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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, child undernutrition remains a daunting challenge, particularly in developing countries' rural areas. Today, frequent extreme weather events harm agricultural production, exacerbating the food shortage problem in these regions. Although off-farm labor is found to be an ex-ante strategy for mitigating weather shocks, little is known about how households' 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 mitigate the effect of rainfall shocks on children's nutritional status, using three waves of nationally representative panel data from rural households in Bangladesh, in conjunction with historical monthly precipitation and temperature data. Our findings show that less rainfall during the main cropping season in the year before the survey is associated with a lower weight for age z-score (WAZ score) of children under the age of five years. The findings indicate that there are heterogeneous mitigating impacts of different types of labor allocation affecting the link between rainfall shocks and child health. While maternal labor allocation plays a role as a mitigation factor, household-level labor time and other household members' labor time are not significantly associated with the link between rainfall shocks and child nutritional status. Findings also show that maternal off-farm self-employment mitigates the negative impact of rainfall shortage, whereas maternal on-farm labor exacerbates the rainfall shock impact. Our results therefore underscore the importance of providing sufficient off-farm employment opportunities for mothers and 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

1. Introduction

Despite significant efforts in recent decades to improve food and nutrient intake worldwide, many children continue to suffer from undernutrition. Globally, the number of children under the age of five who are stunted or wasted in 2022 is 148.1 million and 45 million, respectively (UNICEF et al., 2023), and 12.3% of children are underweight.[1]

In addition to the minimally improving nutrition status, the current changing climate potentially exacerbates the problem of child malnutrition. Climate change increases unpredictable weather patterns or extreme weather events, affecting agricultural production (e.g., Cooper et al., 2019b; Freudenreich et al., 2022). For example, according to Lesk et al.'s (2016) estimation, droughts and extreme heat reported during 1964–2007 significantly reduced national cereal production by 9%–10%. Then, this adverse effect on agricultural production threatens the 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 is the food and nutrient intake path (Amondo et al., 2023; Cooper et al., 2019b). Weather shocks reduce the effectiveness of current production strategies based on the previous climate regime (Bandyopadhyay and Skoufias, 2015), resulting in lower agricultural yields. As a result of this agricultural loss, food availability decreases, particularly in rural areas of developing countries where people rely heavily on agriculture for a living (e.g., Baker and Anttila-Hughes, 2020; Vogel et al., 2019). This results in a worse nutritional status of household members. The second is the disease path (e.g., Hellde´n et al., 2021; Levy et al., 2016). Excessive rainfall will likely worsen water quality (Delpla et al., 2009), leading to a high risk of contracting infectious diseases such as diarrhea (Cooper et al., 2019a). Disease exposure, in turn, lowers the uptake and retention of essential nutrients from food (Omiat and

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[1] UNICEF, World Health Organization, World Bank: Joint child malnutrition estimates (JME). Prevalence of underweight, weight for age (% of children under 5). Available at: https://data.worldbank.org/indicator/SH.STA.MALN.ZS. Accessed 28th December 2023.

Shively, 2020). Therefore, to improve the nutritional resilience of children in the face of climate change, it is crucial to ensure constant food consumption and minimize disease exposure or support children in recovering from disease under weather shocks. One means to mitigate the impact of climate shock is through labor reallocation within the household. This paper investigates whether and how labor reallocation occurs as a strategy to achieve this goal.

Labor reallocation is an important strategy for rural households in developing countries, where adaptation options are limited due to restricted social safety nets and access to credit markets (Branco and Féres, 2021). Rural households in developing countries allocate their labor to various activities: self-employment and wage employment in an off-farm sector and self-employment and wage employment in an on-farm sector. Different potential mechanisms exist between off-farm and on-farm sectors, thereby influencing how labor allocation in these sectors affect child nutrition under weather shocks. Off-farm labor increases household income while decreasing rural households' dependence on their own produced food and allowing them to access food through the market even under weather shock conditions (Nguyen et al., 2017). In addition, household income allows them to increase healthcare expenditures when needed. For example, it allows them to buy proper medicines for infected children. Thus, off-farm labor is likely to reduce the negative effects of weather shocks on child health via food intake and disease paths. Meanwhile, on-farm labor can improve household food consumption if the climate is favorable. However, in the face of weather shocks, households frequently fail to produce enough food unless they plan ahead and adopt effective strategies, such as splitting the doses of fertilizers, adopting extreme-weather-tolerant species (Pandey et al., 2007), and diversifying crop and income (Sibhatu and Qaim, 2018; Matsuura, Luh, and Islam, 2023). Furthermore, such ex-ante strategies are inefficient because farmers do not apriori know the weather predictions during a cropping season when making decisions. On the contrary, mothers' allocation labor to on-farm work potentially increases time available for child care due to the proximity of the on-farm work to the homestead (Debela et al., 2021). Thus, although on-farm labor is vulnerable to weather shocks in terms of ensuring food consumption, it may have a positive impact on child health in a disease environment. Because households can choose between 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 than ex-ante labor strategies in dealing with unexpected weather shocks. Despite the importance of labor allocation for rural households in developing countries, the existing literature has not considered a comprehensive evaluation of various coping strategies (Gao and Mills, 2018). Identifying the heterogeneous impact of various types of labor on child nutritional status under each weather shock would thus assist rural households and policymakers in promoting 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 whether such 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 the nutritional status of children. Specifically, we ask three research questions First, does rainfall shocks negatively influence child nutritional status? Second, how do households allocate their labor into off-farm and on-farm self-employment, and off-farm and on-farm wage employment in response to rainfall shocks during the main cropping season? Third, how does each labor activity mitigate the impact of rainfall shocks on child nutritional status, and whose labor activities are the most crucial in this context?

