Weather shocks and child nutritional status in rural households in Bangladesh: Does labor allocation have a role to play?

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Abstract

Despite substantial efforts to improve food and nutrient intake in the last decades, undernutrition of children remains a daunting challenge, especially in rural areas of developing countries. Today, frequent extreme weather events negatively affect agricultural production, even worsening the food shortage problem in these regions. While off-farm labor is found to play a role in mitigating weather shocks as an ex-ante strategy, little is known about how household labor reallocation in response to weather shocks is associated with child nutritional status as an ex-post strategy. We investigate how different forms of labor activity mitigates the effect of rainfall shocks on child nutritional status, using nationally representative three-wave panel data from rural households in Bangladesh, in conjunction with historical monthly precipitation and temperature data. Our result shows that less rainfall during main cropping season in the year prior to the survey is negatively associated with weight for age z-score (WAZ score) of children under the age of five years. Findings indicate that there exist heterogeneous mitigating impacts of different types of labor affecting the link between

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rainfall shocks and child health. While maternal off-farm self-employment can mitigate the negative impact of rainfall shortage, longer working time of mothers in off-farm labor itself decreases WAZ score. Contrary to maternal labor, household-level labor time and labor time of other household members is not significantly associated with the link between rainfall shocks and child nutritional status. In conclusion, the findings underscore the importance of providing sufficient off-farm opportunities to mothers as well as addressing maternal time constraints through targeted policies to cope with rainfall shocks and improve child nutrition.

Keywords: Child nutrition, Labor allocation, Weather shock, Fixed effect model, Bangladesh

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1. Introduction

Despite significant efforts to improve food and nutrient intake in the last decades over the world, many children still suffer from undernutrition. Globally, the number of children under five who suffer from stunting and wasting in 2020 is 149.2 million and 45.4 million, respectively (UNICEF et al., 2021), and 12.6 % of children suffer from underweight.[1] This situation of child undernutrition can be even worsened by the current changing climate. Climate change increases unpredictable weather patterns or extreme weather events, and such weather shocks negatively affect agricultural production (e.g., Cooper et al., 2019b; Freudenreich et al., 2022). For instance, according to the estimation by Lesk et al. (2016), droughts and extreme heat reported during 1964 – 2007 significantly reduced national cereal production by 9 – 10 %. Then, this adverse effect on agricultural production threatens food and nutritional security of people especially in low-income countries through various ways.

There are two direct mechanisms through which weather shocks influence child nutrition (UNICEF, 2014). The first one is food and nutrient intake path (Amondo et al., 2023; Cooper et al., 2019b). Weather shocks make the prevailing production strategies based on the prior climate regime less effective (Bandyopadhyay and Skoufias, 2015), leading to lower agricultural yields. Then, this agricultural loss decreases food availability especially in rural areas in developing countries, where people highly rely on agriculture for their livelihood (e.g., Baker and Anttila-Hughes, 2020; Vogel et al., 2019), resulting in a worse nutritional status of household members. The second one is disease path (e.g., Helldén et al., 2021; Levy et al., 2016). Excessive rainfall is likely to worsen water quality (Delpla et al., 2009), which leads to high risk of disease infection like diarrhea (Cooper et al., 2019a). Such disease, in turn, lowers

[1] UNICEF, World Health Organization, World Bank: Joint child malnutrition estimates (JME). Prevalence of under- weight, weight for age. 2020. Available at: https://data.worldbank.org/indicator/SH.STA.MALN.ZS. Accessed 21st June 2023.

the uptake and retention of essential nutrients from food (Omiat and Shively, 2020). Therefore, to improve child nutritional resilience in the face of climate change, it is crucial to ensure constant food consumption as well as support children to recover from the disease under weather shocks.

This paper focuses on household labor allocation as a strategy to achieve this goal. This is an important strategy for rural households in developing countries that face restricted adaptation options due to limited social safety nets and limited access to credit markets (Branco and Féres, 2021). Rural households in developing countries allocate their labor to different form of activities: self-employment and employment in an off-farm sector, self-employment and employment in an on-farm sector. There are different potential mechanisms between off-farm and on-farm sec- tors, in terms of how to influence child nutrition under weather shocks. As for off-farm labor, it increases household income while it decreases the dependence of rural households on their own produced food and allows them to have access to food through market even under weather shock conditions (Nguyen et al., 2017). Besides, the household income also allows them to increase healthcare expenditures when needed. For instance, it allows them to buy proper medicines for infected children. Thus, off-farm labor is likely to mitigate the negative effects of weather shocks on child health through both food intake and disease paths. As for on-farm labor, it can improve household food consumption if the climates are favorable. However, under weather shocks, households often fail to produce enough food unless they adopt effective strategies in advance: e.g., split doses of fertilizers, adoption of extreme-weather-tolerant species (Pandey et al., 2007), and crop and income diversification (Sibhatu and Qaim, 2018; Matsuura, Luh, and Islam, 2023). Furthermore, such ex-ante strategies are not efficient because farmers do not know weather conditions during a cropping season when they make decisions. On the other hand, on-farm labor increases the available time for childcare due to its working location (Debela et al., 2021). Thus, on-farm labor is vulnerable to weather shocks in terms of ensuring food consumption, but may positively influence child health under the disease environment. Since households can decide off-farm and on-farm labor participation flexibly even after observing the current weather (Mathenge and Tschirley, 2015), labor reallocation between off-farm and on-farm activities in response to weather shocks would be more efficient to cope with the unexpected weather shocks than ex-ante labor strategies. Despite the importance of labor allocation for rural households in developing countries, previous literature has not considered a comprehensive evaluation of different coping strategies (Gao and Mills, 2018). Therefore, identifying heterogeneous impact of different types of labor on child nutritional status under each weather shock would help rural households and policy makers to promote preferable household labor strategies to improve child nutritional status under weather shocks. To the best of our knowledge, little is known about how households reallocate their labor after the shocks and if the labor reallocation is related to the nexus between weather shocks and child nutritional status.

Given this knowledge gap, this paper seeks to identify how each form of labor mitigates the effect of rainfall shocks on child nutritional status. Specifically, we ask three research questions:

1) How are rainfall shocks associated with child nutritional status?; 2) How do households allocate their labor into off-farm self-employment, off-farm employment, farm self-employment, and farm employment in response to rainfall shocks during the main cropping season?; and 3) How does each labor activity mitigate the impact of rainfall shocks on child nutritional status and whose labor activities are the important in this context?

To answer these questions, we combine three waves of a nationally representative rural house- hold survey in Bangladesh, which include household level labor data as well as individual level anthropometric information, with geo-referenced historical climate data (rainfall and temperature). We employ a fixed effects model to control for potential unobserved heterogeneities on labor allocation choices. Our model exploits variations in child nutritional status within households. That is, we compare nutritional status of children in the same family environment but exposed to different rainfall shocks depending on their birth timing. By doing so, we can remove the effect of specific household time-invariant characteristics on child nutrition and labor decision, and estimate the mitigating impacts of each form of labor activity.

In our study setting, Bangladesh, child undernutrition remains a critical challenge. According to the nationwide survey conducted in 2019, 22.6 % of children under age five are underweight, 28 % are stunted, and 9.8 % are wasted (BBS and UNICEF, 2019). Further, the country is one of the most climate vulnerable countries in the world. Hanifi et al. (2022) find the evidence that average monthly temperature as well as the variability of monthly rainfall have been rising since the 1970s. Hence, identifying coping strategies for weather shocks to improve child nutritional status is vital in this setting.

This study contributes to the literature in several ways. First, we focus on individual-level nutritional outcome. Since it is time-consuming to collect information of all household members, a survey often collects only household-level information. However, foods are not necessarily allocated equally among household members. Our dataset with individual-level anthropometric measures, food intake, and information about disease infection allow us to investigate intrahousehold resource allocation. Second, using three-wave panel data, we look at the dynamics of child nutritional status. While many existing studies use cross sectional data to investigate the association between weather shocks and child nutrition (Cooper et al., 2019b), we provide further evidence of the impact of rainfall shocks on child nutritional status and its underlying mechanisms by analyzing panel data with fixed effect model. Third, contrary to past works about household coping strategies which often focus on an ex-ante behavior, we study an ex-post labor reallocation in response to rainfall shocks. This is more flexible and efficient strategy under the current situation of un- expected increased vulnerability to weather shocks. Further, using the rich information contained in the data about labor activities, we distinguish four different types of labor (i.e., on-farm or off- farm and employment or self-employment). Diversifying labor hours by employment type within the same sector is also important to mitigate some of the entrepreneurial risks of self-employment (Bandyopadhyay and Skoufias, 2015).

2. Conceptual framework

In this section, we aim to conceptualize how rainfall affects child nutritional status and how household labor allocation can influence the associations between rainfall and child nutrition. Although there are several causes of child undernutrition (UNICEF, 2014), [2]we assume that rainfall shock directly affects child nutritional status through two factors: food intake and disease environment. According to Omiat and Shively (2020), the health function of a child i from household h in time t (H_{iht}) is determined by the child's health endowment (μ_{iht}), food in-take of child i (C_{iht}), environmental conditions affecting child disease prevalence (D_{iht}), vectors of exogenous characteristics (X_i) of the child, the child's mother, the household, and the community. In addition, we consider the effect of childcare practices (T_{iht}), such as time for breastfeeding, food preparation, and washing body. Although longer childcare time is likely to benefit the child's health, time available for childcare practices is determined under time constraints. In other words, longer time devoted to labor market or leisure leads to shorter childcare time (Debela et al., 2021). Considering that mothers are often the primary person to take care of their children (Shroff et al., 2009), mother's labor time is in particular important to determine child nutrition. Therefore, child nutritional status can be expressed in the following specification:

[2] They construct a conceptual framework of malnutrition, in which causes of malnutrition are divided into three groups: immediate causes, underlying causes, and basic causes. Although it is difficult to completely separate all channels under the association between rainfall shocks and child nutritional status (Ogasawara and Yumitori, 2019), the aim of this paper is not to entirely list the potential mechanisms linking rainfall shocks with child nutritional status but rather to identify household strategy to mitigate the impacts of rainfall shocks on child nutrition.

$$H_{iht} = f(\mu_{iht}, C_{iht}, D_{iht}, T_{iht}, X_i) \quad (1)$$

where

$$C_{iht} = l\ \{\ Y_{ht-1}\ (R_{ht-1}),\ PF_{ht}\ (L^{off}_{ht}),\ X^{ch}_{i},\ X^{h}_{i},\ X^{co}_{i}\ \}$$

$$D_{iht} = m\ \{\ R_{ht},\ L^{off}_{ht},\ L^{on}_{ht},\ X^{ch}_{i},\ X^{h}_{i},\ X^{co}_{i}\ \} \quad (2)$$

$$T_{iht} = n\ (\ L^{off}_{ht},\ L^{on}_{ht}\ ,\ X^{ch}_{i},\ X^{m}_{i}\ ,X^{h}_{i},\ X^{co}_{i}\ )$$

Equation 2 expresses how recent rainfalls and current household labor affect each child nutritional input. The first input of child nutritional status is current child food intake (C_{it}), which consists of household agricultural yields in the previous year (Y_{ht-1}), the amount of food currently purchased (PF_{ht}), characteristics of the child (X^{ch}_{i}), the household (X^{h}_{i}), and the community (X^{co}_{i}). We assume that previous rainfall (R_{ht-1}) affects food intake by changing agricultural yields, and labor allocation can play a role in mitigating this fluctuation through purchased food. For instance, if a household gets inadequate agricultural yields, they can increase off-farm labor (L^{off}_{ht}), which generates household income and allows them to purchase more food. We assume that on-farm labor does not influence the amount of current purchased food due to time lag between harvesting and purchasing. In addition, the amount of food intake is unlikely to be uniform among children from the same household due to the possibility of unequal intra-household food allocation. Rather, the amounts can be determined depending on the child's age or gender. The second input is disease prevalence (D_{it}), which consists of current rainfall (R_{ht}), off-farm and on-farm labor (L^{on}_{ht}), and other characteristics. As explained already, current rainfall directly influences disease prevalence.

While sufficient rainfall tends to increase crop yields, inadequate rainfall is likely to result in low yields (Omiat and Shively, 2020). Besides, extreme rainfall compared to long-term norms, both low and high, often harms agricultural yields since small-scale farmers cannot adapt to unusual rainfall (Cooper et al., 2019a).However, whether a child actually gets infected with a disease or not and how quickly a child can recover from it depend on household labor. A household can adjust time available for childcare by reallocating labor. For instance, if a child gets a disease, his mother may increase on-farm while decrease off-farm labor to take care of him since on-farm agricultural activities are typically located close to the homestead and easier to combine with childcare (Debela et al., 2021). Whereas, an increase in off-farm labor may also help child recovery from the disease since it is likely to increase household income, which allows them to purchase a proper medicine for a child. Further, child characteristics can capture inherent ability to resist disease, household characteristics can capture the ability that a household takes care of children under the disease environment, and community characteristics can capture the impacts of health facility. The third input is dairy childcare practices. A household labor allocation is likely to change the time available for childcare through an increase in on-farm labor. [3]

Based on the assumptions explained above, the effects of rainfall on each input of child nutritional status can be written as:

$$\frac{dC}{dR_{t-1}} = \frac{dC}{dY}\frac{dY}{dR_{t-1}} + \frac{dC}{dPF}\frac{dPF}{dL^{off}}\frac{dL^{off}}{dR_{t-1}}$$

$$\frac{dD}{dR_t} = \frac{dD}{dR_t} + \frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t} \tag{3}$$

$$\frac{dT}{dR_{t-1}dR_t} = \frac{dT}{dL^k}\left(\frac{dL^k}{dR_{t-1}} + \frac{dL^k}{dR_t}\right)(\mathrm{k} = \text{off or on})$$

[3] Here, we assume that a household maximizes the utility by improving current child nutritional status. However, there are other factors to motivate labor participation in response to rainfall shocks. For instance, agricultural yields in the previous year change current household resource constraints, which affect labor participation decisions especially for self-employment. Alternatively, a household may change on-farm labor based on the expectation of agricultural yields in the end of cropping season, which is determined by the current weather conditions. In any cases, an important thing as a determinant of child nutrition is how much time is devoted to childcare practices while working.

