	No	No	Yes
Observations	12572	12572	12,572	12,572
R-squared	0.124	0.124	0.123	0.122

Robust standard errors are in parentheses. Standard errors are corrected for clustering at the municipality level.
* indicates significance at 10% level; ** at 5% level and *** significance at 1% level of confidence.

The greater vulnerability of boys to climatic shocks during their first year may be due to biological factors. It is a common finding that boys under 5 years are structurally less healthy than girls in Africa. In poor health environments, the male to female sex ratio at birth tend to decrease and the rate of mortality of boys to increase relative to girls (Garenne, 2002). More generally, there is some medical evidence that human males are more fragile than females (Kraemer, 2000).

An asymmetric impact of rainfall shocks

An interesting feature emerges when studying the asymmetric impact of rainfall shocks according to their magnitude and sign (table 6). We distinguish large positive and negative shocks from small positive and negative shocks. Large shocks are above one standard deviation. Small shocks are above a percentage α of the standard deviation. The reference category in the regressions presented in table 6 is constituted by children who experienced a rainfall level at birth year close to the long term average.

Results show that large positive and negative shocks have a symmetric impact on the child nutritional status while the impact of small positive and negative shocks differs significantly. Children do not benefit from small positive shocks but they are significantly and negatively affected by small negative shocks. In other words, all negative shocks matter while only large positive shocks impact child health. Children's vulnerability to small negative shocks suggests that households are not able to compensate for income shocks even when shocks are of low magnitude[8].

These results may reflect the precarious nutritional situation of most children. A small reduction in food supply has adverse effects on health while a large improvement in a child diet is needed to significantly alter her nutritional status.

Table 6. Impact of severe rainfall shocks in prenatal period

	Dependent variable : Height for age z-score					
	OLS	Mother FE	OLS	Mother FE	OLS	Mother FE
	α = 10%	α = 10%	α = 25%	α = 25%	α = 50%	α = 50%
Large positive rainfall shock	0.145*	0.143	0.174***	0.1877**	0.208***	0.267***
	(0.077)	(0.109)	(0.059)	(0.088)	(0.048)	(0.079)
	[2997]		[2997]		[2997]	
Small positive rainfall shock	-0.104	-0.128	-0.063	-0.0778	-0.057	-0.059
	(0.075)	(0.114)	(0.060)	(0.094)	(0.057)	(0.091)
	[4113]		[3447]		[1839]	
Small negative rainfall shock	-0.132*	-0.242*	-0.140**	-0.2526**	-0.126**	-0.123
	(0.075)	(0.124)	(0.059)	(0.101)	(0.062)	(0.106)
	[3737]		[3127]		[1839]	
Large negative rainfall shock	-0.231***	-0.295**	-0.200***	-0.2530**	-0.168***	-0.167
	(0.086)	(0.141)	(0.072)	(0.117)	(0.061)	(0.108)
	[1545]		[1545]		[1545]	
Municipality fixed effects	Yes	No	Yes	No	Yes	No
Observations	12572	6266	12572	6266	12572	6266
R-squared	0.126	0.117	0.127	0.118	0.126	0.116

Large positive (negative) shocks =1 if the shock variable is above (below) the mean + one standard deviation; = 0 otherwise
Small positive shocks =1 if the shock variable belongs to the interval [mean; mean + α SD]; = 0 otherwise
Small negative shocks =1 if the shock variable belongs to the interval [mean; mean - α SD]; = 0 otherwise
Robust standard errors are in parentheses. The standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence. All regressions include child, mother and household characteristics.
In brackets the number of children in each class of shocks.

Shocks mitigation

The ENIAM survey provides information about household expenditures during the month and the year preceding the survey. We use this information to calculate an expenditure variable for the 2007/2008 agricultural year which may be considered as a proxy for the permanent

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[8] According to Wald tests, the impact of small and large negative shocks is not statistically different in all regressions.

income of households. We then test whether children living in wealthier households are less impacted by negative rainfall shocks.

According to our estimations, income has no direct impact on the nutritional status of children. These results are in line with previous studies showing that sanitary conditions, access to health care and food are more important determinants of the child nutritional status than income. When interacted with the rainfall shock variable, income becomes a significant determinant of the child standardized height-for-age (Columns 1, table 7). Better-off households are able to partly compensate for an income loss following a deficit rainy season but this offsetting effect is of minor importance.