To answer these questions, we combine three waves of a nationally representative rural household survey in Bangladesh, which includes household-level labor data and individual-level anthropometric information, with georeferenced 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 the nutritional status of children within households. That is, we compare the nutritional status of children in the same family environment but exposed to different rainfall shocks depending on their birth time. 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 type of labor activity.

Child malnutrition remains a major issue in our study country, Bangladesh. According to a nationwide survey in 2019, 22.6% of children under the age of five are underweight, 28% are stunted, and 9.8% are wasted (BBS and UNICEF, 2019). Furthermore, Bangladesh is one of the world's most vulnerable countries to climate change. Hanifi et al. (2022) found that average monthly temperature and the variability of monthly rainfall have been rising in Bangladesh since the 1970s. Therefore, identifying coping strategies for weather shocks to improve child nutritional status is vital in this setting.

This study contributes to the existing body of knowledge in several ways. First, we focus on individual-level nutritional outcomes. Since collecting information from all household members is time-consuming, a survey often collects only household-level information. However, food is not necessarily allocated equally among household members. Our dataset with individual-level anthropometric measures, food intake, and information about disease infection allows us to investigate the allocation of intra-household resources. Second, we look at the dynamics of child nutritional status using three-wave panel data. Many previous studies have used 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 using a fixed effect model. Third, in contrast to previous research on household coping strategies, which has often focused on ex-ante behavior, we investigate ex-post labor reallocation in response to rainfall shocks. This is a more flexible and efficient strategy given the expected increased vulnerability to weather shocks. Furthermore, we distinguish four different types of labor based on the rich information contained in the data. The labor activities are on-farm employment or self-employment and off-farm employment or self-employment. This is particularly relevant as diversifying labor hours by job type within the same sector is also important for mitigating some of the entrepreneurial risks associated with self-employment (Bandyopadhyay and Skoufias, 2015).

The remainder of this article is organized as follows. In the next section, we introduce conceptual framework. Section 3 outlines the data used for the analyses. After presenting the empirical strategy in Section 4, Section 5 reports the results. We discuss the interpretation and robustness of our results in Section 6. Section 7 concludes the paper.

2. Conceptual framework

In this section, our objective is to conceptualize how rainfall affects child nutritional status and how the allocation of household labor can influence the associations between rainfall and child nutrition. Although there are many causes of child undernutrition (UNICEF, 2014),[2] we assume that rainfall shock has a direct impact on child nutritional status via two factors: food intake and disease environment. Omiat and Shively (2020) state that a child i's nutritional status from household h in time t (H_{iht}) is determined by the child's health endowment (μ_{iht}), food intake of child i (C_{iht}), environmental conditions affecting child disease prevalence (D_{iht}), vectors of exogenous characteristics

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[2] They construct a conceptual framework for malnutrition, in which the 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 article is not to fully list the potential mechanisms linking rainfall shocks with child nutritional status but rather to identify a household strategy to mitigate the impacts of rainfall shocks on child nutrition.

(X_i) of the child, the child's mother, the household, and the community. In addition, this paper considers the effect of childcare practices (T_{iht}), such as time for breastfeeding, food preparation, and washing the body. Although longer childcare time is likely to benefit child health, the time available for childcare practices is determined by time constraints. In other words, more time spent on the labor market or leisure results in less time spent on childcare (Debela et al., 2021). Considering that mothers are often the primary persons who take care of their children (Shroff et al., 2009), mother's labor time is particularly important to determine child nutrition. Therefore, the nutritional status of the child can be expressed in the following specification.