The first line in Equation 3 represents previous rainfall impact on child health through food intake. We hypothesize that $\frac{dC}{dY}\frac{dY}{dR_{t-1}}$ is positive, since more (less) rainfall in the previous year leads to higher (lower) agricultural yields and increases (decreases) current food intake, which results in better (worse) child nutritional status. On the other hand, $\frac{dC}{dPF}\frac{dPF}{dL^{off}}\frac{dL^{off}}{dR_{t-1}}$ can capture household ability to cope with agricultural yield loss due to rainfall shock. Therefore, the requirement that the labor reallocation effect on food intake offsets the agricultural yield effect as a result of rainfall in the previous year is:

$$\frac{dC}{dY}\frac{dY}{dR_{t-1}} + \frac{dC}{dPF}\frac{dPF}{dL^{off}}\frac{dL^{off}}{dR_{t-1}} = 0 \qquad (4)$$

Intuitively higher amount of purchased food increases food intake ($\frac{dC}{dPF}$>0). Further, an increase in off-farm labor is likely to lead to higher household income, mitigating budget constraint including food purchase ($\frac{dPF}{dL^{off}} > 0$). Thus, Equation 4 requires $\frac{dL^{off}}{dR_{t-1}} < 0$. In this case, labor reallocation plays a role in mitigating rainfall impact on child health status through food intake path.

The second line in Equation 4 represents rainfall impacts on child health through disease prevalence. We hypothesize that $\frac{dD}{dR_t}$ is positive, since larger rainfall increases the prevalence of disease. On the other hand, $\frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t}$ can capture household ability to deal with severe disease environment due to current heavy rainfall. Therefore, the requirement that the labor reallocation offsets the negative disease prevalence effect as a result of current rainfall is:

$$\frac{dD}{dR_t} + \frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t} = 0 \qquad (5)$$

Equation 5 require $\frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t} < 0$. Labor should be reallocated to satisfy this requirement. In this case, there are two scenarios. The first one focuses on a role of on-farm labor. When a household is having heavy rainfall, they should increase on-farm labor, which is likely to increase time available for childcare and decrease the prevalence of disease in comparison to off-farm work ($\frac{dD}{dL^{on}} < 0$). The second one focuses on a role of off-farm labor. When a household is having heavy rainfall, they should increase off-farm labor since it can also improve the quality of childcare practices under the risk of disease infection by increasing household income available for healthcare ($\frac{dD}{dL^{off}} < 0$) and decrease the prevalence of disease, despite the decline in time availability for childcare[4].

The last line represents impacts of childcare practices except nursing on child health. Labor reallocation after shock directly determines the availability of childcare practices, which influence child nutrition. There are two hypotheses. On the one hand, on-farm labor can improve childcare practices by increasing time to take care of children. For this, especially working time of a childcare taker is crucial. On the other hand, off-farm labor can also improve childcare practices through higher household income, by which a household can get necessarily goods for children. To cope with rainfall shocks through childcare practices, labor allocation should satisfy the following equation:

$$\frac{dT}{dL^k}\left(\frac{dL^k}{dR_{t-1}} + \frac{dL^k}{dR_t}\right) = 0 \tag{6}$$

[4] We assume that labor change in response to previous rainfall is motivated by agricultural yield change and does not influence disease prevalence ($\frac{dT}{dL^k}\frac{dL^k}{dR_{t-1}} = 0$ | k=off or on)

It implies that labor should react to previous rainfall and current rainfall in opposite directions. From Equation 4, 5, and 6, we derive the following household labor strategy to mitigate recent rainfall shocks on child health:

$$\frac{dL^{off}}{dR_{t-1}} < 0, \frac{dL^{off}}{dR_t} > 0, \ \frac{dL^{on}}{dR_{t-1}} > 0, \frac{dL^{on}}{dR_t} < 0 \qquad (7)$$

3. Data

3.1. Household data

The main data for this study comes from the Bangladesh Integrated Household Survey (BIHS), which is three-wave panel survey collected in 2011/2012, 2015, and 2018/2019. [5] The design and implementation of the survey were conducted by researchers at the International Food Policy Research Institute (IFPRI). The survey sites are rural areas of each seven administrative divisions of the county. The total sample size in the first, second, and third waves are 6503, 5430 and 4891 households, respectively.[6] The sample is nationally representative of rural Bangladesh as well as representative of rural areas of each of the seven administrative divisions of the country.

The BIHS dataset has anthropometric measures of all household members. Since our focus is child nutritional status, we restrict sample into households which have at least one child who aged under five for each wave. Thus, our sample is not balanced. We drop individuals with missing values in any variables which we use in the estimation from our sample. In the end, our sample size for the first, second, and third waves becomes 1,244, 2,385, and 1,879 children from 925, 1,720, and 1,308 households, respectively.

[5] The data source is available in the following link: https://dataverse.harvard.edu/dataverse/IFPRI/?q=title%3A%22Bangladesh+Integrated+Household+Survey+%28BIHS%29%22

[6] This is the original sample and we ignore split samples due to marriage. The attrition rate per year is low. In addition, Ahmed and Tauseef (2022) states that the attrition between 2011/12 and 2018/2019 is random. Thus, we don't adjust our estimates for attrition.

As an outcome variable, we employ weight for age z-score (WAZ score) [7]for children aged under five. The WAZ score captures the prevalence of being underweight. Underweight is severe problem in developing countries since it is associated with higher risks for mortality in children under 5 (e.g., Black et al., 2003; Fishman et al., 2004), and Bangladesh is one of the highest under- weight prevalent countries (Chowdhury et al., 2018). Besides, WAZ score captures both chronic and acute nutritional deficiencies, which suits our focus on both food intake and disease paths. Table 1 presents summary statistics of the variables of interest. Average WAZ scores in waves 1, 2, and 3 are -1.590, -1.541, and -1.278, respectively, which slightly improve over time but are still negative. The prevalence of underweight in waves 1 and 2 are more than 30 % but in wave 3 decrease into 23.9 %. As for household characteristics, more than 80 % of households are headed by male. Schooling year of household head is slightly increasing over time, and average market access is improving from wave 1 to wave 3. Ownership of livestock varies over survey waves. Access to clean water supply (i.e., piped drinking water and sanitary toilet) is improving over time but still quite low. Age of mothers is consistent over time, while their schooling year is increasing on average. As for labor time, at household level, off-farm self-employment accounts for the largest part of their labor, followed by off-farm employment or on-farm self-employment depending on survey wave, and on-farm employment time is the shortest for all waves. On the other hand, maternal labor time has a different trend. They spend most of their time for off-farm labor. Their on-farm labor time, both self-employment and employment, is less than one hour per week on average. This is due to the fact that majority of mothers do not engage in on-farm labor, which implied 0 hours of on-farm labor. As for household level daily wage, which is only available for employment labor and not for self-employment labor, off-farm wage increases over time, while on-farm wage is relatively stable.

[7] The WAZ score in this survey is calculated based on the 2006 WHO growth standards.

Table 1: Summary Statistics

	Round 1		Round 2		Round 3	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Child characteristics						
Weight-for-age Z-score	-1.590	(1.064)	-1.541	(1.053)	-1.278	(1.066)
Underweight (=1)	0.330	(0.470)	0.328	(0.470)	0.239	(0.427)
Age of child in months	28.991	(16.955)	29.971	(17.094)	29.850	(17.339)
Gender of child (=1 if male)	0.490	(0.500)	0.525	(0.500)	0.508	(0.500)
HH characteristics						
Male HH head (=1)	0.950	(0.218)	0.852	(0.356)	0.830	(0.376)
Age of HH head	41.531	(13.688)	40.903	(13.486)	43.885	(13.823)
Schooling year of HH head	3.597	(3.924)	3.690	(3.855)	3.878	(3.994)
Household size	5.423	(1.956)	5.862	(2.170)	7.016	(2.684)
Market access (minute)	18.191	(11.258)	15.907	(9.643)	13.412	(8.748)
Asset index (Scores for component 1)	0.360	(1.868)	-0.500	(2.021)	0.367	(1.893)
Livestock ownership (=1)	0.925	(0.263)	0.156	(0.363)	0.244	(0.430)
Farm Size(decimal)	148.729	(174.218)	101.072	(176.648)	105.675	(161.951)
Irrigation(=1)	0.885	(0.319)	0.436	(0.496)	0.457	(0.498)
Piped water access (=1)	0.015	(0.123)	0.021	(0.145)	0.043	(0.202)
Sanitary toilet access (=1)	0.277	(0.447)	0.436	(0.496)	0.506	(0.500)
HH Daily wage: Off farm, Emp.	27.973	(91.567)	57.508	(152.627)	71.771	(187.568)
HH Daily wage: On farm, Emp.	42.677	(97.996)	49.855	(122.441)	46.817	(140.114)
Age of Mother	27.358	(6.251)	27.384	(5.683)	27.527	(5.916)
Schooling year of Mother	5.029	(3.562)	5.422	(3.499)	6.318	(3.587)
Labor						
HH Labor hours: Off farm, Self	29.990	(30.770)	31.621	(34.853)	33.872	(38.894)
HH Labor hours: Off farm, Emp.	14.312	(24.255)	18.617	(29.865)	23.374	(36.020)
HH Labor hours: On farm, Self	23.439	(28.559)	10.896	(22.253)	9.746	(23.120)
HH Labor hours: On farm, Emp.	7.342	(17.410)	6.569	(17.100)	4.439	(14.165)
Mother Labor hours: Off farm, Self	6.604	(8.490)	5.130	(8.536)	5.175	(18.500)
Mother Labor hours: Off farm, Emp.	2.813	(6.956)	3.181	(8.315)	4.321	(10.344)
Mother Labor hours: On farm, Self	0.349	(2.597)	0.340	(3.305)	0.173	(1.928)
Mother Labor hours: On farm, Emp.	0.198	(2.206)	0.114	(1.767)	0.136	(2.314)
HH Daily wage (TK): Off farm, Emp.	27.973	(91.567)	57.508	(152.627)	71.771	(187.568)
HH Daily wage (TK): On farm, Emp.	42.677	(97.996)	49.855	(122.441)	46.817	(140.114)
Climate						
Past rainfall shock	-0.650	(0.605)	-1.242	(0.247)	-0.724	(0.345)
Current rainfall shock	-1.170	(0.481)	-1.157	(0.427)	-0.218	(0.487)
Historical rainfall CV	0.360	(0.068)	0.383	(0.071)	0.362	(0.066)
Historical average rainfall (mm)	69.939	(20.785)	71.396	(20.227)	67.597	(19.082)
Past temperature shock	0.138	(0.013)	-0.693	(0.065)	-0.004	(0.036)
Current temperature shock	-0.270	(0.031)	-0.377	(0.073)	-0.182	(0.026)
Historical temperature CV	0.102	(0.005)	0.103	(0.006)	0.105	(0.006)
Historical average temperature (°C)	20.865	(0.860)	20.836	(0.937)	20.744	(0.980)
Observations	1244		2385		1879	

3.2. Climate data

Climate data is drawn from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset, which includes monthly rainfall and temperature from January 1980 to December 2019 on a global grid with 0.5-degree latitude by 0.5-degree longitude. Using the geographical location data for each household of BIHS sample, that climate information is merged with BIHS data at household level.

To capture recent climate situations during main cropping season, called Rabi season, [8]we construct weather (i.e., rainfall and temperature) shock variables for each household by following

the study by Makate et al. (2022). Rainfall shock variable is defined as a normalized deviation in Rabi season rainfall in a specific year from the historical average Rabi season rainfall. That is,

$$Rainshock_{ht} = rain_{ht} - \overline{rain}_h \, \rho_{rain_h} (8)$$

where $rain_{hdt}$ is total rainfall that household h receives during Rabi season in year t, $\overline{rain}_h$ is the average Rabi season rainfall for household h over the last 31 years from year t, and ρ_{rain_h} is the standard deviation of rainfall during the same period. In other words, this implies how far seasonal rainfall in year t is from the expected amount calculated by historical average rainfall. We calculated this variable for each survey year (t) as well as each year prior to the survey ($t-1$), and used them as main explanatory variables. [9]Temperature shock variables are also calculated in the same way but used as control variables.

Table 1 gives climate characteristics for each wave. Rainfall shocks in each survey year are -1.170 in wave 1, -1.157 in wave 2, and -0.218 in wave 3, meaning that rainfall during Rabi season in survey periods tends to be lower than the historical average rainfall during the same season for the past 31 years

[8] Rabi season in Bangladesh is from November to February.

[9] The reason why we use rainfall shock variable as a continuous variable, instead of dummy variables implying flood or drought events, is that some households receive only moderate rainfall over time, which means all the explanatory variables are zero. In this case, we cannot identify the impact of rainfall. However, we also define flood and drought dummy variables and analyze the impact of extreme rainfall as a robustness check. These results are summarized in Section A.1

(i.e., 69.939, 71.396, and 67.597 for each wave). Table 1 also indicates that average monthly temperature during Rabi season in survey periods tends to be lower than the historical average temperature during the same season for the past 31 years (around 20 °C for all waves), except the year prior to the first survey wave. We focus on Rabi season because survey was mainly conducted during Rabi season. That is, child nutritional status is measured at the survey and it is likely to be influenced by weather conditions at the survey timing. However, we also check the impact of rainfall shocks in other season (i.e., Kharif season) in Section 6.4.

