Rainfall shocks effects on children malnutrition in Senegal

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Abstract:
The links between rainfall shocks and child nutrition remain insufficiently documented in the literature and no studies have been done to explore its effects in the Senegalese context. To assess these effects, we used a survey with a sample of 3645 children (0-5 years) living in 1627 rural households in Senegal in 2014. Three main indicators of nutritional status based on anthropometric measures were considered: weight-for-age, weight-for-height and height-for-age.
It is found that rainfall shocks occurring before birth have a significant and positive effect on child malnutrition as they mainly reduce the z-scores of height-for-age. We also identified income by crop and the use of the mother's time as relevant transmission channels through which rainfall shocks have negative effects on the nutritional status of children.
Keywords: children; malnutrition; rainfall

Résumé :
Les liens entre les chocs dus aux précipitations et la nutrition des enfants restent insuffisamment documentés dans la littérature et aucune étude n'a été faite pour explorer ses effets dans le contexte sénégalais. Pour évaluer ces effets, nous avons utilisé une enquête avec un échantillon de 3645 enfants (de 0 à 5 ans) vivant dans 1627 ménages ruraux au Sénégal en 2014. Trois principaux indicateurs de sur l'état nutritionnel basés sur des mesures anthropométriques ont été considérés : le poids-pour-âge, le poids-pour-taille et la taille-pour-âge.
Il est constaté que les chocs pluviométriques survenant avant la naissance ont un effet significatif et positif sur la malnutrition de l'enfant car réduisant principalement le z-scores de la taille pour-âge. Nous avons également identifié le revenu par culture et l'utilisation du temps de la mère comme des canaux de transmission pertinents par lequel les chocs pluviométriques exercent des effets négatifs sur le statut nutritionnel des enfants.
Mots-clefs : enfants ; malnutrition ; pluviométrie s

Introduction:

This paper investigates whether rainfall shocks exert significant effects on children malnutrition in Senegal. Barker (1990), in a seminal paper, has shed light on the effects that prenatal conditions could have in determining the well-being of the future child. Findings emphasize that in-utero living conditions may have impacts on child health. Things could even get worse and may persist with the presence of long term effects until adulthood (van den Berg et al., 2007; Maccini et Yang, 2009). Exploring rainfall relationships with respect to children malnutrition is very relevant in developing countries settings. Malnutrition is major public issue in developing countries, especially in Subsaharan Africa (Müller et Krawinkel, 2005; Smith et Haddad, 2000). Moreover, particularly in rural areas, rain-fed agriculture plays a dominant role in households livelihoods. Agriculture accounts for a large share of the households income and contributes significantly to their food security. During these last three decades, rainfall patterns have been subject to significant changes. In West Africa, recurrent droughts in 1970s' and 1980s' have resulted to serious losses for farmers and pastorals. Between 30% and 50% of production decline are attributed to climate factors (Mertz et al., 2010). Thus, the occurrence of negative rainfall shocks may affect agricultural yields (Roudier, 2012) and further reduce households income. While malnutrition is recognized as one of the five largest health outcomes affected by climate change (Phalkey et al., 2015), it can be, from an economic perspective, interesting to assess how important are the effects (if any) of rainfall shocks on children nutritional status. Moreover, describing linkages based on findings can, in a public policy standpoint, raise awareness on potential consequences and suggest relevant recommendations to address these issues.

In this study, we explored the effects of prenatal and postnatal shocks on children nutritional status in Senegal. We also identified the causal transmission channels through which rainfall shocks can exert significant effects on children malnutrition.

A finer analysis on prenatal and postnatal rainfall shocks on children malnutrition yielded to mixed evidence. Ogasawara and Yumitori (2019) found that boys are more exposed to stunting for prenatal shocks than girls. The rationale of such a finding is explained by the fact that male foetuses are more vulnerable to climate shocks than female foetuses. A growing body of the literature have found similar results showing the consistency of that statement.

Drawing from the literature, the main contributions of this paper are based on three evidence gaps. First, we will assess rainfall shocks effects on three malnutrition indicators (stunting, wasting, underweight) in a West African context whereas most of studies made a focus only on stunting. Second, the mixed evidence on critical period of vulnerability led us to have a closer look on prenatal and postnatal rainfall shocks. This strategy will shed the light on which period public policies should care about. Third, we investigate two causal transmission channels effects through which these shocks may have an impact on malnutrition: the household income and the women time use in agricultural activities. While many studies investigates the income transmission channel only, very few papers tried to pinpoint mother time allocation effects on children nutrition as a transmission channel.