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

where

$$\begin{aligned} C_{iht} &= l\,\{ Y_{ht-1}\,(R_{ht-1}), PF_{ht}\,(L^{off}_{ht}), X^{ch}_{i}, X^{h}_{i}, X^{co}_{i} \} \\ D_{iht} &= m\,\{ R_{ht}, L^{off}_{ht}, L^{on}_{ht}, X^{ch}_{i}, X^{h}_{i}, X^{co}_{i} \} \quad (2) \\ T_{iht} &= n\,(L^{off}_{ht}, L^{on}_{ht}, X^{ch}_{i}, X^{m}_{i}, X^{h}_{i}, X^{co}_{i}) \end{aligned}$$

Equation 2 expresses how recent rainfall and current household labor affect the nutritional status of each child. The first input into the nutritional status of the child is the current intake of food for child i (C_{iht}), which consists of the agricultural production of the household 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 that labor allocation can play a role in mitigating this fluctuation through purchased food. For example, if a household's agricultural yields are insufficient, they can increase off-farm labor (L^{off}_{ht}), which generates household income and allows them to purchase more food. Due to the time lag between harvesting and purchasing, we assume that current on-farm labor has no effect on the amount of currently purchased food. Furthermore, due to the possibility of unequal intra-household food allocation, the amount of food consumed is unlikely to be uniform among children from the same household. Instead, the amounts can be determined depending on the child's age or gender.

The second input is the prevalence of the disease (D_{it}), which is affected by the current rainfall (R_{ht}), off-farm and on-farm labor ($L^{on}{}_{ht}$), and other characteristics. Although sufficient rainfall tends to increase crop yields, inadequate rainfall will likely result in low yields (Omiat and Shively, 2020). Furthermore, extreme low and high rainfall often harms agricultural yields because small-scale farmers cannot adapt to unusual rainfall (Cooper et al., 2019a). However, whether a child becomes infected with a disease and how quickly a child recovers depend on household labor. By reallocating labor, a household can adjust the amount of time available for childcare. For example, if a child contracts a disease, his mother may increase on-farm while decreasing 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). However, an increase in off-farm labor may also help the child recover from the disease since it is likely to increase household income, which allows them to purchase a proper medicine for a child. Furthermore, child characteristics can capture the inherent ability to resist disease, while household characteristics can capture the ability that a household takes care of the child in the disease environment, and community characteristics can capture the impacts of health facilities.

Daily childcare practices (T_{iht}) are the third input in Equation (2). Here, we assume that a household maximizes the utility by improving the nutritional status of the current child. However, other factors motivate labor participation in response to rain shocks. For example, agricultural yields in the previous year change household resource constraints, affecting labor participation decisions especially for self-employment. Alternatively, a household can change farm labor based on the expectation of agricultural yields at the end of the cropping season, which is determined by current weather conditions. An important determinant of child nutrition is how much time is devoted to childcare practices while working.

Based on the assumptions explained in the preceding, the effects of rainfall on each input of the child's nutritional status can be written as follows:

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

$$\frac{dD}{dR_t} = \frac{dD}{dR_t} + \frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t} \qquad (3)$$

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

The first line in Equation 3 represents the impact of previous rainfall 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 a better (worse) nutritional status of the child. Meanwhile, $\frac{dC}{dPF}\frac{dPF}{dL^{off}}\frac{dL^{off}}{dR_{t-1}}$ can capture the ability of households to cope with agricultural yield loss due to rainfall shock. Therefore, the requirement that the effect of reallocation of labor on food intake compensates for the agricultural yield effect because 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, a higher amount of purchased food increases food intake ($\frac{dC}{dPF}$ >0). Furthermore, an increase in off-farm labor is likely to lead to higher household income, mitigating budget constraints, including food purchase ($\frac{dPF}{dL^{off}} > 0$). Thus, Equation 4 requires $\frac{dL^{off}}{dR_{t-1}} < 0$. In this case, the reallocation of labor plays a role in mitigating the impact of rain on the health status of the child through the food intake path.

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

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

Equation 5 requires $\frac{dD}{dL^{off}}\frac{dL^{off}}{dR_t} + \frac{dD}{dL^{on}}\frac{dL^{on}}{dR_t} < 0$. The labor should be reallocated to satisfy this requirement. In this case, there are two scenarios. The first focuses on the role of off-farm labor. Off-farm labor can improve the quality of childcare practices by increasing the available household income for healthcare, which is likely to decreases the prevalence of disease ($\frac{dD}{dL^{off}} < 0$). Thus, a household should increase off-farm labor in response to current heavy rain ($\frac{dL^{off}}{dR_t} > 0$), while decrease on-farm labor ($\frac{dL^{on}}{dR_t} < 0$) due to time constraints. The second focuses the role of on-farm labor. Longer working time in on-farm labor is likely to increase time available for childcare and decrease disease prevalence when compared to off-farm work ($\frac{dD}{dL^{on}} < 0$). Thus, a household should increase on-farm labor in response to current heavy rain ($\frac{dL^{on}}{dR_t} > 0$), while decrease off-farm labor ($\frac{dL^{off}}{dR_t} < 0$) due to time constraints. In conclusion, to deal with a severe disease environment due to current heavy rainfall, a household can increase either off-farm labor or on-farm labor, but not bot he of them because of time constraints.[3]