Besides, Figure 1 visually gives us rainfall shock variations for each year. As you can see, rainfall is quite deviated depending on year.

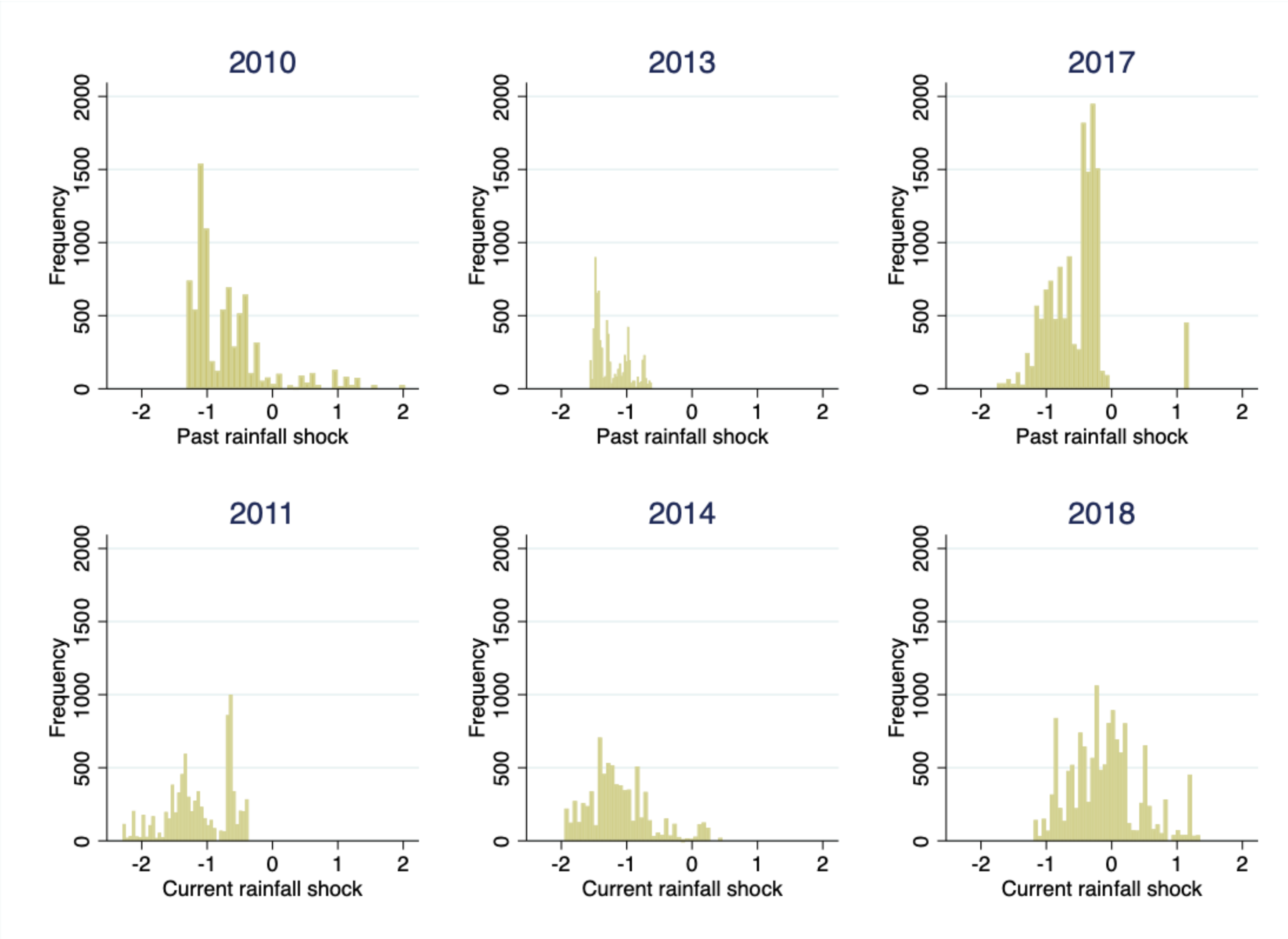

Figure 1: Histogram of rainfall shocks during Rabi season for each year

Note: Calculation by authors.

As defined, positive values in rainfall shock variable imply there are more rainfall than normal amount, and negative values imply there are less rainfall than normal amount. Since more wet weather condition and more dry weather condition are likely to have different impacts on child health, we also defined positive and negative shock variables as follows:

$$PositiveRain_{ht} = \frac{rain_{ht} - \overline{rain}_h}{\rho_{rain_h}} \quad (9)$$

if $rain_{ht} > \overline{rain}_h$, and 0 otherwise.

$$NegativeRain_{ht} = \frac{rain_{ht} - \overline{rain}_h}{\rho_{rain_h}} \times (-1) \quad (10)$$

if $rain_{ht} < \bar{rain}_h$, and 0 otherwise. By including positive and negative rainfall shock variables together into our estimation, we allow positive and negative rainfall shocks to influence child nutritional status differently.

To capture historical climate patterns, we calculate historical average rainfall and temperature over the last 31 years and their coefficient of variation during Rabi season. Coefficient of variation of historical rainfall and temperature can capture fluctuation of climate condition for each place. Since fluctuation of climate conditions makes it difficult to predict climate in future, house- holds need to have specific strategies to avoid the risks caused by weather shocks. In other words, households living in more fluctuated climate spots may adopt systematically different labor strategies with those living in less fluctuated climate spots. To distinguish such an ex-ante strategy from an ex-post coping strategy after the shocks, we include coefficient of variation of historical climates (rainfall and temperature) and their historical average into our estimation as control variables. These controls allow us to identify the impacts of labor changes in response to recent rainfall shocks as coefficients of rainfall shock variables.

4. Empirical Strategy

To estimate change of labor allocation in response to recent rainfall shocks and its effects to mitigate impacts of rainfall shock on child nutritional status, we employ a fixed effects panel data model. Household labor decision is likely to be related to household's observed and unobserved characteristics, which would result in endogeneity problem.[10] For instance, compared to a husband with old gender inequality opinions, a husband with progressive points of view is likely to allow his wife to seek a job outside of their home, at the same time, this progressive attitude may lead to his

[10] Simultaneity bias is another common problem to cause endogeneity issues, however, in our setting, reverse causality may not be problematic since weather is decided exogenously.

better treatment of his children (Duflo, 2012). Then, the unobserved differences in perspectives of gender equality would affect household food consumption in favor of children after rainfall shocks, irrespective of labor changes. In this case, we cannot distinguish impacts of labor reallocation after households experience shocks from impacts of specific household characteristics, that is a stronger mother.[11]

To address unobservable heterogeneity, multi-period panel data is useful. One way to analyze panel data is random effects model. According to Gao and Mills (2018), random effects model is especially suitable when over-time variation in the dependent and independent variables is small, compared to cross-sectional variation in time *t*. However, this model needs the assumption that time-invariant effects are uncorrelated with the explanatory variables, which does not suit our setting. For instance, geographical characteristics of resident place (e.g., altitude) do not dramatically change over time, but are likely to be correlated with rainfall patterns, which are our main explanatory variables, as well as resident's health status.

Thus, using three waves panel data, we employ a fixed effect model with household and time fixed effects. This method allows us to get rid of all time-invariant unobserved heterogeneity without the assumption mentioned above (Wooldridge, 2015).[12]Our model exploits variation in child nutritional status within households with multiple children of the same family environment but exposed to different rainfall shocks depending on their birth timing. By this, we can remove the effect of specific household time-invariant characteristics on child nutrition and estimate the impacts of each labor form to mitigate rainfall effects on child nutritional status. However, we admit

[11] Although there are several indicators to capture women empowerment, it is difficult to directly measure household head's opinion against gender equality due to limitation of our data

[12] As an additional check to choose preferable method, we conduct Hausman test and compare the results from fixed effect model and random effect model. Besides, as robustness check, we employ correlated random effect model.

that our fixed effect model with various controls cannot perfectly overcome the potential endogeneity problem caused by time-variant unobservable heterogeneity. Therefore, the results should be interpreted as correlation rather than causation.

4.1. Model specification

4.1.1. Rainfall shock impact on child nutritional status

First, we estimate the (total) effect of rainfall shocks on child nutritional status in the following specification:

$$y_{ihdt} = \alpha_0 + \alpha_1 RainShock_{hdt-1} + \alpha_2 RainShock_{hdt} + \alpha_3 W_{hdt} + X^C_{ihdt}\alpha_C + X^H_{hdt}\alpha_H + \theta_h + \gamma_t + \epsilon_{ihdt} \quad (11)$$

where y_{ihdt} is weight for age Z-score for a child i from household h living in division d in year t. $RainShock_{hdt-1}$ and $RainShock_{hdt}$ are rainfall shock variables during Rabi season in previous year of the survey and in survey year, respectively, which are our main explanatory variables. W_{hdt} captures climate characteristics for each residence place, including temperature shock variables for previous year of the survey and survey year, historical average rainfall and temperature during Rabi season for the past 31 years and their coefficient of variations. Historical climate control variables help us to distinguish household ex-ante and ex-post labor decisions making (Rose, 2001). Furthermore, we control for individual-level child characteristics (X^C_{ihdt}), such as gender and age in months, as well as a vector of time-variant household characteristics (X^H_{hdt}): demographic indica- tors of the household head and mother of child i, household size, market access, asset index, farm size, irrigation system, access to clean water supply, and daily wage of employment labor. We also include household and year fixed effects (θ_h and γ_t, respectively). Household fixed effect is included to remove the effect of time-invariant characteristics at the household level. Year fixed effect accounts for specific events in survey year, which affect outcome variables. Standard errors are clustered at the household level.

4.1.2. Labor reallocation and labor mitigating impacts

Next, in order to estimate labor reallocation in response to recent rainfall shocks, we employ the same set of explanatory and control variables with Equation 11. An outcome variable is changed to labor time for each labor activity which is off-farm self-employment, off-farm employment, on- farm self-employment, and on-farm employment, respectively. These variables are calculated as labor hours for one week either at the household level or mother level. Since a household needs to allocate total amount of available working time to different labor activities, each labor time is likely to be decided simultaneously, which would bring an endogeneity. We address this problem as a future work.

Lastly, as for mitigating impacts of each labor activity, we include interaction terms between each labor time and rainfall shock variables into Equation 11. The estimation model is written as follows:

$$y_{ihdt} = \beta_0 + \beta_1 L^k_{hdt} + \beta_2 L^k_{hdt} \times RainShock_{hdt-1} + \beta_3 L^k_{hdt} \times RainShock_{hdt} + \beta_4 Shock_{hdt-1} + \beta_5 Shock_{hdt} + \beta_6 W_{hdt} + X^C_{ihdt}\beta_C + X^H_{hdt}\beta_H + \theta_h + \gamma_t + \epsilon^2_{ihdt} \quad (12)$$

where L^k_{hdt} is weekly working time of labor k of household h living in division d in year t, at either household level or mother level depending on specifications. We examine the mitigating impacts for each form of labor. While β_1 captures direct effect of labor on WAZ score, β_2 and β_3 represent for labor impacts on the relationship between one-year prior rainfall shock and child nutritional status and between current rainfall shock and child nutritional status, respectively. By comparing those labor impacts with rainfall shock effects, we confirm which labor type can mitigate negative effects of rainfall shocks or not. Besides, by comparing the labor mitigating impacts between at household-level and mother-level, we analyze whose labor is important to achieve better child nutritional status under rainfall shocks.

5. Results

5.1. Rainfall shocks and child nutritional status

Table 2 summarizes the effect of rainfall shocks on children's WAZ score. Column (1) shows that as rainfall in the year prior to the survey year is larger than the historical average rainfall, WAZ score for a child under five years old tends to increase. However, as rainfall in the survey year becomes larger than the historical average rainfall, WAZ score for a child under five years old tends to decrease. The opposite effects of rainfall shock by year can be explained as the different paths through which rainfall is associated with WAZ score, that is food consumption path or disease path (Omiat and Shively, 2020). We will discuss these potential paths in Section 6.

To investigate the association between rainfall and WAZ score more precisely, we distinguish positive and negative rainfall shocks and include them in our specification together as explanatory variables (Columns (2), (3), and (4)).[13] In Column (2), we distinguish positive and negative rainfall shocks only for past rainfall, while in Column (3), only for current rainfall. Then, in Column (4) we distinguish them for both past and current. Since the coefficient of rainfall shock variable includes the impact of both positive and negative rainfall shocks, it is difficult to interpret. Therefore, hereinafter we only interpret the results of positive and negative rainfall shock variables. Column (4) shows that while negative past rainfall shock does not have significant effect on WAZ score, positive past rainfall shock is positively and significantly associated with WAZ score. This result implies that the positive association between prior rainfall shock and WAZ score is mainly driven by positive effect of more rainfall and not by negative effect of less rainfall. In other words, more rainfall in

[13] In this paper, we focus on household ability to mitigate rainfall shocks on child nutritional status through labor allocation, and do not deeply investigate mechanism under the relationship between rainfall shock and child nutritional outcome. However, we confirm that inadequate rainfall in the previous year (i.e., negative prior rainfall shock) is negatively and significantly associated with agricultural harvest (Table A9 in the appendix). This result explains food consumption path because less harvest may lead to less food consumption, which results in lower WAZ score. Moreover, we confirm that less rainfall in the survey year (i.e., negative current rainfall shock) is negatively and significantly associated with the prevalence of diarrhea (Table A10 in the appendix). This result explains disease path because lower prevalence of disease is likely to improve WAZ score.

the previous year than the historical average rainfall significantly increases WAZ score. Specifically, on average, a one standard deviation increase in previous rainfall is associated with a 0.360 standard deviation increase in WAZ score, which is 24.5 % of mean WAZ score for whole sample (-1.470). As for the current rainfall shock, while positive rainfall shock does not have significant effect on WAZ score, negative rainfall shock is positively and significantly associated with WAZ score. This result implies that the negative association between current rainfall shock and WAZ score is mainly driven by positive effect of less rainfall and not by negative effect of more rainfall. In other words, less rainfall in the survey year than the historical average rainfall significantly increases WAZ score. Specifically, a one standard deviation decrease in the survey year rainfall is associated with a 0.181 standard deviation increase in WAZ score, which is 12.3 % of mean WAZ score for whole sample (-1.470).