1. Data and descriptive statistics

1.1. Socio-economic data

This paper uses socioeconomic data from the USAID-Feed the Future baseline survey. The program aimed to provide support government, with multiple interventions, to tackle poverty and food insecurity issues. They collected data in October-December 2014 which refer to a set of detailed household and individual socioeconomic information. Interviews cover modules pertaining to household information, agriculture outcomes, household income and expenditures, health,…. The sampling strategy targeted 2500 households distributed among 13 administrative regions with 250 villages. In each village, 10 households were selected randomly and the heads of households were, in priority, targeted for interviews. Regarding women independence and children modules, head of household spouses and any woman older than 15 years were also taken into account. The survey resulted to a collection of 4357 children data regarding their gender, age, anthropometric measures. We performed four main treatments to the original dataset to fit in with our estimations strategy. First, we only considered rural areas in the sub-sample of this paper. This exclusion is necessary because the analysis is more relevant for rural areas where agricultural systems are mostly rain-fed. Second, we restricted the sample only to households having children aged 60 months or below. Third, we did not take into account data related to the region of Diourbel for outliers issues in data collection. Finally, we removed observations for children having z-scores over 6 or below -6 standard deviations. These extreme values probably result from data misreporting and potentially lead to biased estimates. Our final sub-sample size refers to 3645 children aged between 0 and 60 months living in 1627 households.

We used the anthropometric module to calculate variables pertaining to children's nutritional status. In the module, data regarding age, gender and children measurements such as height, weight were useful to compute these outcomes of interest. Our three key indicators are: weigh-for-height, height-for-age and weight-for-age

$$Z\ score = \frac{Observed\ value - median\ value\ of\ the\ reference\ population}{Standard\ deviation\ value\ of\ the\ reference\ population}$$

We computed z-scores using age, gender, weight and height of the children. We rely on our three outcomes of interest, which are continuous and normally distributed, for our estimations. Children with a z-score less than -2 Standard Deviations (SD) are considered as malnourished for the indicator considered. Likewise, children having a z-score lower than -3 SD are considered as severely malnourished.

We harnessed income and women's independence modules to account for transmission channels analysis. Income is defined at the household level and is a combination of all activities (on-farm and off-farm) generating financial resources from active members. We calculate on-farm income by valuing crop production with the current price in the nearest market. All other activities yielding revenues for the household are included in the off-farm income.

1.2. Rainfall and agricultural calendar data

Rainfall data are measured in mm and monthly available from a set of stations. The available data refer to 17 stations spanning from 2000 to 2014.

Following Maccini et Yang (2009) estimation procedure, we defined rainfall shocks in three steps. Firstly, we calculate a decadal rainfall index (ten years) on each station covering the 2004-2009 period. This decadal rainfall index will be considered as the long-term mean rainfall. We should calculate the index on a 20-year period at least, but data collected did include years before 2000.

Secondly, we set an annual rainfall index for each station which is the cumulative sum of precipitations occurred during the rainy season. In Senegal, the rainy season is usually between June and October, whereas the dry season extends over seven months from November to May. However, we included for each station only relevant months, depending on when the rainy season starts and when it ends. Finally, we estimate the rainfall shocks variable with the following equation:

$$P_{iht} = \frac{S_{iht} - \bar{S}_{ih}}{\bar{S}_{ih}} \qquad (8)$$

With S referring to annual rainfall index and $\bar{S}$ the decadal rainfall index. For each child, we matched rainfall shocks data from the closest station and the corresponding year (gestation year, first year of the child depending on the age recorded in the dataset). In the case there is no close rainfall station (around 50km), data of the second closest station will be assigned.