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

The last line represents the impacts of childcare practices on child health. The availability of childcare practices is directly determined by labor reallocation following shock. There are two hypotheses. On the one hand, on-farm labor can improve childcare practices by increasing parents' time to care for their children. The working time of a childcare provider is especially important for this. On the other hand, off-farm labor can improve childcare practices by increasing household income, which allows a household to purchase necessary goods for children. To deal with rainfall shocks through childcare practices, labor allocation should satisfy the following equation:

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

This requires $\frac{dL^k}{dR_{t-1}}=-\frac{dL^k}{dR_t}$, which implying that labor should react to previous and current rainfall in opposite directions. From Equations 4, 5, and 6, we derive the following household labor strategy to mitigate recent rainfall shocks on child health:

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

3. Data

3.1. Household data

The primary source of data for this study is the Bangladesh Integrated Household Survey (BIHS), a three-wave panel survey conducted in 2011/2012, 2015, and 2018/2019.[4] The design and implementation of the survey were conducted by researchers at the International Food Policy Research Institute. The survey locations are rural areas in each of the county's seven administrative divisions. The total sample sizes in the first, second, and third waves are

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[4] 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

6,503, 5,430, and 4,891 households, respectively.[5] The sample is nationally representative of rural Bangladesh and representative of rural areas of each of the seven administrative divisions of the country.

The BIHS dataset has anthropometric measures of all household members. Our focus is child nutritional status. Hence, we restricted the sample to households that have at least one child who is under five for each wave. Thus, our sample is not balanced. We drop individuals with missing values in any variables we use in our estimation. 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.

As an outcome variable, we employ weight for age z-score (WAZ score)[6] for children under five years of age. The WAZ score captures the prevalence of being underweight. Underweight is a severe problem in developing countries, as it is associated with higher risks of mortality in children under 5 (e.g., Black et al., 2003; Fishman et al., 2004), and Bangladesh is one of the countries with the highest prevalence of underweight (Chowdhury et al., 2018). In addition, the WAZ score captures both chronic and acute nutritional deficiencies, which is consistent with our focus on food intake and disease pathways. Panel A in Table 1 presents summary statistics of the main variables of interest (The full table for all variables is available in Table A1 in the Appendix). The average WAZ scores for 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, it decreases to 23.9%.

As the main explanatory variable, we measure weekly working time for each type of labor (off-farm and on-farm self-employment, and off-farm and on-farm wage employment).[7] We construct the labor variables at both household level and maternal (individual) level. Panel A in Table 1 shows that at household level, off-farm self-employment accounts for the majority of

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[5] This is the original sample, and we ignore split samples due to marriage. The attrition rate per year is low. Furthermore, Ahmed and Tauseef (2022) stated that the attrition between 2011/12 and 2018/2019 is random. Thus, we do not adjust our estimates for attrition.

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

[7] The recall period is the last 7 days.

their labor, followed by off-farm employment or on-farm self-employment depending on survey wave, and on-farm employment time is the shortest across all waves. Meanwhile, maternal labor time has a different pattern. They spend most of their time on off-farm labor. Their average on-farm labor time, including self-employment and employment, is less than 1 h per week. This is because the majority of mothers do not work on-farm. On the other hand, mothers spend 5-6 and 2-4 hours per week on off-farm self-employment and off-farm employment, respectively. As for the household-level daily wage, which is only available for employment labor and not for self-employment labor, the off-farm wage increases over time, whereas the on-farm wage is relatively stable.

3.2. Climate data

Climate data is derived from the Climate Hazards Group Infrared Precipitation with Station dataset, which contains monthly rainfall and temperature from January 1980 to December 2019 on a global grid with 0.5-degree latitude by 0.5-degree longitude. Climate information is merged with BIHS data at the household level using geographical location data for each household in the BIHS sample.

To capture recent climate situations during the main cropping season, called Rabi season,[8] we construct weather (i.e., rainfall and temperature) shock variables for each household following the study by Makate et al. (2022). The 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,

$$Rainshock_{ht} = \frac{rain_{ht} - \overline{rain_{ht}}}{\rho_{rain_{ht}}} \tag{8}$$

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[8] Rabi season in Bangladesh is from November to February. Before the green revolution, Kharif season (from March to June) was the main cropping season, but now due to expansion of the irrigation system, Rabi season is the main cropping season, when the main rice (Boro rice) and many other winter crops are grown.