Table 2: The effect of rainfall shock on weight for age Z-score

	(1)	(2)	(3)	(4)
Past				
Past rainfall shock	0.203*		0.198*	
	(0.107)		(0.108)	
Positive past rainfall shock		0.276		0.360*
		(0.200)		(0.216)
Negative past rainfall shock		-0.183		-0.151
		(0.113)		(0.119)
Current				
Current rainfall shock	-0.166***	-0.167***		
	(0.059)	(0.059)		
Positive current rainfall shock			-0.036	0.042
			(0.178)	(0.205)
Negative current rainfall shock			0.175***	0.181***
			(0.062)	(0.062)
Controls				
Past temperature shock	0.523	0.697	0.558	0.972
	(0.893)	(1.010)	(0.892)	(1.059)
Current temperature shock	-1.013*	-1.084*	-1.066*	-1.259**
	(0.574)	(0.610)	(0.579)	(0.642)
Historical rainfall CV	0.043	-0.282	-1.091	-2.514
	(3.166)	(3.241)	(3.551)	(3.945)
Historical temperature CV	-172.489	-173.984	-176.635	-182.524
	(122.219)	(122.157)	(121.183)	(120.469)
Historical average rainfall (mm)	0.024	0.023	0.018	0.012
	(0.019)	(0.019)	(0.021)	(0.022)
Historical average temperature (°C)	-1.430	-1.461	-1.434	-1.505
	(1.219)	(1.203)	(1.189)	(1.132)
Year FE	Yes	Yes	Yes	Yes
HH FE	Yes	Yes	Yes	Yes
N	5508	5508	5508	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. Child characteristics (sex, age), mother characteristics (age and educational attainment) and household characteristics (household head's characteristics such as age and educational attainment, household size, market access, asset, livestock, farm size, irrigation, access to clean water, daily labor wage) are controlled but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

5.2. Labor reallocation

In this section, we examine household labor reallocation in response to rainfall shocks. Table 3 reports the results for labor change in response to prior and current rainfall shocks. In Columns (1), (2), (3), and (4), we use household-level labor time (average weekly hours) for each activity as outcome variables. Results indicate that as households have more rainfall during Rabi season in the previous year than historical average rainfall, they are more likely to decrease labor time for off-farm employment and on-farm self-employment. On average, a one standard deviation increase in previous rainfall is associated with about 15.5 hours decrease in off-farm employment labor time and 9.3 hours decrease in on-farm self-employment labor time. As for the current rainfall shocks, more rainfall leads to a decline in off-farm self-employment labor time. Specifically, on average, a one standard deviation increase in current rainfall is associated with about 12.7 hours decrease in off-farm self-employment labor time.

To sum, a household tends to decrease working time for its off-farm employment and on-farm self-employment in response to adequate rainfall during Rabi season in the previous year. Furthermore, a household tends to decrease working time for its off-farm self-employment in response to adequate rainfall during Rabi season in the current year. We assume that the reactions against the past rainfall shocks result from total agricultural yields in the previous year and the reactions against the current rainfall shocks are based on the expectation of agricultural yields at the end of current cropping season.

In Columns (5), (6), (7), and (8), we focus on maternal labor time, instead of household-level. On the one hand, one standard deviation increase in previous rainfall is associated with 5.7 hours decrease in off-farm employment labor time and 2.7 hours decrease in on-farm self-employment labor time, which are consistent with the result of household-level labor time. On the other hand, contrary to the results of household-level labor time, only maternal off-farm employment labor time is significantly associated with current rainfall shock in Column (6). It indicates that one standard deviation increase in current rainfall is also associated with 4.9 hours decrease in off-farm employment labor time. Moreover, one standard deviation decrease in current rainfall is associated with 2.1 hours increase in off-farm employment labor time.

In addition to Table 3 we also analyze labor change of household members except mothers in response to recent rainfall shocks (Table A12 in the appendix). We find the different patterns of labor changes, depending on the form of labor. First, as for off-farm self-employment, labor time changes at household-level are likely to be driven mainly by household members except mothers. That is, in response to positive past rainfall shock, mothers do not change their labor time for off- farm self-employment while other members decrease their labor time for off-farm self-employment. In addition, in response to positive current rainfall shock, also only household members except mothers significantly decrease their labor time. Second, as for off-farm employment and on-farm self-employment, labor time changes at household-level are likely to be driven mainly by mothers since labor time of other household members does not significantly change in response to any rainfall shocks. Lastly, as for on-farm employment, no household members are likely to change their labor time in response to any rainfall shocks.

Table 3: Labor change in response to prior and current rainfall shocks

	(1) HH Off, Self-emp.	(2) HH Off, Emp.	(3) HH On, Self-emp.	(4) HH On, Emp.	(5) Mother Off, Self-emp.	(6) Mother Off, Emp.	(7) Mother On, Self-emp.	(8) Mother On, Emp.
Past								
Positive past rainfall shock	-9.715	-15.469**	-9.261*	1.015	3.950	-5.729**	-2.704**	-0.126
	(7.339)	(6.741)	(5.092)	(2.638)	(2.429)	(2.444)	(1.172)	(0.601)
Negative past rainfall shock	0.401	-2.283	-0.923	0.067	0.446	0.875	-0.087	-0.032
	(4.327)	(3.954)	(3.368)	(1.231)	(1.068)	(1.396)	(0.264)	(0.381)
Current								
Positive current rainfall shock	-12.698*	-9.091	0.911	3.609	-1.328	-4.934**	-1.508	0.666
	(7.330)	(5.531)	(5.022)	(2.822)	(2.614)	(2.052)	(0.982)	(0.611)
Negative current rainfall shock	1.976	2.448	0.462	-0.792	0.625	2.125***	0.210	0.016
	(2.081)	(1.565)	(1.829)	(0.753)	(0.527)	(0.541)	(0.222)	(0.118)
Controls								
Daily wage: Off farm, Emp.	-0.039***	0.096***	-0.011**	-0.003	-0.001	0.001	0.000	0.000
	(0.007)	(0.006)	(0.005)	(0.002)	(0.001)	(0.002)	(0.001)	(0.000)
Daily wage: On farm, Emp.	-0.040***	-0.017***	-0.018***	0.101***	0.000	-0.003*	-0.000	0.004***
	(0.006)	(0.004)	(0.005)	(0.005)	(0.002)	(0.002)	(0.001)	(0.001)
Past temperature shock	54.784	8.171	-23.351	-9.402	-4.521	11.618	-7.015	5.076
	(39.296)	(36.921)	(28.073)	(11.849)	(11.910)	(11.592)	(5.379)	(3.173)
Current temperature shock	-23.127	18.141	21.742	0.678	0.381	-0.810	6.199*	-1.902
	(23.625)	(20.747)	(16.191)	(8.658)	(7.522)	(6.917)	(3.510)	(1.654)
N	5508	5508	5508	5508	5507	5507	5507	5507

Notes: The unit of outcome is hours per week. Column (1) to (4) employ labor hours at household level, and column (5) to (8) employ labor hours of mother (individual level) as outcome variables. Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Table 4: Mitigating impacts of maternal labor time

	(1) Off, Self-emp.	(2) Off, Emp.	(3) On, Self-emp.	(4) On, Emp.
Maternal Labor hours	-0.018***	0.001	0.063***	0.079***
	(0.006)	(0.006)	(0.016)	(0.019)
Positive past × Labor	0.018	0.059	0.003	
	(0.019)	(0.045)	(0.063)	
Negative past × Labor	0.012**	-0.004	-0.035*	-0.039*
	(0.005)	(0.006)	(0.021)	(0.018)
Positive current × Labor	-0.010	0.003	-0.050	-0.085**
	(0.017)	(0.013)	(0.035)	(0.043)
Negative current × Labor	-0.000	0.005	-0.025*	-0.015
	(0.004)	(0.004)	(0.015)	(0.016)
Past				
Positive rainfall shock	0.280	0.291	0.365	0.372*
	(0.258)	(0.228)	(0.225)	(0.217)
Negative rainfall shock	-0.216*	-0.134	-0.147	-0.135
	(0.125)	(0.121)	(0.119)	(0.117)
Current				
Positive rainfall shock	0.080	0.075	0.079	0.080
	(0.230)	(0.220)	(0.208)	(0.203)
Negative rainfall shock	0.180***	0.153**	0.192***	0.185***
	(0.064)	(0.063)	(0.062)	(0.062)
N	5507	5507	5507	5507

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The coefficient of Line 2 in Column (4) is dropped in household fixed effect model. CRE model shows that the coefficient is insignificant.

5.3. Labor mitigating impacts

Then, we investigate how working time changes in each labor are associated with the effects of rainfall shocks on child nutritional status, that is positive impact of larger past rainfall and positive impact of smaller current rainfall on WAZ score. Since mothers are the primary person to take care of their children (Shroff et al., 2009), their labor time should most strongly influence child nutritional status. We confirm it with our dataset by analyzing mitigating impacts of labor time at household-level as well as labor time of household members except mothers (Table A13 and A14 in the appendix). The results show that both household-level labor time and except mother's labor time do not have the important impacts on the association between rainfall shocks and child nutritional status in terms of the size of coefficient and statistically significant level. Thus, in the present section, we only report the result of mother's labor time.

Table 4 presents the results for mitigating impacts of maternal labor time. First, we focus on the direct effect of labor time on child nutritional status. While off-farm self-employment labor time is negatively and significantly associated with WAZ score in Column (1), on-farm employment and self-employment are positively and significantly associated with WAZ score in Columns (3) and

(4). We address this opposite association of labor time itself on WAZ score between off-farm and farm labor in Section 6.

Second, we focus on interaction terms between rainfall shocks and each labor time to capture mitigating impacts of labor. On the one hand, the coefficient of interaction term between negative past rainfall and off-farm self-employed labor time is 0.012. This result implies that if maternal labor time of off-farm self-employment increases by one hour per week, the negative association between less rainfall in the previous year and WAZ score (food consumption path) is mitigated by 0.012 standard deviations.

On the other hand, on-farm labor has different impacts on the relationship between rainfall shocks and child nutritional status. The coefficient of interaction term between negative past rain- fall and on-farm labor time (both self-employment and employment) is significantly negative. This means that as a mother works longer in on-farm labor, the negative effect of inadequate past rain- fall on WAZ score is worsened (food consumption path). Moreover, the coefficient of interaction term between positive current rainfall and on-farm employment time is significantly negative. It means that the more a mother involves in on-farm employment, the worse the negative association between more current rainfall and WAZ score is (disease path). Furthermore, the coefficient of interaction term between negative current rainfall and on-farm self-employment time is also significantly negative. It means that the more a mother involves in on-farm self-employment, the worse WAZ score is despite that less current rainfall is likely to improve child nutritional status. Overall, while on-farm labor time itself is positively and significantly associated with WAZ score, it may worsen the negative effect of rainfall shocks on child nutritional status.

5.4. Heterogeneous impacts among child gender

We investigated how each form of labor mitigates the impacts of rainfall shocks on WAZ score, however the mitigating impacts may differ among child gender. As explained in Section 2, child characteristics, such as gender and age, are likely to influence intra-household resource allocation, which results in different health outcome. In this section, focusing on gender aspect, we analyze heterogeneous impacts of labor between boys and girls. Table 5 shows different heterogeneities depending on the form of labor.

Off-farm self-employment significantly decreases WAZ score of only girls. This implies the possibility that when a mother has less time to take care of her children due to time constraints through off-farm work, girls are more likely to get damaged by a decrease in childcare time than boys. In other words, when a mother does not have enough time for childcare practices, she may prioritize boys to spend her time. Whereas, the impacts of on-farm self-employment and on-farm employment are significant only for boys and girls, respectively. In addition, the direct effect of on-farm self-employment also shows this trend. That is, longer working time of on-farm self-employment is significantly associated with better nutritional status of boys, but not girls. Our empirical results about gender heterogeneity suggest the potential gender discrimination of child health.

Table 5: Mitigating impacts of mother's labor time

	(1) Boys Off, Self-emp.	(2) Girls Off, Self-emp.	(3) Boys Off, Emp.	(4) Girls Off, Emp.	(5) Boys On, Self-emp.	(6) Girls On, Self-emp.	(7) Boys On, Emp.	(8) Girls On, Emp.
Mother Labor hours: Self	-0.015	-0.019**	0.014	0.001	0.062*	0.038	0.015	0.156*
	(0.011)	(0.008)	(0.013)	(0.007)	(0.029)	(0.030)	(0.093)	(0.092)
Positive past × Labor	0.026	0.023	0.036	0.156*	[1]	-0.088	[2]	[3]
	(0.023)	(0.041)	(0.107)	(0.085)		(0.082)		
Negative past × Labor	0.013	0.012	-0.012	-0.007	-0.035	-0.036	0.007	-0.093**
	(0.010)	(0.008)	(0.011)	(0.008)	(0.025)	(0.041)	(0.093)	(0.045)
Positive current × Labor	0.006	-0.061*	-0.012	0.022	-1.426***	0.006	-0.060	-0.203***
	(0.025)	(0.035)	(0.040)	(0.018)	(0.307)	(0.113)	(0.060)	(0.057)
Negative current × Labor	-0.005	0.003	0.002	0.006	-0.008	0.016	[4]	-0.059
	(0.006)	(0.005)	(0.008)	(0.005)	(0.013)	(0.053)		(0.085)
N	2815	2692	2815	2692	2815	2692	2815	2692

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. [1,2,3,4]Those coefficients are dropped in household fixed effect model. In CRE model, the coefficient for [1], [2], [3], and [4] are positive and significant at 1% level, positive and significant at 10 % level, negative and significant at 1% level, and negative and significant at 1% level, respectively.