2. Empirical strategy

We carry out the empirical strategy under two stages. This procedure will firstly explore empirical relationships between shocks and nutritional status, and in a second stage will highlight the effects of the transmission channels. We now set up our regression equation as follows :

$$Y_{iht} = \alpha + \theta P_{iht} + \delta X_{iht} + \varepsilon_{iht} \qquad (5)$$

Y represents the outcome of interest assessing the nutritional status of children. As exposed earlier, we consider three children outcomes referring to three anthropometric indicators: height-for-age, weight-for-age and weight-for-height. P represents the rainfall shock and X is a vector of control variables. The following indices i , h, c, t and krepresent respectively the child, the household, the village, the season considered. We included age and gender clustering to check the presence of fixed effects regarding these variables.

In the second stage of the empirical strategy, we tested the relationship between the transmission channels we identified earlier (household income and allocation of mother work time) and rainfall shocks. This empirical estimation will be performed with the following equations:

$$R_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} \qquad (6)$$

$$W_{iht} = \alpha + \gamma P_{iht} + X_{iht} + \varepsilon_{iht} \qquad (7)$$

Equations 6 and 7 refer to the transmission channels and are used for the estimation of rainfall shocks, respectively, on income and the allocation of mother time. R represents household income and W (from equation 7) refers to the mother percentage of time allocation within different activities undertaken the day prior the survey. P is the variable related to rainfall shocks and X is a vector of control variables. The indices i , h, c and t represent respectively the child, the household concerned, the village in which the child lives and the season considered.

3. Results

3.1. Effects of prenatal rainfall shocks on nutritional status

We reported results derived from equation (5) in ***Table 1*** for our three malnutrition indicators. We included rainfall shocks variable of the current year besides in-utero rainfall shocks for each child. We made the assumption that, beyond income mother allocating time effects, there are transitory effects that might arise. While positive shocks may positively affect in the long run in the children’s well-being through the income channel, a higher amount of rainfall in the shorter-run might increase the probability of environmental diseases. Findings display a significant effect of prenatal rainfall shocks on height-for-age and weight-for-age z-scores respectively at 1% and 10% level. Effects are slightly more predominant on weight-for-age as a 1% increase in prenatal rainfall shocks would likely increase children weight-for-age z-score by 0.261. Current rainfall shocks also exert significant but negative effects on height-for-age and weight-for-age z-scores. Unlike positive effects of in-utero shocks, the negative coefficient of current season shocks proves children are prone to rainfall related diseases when there is an excess of rainfall. The observed current rainfall coefficient is by far greater than the prenatal shock coefficient. It means diseases stemming from current an excess of rainfall can have dangerous implications on children well-being that positive in-utero positive shocks may not counterbalance. These findings refer to children older than 12 months because, as explained earlier, translation of shocks into detectable effects may require a certain amount of time (Mendiratta, 2015). We also introduced season birth fixed effects to estimate their implications on our outcomes. However, no significant effect was detected when we considered these birth season fixed effects.

Table 1: Effects of prenatal shocks on nutritional status

VARIABLES	(1) Height-for-age (Stunting)	(2) Weight-for-age (Underweight)	(3) Weight-for-height (Wasting)
Prenatal rainfall shock	0.261***	0.126*	-0.0101
	(0.0897)	(0.0693)	(0.0738)
Current year rainfall shock	-0.742***	-0.339**	0.137
	(0.178)	(0.137)	(0.146)
Number of dependent children	0.00136	-0.000557	0.000185
	(0.00916)	(0.00708)	(0.00754)
Household size	-0.00925***	-0.00311	0.00286
	(0.00348)	(0.00269)	(0.00286)
Farm size	7.15e-06	-2.31e-05	-7.11e-05
	(0.000144)	(0.000111)	(0.000118)
Is the child up to date with vaccinations (*1=Yes*)	0.0808	0.00211	-0.0738
	(0.0638)	(0.0493)	(0.0525)
Monogamous household (*1=Yes*)	0.0569	0.0208	-0.0361
	(0.0539)	(0.0417)	(0.0444)
Reported diarrhea in the last 15 days (*1=Yes*)	-0.277***	-0.224***	-0.106**
	(0.0545)	(0.0421)	(0.0449)
Household wealth index	-0.107***	-0.104***	-0.0655***
	(0.0281)	(0.0217)	(0.0231)
Constant	-1.431***	-1.168***	-0.532***

	(0.105)	(0.0810)	(0.0862)
Observations	2,688	2,688	2,688
R-squared	0.026	0.024	0.009