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

Panel B in Table 1 presents the climate characteristics of each wave. Rainfall shocks in each survey year are −1.170, −1.157, and −0.218 in waves 1, 2, and 3, respectively, which means that rainfall during the Rabi season in survey periods is typically lower than the historical average rainfall during the same season over the previous 31 years (i.e., 69.939, 71.396, and 67.597 for each wave). Table 1 also shows that, with the exception of the year preceding the first survey wave, the average monthly temperature during Rabi season in survey periods tends to be lower than the historical average temperature during the same season for the previous 31 years (around 20 °C for all waves). We focus on the Rabi season because the survey was mainly conducted during the Rabi season. That is, child nutritional status is measured in the survey and is likely to be influenced by weather conditions at the survey time. However, we also check the impact of rainfall shocks in other season (i.e., Kharif season) in Section 6.4. Additionally, Figure 1 visually shows the rainfall shock variations for each year. As you can see, rainfall differs quite a bit depending on the year.

As defined, positive (negative) values in the rainfall shock variable imply that there is more (less) rainfall than the historical average. Since a more wet weather condition and a more dry

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[9] We use the rainfall shock variable as a continuous variable, instead of dummy variables that imply flood or drought events, because some households receive only moderate rainfall over time, which means that all 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.2.

weather condition are likely to have different impacts on child health, we also defined positive and negative shock variables as follows:

$$PositiveRain_{ht} = \frac{rain_{ht} - \overline{rain_{ht}}}{\rho_{rain_{ht}}} \qquad (9)$$

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

$$NegativeRain_{ht} = \frac{rain_{ht} - \overline{rain_{ht}}}{\rho_{rain_{ht}}} \times (-1) \qquad (10)$$

if $rain_{ht} < \overline{rain_{ht}}$, and 0 otherwise. By including positive and negative rainfall shock variables together in 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 the Rabi season. The coefficient of variation of historical rainfall and temperature can capture the fluctuation of the climate conditions for each place. Since the fluctuation of climate conditions makes it difficult to predict climate in the future, households need specific strategies to avoid the risks caused by weather shocks. In other words, households in more fluctuating climate zones may employ systematically different labor strategies than those in less fluctuating climate spots. To distinguish such an ex-ante strategy from an ex-post coping strategy after the shocks, we include the coefficient of variation of historical climates (rainfall and temperature) and their historical average into our estimation as control variables. These controls enable us to identify the impacts of labor changes in response to recent rainfall shocks as rainfall shock variable coefficients.

4. Empirical strategy

To estimate the change in labor allocation in response to recent rainfall shocks and its effects to mitigate the impacts of rainfall shock on child nutritional status, we employ a fixed effects panel data model. Household labor allocation decision is likely to be related to observed and unobserved characteristics of the household, resulting in an endogeneity problem.[10]

For example, a husband with progressive views on gender inequality is more likely to allow his wife to work outside the home. At the same time, this progressive attitude may lead to better treatment of children by the husband (Duflo, 2012). In such a case, regardless of labor changes, unobserved differences in gender equality perspectives would affect household food consumption in favor of children after rainfall shocks. Hence, one cannot distinguish impacts of labor reallocation after households experience shocks from impacts of specific household characteristics, i.e., a more mother.[11]

Multi-period panel data is useful to address unobservable heterogeneity. One way to analyze panel data is the random effects model. According to Gao and Mills (2018), the random effects model is particularly appropriate when the over-time variation in the dependent and independent variables is small in comparison to the cross-sectional variation in time *t*. However, this model requires the assumption that time-invariant effects are uncorrelated with the explanatory variables, which does not apply in our case. For example, the geographical characteristics of the location of the resident place (e.g., altitude) do not change dramatically over time, but are likely to be correlated with the rainfall patterns, which are our main explanatory variables, as well as the health status of the resident.

Thus, using three-wave panel data, we employ a fixed effect model with household and time fixed effects. This method eliminates all time-invariant unobserved heterogeneity while

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[10] Simultaneity bias is another common cause of endogeneity issues, however, in our setting, reverse causality may not be problematic since weather condition is exogeneous.

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

avoiding the above-mentioned assumption (Wooldridge, 2015).[12]

Our model takes advantage of variation in child nutritional status within households with multiple children who are raised in the same family environment but are exposed to different rainfall shocks depending on when they are born. This allows us to remove the effect of specific household time-invariant characteristics on child nutrition and estimate the impacts of each labor form on mitigating the effects of rainfall on child nutritional status. However, we acknowledge that our fixed effect model with multiple controls cannot completely eliminate the potential endogeneity problem caused by time-variant unobservable heterogeneity. Therefore, the results should be interpreted as correlation rather than causal relationship.