6. Discussion

6.1. Potential paths linking rainfall to child nutritional status

As explained in Section 5, rainfall shocks both in the previous year and in the survey year are associated with WAZ score for children in opposite directions. This is due to the different paths through which each rainfall shock influences child health. First, positive association between past rainfall and WAZ score can be explained by changes in agricultural yields. According to the literature, while adequate rainfall often enhances agricultural yields, shortage of rainfall is likely to result in decline of yields for rural farmers who cannot manage the irrigation cost (Adeleke and Babalola, 2020). Empirically, we confirm that less rainfall in the previous year (i.e., negative past rainfall shock) is significantly associated with lower agricultural harvest (Table A9 in the appendix). In rural areas in developing countries, a large part of agricultural products is consumed by the households. There- fore, lower agricultural yields are directly translated to smaller amount of food consumption, which leads to worse child nutritional status. Considering that the surveys were conducted during main cropping season in each year, nutritional status at the survey timing is influenced by household agricultural yields before the survey, which are determined by rainfall in the year prior to the survey (i.e., past rainfall shock). In summary, our result of positive association between past rainfall and WAZ score results from an increase in food consumption caused by higher agricultural yields in the previous year due to more rainfall.

Second, negative association between current rainfall and WAZ score can be explained by disease prevalence path. It is well documented that excessive rainfall increases the prevalence of diseases like diarrhea, which prevents essential nutrients from being absorbed and causes a huge impact on child health status (Omiat and Shively, 2020; Le and Nguyen, 2021; Levy et al., 2016; Rabassa et al., 2014). One important note is that this disease prevalence path depends on the access to clean water. It might be the case that children without the access to clean water not only get more strongly influenced by rainfall shock but also originally have lower health status than those with the access to clean water. Therefore, we control for the access to piped drinking water and sanitary toilets in our estimations. We confirm that smaller current rainfall (i.e., negative current rainfall shock) is negatively and significantly associated with the prevalence of diarrhea (Table A10 in the appendix). Although current rainfall affects agricultural production in the survey year, harvest timing is in the end of cropping season. Thus, current rainfall cannot affect nutritional status through agricultural yields. To sum up, our result of negative association between current rainfall and WAZ score (or positive association between negative current rainfall shock and WAZ score) is likely to result from a decrease in the prevalence of disease due to lower current rainfall.

6.2. Labor reallocation

We identify how a household changes labor portfolio in response to previous and current rainfall. As for the past rainfall shock, larger rainfall than historical average amount leads to decline in off-farm employment and on-farm self-employment, at both household level and mother level. We interpret these responses as a result of larger agricultural yields in the previous year due to adequate previous year rainfall. As we confirmed, more previous rainfall is associated with higher agricultural yields in the last 12 months. First, the additional agricultural yields are likely to enhance household food consumption after harvest season in the previous year until harvest season in the current year. Therefore, a household may feel less need for agricultural production to feed household members as well as income to purchase food, which results in shorter labor time in both off-farm employment and on-farm self-employment. Although we cannot observe this mechanism directly, we confirmed that more rainfall in the previous year is associated with higher household dietary diversity score, which is calculated based on the last 7 days food consumption information (Column (1) in Table A11 in the appendix). Furthermore, the larger agricultural yields are also likely to enhance household income through the sales of their products. We confirm positive association between more current rainfall and current income from on-farm activities (Column (2) in Table

A11 in the appendix).As for the current rainfall shocks, more rainfall than historical average rainfall tends to decrease labor time in off-farm activities while less rainfall than historical average rainfall tends to increase labor time in off-farm employment labor. The findings show consistent pattern of a household strategy with previous literature (Branco and Féres, 2021; Ito and Kurosaki, 2009). We interpret these responses as a result of expectation of agricultural yields at the end of the season. As we confirm with our dataset, more rainfall is likely to enhance agricultural yields. Moreover, Ito and Kurosaki (2009) show that farmers faced with more production risk in their farm production engage in non- agricultural work more. Thus, if households observe less rainfall during cropping season, they are likely to put less efforts to on-farm labor by expecting that they would get lower agricultural yields, whereas they increase off-farm labor.

It is important to mention that flexibility of labor changes differs among the form of labor as well as household members. As for off-farm self-employment, only household members except mothers change their working time in response to rainfall shocks. Whereas, as for off-farm employment and on-farm self-employment, only mothers change their working time. Besides, as for on-farm employment, no one changes the working time in response to rainfall shocks. Especially focusing on maternal labor, mothers flexibly react to rainfall shock by changing their working time of off-farm employment. This implies that off-farm employment is the most flexible labor form to react to rainfall shocks for mothers. Conversely, to cope with rainfall shock, mothers may need supports to change other forms of labor.

6.3. Labor mitigating impacts

Now, we investigate how each form of mother's labor mitigates the impacts of rainfall shocks on child nutritional status. First, we find opposite effects of labor time itself on WAZ score between on-farm and off-farm labor. That is, while longer working time of farm activities leads to higher WAZ score, longer working time of off-farm activities leads to lower WAZ score. This result is likely to be caused by difference in working places. Since people engaging in farm labor in developing countries mainly work on their own family farm or the places where are close to their home, farm labor may be easier to balance work and childcare practices compared to off-farm labor whose working places tend to be away from the home (Debela et al., 2021). Thus, if mothers work longer for farm labor, they can more easily have time to spend with their children. On the other hand, if mothers work longer for off-farm labor, it is more difficult to use time for childcare practices. Moreover, when mothers have less time for domestic works, they first tend to decrease cooking time, which leads to less dietary diversity (Komatsu et al., 2018). Although such time constraints may be offset by other household members' help (Johnston et al., 2018), we find that results do not change when we control for household working capacity (number of working age household members) as shown in Table A18 in the appendix. Therefore, we conclude that such time constraints of mothers would result in lower child health status.

Then, we also find the differences among each labor in the impacts on the relationship between rainfall shocks and WAZ score. As for off-farm labor, we find that longer working time is likely to mitigate negative association between past rainfall shock and WAZ score. Potential mechanism is that longer working hours is likely to be associated with higher income from off-farm activities, which results in better household food security, therefore better nutritional status. This result is consistent with previous literature finding positive effect of off-farm income on food security (e.g., Dzanku, 2019; Gao and Mills, 2018).

Contrary to these results, as for on-farm labor, we find that longer working time may worsen negative effects of both past rainfall and current rainfall shocks on WAZ score. First, negative coefficients of interaction terms between farm activities and negative past rainfall shock suggest that when rainfall is not adequate for agricultural production in the previous year, an increase in maternal on-farm labor time may harm their child nutritional status. This is because that if a household does not have enough food due to less harvests, they need to purchase foods. However, longer working time in farm labor leads to shorter working time in off-farm labor, which is likely to decrease household income. Thus, labor should be switched to off-farm labor. Second, negative coefficients of interaction terms between on-farm activities and positive current rainfall shock suggest that when there is higher probability of disease prevalence due to larger rainfall, an increase in ma- ternal on-farm labor time may harm their child nutritional status. Once children get disease, parents need to take care of children in person while purchase appropriate medical goods to support their recover. If mothers work longer in on-farm, they are more likely to spend their time for childcare. However, longer working time in on-farm labor leads to shorter working time in off-farm labor, which increases the probability that mothers cannot afford to expend enough healthcare. Thus, this result implies that the negative impact of increasing on-farm labor exceeds the positive impact of increasing on-farm labor.

To sum up, regarding maternal labor time, our findings suggest that while longer working time of on-farm labor itself has positive impact on child nutritional status, on-farm labor does not play a role in coping with rainfall shocks and mothers should switch their labor into off-farm labor. Considering that longer working time in off-farm labor itself is negatively associated with child nutritional status due to time constraints, it is crucial to provide mothers with sufficient off-farm opportunities as well as childcare supports during their work as ex post strategy after rainfall shock. Besides, we conducted the same analysis with household-level labor time as well as labor time of household members except mothers. Results show that working time for all forms of labor and their interaction terms with rainfall shocks are insignificantly associated with WAZ score when we con- sider both statistic and economic significances. This implies that in the context of child nutritional status, how mothers allocate labor is more important than household-level labor allocation.

6.4. Survey timing and seasonality

The main reason why we focus on rainfall during Rabi season is because survey was mainly con- ducted during Rabi season and recall periods of much information in our dataset are included in Rabi season. Although specific survey timing (e.g., survey month) may be correlated to our results, we do not find complete information about survey timing. Thus, we could not control for it, which is our limitation.

In Bangladesh, there is another cropping season called Kharif 1, which is from March to June. Using Equation 11, we investigate the impacts of rainfall shock during Kharif season in the survey year as well as the year prior to the survey. We find that past Kharif rainfall shock has a similar trend with past Rabi rainfall shock. That is, more rainfall in the previous year than the historical average rainfall significantly increases WAZ score at 1% level (Column (1) in Table A4). Whereas, the result show that current rainfall shocks during Kharif season are not significantly associated with WAZ score. This is probably due to time lag between Kharif season and the survey date. Since diarrhea prevalence is sensitive to current rainfall, the rainfall in Kharif season would not change the prevalence of diarrhea during the survey (Column (4) in TableA4), leading to insignificant impacts of rainfall shocks during Kharif season on child nutritional status.

6.5. Robustness check

To confirm the robustness of our findings, we conduct additional analysis. First, we analyze the as- sociation between rainfall shocks and WAZ score by using five different methods: pooled OLS model with covariates, pooled OLS model with household fixed effect, household fixed effect model without singleton observations, individual fixed effect model, and correlated random effect (CRE) model. By this, we confirm the robustness of our empirical strategy. Second, we employ an alternative definition of rainfall shocks and reanalyze the impacts of rainfall to check the possibility of measurement error. We define a dummy variable, which equals one if survey year rainfall is larger than historical average rainfall. Besides, we define flood and drought variables to capture the extreme rainfall shocks. Third, to overcome our limitation of unavailable survey date information, we only focus on first months of Rabi season and compare the rainfall impacts with impacts of whole Rabi season rainfall. Then, instead of labor reallocation, we investigate other coping strategy such as total labor time change, migration, and livestock sale after rainfall shocks. Lastly, we study the impacts of rainfall shocks on child malnutrition captured by other measures like underweight, wasting, and stunting. This analysis provides us further information about child malnutrition problem in Bangladesh. More detailed descriptions of each analysis and result are summarized in Section A.1 in the appendix.

7. Conclusion

The undernutrition of children remains a critical challenge in rural areas of developing countries. Rural households need to properly allocate their labor into farm and off-farm activities to achieve household food security under weather shocks. Identifying how each form of labor mitigates the effect of weather shock on child nutritional status would help farmers to choose suitable labor al- location to cope with weather shocks.

Using the data from three waves panel survey in Bangladesh, we investigate impacts of each form of labor on the association between rainfall shocks and child nutritional status. First, our findings show that child nutritional status is improved by more rainfall in the previous year through better agricultural yields as well as less rainfall in the survey year through lower prevalence of dis- ease. Moreover, we find significant mitigating impacts of maternal off-farm self-employment. That is, longer working time of maternal off-farm self-employed labor mitigates negative association between rainfall shortage in the previous year and WAZ score. However, an increase in maternal on-farm labor supply may worsen negative effect of inadequate past rainfall on WAZ score. It im- plies that on-farm labor does not play a role in coping with rainfall shocks, thus mothers should switch their labor into off-farm labor under the situation of rainfall shortage in the previous year. Furthermore, we show that maternal labor has significant impacts in the case of extreme rainfall shocks (i.e., flood and drought).

Whereas, it is also important to consider the direct impact of labor time itself on child health. Our empirical results find that while longer maternal off-farm labor time is negatively associated with WAZ score, longer maternal on-farm labor time significantly improves WAZ score, probably due to the difference in working places. Since people engaging in farm labor in developing countries mainly work on their own family farm or the places where are relatively close to their home, on-farm labor may be easier to balance work and childcare practices (Debela et al., 2021). Lastly, we find heterogeneous labor mitigating impacts among household members. Contrary to maternal labor, we do not find any significant mitigating impacts of household-level labor or labor of house- hold members except mothers. Therefore, we conclude that in the context of child health, maternal labor allocation plays an important role in coping with rainfall shocks.

The present paper contributes to the literature by showing the different impacts of different form of labor under the same conditions. Considering the possibility of further increasing extreme weather in near future, it is even more important for households to adapt to rainfall fluctuation through labor reallocation. Our findings can navigate rural households to make their labor decision after experiencing rainfall shocks. Furthermore, by comparing the impacts of labor at different units (i.e., household-level, a mother, and other household members), we provide insights about whose labor time is important in the context of child health, which had not been well studied to our knowledge. However, we admit that there is still a potential endogeneity problem caused by simultaneous decision making of labor time despite various robustness checks. Our future work will address it by employing different econometric models such as seemingly unrelated regression.