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author data

a. 3.2. Effects of rainfall shocks occurring during the first year of life on current nutritional status

Table 3 reports the empirical results on rainfall shocks effects occurring during the first year of life on current nutritional status of children. We found, among our three indicators considered, rainfall shocks only affect height-for-age (stunting). A 1% reduction of rainfall, compared to its average long term, implies a 0.192 reduction of height-for-age z-score of children. It appears with introducing birth season clustering that rainfall shocks have no longer significant effects on height-for-age. However, at the 10% level of significance, a positive postnatal shock will likely shrink weight-for-height. This finding is surprising as we expected a positive coefficient sign. However, we should be more cautious on the robustness of the result rather than the result itself. The low level of significance (10%) may be a hint on the necessity to dig deeper to see whether this finding still holds.

Table 2: Shock effects precipitation of the first year of life on malnutrition indicators for children over 12 months

VARIABLES	(1) Height-for-age (Stunting)	(2) Weight-for-age (Underweight)	(3) Weight-for-height (Wasting)	(4) Height-for-age (Stunting)	(5) Weight-for-age (Underweight)	(6) Weight-for-height (Wasting)
Postnatal rainfall shock	0.192**	0.0296	-0.0923	0.193	0.0311	-0.0913*
	(0.0882)	(0.0679)	(0.0727)	(0.226)	(0.133)	(0.00869)
Current year rainfall shock	-0.664***	-0.301**	0.126	-0.664	-0.301	0.126
	(0.170)	(0.131)	(0.140)	(0.299)	(0.128)	(0.0574)
Number of dependent children	0.00479	-0.00118	-0.00362	0.00503	-0.000908	-0.00343
	(0.00897)	(0.00690)	(0.00739)	(0.0126)	(0.00367)	(0.0156)
Household size	-0.00853**	-0.00204	0.00396	-0.00860	-0.00212	0.00391
	(0.00341)	(0.00263)	(0.00281)	(0.00393)	(0.00260)	(0.000775)
Farm size	2.22e-06	-2.51e-05	-6.90e-05	2.26e-06	-2.50e-05	-6.90e-05**
	(0.000145)	(0.000112)	(0.000120)	(0.000151)	(7.74e-05)	(3.03e-06)
Monogamous household	0.0632	0.0346	-0.0203	0.0622*	0.0334**	-0.0212

(*1=Yes*)						
	(0.0527)	(0.0406)	(0.0435)	(0.00853)	(0.00127)	(0.00465)
Reported diarrhea in the last 15 days (*1=Yes*)	-0.270***	-0.227***	-0.115***	-0.271	-0.228*	-0.116*
	(0.0533)	(0.0410)	(0.0439)	(0.0607)	(0.0290)	(0.0138)
Household wealth index	-0.107***	-0.0918***	-0.0463**	-0.107	-0.0919**	-0.0464
	(0.0273)	(0.0210)	(0.0225)	(0.0194)	(0.00192)	(0.0141)
Constant	-1.366***	-1.170***	-0.598***	-1.364**	-1.169*	-0.597*
	(0.0913)	(0.0703)	(0.0753)	(0.0960)	(0.108)	(0.0843)
Birth season fixed effects	No	No	No	Yes	Yes	Yes
Observations	2,862	2,862	2,862	2,861	2,861	2,861
R-squared	0.023	0.020	0.007	0.023	0.020	0.007

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author data

b. 3.3. Transmission channels

3.3.1. Effects on household income

In Table 4, we reported findings rainfall shocks effects through income transmission channel. We defined rainfall shocks here with data from the year prior to the survey to account for lags to observe for the detection of any significant effect. Findings show that household income is not a strong transmission channel to explain children nutrition outcomes changes. We exepected a positive and significant effect on household income as positive rainfall shocks could induce higher income which would improve children nutritional status. However, no significant was detected either on household income, farm income or off-farm income.

We paid a closer attention to agricultural income to explore what are what its effects on each crop revenue. Rainfall shocks on revenue for each crop are detailed on Table 5. Unlike Table 4 findings on gross household income, we found rainfall shocks do have significant positive effects on 4 out of 5 majors crops. Effects are significant at 1% level on peanut and millet while level of significance is at the 5% and 1% respectively for maize and soghum. In the case of negative rainfall shocks, children living in households dependent to peanut production may be at risk regarding their nutritional status. The coefficient related to peanut changes induce rainfall shocks is large enough, with 230,104 FCFA for a 1% increase in shocks, to deeply affect children nutritional scores. The same observation is applied to millet with a coefficient of 66,296 FCFA[1].