4.1. Model specification

4.1.1. Impact of rainfall shock on child nutritional status

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

$$y_{ihdt} = \alpha_0 + \alpha_1 RainShock_{hdt-1} + \alpha_2 RainShock_{hdt} + \alpha_3 W_{hdt} + X^C_{ihdt}\alpha_C$$

$$+X^H_{ihdt}\alpha_H + \theta_h + \gamma_t + \epsilon_{ihdt} \qquad (11)$$

where y_{ihdt} is the weight for the age z-score for a child i from household h living in division d[13] in year t. $RainShock_{hdt-1}$ and $RainShock_{hdt}$ are rainfall shock variables during Rabi season in the previous year of the survey and in the survey year, respectively, which are our main explanatory variables. W_{hdt} captures the climate characteristics for each residence place, including the temperature shock variables for the previous year of the survey and the survey

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

[13] Bangladesh was divided into seven administrative divisions during the survey periods: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, and Sylhet.

year, the historical average rainfall and temperature during Rabi season for the past 31 years, and their coefficient of variation. Historical climate control variables help us distinguish household ex-ante and ex-post labor decision making (Rose, 2001). Furthermore, we control for individual-level child characteristics (X^C) such as gender and month of age, as well as a vector of time-variant household characteristics (X^H): demographic indicators 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 rate. We also include fixed effects for households and years (θ_h and γ_t, respectively). A fixed household effect is included to remove the effect of time-invariant characteristics at the household level. The year fixed effect accounts for specific events in the survey year that affect the outcome variables. Standard errors are clustered at the household level.

4.1.2. Labor reallocation and labor-mitigating impacts

Next, we use the same set of explanatory and control variables as in Equation 11 to estimate labor reallocation in response to recent rainfall shocks. For each labor activity (off-farm self-employment, off-farm wage employment, on-farm self-employment, and on-farm wage employment), a variable is generated measuring labor time. These variables are calculated as weekly labor hours at the household or mother level.[14]

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

$$y_{ihdt} = \beta_0 + \beta_1 L^k + \beta_2 L^k \times RainShock_{hdt-1} + \beta_3 L^k \times RainShock_{hdt} + \beta_4 RainShock_{hdt-1} +$$

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[14] Because a household must allocate the total amount of available working time to different labor activities, each labor time is likely to be decided concurrently, potentially causing endogeneity. Therefore, we do not claim causality based on the results.

$$\beta_5 RainShock_{hdt} + \beta_6 W_{hdt} + X_{ihdt}^{C}\beta_C + X_{ihdt}^{H}\beta_H + \theta_h + \gamma_t + \epsilon_{ihdt}^{2} \quad (12)$$

where L^k is weekly working time of labor *k* of household *h* living in division *d* in year *t*, at the household level or the mother level, depending on the specifications. We examine the mitigating impacts for each form of labor. β_1 captures the direct effect of labor on the WAZ score, and β_2 and β_3 represent the effects of labor on the relationship between the one-year prior rainfall shock and the nutritional status of the child and between the current rainfall shock and the nutritional status of the child, respectively. By comparing those labor impacts with rainfall shock effects, we confirm which labor type can mitigate the negative effects of rainfall shocks or not. Further, by comparing the labor-mitigating impacts between the mothers and other household members, 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 the WAZ score of children. 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 of age tends to increase. However, as rainfall in the survey year increases above the historical average rainfall, WAZ score for a child under five years of age tends to decrease. The opposite effects of rainfall shock by year can be explained as the different paths through which rainfall is associated with the WAZ score: food consumption path or disease path (Omiat and Shively, 2020). We will discuss these potential paths in Section 6.

To investigate the relationship between rainfall and WAZ score more precisely, we separate positive and negative rainfall shocks and include them as explanatory variables in our specification (Columns (2)).[15]

Column (2) shows that negative past rainfall shock is not significantly associated with WAZ score, but positive past rainfall shock is positively and significantly associated with WAZ score. This result implies that the positive association between the prior rainfall shock and the WAZ score is mainly driven by the positive effect of more rainfall and not the negative effect of less rainfall. In other words, more rainfall in the previous year than the historical average rainfall increases the WAZ score significantly. In particular, a one-standard-deviation increase in previous rainfall is associated with an average 0.360 standard-deviation increase in WAZ score, which is 24.5% of the mean WAZ score for the entire sample (−1.470). Regarding the current rainfall shock, while the positive rainfall shock does not have a significant association with the WAZ score, the negative rainfall shock is positively and significantly associated with WAZ score. This result implies that the negative association between the current rainfall shock and the WAZ score is mainly driven by the positive effect of less rainfall and not by the 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 the WAZ score, which is 12.3% of the mean WAZ score for the whole sample (−1.470).

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[15] In this paper, we focus on the ability of households to mitigate rainfall shocks on child nutritional status through labor allocation, and do not thoroughly investigate the 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 A5 in the Appendix). This result explains the path of food consumption because less harvest may lead to less food consumption, resulting in a lower WAZ score. Furthermore, 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 A6 in the Appendix). This result explains the path of the disease because a lower prevalence of the disease is likely to improve the WAZ score.