Table 7. Factors of shocks mitigation

Dependent variable : Height for age z-score	(1)	(2)
Positive rainfall shock in prenatal period (PT_0)	0.439***	0.448***
	(0.149)	(0.150)
Negative rainfall shock in prenatal period (NT_0)	-0.815***	-0.911***
	(0.276)	(0.307)
Expenditure	-6.20e-07	
	(6.04e-07)	
NT_0 * Expenditure	7.48e-06**	
	(3.74e-06)	
Access to safe drinking water		-0.0756
		(0.0485)
NT_0 * access to safe drinking water		0.703**
		(0.313)
Municipality fixed effects	Yes	Yes
Observations	12,572	12,572
R-squared	0.124	0.124

(1) Annual per capita expenditure including food, health, educational expenditures, agricultural inputs, livestock purchase, household goods, ceremonies, housing, debts repayment and remittances
(2) Improved water access refer to tap water, drinking fountain and piped water
Robust standard errors are in parentheses. The standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence. All regressions include child, mother and household characteristics.

Access to safe drinking water, through communal standpipes or private tap water, has more important mitigating effects. Children living in household having access to safe water are less impacted by negative rainfall shocks. The safe water access variable is only significant in interaction with the negative rainfall shock variable. Having access to an improved water source appears to be of most importance in a drought period when the wells and rivers run dry. An interpretation is that pregnant women and children whose bodies are weakened by poor nutrition after a drought are more vulnerable to water borne diseases.

6. Robustness tests and discussion

Results from the previous section suggest that rainfall shocks in the prenatal period have a significant impact on the nutritional status of the child. In this section, we test the robustness of these results by using the difference-in-differences estimator, conducting placebo regressions and sensitivity tests to measurement errors in some exogenous variables.

The difference-in-differences estimator

There are several potential sources of bias in estimating the impact of climate shocks on child health. First, rainfall shocks may be correlated with the mean rainfall level resulting in a selection bias: children living in poor arid regions are more vulnerable to shocks than children living in wealthier regions with better weather conditions. Second, children's exposure to rainfall shocks partly depends on household's crop decisions. In both cases, the rainfall shock variable is correlated with the error term. To control for these potential endogeneity biases, we focus on the impact of the negative rainfall shocks recorded during a specific year in order to use the difference-in-differences estimator (Akresh et al. 2011, 2009).

The 2006 climatic year appears to be a good candidate for this identification strategy. The rainfall shocks are fairly well spatially distributed in 2006 and a rather large population have been affected by drought (42 % of children aged 0-12 months). However, shocks had no significant impact on grain prices which stayed at a low level in 2006 on the main markets of Burkina Faso. As a consequence, the production loss induced by rainfall deficits clearly resulted in an income loss for farmers affected by shocks.

In contrast, the number of children born in 2003 is too low to work on the 2002 rainfall shock (table 8). In 2004, all urban and rural households have been affected by the general food price increase that followed the 2004 drought - the most severe rainfall shock of the last two decades. The 2004 shock therefore violates the stable unit treatment value assumption (SUTVA) condition. 2007 is also not a good candidate for a difference in differences analysis because there is no counterfactual sample. As the database includes children born until July 2008, all the children were born at the time of the rainfall shocks of 2007.

Table 8. Number of children according to their year of birth

	2003	2004	2005	2006	2007	2008
Birth cohort size	671	2573	2676	2768	3112	1480
Male	335	1383	1331	1423	1554	734
Female	336	1190	1345	1345	1558	746
Ratio Male/Female	1,00	1,16	0,99	1,06	1,00	0,98

The estimated equation is given by (7):

$$H = \gamma T.\delta_t + \beta_C'.X_C + \beta'_M.X_M + \beta'_H.X_H + \beta'_V.X_V + \beta'_y.X_y + \varepsilon \qquad (7)$$

X_C is a vector of child characteristics; X_M is a vector of maternal characteristics; X_H is a vector of household characteristics; X_v is a vector of municipality dummies; X_y is a vector of month and year of birth dummies

T is the treatment variable. *T* is equal to 1 if the 2006 rainfall shock in the child's municipality is lower than minus one standard deviation; *T* is equal to 0 otherwise.
δ_t is a dummy variable that takes on a value of 1 if the child was alive during the shock or born in the following 12 month; equal to 0 otherwise.

γ measures the impact of the 2006 drought on children born until August 2007 and living in regions affected by the rainfall shock, the so called "treated" children. These children were aged 0 to 51 months during the economic shock period that follows the 2006 drought.

Table 9. Estimation results from the DD estimator.