Bangladesh still suffers from the problem of child undernutrition, despite the substantial efforts to improve food and nutrient in the last decades. Specific projects, such as social safety net or money transfer, are of course effective methods for rural households to cope with income shocks, but the recipients of those projects are limited (Branco and Féres, 2021). However, labor reallocation corresponding to shocks can be adapted by any households. Therefore, our results of off-far self-employment labor mitigating impact implicate the importance of policy which provides off- farm labor opportunities to mothers in rural settings to cope with rainfall shocks. A variety of off-farm labor opportunities allows mothers to choose more suitable job depending on their situations, which would lead to a higher rate of working mothers with children away from their home. Besides, such a policy should consider maternal time constraints at the same time. Supporting mothers who engage in both childcare and working is another crucial role of those policies. Possible ways are an introduction of childcare spaces at a working place, adoption of kinder gardens at rural areas, and implementation of babysitter services.

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A Appendix

A.1 Robustness check

A.1.1 Analysis with different estimation strategies

First, we analyze the association between rainfall shocks and WAZ score by using five different methods. That is, pooled OLS model with covariates, pooled OLS model with household fixed effect, household fixed effect model without singleton observations, individual fixed effect model, and correlated random effect (CRE) model. Table A1 shows the results. Overall, we find positive association between past rainfall and WAZ score as well as negative association of current rainfall and WAZ score. By this, we confirm the robustness of our results regarding to the impact of rainfall shocks on child nutritional status.

Table A1: The effect of rainfall shock on WAZ score: Different methods

	(1)	(2)	(3)	(4)	(5)
Past					
Positive past rainfall shock	0.072	0.360	0.360*	0.098	0.057
	(0.132)	(0.337)	(0.217)	(0.125)	(0.122)
Negative past rainfall shock	-0.135***	-0.151	-0.151	-0.099**	-0.130***
	(0.050)	(0.185)	(0.119)	(0.048)	(0.047)
Current					
Positive current rainfall shock	0.060	0.042	0.042	0.056	-0.016
	(0.108)	(0.319)	(0.205)	(0.103)	(0.100)
Negative current rainfall shock	0.090**	0.181*	0.181***	0.090**	0.090**
	(0.046)	(0.096)	(0.062)	(0.043)	(0.043)
Model	Pooled OLS	Pooled OLS	Fixed effect	Fixed effect	CRE
HH FE	No	Yes	Yes	No	No
Child FE	No	No	No	Yes	No
N	5508	5508	3753	5508	5508

Notes: Robust standard errors clustered by household in parentheses. Child characteristics (sex, age), mother characteristics (age, educational attainment, occupation) and household characteristics (household head's characteristics such as age, educational attainment, and occupation, household size, market access, asset, livestock, farm size, irrigation) are controlled in all regressions but not reported. In column (3), we exclede observations which show up only one round. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

A.1.2 Alternative measurements of rainfall shocks

Next, we use an alternative definition of rainfall shocks and analyze the association between rainfall shocks and WAZ score as well as labor reallocation in response to rainfall shocks. To differentiate positive and negative values in rainfall shock, we define the dummy variable as follows:

$$PositiveRainDummy_{ht} = 1 \text{ if } rain_{ht} > \overline{rain}_h, \text{ and } 0 \text{ if } rain_{ht} < \overline{rain}_h$$

By doing so, we can specify whether household *h* gets more rainfall than historical average in year *t* or less. Here, we do not create negative rainfall dummy since negative rainfall shock is fully captured as 0 in positive rainfall dummy. In addition, to capture extreme rainfall shocks, we define flood and drought variables as follows:

$$Flood_{ht} = 1 \text{ if } Rainshock_{ht} > 1, \text{ and 0 otherwise}$$

$$Drought_{ht} = 1 \text{ if } Rainshock_{ht} < -1, \text{ and 0 otherwise}$$

Since the extreme rainfall is likely to cause more severe impacts on both agricultural yields and disease prevalence, the analysis with flood and drought variables would show additional evidence about mechanisms for labor mitigating impacts. We employ both fixed effect and CRE models for this analysis.

Column (1) and (2) in Table A2 summarize the impacts of rainfall shocks on WAZ score. Column (1) shows that the sings for the coefficients of the associations between rainfall shocks and WAZ score are the same with Table 2, but the results are only significant for current rainfall shock (Line 4 in Panel A). The reason of this insignificant result for past rainfall shock is probably due to dummy variable which cannot capture the variations in rainfall. Column (2) shows the result for the impacts of rainfall shocks measured by flood and drought variables on WAZ score. As for past rainfall shock, we get consistent results with Table 2, but the results are not significant in fixed effect model. The interpretation of the results is that when households experience drought during Rabi season in the previous year, WAZ score of children from those households tends to decrease. This makes sense since drought is likely to damage agricultural yields. As for current rainfall shock, we find both flood and drought are positively associated with WAZ score in fixed effect model. Positive relationship between current drought and WAZ score is a consistent result with Table 2, which is explained by disease prevalence path. However, positive relationship between present flood and WAZ score is inconsistent with the previous literature. Possible explanation of this result is that there are quite few households experiencing flood at the survey year ($CurrentFlood_{ht} = 1$). In this case, the coefficient is very sensitive to values of small number of observations which take one. In future work, we will study the mechanisms under which flood influences child nutritional status.

Column (3) - (6) present labor reallocation in response to rainfall shocks measured by positive rainfall dummy. As households have more rainfall during Rabi season in the previous year than historical average rainfall, mothers from those households tend to significantly increase off-farm self-employment while de- crease off-farm employment and on-farm self-employment. The results are consistent with Table 3, although off-farm self-employment increase is not significant in Table 3. Whereas, as for the current rainfall shocks, we do not find significant decrease in off-farm employment in response to more current rainfall. [16] As ex- plained before, this insignificant result may be driven by that a dummy variable cannot capture the variations in rainfall.

Columns (7) - (10) show maternal labor reallocation in response to rainfall shocks measured by flood and drought variables. If households face with flood in the previous year, mothers tend to decrease on-farm self-employment, which is consistent with Table 3. However, contrary to the previous result, we do not find significant changes in off-farm activities in fixed effect model. As for the current flood and drought incidences, we find consistent off-farm labor reactions. That is, if households face with flood in the current year, mothers tend to decrease their off-farm labor, while if households face with drought in the current year, mothers tend to increase their off-farm labor. It implies that generally high rainfall can be an incentive to increase on-farm labor based on higher yields expectation while decrease off-farm labor due to time constraint, whereas low rainfall can threaten their agricultural production, therefore encourage them to switch to off-farm labor. However, we also find that mothers decrease their on-farm self-employment in response to current flood. To understand this result, we analyze household-level and household members except mothers' labor reallocation in response to flood and drought. Results are presented in Table A15. We find that as for off-farm labor, household members except mothers do not change their labor in response to flood and drought, however, as for on-farm labor, they increase on-farm self-employment in response to current flood. To summarize, our findings imply that a household tries to cope with a flood by increasing off-farm labor of mothers while increasing on-farm labor of other household members.

[16]Only off-farm employment significantly changes in response to current rainfall shock in Table 3

Table A2: Child nutrition and maternal labor change in response to prior and current rainfall shocks: Different definitions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
A. Model: FE	WAZ	WAZ	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Past										
Positive past rain dummy	0.248		2.792*	-3.123*	-1.652**	-0.699				
	(0.170)		(1.675)	(1.645)	(0.786)	(0.671)				
Past Flood		0.213					2.647	-2.775	-3.579***	0.441
		(0.229)					(3.134)	(3.189)	(1.289)	(0.484)
Past Drought		-0.052					0.047	-0.261	0.016	0.037
		(0.059)					(0.718)	(0.551)	(0.211)	(0.121)
Current										
Positive current rain dummy	-0.160*		0.584	-1.283	-0.082	-0.028				
	(0.091)		(1.150)	(0.906)	(0.314)	(0.184)				
Current Flood		0.497**					-3.321*	-0.316	-1.113**	0.714
		(0.252)					(1.986)	(2.112)	(0.505)	(0.854)
Current Drought		0.102*					1.229*	1.886***	0.001	-0.113
		(0.059)					(0.693)	(0.535)	(0.236)	(0.136)
B. Model: CRE	WAZ	WAZ	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Past										
Positive past rain dummy	0.160		0.511	-2.138***	-0.778**	0.308				
	(0.104)		(1.316)	(0.704)	(0.310)	(0.387)				
Past Flood		0.084					-0.000	-1.612*	-1.307***	1.528*
		(0.164)					(2.493)	(0.891)	(0.408)	(0.863)
Past Drought		-0.103***					-0.083	-0.280	0.174	0.021
		(0.033)					(0.529)	(0.325)	(0.116)	(0.077)
Current										
Positive current rain dummy	-0.070		-0.421	0.068	0.026	0.110				
	(0.049)		(0.662)	(0.525)	(0.130)	(0.115)				
Current Flood		0.250					-3.742**	2.273	-0.371**	0.457
		(0.173)					(1.507)	(2.232)	(0.177)	(0.601)
Current Drought		0.015					0.008	1.208***	0.022	-0.167
		(0.039)					(0.564)	(0.307)	(0.116)	(0.108)
N	5508	5508	5507	5507	5507	5507	5507	5507	5507	5507

Notes: The unit of outcome is waz score and maternal working hours per week for each labor. Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Then, we check the robustness of results for labor mitigating impacts. Panel A shows results with positive rainfall dummy. As for labor direct impacts, while longer working time of off-farm self-employment leads to lower WAZ score, longer working time of on-farm employment leads to higher WAZ score, which are consistent with Table 4. As for labor mitigating impacts, we do not find significant impact of off-farm self-employment in Column (1). However, we find negative significant impact of on-farm employment on the association between positive current dummy and WAZ score in Column (4), which is consistent with Table 4. Moreover, we find negative significant impact of off-farm employment on the association between positive current dummy and WAZ score in Column (2). Although we do not find the mitigating impact of off-farm self-employment, this is likely to be because the problem of the positive rainfall dummy variable. This dummy cannot capture any differences in the scale of rainfall that each household receives.

Whereas, Panel B shows results with flood and drought variables. As for labor direct impacts, while longer working time of off-farm labor leads to lower WAZ score, longer working time of on-farm labor leads to higher WAZ score, which are consistent with Table 4. Thereby, we confirm the quite robust result of negative direct off-farm impact and positive direct on-farm impact. As for labor mitigating impacts, we find that off-farm self-employment is likely to mitigate both past flood and drought impacts on child nutritional status. Besides, off-farm employment is likely to mitigate current drought impact on child nutritional status. Whereas, longer working time of on-farm self-employment in response to flood event in the previous year and drought event in the current year is likely to worsen child nutritional status. Lastly, longer working time of on-farm employment in response to drought event in the previous year and flood event in the current year is likely to worsen child nutritional status. In summary, our results indicate that while off-farm labor in response to extreme rainfall events is likely to mitigate the decline in child health, on-farm labor in response to extreme rainfall events may worsen child nutritional status. In other words, off-farm labor can be a household coping strategy against a rainfall shock even in the case of extreme rainfall.

A.1.3 Survey timing

Although survey was mainly conducted during Rabi season, the date of interview varies among households. Unfortunately, interview date information is not available, thus we cannot control for survey timing differences. In this section, we construct the rainfall shock variables for the first month of Rabi season (i.e., November) and the first and second months of Rabi season (i.e., November and December) to investigate our findings more. Table A4 summarizes the impacts of rainfall shocks on WAZ score (Column (2) and (3))

and diarrhea prevalence (Column (5) and (6)). In Column (2), both positive and negative November rainfall shocks are positively and significantly associated with WAZ score. Whereas, both positive and negative November - December rainfall shocks are not significantly associated with WAZ score in Column (3). This implies there is heterogeneous impacts of different timing of rainfall even within the same season. Further

Table A3: Mitigating impacts of maternal labor time: Different rainfall definitions

	(1)	(2)	(3)	(4)
Panel A: Dummy	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
HH Labor hours	-0.005**	0.003	-0.002	0.037**
	(0.002)	(0.002)	(0.009)	(0.017)
Positive past × Labor	-0.003	0.046	0.032	
	(0.021)	(0.040)	(0.047)	[1]
Positive current × Labor	-0.003	-0.010*	0.023	-0.045**
	(0.005)	(0.006)	(0.015)	(0.022)
Controls				
Positive past rain dummy	0.285	0.152	0.241	0.270
	(0.207)	(0.178)	(0.171)	(0.171)
Positive current rain dummy	-0.141	-0.101	-0.165*	-0.153*
	(0.098)	(0.095)	(0.091)	(0.091)
Panel B: Flood, Drought	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
HH Labor hours	-0.011***	-0.000	0.027***	0.052***
	(0.003)	(0.002)	(0.009)	(0.013)
Flood past × Labor	0.038***	0.058	-0.441***	[2]
	(0.011)	(0.054)	(0.073)	
Drought past × Labor	0.007*	-0.003	-0.015	-0.044**
	(0.004)	(0.004)	(0.011)	(0.015)
Flood current × Labor	-0.077	0.013	[3]	-0.152***
	(0.061)	(0.027)		(0.017)
Drought current × Labor	0.004	0.008*	-0.032***	-0.017
	(0.004)	(0.005)	(0.010)	(0.020)
Controls				
Past Flood	-0.108	0.107	0.298	0.226
	(0.273)	(0.243)	(0.240)	(0.229)
Past Drought	-0.089	-0.042	-0.044	-0.045
	(0.064)	(0.060)	(0.059)	(0.059)
Current Flood	0.777**	0.431	0.525**	0.627***
	(0.338)	(0.406)	(0.254)	(0.231)
Current Drought	0.081	0.068	0.103*	0.111*
	(0.065)	(0.060)	(0.060)	(0.059)
N	5507	5507	5507	5507

Notes: Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. [1], [2], [3]Those coefficients are dropped in household fixed effect model. In CRE model, the coefficient for [1] and [3] are both insignificant, and the coefficient for [2] is again dropped.