5.2. Labor reallocation

In this section, we examine the reallocation of household labor in response to rainfall shocks. Table 3 reports the results of the change in labor in response to previous 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. The results indicate that since households had more rainfall during Rabi season in the previous year than the historical average rainfall, they were more likely to decrease the labor time for off-farm wage employment and on-farm self-employment. On average, a one-standard-deviation increase in previous rainfall is associated with a decrease of approximately 15.5 h in the off-farm wage employment time and a decrease of 9.3 h in the on-farm self-employment labor time. Regarding the current rainfall shocks, more rainfall leads to a decrease in off-farm self-employment labor time. Specifically, on average, a one-standard-deviation increase in current rainfall is associated with about 12.7 h decrease in off-farm self-employment labor time.

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

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

In addition to Table 3, we analyze the labor changes of household members other than mothers as a result of recent rainfall shocks (Table A2 in the Appendix). We find that the different patterns of labor change depending on the type of labor. First, as with off-farm self-employment, changes in labor time at the household level are likely to be driven primarily by household members other than mothers. 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. Furthermore, only household members other than mothers significantly decrease their labor time in response to a positive current rainfall shock. Second, as with off-farm employment and on-farm self-employment, labor time changes at the household level are likely to be driven primarily by mothers, as labor time for other household members does not change significantly in response to rainfall shocks. Lastly, regarding on-farm wage employment, no household members are likely to change their labor time in response to rain shocks.

5.3. Labor-mitigating impacts

Then, we investigate how changes in working time in each labor are associated with the effects of rainfall shocks on child nutritional status, specifically the positive impact of higher past rainfall and the positive impact of lower current rainfall on WAZ score. Because mothers are the primary caregivers for their children (Shroff et al., 2009), their labor time should have the greatest influence on child nutritional status. We confirm it with our data set by analyzing the mitigating impacts of labor time at the household level, as well as the labor time of household members except mothers (Table A3 and A4 in the Appendix). The results show that household-level labor time allocation, except the mother's labor time, does not have important impacts on the association between rainfall shocks and child nutritional status in terms of coefficient size and statistically significant level. Therefore, in the present section, we only report the result of mother's labor time.

Table 4 presents the results to mitigate the impacts of maternal labor time. First, we focus on the direct effect of labor time on child nutritional status. Although off-farm self-employment labor time is negatively and significantly associated with the WAZ score in Column (1), on-farm employment and self-employment are positively and significantly associated with the WAZ score in Columns (3) and (4). We discuss this opposite association of labor time on the 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 labor-mitigating impacts. On the one hand, the interaction term coefficient for negative past rainfall and off-farm self-employed labor time is 0.012. This result implies that increasing maternal labor time for off-farm self-employment by 1 h per week increases the negative association between less rainfall in the previous year and WAZ score (food consumption path) by 0.012 standard deviations. On the other hand, farm labor has different impacts on the relationship between rainfall shocks and the nutritional status of the child. The coefficient of interaction term between negative past rainfall and 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 farm employment time is significantly negative. It means that the more a mother engages in on-farm employment, the worse the negative association between more current rainfall and the WAZ score (disease path). Furthermore, the interaction term's coefficient between negative current rainfall and on-farm self-employment time is significantly negative. It means that the more a mother engages in on-farm self-employment, the lower the WAZ score, even though less current rainfall is likely to improve her child's nutritional status. While the direct impact of on-farm labor time on WAZ score is positive and significant, on-farm labor may exacerbate 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, the characteristics of the child, such as sex and age, are likely to influence intra-household resource allocation, resulting in different health outcomes. In this section, focusing on the gender aspect, we analyze heterogeneous impacts of labor between boys and girls. Table 5 shows different heterogeneities depending on the form of labor.

By comparing Columns (1) and (2), we show that off-farm self-employment decreases only girls' WAZ scores significantly. This implies that when a mother has less time to care for her children due to time constraints imposed by off-farm work, girls are more likely than boys to be negatively impacted. In other words, if a mother does not have enough time for childcare practices, she may prefer to spend her time with boys.

The impacts of farm self-employment in Columns (5) and (6) and farm employment in Columns (7) and (8) 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 in farm self-employment is significantly associated with a better nutritional status of boys, but not girls. Our empirical results on gender heterogeneity suggest the potential gender discrimination of child health.

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 the WAZ score for children in opposite directions. This is because each rainfall shock affects child health in a different way. First, changes in agricultural yields can explain the positive association between past rainfall and WAZ score. According to the literature, while adequate rainfall frequently increases agricultural yields, a lack of rainfall is likely to result in lower yields for rural farmers who cannot afford irrigation (Adeleke and Babalola, 2020). We confirm empirically that less rainfall the previous year (i.e., negative past rainfall shock) is significantly associated with lower agricultural harvest (Table A5 in the Appendix). A household in developing countries' rural areas tends to rely on local agricultural products for their food consumption. Therefore, lower agricultural yields directly translate to a smaller amount of food consumption, which leads to a worse nutritional state of the child. Considering that the surveys were conducted during the main cropping season in each year, the nutritional status at the survey timing is influenced by the agricultural yields of households before the survey, which are determined by rainfall in the year prior to the survey (i.e., past rainfall shock). In summary, our finding of a positive association between past rainfall and WAZ score is due to an increase in food consumption caused by higher agricultural yields the previous year as a result of more rainfall.