Dependent variable : Height for age z-score	(1)	(2)	(3)
Born before the shock * shock region	-0.0539		
[In utero - 51 months]	(0.122)		
Cohort Sept 2006 to Aug 2007 * shock region		-0.283**	
[In utero - 12 months]		(0.128)	
Cohort Sept 2005 to Aug 2006 * shock region		0.259	
[2 - 24 months]		(0.167)	
Cohort Sept 2004 to Aug 2005 * shock region		-0.0505	
[14 - 36 months]		(0.138)	
Cohort June 2003 to Aug 2004 * shock region		-0.0691	
[26 - 51 months]		(0.175)	
Born after the shock * shock region			0.0547
			(0.122)
Municipality fixed effects	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes
Observations	12,569	12,572	12,572
R-squared	0.169	0.169	0.169

Robust standard errors are in parentheses. The standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence. All regressions include child, mother and household characteristics.

The impact of the 2006 drought on all “treated” children is not significantly different from zero (table 9, column 1). However, when interacting the shock variable with the birth cohort, younger children appear to be significantly and negatively affected by the drought while older children are not. Children born during the crop year following the 2006 drought in a deficit region have a 0.283 lower height-for-age z-score. These results corroborate the previous ones: children under one year are more vulnerable to economic shocks than older ones.

As a robustness check, we test the effect of the 2006 climatic conditions on children born after August 31, 2007. These cohorts have never been exposed to the 2006 weather shock (even at time of conception) so that the impact of the shock on these children is expected to be non-existent. Results do not show any systematic bias in our results (table 9, column 2), the coefficient of the shock variable being not significantly different from zero.

Other robustness checks

An impact limited to rural areas

Rainfall shocks if not generalized to the whole country should have no impact on the income of urban households and food intake of children living in urban areas. As expected, when restricting the sample to children living in urban areas, the rainfall shock variable becomes non-significant (table 10, column 1 and 2). In this placebo regression, the height for age z-score of children living in urban areas is unaffected by rainfall shocks in the rainy season preceding their birth date.

Table 9. Impact of rainfall shocks in prenatal period on restricted samples.

	Dependent variable: Height for age z-score			
	OLS	Mother FE	OLS	Mother FE
Rainfall shock in prenatal period	0.1828 (0.220)	0.2714 (0.460)	0.5356*** (0.105)	0.6522*** (0.181)
Child characteristics	Yes	Yes	Yes	Yes
Mother characteristics	Yes	No	Yes	No
Household characteristics	Yes	No	Yes	No
Municipality fixed effects	Yes	No	Yes	No
Sample	Urban areas	Urban areas	Date of birth certified	Date of birth certified
Observations	1974	768	9575	4668
R-squared	0.144	0.179	0.145	0.152

Robust standard errors are in parentheses. Standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significant at 1% level of confidence. All regressions include child, mother and household characteristics

Sensitivity to the child's birth date

To identify rainfall shocks in prenatal period, we need precise information on the year and month of birth of the children. This information is available in the survey. Mothers were asked to show written records (such as child health cards or birth certificates) to the survey team. If the birth certificate was available, the date of birth was taken directly from it. If written records were missing, the age in months was determined using a tool known as the calendar of events. The most useful events are generally related to the agricultural calendar (rainy season, dry season, planting, harvest, etc.) and religious festivals or public holidays. In this case, the birth date may be measured with error. In the estimations presented above, we did not distinguish between children whose date of birth is known with certainty and the others.

To test a potential bias due to measurement error in the child's date of birth, we restrict the sample to the children whose birth date is certified by a written record. Results in column 3 and 4 of table 10 confirm our previous findings. The estimated coefficients are significant and even larger when the sample is restricted to those children whose reported birth date is supported by written evidence.

Sensitivity to the measure of shocks

The sensitivity of the main results to the measure of shocks have been tested by calculating the long-term rainfall mean as the average rainfall during the 1995-2008 period, and alternatively, as the average rainfall during the 1995-2002 period prior to children birth. Estimation results are unchanged (see table A3 and A4 in the Appendix).

Discussion

Rainfall shocks and diseases

Rainfall is a key determinant of the harvest yield which conditions food availability, income and nutrition over the following twelve months. But rainfall also acts on the prevalence of vector-borne disease during the rainy season. A high level of precipitations favors the expansion of malaria and cholera for instance but is a condition for a good harvest. Our estimations mainly capture the impact of rainfall through food supply since we measure the impact of rainfall on unborn children at the time of the rainy season. In this respect, our estimates should be regarded as overestimating the global impact of rainfall on health.