Table A4: The effect of rainfall shock: Different definitions

	(1)	(2)	(3)	(4)	(5)	(6)
Outcome	WAZ	WAZ	WAZ	Diarrhea	Diarrhea	Diarrhea
Past						
Positive Kharif rainfall shock	0.342***			-0.238		
	(0.131)			(0.276)		
Negative Kharif rainfall shock	0.044			0.168		
	(0.089)			(0.195)		
Positive rainfall shock		0.362*	0.219		-0.192	-0.391
		(0.202)	(0.208)		(0.536)	(0.537)
Negative rainfall shock		-0.206*	-0.192*		-0.146	-0.064
		(0.112)	(0.115)		(0.322)	(0.344)
Current						
Positive Kharif rainfall shock	0.119			-0.362		
	(0.214)			(0.416)		
Negative Kharif rainfall shock	0.133			-0.396		
	(0.133)			(0.304)		
Positive rainfall shock: Nov.		3.903**			2.979	
		(1.581)			(2.781)	
Negative rainfall shock: Nov.		0.392*			-0.331	
		(0.237)			(0.309)	
Positive rainfall shock: Nov.& Dec.			-1.010			[1]
			(1.152)			
Negative rainfall shock: Nov.& Dec.			0.055			-0.416
			(0.133)			(0.270)
N	5508	5508	5508	1396	1396	1396

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. [1]Most of the sample receive negative rainfall shock. Therefore, the coeeficient of this term is dropped. The coefficient is also dropped in CRE model.

investigations about the mechanism through which each timing of rainfall differently influences child health would be our future work. As for the impact on diarrhea prevalence, we do not find any significant impact of different timing of rainfall. The possible explanation of this result is that diarrhea prevalence is sensitive to current rainfall and November and December rainfall is not important for diarrhea prevalence of households that have interview after December.

A.1.4 Other coping strategy against rainfall shock

This paper focuses on household labor reallocation in response to rainfall shock as an ex-post strategy. However, there are other strategies that households can adapt after shocks. In this section, we analyze the adaptation of total labor time change, migration, and livestock sale after rainfall shocks and their mitigating impacts. Total labor time is measured as total working time of all types of labor activities for the past 7 days at both household-level and maternal level. Migration strategy is captured by a dummy variable which equals 1 if anyone of household members has been currently a migrant and 0 otherwise. [17] Livestock sale is measured as total value of selling livestock for the last 12 months (1000 Bangladesh Taka). First, we investigate household coping strategy changes in response to rainfall shocks. Then, we analyze mitigating impacts of each coping strategy. Results are summarized in Table A5 and A6, respectively.

Column (1) in Table A5 shows that at household-level total labor time significantly decreases in response to more rainfall than historical average rainfall in the previous year and also in response to more rainfall than historical average rainfall in the current year. Whereas, at maternal-level, total labor time significantly decreases in response to more rainfall than historical average rainfall in the survey year but significantly increases in response to less rainfall than historical average rainfall in the survey year (Column (2)). Those results correspond with labor allocation results in Table 3. [18] In other words, a household is likely to change total working time to change a specific form of labor time, instead of changing the allocation of working time to each form of labor. However, we also analyze mitigating impact of changing total labor time. Column

(1) and (2) in Table A6 indicate that total labor change at both household-level and maternal level does not

[17]This variable is constructed based on the question: Has anyone, who was a member of your household in the last baseline survey, currently a migrant (living away for 6 months or more) within the country (but not in same upazilla) or abroad?

[18]Household-level off-farm employment and on-farm self-employment decrease in response to positive past rainfall shock and household-level off-farm self-employment decreases in response to positive current rainfall shock. Maternal off-farm employment decreases in response to positive current rainfall shock while increase in response to negative current rainfall shock.

influence the associations between rainfall shocks and WAZ score. Therefore, we conclude that to mitigate the negative impacts of rainfall shocks on child nutritional status, the form of labor that a household change is important, but total labor time itself does not matter.

As for the analysis of migration and livestock sale, we only include past rainfall shocks since decisions for migration and livestock sale are already made before the main cropping season in the survey year. In Column (3) in Table A5 shows that households that receive more rainfall in the previous year are less likely to have a migrant. Since migration is one of the major coping strategies for farmers against negative shock on agricultural production, this result is consistent with those previous literature. If a household receives adequate rainfall, they are likely to have higher agricultural yields, thus they have less need to have a migrant to get an additional income. Whereas, Column (3) in Table A6 shows that migration does not have a role in improving child nutritional status under rainfall shocks. Rather, migration is even negatively associated with the impact of positive current rainfall shock on child nutritional status. One concern of migration analysis is sample selection bias. There are two types of migration. One is all household members move out from rural areas. In this case, such households drop from our sample and we cannot observe them in the following survey. However, as we confirm that the attrition is random, this would not be the problem. The other is some members migrate but the household stays in the same area. In this case, the capacity of household labor (e.g., number of workers) is changed, which can cause the self-selection of labor allocation. Although the remittance from a migrant can capture the labor capacity of the migrant and control for the migrant effect, the information about the remittance in our data has a lot of missing values. Thus, we cannot use it in our estimation. Alternatively, we consider the working capacity of each household: i.e., the number of working age (older than 12 years old) household members. We add it to the estimation as a control. Results are summarized in Table A17 and A18 in the appendix and we confirm that the results of labor reallocation and labor mitigating impacts do not change after controlling for the working capacity.

Table A5: Other coping strategies in response to prior and current rainfall shocks

	(1) Total HH labor	(2) Total maternal labor	(3) Migration	(4) Livestock sale
Past				
Positive past rainfall shock	-33.429***	-4.609	-0.168**	-25.409*
	(10.060)	(3.364)	(0.074)	(14.717)
Negative past rainfall shock	-2.738	1.202	-0.034	1.579
	(5.619)	(1.680)	(0.050)	(5.987)
Current				
Positive current rainfall shock	-17.269*	-7.105**		
	(9.022)	(3.338)		
Negative current rainfall shock	4.094	2.976***		
	(2.682)	(0.750)		
Controls				
Past temperature shock	30.202	5.159	-0.235	35.694
	(49.962)	(16.917)	(0.286)	(41.311)
Current temperature shock	17.435	3.869		
	(31.219)	(10.667)		
N	5508	5507	5286	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

In Column (4) in Table A5 shows that households that receive more rainfall in the previous year tend to decrease livestock sale. This result makes sense since if there are adequate rainfall, households have enough agricultural yields and they do not need to sell their livestock to buy additional foods. However, Column

(4) in Table A6 shows that livestock sale does not influence the associations between rainfall shocks and WAZ score. Therefore, we conclude that livestock sale cannot be a coping strategy against rainfall shocks in the context of child health. In conclusion, we confirm that as an ex-post coping strategy, maternal labor reallocation is more effective than other strategies to improve child health under rainfall shocks.

Table A6: Mitigating impacts of other coping strategies

Strategy	(1) Total HH labor	(2) Total maternal labor	(3) Migration	(4) Livestock sale
Strategy	-0.001	-0.003	0.038	0.000
	(0.001)	(0.005)	(0.177)	(0.001)
Positive past × Strategy	-0.006	0.004	0.039	0.012
	(0.006)	(0.017)	(1.720)	(0.017)
Negative past × Strategy	-0.000	0.000	-0.030	0.001
	(0.001)	(0.005)	(0.169)	(0.001)
Positive current × Strategy	0.000	-0.012	-0.683**	-0.001
	(0.004)	(0.010)	(0.282)	(0.002)
Negative current × Strategy	0.001	0.002	0.017	-0.000
	(0.001)	(0.003)	(0.117)	(0.000)
N	5508	5507	5286	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. ** denotes significance at 5%.

A.1.5 Alternative measurements of child nutritional status

In this section, we analyze the impacts of rainfall shocks on child malnutrition captured by other measure: underweight, weight for height z-score (WHZ), wasting, height for age z-score (HAZ), and stunting. [19] Those measurements were calculated based on the 2006 WHO growth standards. Underweight, wasting, and stunting are defined as dummy variables, which equal 1 if WAZ, WHZ, and HAZ scores are smaller than -2 standard deviations, respectively. Column (1) in Table A7 shows that larger past rainfall as well as smaller current rainfall significantly decrease the occurrence of underweight, which is consistent with WAZ score. In other words, recent rainfall shocks tend to influence not only the severity but also the occurrence of child underweight. On the other hand, while we do not find significant impacts of rainfall shocks on WHZ score (Columns (2)), we do find the evidence of the same patterns of rainfall impacts on child health measured by wasting dummy, HAZ score, and stunting dummy (Columns (3), (4) and (5)).

[19]Stunting captures chronic nutritional deficiency, while wasting is a acute nutritional deficiency measure. Underweight is a composite measure of both chronic and acute deficiencies. (Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al. 2018. Guide to DHS Statistics. Rockville, Maryland, USA: ICF.)

Table A7: The effect of rainfall shock on child malnutrition: Different measures

	(1) Underweight	(2) WHZ	(3) Wasted	(4) HAZ	(5) Stunted
Past					
Positive past rainfall shock	-0.207*	0.174	-0.076	0.425	-0.095
	(0.107)	(0.282)	(0.090)	(0.313)	(0.122)
Negative past rainfall shock	0.057	0.197	-0.080*	-0.556***	0.149**
	(0.059)	(0.155)	(0.048)	(0.179)	(0.061)
Current					
Positive current rainfall shock	-0.070	0.314	-0.120	-0.267	0.191*
	(0.106)	(0.276)	(0.086)	(0.302)	(0.102)
Negative current rainfall shock	-0.056*	0.037	-0.003	0.250***	-0.014
	(0.030)	(0.077)	(0.023)	(0.086)	(0.032)
N	5508	5488	5488	5495	5495

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Given our findings, we finally check labor mitigating impacts using underweight dummy, wasting dummy, and stunting dummy. Results are summarized in Table A8. We find consistent results of labor mitigating impacts for underweight. That is, while off-farm maternal labor can decrease the occurrence of undernutrition due to rainfall shocks although longer working time itself may increase the occurrence, on-farm maternal labor may accelerate the occurrence due to rainfall shocks despite the positive impact of on-farm working time itself. One exception is that longer working time of on-farm self-employment after more rainfall than historical average in the previous year is likely to have positive impact on child nutritional status. This result implies that on-farm self-employment would be associated with the negative impact of rainfall shock on child nutritional status, especially through disease path. As for wasting, we find similar trend of labor impacts on the association between past rainfall shocks and child nutritional status. As for stunting, we find similar trend of labor impacts only for off-farm labor and not for on-farm labor. The plausible explanation is that since our labor variables are based on the information about labor in the last seven days, the recall period of our labor variables is the last seven days, which are too short to influence

Table A8: Mitigating impacts of maternal labor time: other child health variables

Panel A Underweight	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Maternal Labor hours	0.006**	0.003	-0.015*	-0.006
	(0.003)	(0.002)	(0.009)	(0.012)
Positive past × Labor	-0.000	-0.044**	-0.046***	[1]
	(0.008)	(0.020)	(0.017)	
Negative past × Labor	-0.006**	-0.000	0.002	0.005
	(0.003)	(0.002)	(0.008)	(0.009)
Positive current × Labor	0.002	-0.005	0.029**	0.003
	(0.008)	(0.008)	(0.013)	(0.008)
Negative current × Labor	0.002	-0.003*	0.012*	-0.008
	(0.002)	(0.002)	(0.006)	(0.007)
N	5507	5507	5507	5507
Panel B **Wasting**	**Off, Self-emp.**	**Off, Emp.**	**On, Self-emp.**	**On, Emp.**
Maternal Labor hours	0.003	-0.003	-0.010	-0.020***
	(0.003)	(0.002)	(0.011)	(0.007)
Positive past × Labor	-0.007	-0.040**	0.016	[2]
	(0.009)	(0.019)	(0.013)	
Negative past × Labor	-0.004	0.002	0.003	0.011*
	(0.003)	(0.002)	(0.009)	(0.006)
Positive current × Labor	0.003	0.006	0.014	0.023
	(0.012)	(0.008)	(0.011)	(0.023)
Negative current × Labor	0.001	-0.001	0.003	0.002
	(0.002)	(0.001)	(0.004)	(0.006)
N	5494	5494	5494	5494
Panel C **Stunting**	**Off, Self-emp.**	**Off, Emp.**	**On, Self-emp.**	**On, Emp.**
Maternal Labor hours	0.006*	0.003	-0.002	0.007
	(0.004)	(0.003)	(0.012)	(0.012)
Positive past × Labor	-0.002	0.003	-0.037	[3]
	(0.009)	(0.023)	(0.038)	
Negative past × Labor	-0.007**	0.002	-0.001	-0.003
	(0.003)	(0.003)	(0.011)	(0.006)
Positive current × Labor	-0.005	-0.004	0.008	-0.008
	(0.007)	(0.007)	(0.014)	(0.019)
Negative current × Labor	0.005**	-0.003*	0.006	-0.003
	(0.002)	(0.002)	(0.006)	(0.013)
N	5494	5494	5494	5494

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. [1], [2], [3]Those coefficients are dropped in both fixed effect model and CRE model.

stunting occurrence.