Table 3: Effects of rainfall shocks on annual household income

VARIABLES	(1) Household income	(2) Farm income	(3) Off-farm income
2013 rainfall shocks	216,745	373,144	-156,400
	(278,299)	(259,824)	(95,339)
Observations	3,645	3,645	3,645
R-squared	0.020	0.007	0.054

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author data

Table 4: Rainfall shocks effects on income per crop

VARIABLES	(1) Rice income	(2) Maize income	(3) Sorghum income	(4) Peanut income	(5) Millet income
2013 rainfall shocks	-227,572	9,851**	1,045*	230,104***	66,926***
	(249,842)	(3,988)	(612.9)	(18,488)	(6,095)
Observations	3,645	3,645	3,645	3,645	3,645
R-squared	0.003	0.011	0.003	0.093	0.036

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author data

i. 3.3.2. Effects on the allocation of time relative to the working mother

We analyzed in this subsection how the mother responds to a rainfall shock for her working time allocation. The analysis intended is to see whether the mother allocates more time on the child-caring or working more in the field (household economic activities) to maintain at least constant the household income in presence of shocks. All five major activities groups are significantly affected at the 1% level by rainfall shocks as reported by Table 6. All coefficients but time for resting are positive. A 1% increase in rainfall would induce a 23% decrease on time devoted to resting for the mother. The coefficient of time allocated for income-generating activities is the largest one and suggest a higher sensitivity for mothers to allocate more time to

[1] Stands for « Franc de la Communauté Financière Africaine" which is the Senegal currency shared with other countries in West Africa. 1 US dollar is equivalent to 500 FCFA.

these activities when rainfall conditions are better. The same rationale can arguably be applied to time for household economic activities. Moreover, a 1% increase of rainfall shocks may increase by 4.98% the time for housework which encompasses child-caring related activities.

Table 5: Shock Effects rainfall on working time allocated to the mother of income generating activities

VARIABLES	(1) Time for housework	(2) Time for income-generating activities	(3) Time for household economic activities	(4) Time for resting	(5) Time for leisure
2013 rainfall shocks	4.982***	9.558***	4.090***	-23.00***	1.667***
Observations	3,607	3,607	3,607	3,607	3,607
R-squared	0.021	0.056	0.014	0.134	0.017

Source: Author data

Conclusion

This paper aimed to provide informative and consistent insights on the relationship between rainfall patterns and children well-being in rural settings. Evidence in the literature is mixed regarding prenatal and postnatal rainfall shocks effects on children malnutrition. Findings show that prenatal have significant and positive effects on stunting. A 1% decrease of rainfall during in-utero period, compared to its average long term run, would decrease height-for-age z-score by 0.216. Postnatal rainfall shocks will also likely affect stunting as a 1% decrease of these shocks would decrease height-for-age z-score by 0.192.

We explored transmission channels effects induced by rainfall shocks, namely the household income and the mother time use. For household income, findings do not firstly show significant effects induced by rainfall shocks. However, estimates with income per crop show rainfall shocks would have an impact for households growing peanut, millet, maize and sorghum. For time use, positive shocks will affect all activities undertaken by the mother. A positive shock is likely to reduce time used for resting while increasing activities related to housework, income generating activities, leisure.

These results can contribute to draw effective policy implications to tackle malnutrition in Senegal. The recurrence of extreme events should create incentives for policies support emerging and innovative solutions such as index insurance, but also to provide incentives for its scaling-up. Insurance has the potential to prevent agricultural investments from being affected by rainfall shocks. In addition, in-utero shocks may lead to long term effects on children stunting. Health programs aiming to closely monitor mother mother pregnancy should be promoted.

However, for addressing robustness issues with findings, we need to carry out additional research questions. There is a scope of interest to explore in details interrelations between both transmission channels identified in this paper. For instance, how time for childcaring changes induced by rainfall shocks would affect income (and vice versa). What are their net effects on children malnutrition?

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