Potential Selection bias

Like other studies of this type, we are confronted with a potential attrition bias due to selective migration, mortality and conception rate in relation to the rainfall shocks.

Migration is a potential source of attrition bias which direction is undetermined. More vulnerable households may have migrated from rural to urban areas in reaction to a negative rainfall shock. They may also send out children to relatives living in areas preserved from food shortage. Whether wealthier or poorest households migrate is unknown. In the same way, fostered child can be the more or the less healthy (Akresh, 2009). Unfortunately, the survey does not provide any information that could shed light on this issue.

The estimated impact of a rainfall deficit on child's health is also likely to be underestimated if shocks result in selective mortality. The impact of shocks is estimated on surviving children who may be genetically different according to the nature of the rainfall shock in prenatal period. Large negative shocks are likely to result in increased mortality so that surviving children may be genetically more resistant to deprivation. The survey does not provide information on child mortality nor on miscarriage and still birth.

Weather conditions may also determine parental choice regarding the timing of birth. Some types of parents may decide to delay birth after a negative rainfall shock (or conversely), generating a selection bias. However, the magnitude of this phenomenon should not be overstated since birth control and contraceptive means are not widespread in rural areas of Burkina Faso. Moreover, the within family estimates controlling for parental characteristics should control for this potential bias.

Keeping these potential selection biases in mind, our results should be interpreted as the impact of rainfall shocks on the nutritional status of children conditional on the surviving child to be recorded in the survey (Akresh et al. 2011).

7. Concluding remarks

The econometric results emphasise four important points. First, the significant impact of rainfall shocks in prenatal period on child health shows that households are not able to smooth income shocks related to weather conditions. Children are vulnerable not only to large negative shocks but also to negative shocks of lesser importance.

Second, young children below 12 months are more vulnerable to economic shocks. The in utero period and the first months of life appear to be a critical period. Negative shocks occurring at a age lower than 12 months should be considered as having a permanent effect. These results are consistent with those of Akresh et al. (2012). Based on a sample of children living in the Nahouri region of Burkina Faso, these authors found that children exposed to a negative rainfall shock while in utero or in their first year of life have lower cognitive abilities.

Third, rainfall shocks translate in nutritional shock with a delay. In this respect, a drought has an adverse effect on the nutritional status of children born within 11 months after the shock. This is a consequence of the lack of diversification of rural household income. The farm income which is concentrated over a short period of the year determines the access to food and health care during the rest of the year.

Fourth, results do not confirm the existence of a bias detrimental to girl in resource allocation within households. On the contrary, young boys appear to be more vulnerable to shocks than girls. This finding is consistent with the higher rate of mortality of boys during the neonatal period that is commonly observed in Africa. This gender effect should not be interpreted as reflecting a behavioural but rather a biological phenomenon.

Results have important policy implications. First, they provide additional support for public interventions aiming at protecting rural households from climate shocks. In this respect, promoting the development of weather–based insurance tools appears to be highly desirable. Results also call for strengthening the early warning systems and the aid disposal in case of crop deficit.

Second, results have implications on the targeting and timing of assistance in case a negative rainfall shock. Assistance should be more specifically targeted at pregnant women and young children who are the most vulnerable. Distribution of dietary supplement to rural women in case of drought will have a positive impact on the health outcomes of the unborn child. Assistance should be provided as earlier as possible in the crop year and not only during the so-called “hunger season”.

Third, results call for further research on intra-household resource allocation. The poor nutritional status of children may reflect gender inequality in food access within the household between men and women.

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Appendix

17 variables have been used to calculate the household wealth index. Table 1 provides the scoring factors of the five principal components. The five factors with an eigenvalue larger than 1 have been kept. The first component accounts for 22 percent of the total variation across the 17 indicators.