Table A9: The effect of rainfall shock on agricultural harvest (kg)

	(1)	(2)	(3)	(4)	(5)
Past					
Positive past rainfall shock	582.490	604.434	580.860		
	(750.569)	(739.796)	(733.919)		
Negative past rainfall shock	-1.6e+03**	-1.6e+03**	-1.5e+03**		
	(786.853)	(787.537)	(771.140)		
Positive rain dummy				290.455	
				(640.698)	
Flood					497.440
					(944.923)
Drought					-707.841***
					(267.301)
Controls					
Past temperature shock	3046.158	3200.003	3238.544	6133.400	5001.883
	(4094.631)	(4239.844)	(4239.076)	(4117.274)	(4021.600)
HH controls	Yes	Yes	Yes	Yes	Yes
Mother controls	No	Yes	Yes	Yes	Yes
Child controls	No	No	Yes	Yes	Yes
N	5508	5508	5508	5508	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

A.2 Other supplementary tables

Table A10: The effect of weather shock on prevalence of diarrhea

	(1)	(2)	(3)
Past			
Past rainfall shock	-0.065		
	(0.272)		
Positive past rainfall shock		-0.010	
		(0.675)	
Negative past rainfall shock		0.077	
		(0.351)	
Positive rain dummy			
Flood			-0.479
			(0.642)
Drought			-0.227**
			(0.102)
Current			
Current rainfall shock	0.166**		
	(0.081)		
Positive current rainfall shock		0.533	
		(2.499)	
Negative current rainfall shock		-0.159*	
		(0.083)	
Positive rain dummy			
Flood[1]			
Drought			-0.123
			(0.076)
Controls			
Past temperature shock	-2.359	-2.328	-2.633*
	(1.586)	(1.620)	(1.515)
Current temperature shock	1.486	1.392	2.620***
	(0.979)	(1.070)	(0.874)
N	1396	1396	1396

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. Sample is restlicted to children under 24 months. [1]The coefficient of current flood dummy is missing in fixed effect model because only a quite few households experience flood during Rabi season in the survey year and most of the values takes 0. Even when using CRE model, this term is dropped. Thus, we cannot specify the impact of current flood on the prevalence of diarrhea in our setting.

Table A11: The effect of rainfall shock on household dietary diversity score and farm income

	(1)	(2)
Outcome	HDDS	Farm income
Past		
Positive rainfall shock	0.550**	
	(0.278)	
Negative rainfall shock	0.217	
	(0.141)	
Current		
Positive rainfall shock		3.5e+04**
		(1.4e+04)
Negative rainfall shock		-982.818
		(3479.434)
N	5508	5508

Notes: Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level and ** at 5% level.

Table A12: Labor change in response to prior and current rainfall shocks: Household members except mothers

	(1)	(2)	(3)	(4)
	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Past				
Positive past rainfall shock	-14.157*	-9.802	-6.495	1.157
	(7.246)	(6.351)	(4.974)	(2.743)
Negative past rainfall shock	-0.021	-3.155	-0.839	0.099
	(4.148)	(3.732)	(3.357)	(1.232)
Current				
Positive current rainfall shock	-11.660*	-4.193	2.456	2.952
	(6.916)	(5.317)	(4.872)	(2.809)
Negative current rainfall shock	1.338	0.321	0.253	-0.807
	(2.029)	(1.454)	(1.821)	(0.759)
Controls				
Daily wage: Off farm, Emp.	-0.039***	0.095***	-0.011**	-0.003
	(0.006)	(0.006)	(0.005)	(0.002)
Daily wage: On farm, Emp.	-0.041***	-0.014***	-0.018***	0.097***
	(0.006)	(0.004)	(0.005)	(0.005)
Past temperature shock	59.219	-3.458	-16.326	-14.475
	(37.332)	(35.281)	(27.555)	(12.049)
Current temperature shock	-22.502	19.078	15.417	2.548
	(21.890)	(19.360)	(15.789)	(8.775)
N	5507	5507	5507	5507

Notes: The unit of outcome is hours per week. Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. ** denotes significance at 5% level and * at 10% level.

Table A13: Mitigating impacts of labor time, HH-level

	(1) Off, Self-emp.	(2) Off, Emp.	(3) On, Self-emp.	(4) On, Emp.
HH Labor hours	-0.000	-0.003**	-0.000	0.006
	(0.001)	(0.002)	(0.002)	(0.005)
Positive past × Labor	-0.003	0.002	-0.004	-0.004
	(0.005)	(0.006)	(0.008)	(0.008)
Negative past × Labor	-0.001	0.000	0.000	-0.003
	(0.001)	(0.002)	(0.002)	(0.003)
Positive current × Labor	-0.007*	0.006	0.007	0.003
	(0.004)	(0.006)	(0.006)	(0.009)
Negative current × Labor	-0.000	0.001	0.000	-0.002
	(0.001)	(0.001)	(0.001)	(0.002)
N	5508	5508	5508	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. * denotes significance at 10% level.

Table A14: Mitigating impacts of labor time, Household members except mothers

	(1) Off, Self-emp.	(2) Off, Emp.	(3) On, Self-emp.	(4) On, Emp.
Labor hours	0.001	-0.004*	-0.001	0.003
	(0.002)	(0.002)	(0.002)	(0.005)
Positive past × Labor	-0.004	-0.000	-0.004	-0.002
	(0.005)	(0.006)	(0.008)	(0.008)
Negative past × Labor	-0.001	0.000	0.000	-0.001
	(0.001)	(0.002)	(0.002)	(0.003)
Positive current × Labor	-0.007*	0.006	0.008	0.007
	(0.004)	(0.007)	(0.006)	(0.009)
Negative current × Labor	-0.000	0.001	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)
N	5507	5507	5507	5507

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported.

Table A15: Labor change in response to prior and current rainfall shocks: Different definitions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. HH-level	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Past								
Positive past rain dummy	-4.666	-13.847***	-12.611***	3.657				
	(5.397)	(4.885)	(4.257)	(3.237)				
Past Flood					-7.715	-5.964	-4.812	3.076
					(8.389)	(7.007)	(5.581)	(3.069)
Past Drought					-2.461	-0.367	1.720	0.140
					(2.047)	(1.795)	(1.550)	(0.636)
Current								
Positive current rain dummy	-1.405	-4.499*	-2.284	0.999				
	(3.113)	(2.551)	(2.232)	(1.272)				
Current Flood					-12.726	-1.216	10.722*	0.997
					(9.608)	(4.514)	(5.577)	(3.036)
Current Drought					-1.301	2.798*	0.054	-0.199
					(2.140)	(1.478)	(1.725)	(0.737)
N	5508	5508	5508	5508	5508	5508	5508	5508
B. HH except mothers	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
Past								
Positive rain dummy	-7.670	-10.745**	-10.931***	4.362				
	(5.390)	(4.591)	(4.197)	(3.247)				
Flood					-10.803	-3.221	-1.177	2.648
					(8.664)	(6.478)	(5.481)	(3.165)
Drought					-2.382	-0.097	1.688	0.099
					(1.890)	(1.698)	(1.541)	(0.643)
Current								
Positive rain dummy	-1.873	-3.205	-2.217	1.023				
	(2.930)	(2.379)	(2.205)	(1.266)				
Flood					-9.396	-0.900	11.834**	0.282
					(9.357)	(3.963)	(5.480)	(3.454)
Drought					-2.607	0.906	0.063	-0.084
					(2.037)	(1.383)	(1.706)	(0.744)
N	5507	5507	5507	5507	5507	5507	5507	5507

Notes: The unit of outcome is household-level working hours per week for each labor. Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Table A16: Mitigating impacts of household labor time

	(1)	(2)	(3)	(4)
Dummy	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
HH Labor hours	-0.001	-0.000	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)
Positive past × Labor	-0.002	-0.004	-0.003	0.002
	(0.004)	(0.005)	(0.007)	(0.004)
Positive current × Labor	-0.003**	-0.001	0.004	0.002
	(0.001)	(0.002)	(0.002)	(0.004)
Positive past rain dummy	0.322*	0.307*	0.350	0.261
	(0.194)	(0.180)	(0.213)	(0.181)
Positive current rain dummy	-0.067	-0.130	-0.193**	-0.158*
	(0.105)	(0.099)	(0.098)	(0.095)
Flood, Drought	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.
HH Labor hours	-0.001	-0.002	0.000	0.002
	(0.001)	(0.001)	(0.001)	(0.003)
Flood past × Labor	-0.004	0.012**	-0.006	-0.000
	(0.006)	(0.006)	(0.011)	(0.011)
Drought past × Labor	-0.001	0.000	-0.001	-0.003
	(0.001)	(0.001)	(0.002)	(0.003)
Flood current × Labor	-0.004	0.024	-0.013	0.005
	(0.008)	(0.033)	(0.010)	(0.012)
Drought current × Labor	0.001	0.001	0.000	-0.004
	(0.001)	(0.001)	(0.001)	(0.002)
Past Flood	0.358	0.108	0.366	0.232
	(0.303)	(0.270)	(0.283)	(0.237)
Past Drought	-0.037	-0.057	-0.042	-0.038
	(0.069)	(0.062)	(0.063)	(0.060)
Current Flood	0.598	0.228	0.667**	0.394*
	(0.433)	(0.518)	(0.330)	(0.204)
Current Drought	0.089	0.089	0.093	0.124**
	(0.067)	(0.062)	(0.063)	(0.060)
N	5508	5508	5508	5508

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. Year and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Table A17: Labor change in response to prior and current rainfall shocks by controlling for working capacity

	(1) HH Off, Self-emp.	(2) HH Off, Emp.	(3) HH On, Self-emp.	(4) HH On, Emp.	(5) Mother Off, Self-emp.	(6) Mother Off, Emp.	(7) Mother On, Self-emp.	(8) Mother On, Emp.
Past								
Positive rainfall shock	-8.600	-13.890**	-8.471*	1.039	3.804	-5.859**	-2.707**	-0.136
	(7.147)	(6.683)	(5.037)	(2.639)	(2.433)	(2.500)	(1.176)	(0.593)
Negative rainfall shock	0.985	-1.457	-0.509	0.080	0.370	0.806	-0.088	-0.037
	(4.311)	(3.964)	(3.290)	(1.230)	(1.065)	(1.420)	(0.266)	(0.383)
Current								
Positive rainfall shock	-12.074*	-8.206	1.354	3.622	-1.410	-5.008**	-1.510	0.660
	(7.240)	(5.546)	(5.008)	(2.818)	(2.615)	(2.067)	(0.981)	(0.607)
Negative rainfall shock	2.034	2.529	0.502	-0.790	0.617	2.118***	0.210	0.016
	(2.060)	(1.599)	(1.773)	(0.754)	(0.528)	(0.540)	(0.223)	(0.118)
Controls								
HH Daily wage (TK): Off farm, Emp.	-0.041***	0.093***	-0.012**	-0.003	-0.000	0.001	0.000	0.000
	(0.006)	(0.006)	(0.005)	(0.002)	(0.001)	(0.002)	(0.001)	(0.000)
HH Daily wage (TK): On farm, Emp.	-0.042***	-0.019***	-0.020***	0.101***	0.001	-0.003*	-0.000	0.004***
	(0.006)	(0.004)	(0.005)	(0.005)	(0.002)	(0.002)	(0.001)	(0.001)
Working capacity	3.386***	4.794***	2.401*	0.075	-0.445**	-0.399	-0.009	-0.029
	(1.267)	(1.478)	(1.350)	(0.216)	(0.190)	(0.421)	(0.058)	(0.040)
Past temperature shock	59.886	15.396	-19.734	-9.289	-5.191	11.017	-7.028	5.032
	(38.976)	(36.539)	(27.839)	(11.800)	(11.938)	(11.839)	(5.394)	(3.158)
Current temperature shock	-27.391	12.104	18.718	0.584	0.940	-0.308	6.210*	-1.865
	(23.289)	(20.016)	(16.073)	(8.633)	(7.553)	(7.114)	(3.518)	(1.635)
N	5508	5508	5508	5508	5507	5507	5507	5507

Notes: The unit of outcome is hours per week. Colmun (1) to (4) employ labor hours at household level, and column (5) to (8) employ labor hours of mother (individual level) as outcome variables. Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

Table A18: Mitigating impacts of maternal labor time by controlling for working capacity

	(1) Off, Self-emp.	(2) Off, Emp.	(3) On, Self-emp.	(4) On, Emp.
Maternal Labor hours	-0.018***	0.001	0.063***	0.079***
	(0.006)	(0.006)	(0.016)	(0.019)
Positive past × Labor	0.018	0.059	0.003	
	(0.019)	(0.045)	(0.063)	
Negative past × Labor	0.012**	-0.004	-0.036*	-0.039*
	(0.005)	(0.006)	(0.021)	(0.018)
Positive current × Labor	-0.010	0.003	-0.050	-0.085**
	(0.017)	(0.013)	(0.035)	(0.043)
Negative current × Labor	-0.000	0.005	-0.025*	-0.015
	(0.004)	(0.004)	(0.015)	(0.016)
Past				
Positive rainfall shock	0.281	0.295	0.367	0.374*
	(0.258)	(0.227)	(0.225)	(0.216)
Negative rainfall shock	-0.216*	-0.132	-0.146	-0.134
	(0.126)	(0.122)	(0.120)	(0.117)
Current				
Positive rainfall shock	0.080	0.076	0.079	0.081
	(0.230)	(0.220)	(0.208)	(0.203)
Negative rainfall shock	0.180***	0.153**	0.192***	0.186***
	(0.064)	(0.063)	(0.062)	(0.062)
N	5507	5507	5507	5507

Notes: Household fixed effect model is employed. Robust standard errors clustered by household in parentheses. The same set of controls as in Table 2 are included but not reported. District, year, and household fixed effects are included but not reported. Rainfall shock variables are also included but not reported. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The coefficient of Line 2 in Column (4) is dropped in household fixed effect model. CRE model shows that the coefficient is insignificant.