Table A1. Composition of the wealth index

Variable	Component 1	Component 2	Component 3	Component 4	Component 5	Mean	S.d
Radio	0,220	0,002	-0,259	-0,369	0,238	0,742	0,438
Table	0,274	0,175	-0,255	-0,158	0,242	0,380	0,485
Chair	0,350	-0,495	0,123	0,100	-0,019	0,653	0,476
Bed	0,236	0,232	-0,279	-0,087	0,242	0,434	0,496
Cart	0,302	-0,200	0,067	-0,013	-0,137	0,513	0,500
Plough	0,350	-0,495	0,123	0,100	-0,019	0,653	0,476
Phone	0,286	0,178	-0,042	-0,211	-0,091	0,303	0,460
Television	0,235	0,249	0,195	-0,172	-0,214	0,066	0,248
Bicycle	0,173	-0,221	-0,098	-0,138	0,231	0,933	0,250
Motorbike	0,327	0,094	-0,019	-0,157	-0,174	0,333	0,471
Car	0,071	0,135	0,596	-0,153	0,236	0,003	0,053
Walls in cement or stones	0,137	0,266	0,188	0,305	-0,157	0,036	0,187
Improved roof (cement, tiles or cogurrated iron)	0,285	0,178	0,023	0,377	-0,079	0,392	0,488
Improved floor (cement or tiles)	0,261	0,248	0,023	0,412	-0,040	0,226	0,418
Electricity	0,010	0,093	0,545	-0,182	0,424	0,004	0,064
Improved water access (tap water, drinking fontain, piped water)	0,035	0,007	-0,128	0,482	0,627	0,653	0,476
Improved toilet facilities (private toilet or flush toilets)	0,191	0,206	-0,027	-0,032	-0,087	0,156	0,363
Eigenvalue	3,744	1,755	1,148	1,112	1,025		
Share of variance associated	0,220	0,103	0,068	0,065	0,060		

Table A2. Summary statistics

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Weight-for-height (WHZ)	12403	-0,62	1,26	-5	4,94
Height-for-age (HAZ)	12572	-1,53	1,64	-6	5,94
Weight-for age (WAZ)	12497	-1,31	1,26	-5,95	5
WHZ<2	12403	0,12	0,33	0	1
HAZ<2	12572	0,39	0,49	0	1
WAZ<2	12497	0,27	0,45	0	1
WHZ<3	12403	0,04	0,19	0	1
HAZ<3	12572	0,16	0,37	0	1
WAZ<3	12497	0,09	0,29	0	1
Child age (in months)	12572	27,14	16,57	0	60
Child sex (male=1)	12572	0,51	0,50	0	1
Twin (=1 if a child has a twin)	12572	0,03	0,16	0	1
Household size	12572	12,05	6,69	2	61
Mother's age (in years)	12572	29,93	7,57	15	60
Household head age	12572	47,88	13,56	17	100
Mother's literacy	12572	0,08	0,27	0	1
Mother's primary education	12572	0,06	0,23	0	1
Mother's secondary education	12572	0,01	0,12	0	1
Mother's other education	12572	0,00	0,05	0	1
Household head literacy	12572	0,10	0,30	0	1
Household head primary education	12572	0,10	0,30	0	1
Household head secondary education	12572	0,03	0,17	0	1
Household head other education	12572	0,03	0,16	0	1
Wealth index	12572	0,01	0,90	-1,41	7,42

Table A3. Impact of a rainfall shock in the child's birth year using two alternative measures of long-term rainfall mean

	Dependent variable: Height for age z-score			
	(1)	(2)	(3)	(3)
Rainfall shock at birth year (T_0)	0.449***	0.5783***	0.481***	0.6139***
	(0.0943)	(0.114)	(0.0987)	(0.121)
T_0 * Girls		-0.2622**		-0.2711**
		(0.120)		(0.138)
Child characteristics	Yes	Yes	Yes	Yes
Mother characteristics	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes
Long term rainfall mean	**1995-2002**		**1995-2008**	
Observations	12572	12572	12572	12572
R-squared	0.124	0.124	0.124	0.124

T_0: Rainfall deviation from mean at birth year

NT_0: Absolute value of negative rainfall deviation from mean at birth year

Robust standard errors are in parentheses. Standard errors are corrected for clustering at the municipality level.

* indicates significance at 10% level; ** at 5% level and *** significance at 1% level of confidence.

Table A4. Impact of a rainfall shock at age one and two with two estimation of long-term rainfall mean

	Dependent variable: Height for age z-score					
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall shock in birth year (T_0)	0.449*** (0.0943)			0.481*** (0.0987)		
Rainfall shock at age one (T_1)		0.0152 (0.115)			0.00745 (0.122)	
Rainfall shock at age two (T_2)			0.153 (0.112)			0.165 (0.119)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Long term rainfall mean		**1995-2002**			**1995-2008**	
Observations	12572	10164	7370	12572	10164	7370
R-squared	0.124	0.080	0.095	0.124	0.080	0.095

Shock variable: rainfall deviation from mean

Robust standard errors are in parentheses. The standard errors are corrected for clustering at the municipality level. * indicates significance at 10% level; ** at 5% level and *** significance at 1% level of confidence. All regressions include child, mother and household characteristics.