Second, the path of disease prevalence can explain the negative association between current rainfall and WAZ score. It is well documented that excessive rainfall increases the prevalence of diseases such as diarrhea, which prevents essential nutrients from being absorbed and has a huge impact on the health status of children (Omiat and Shively, 2020; Le and Nguyen, 2021; Levy et al., 2016; Rabassa et al., 2014). An important note is that this path to prevalence of the disease depends on access to clean water. It could be the case that children without access to clean water are not only more strongly influenced by rainfall shock, but they also originally have a lower health status than those with access to clean water. Therefore, we control for the access to piped drinking water and sanitary toilets in our estimations. We confirm that lower current rainfall (i.e., negative current rainfall shock) is negatively and significantly associated with diarrhea prevalence (Table A6 in the Appendix). Although current rainfall has an impact on agricultural production in the survey year, change in agricultural production would affect nutritional status after it is harvested at the end of the cropping season. Therefore, considering that the survey was conducted during the cropping season, current rainfall cannot affect nutritional status through agricultural yields. To summarize, our finding of a negative association between current rainfall and WAZ score (or a positive association between negative current rainfall shock and WAZ score) is most likely due to a decrease in disease prevalence caused by lower current rainfall.

6.2. Labor reallocation

We identify how a household changes the portfolio of labor in response to previous and current rainfall. Regarding the past rainfall shock, larger rainfall than the historical average amount leads to a decline in off-farm employment and on-farm self-employment, both at household level and the mother level. We interpret these responses as a result of higher agricultural yields in the previous year due to adequate previous year rainfall. We confirmed that more previous rainfall is associated with higher agricultural yields in the last 12 months. First, additional agricultural yields are likely to improve household food consumption after the harvest season in the previous year until the harvest season in the current year. As a result, a household may feel less need for agricultural production to feed household members and income to buy food, resulting in shorter labor time in both off-farm employment and on-farm self-employment. Although we cannot directly observe this mechanism, we confirmed that more rainfall in the previous year is associated with a higher household dietary diversity score, which is calculated based on the last 7 days of food consumption information (Column (1) in Table A7 in the Appendix). Furthermore, larger agricultural yields are also likely to improve household income through sales of their products. We confirm a positive association between higher current rainfall and higher current income from on-farm activities (Column (2) in Table A7 in the Appendix). As for current rainfall shocks, higher rainfall than historical average rainfall tends to decrease labor time in off-farm activities, while lower rainfall than historical average rainfall tends to increase labor time in off-farm employment labor. Our findings of the household strategies are consistent with previous literature (Branco and Féres, 2021; Ito and Kurosaki, 2009). These responses are interpreted as a result of expectations for agricultural yields at the end of the season. More rainfall, as confirmed by our dataset, is likely to boost 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. Therefore, if households observe fewer rainfall during the cropping season, they are likely to put less effort into farm labor expecting to get lower agricultural yields, whereas they increase off-farm labor.

It is important to mention that the flexibility of labor changes differs among the form of labor as well as among household members. As for off-farm self-employment, only household members, except mothers, change their working time in response to rainfall shocks. However, in terms of off-farm employment and on-farm self-employment, only mothers change their working time. In addition, in terms of on-farm employment, no one changes the working time in response to rainfall shocks. Especially by focusing on maternal labor, mothers react flexibly to the rain shock by changing their off-farm employment work time. This implies that off-farm employment is the most flexible labor form to react to rainfall shocks for mothers. In contrast, to cope with rainfall shock, mothers may need support 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 nutrition status. First, we find opposite effects of labor time itself on the WAZ score between on-farm and off-farm labor. That is, a longer working time for farm activities leads to a higher WAZ score, whereas a longer working time for off-farm activities leads to a lower WAZ score. This result is most likely due to differences in working environments. Farm labor may be easier to balance work and childcare practices in developing countries than off-farm labor because people engaged in farm labor primarily work on their own family farm or in locations close to their home (Debela et al., 2021). Thus, if mothers work longer hours for farm labor, they will have more time to spend with their children. However, if mothers work longer for off-farm labor, it is more difficult to use the time for childcare practices. Furthermore, when mothers have less time for domestic work, they tend to first decrease cooking time, which leads to less dietary diversity (Komatsu et al., 2018). Although such time constraints can be offset by the help of other household members (Johnston et al., 2018), we find that the results do not change when we control for the working capacity of the household (number of working-age household members) as shown in Table A8 in the Appendix. Therefore, we conclude that such time constraints of mothers would result in a lower child health status.

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

Contrary to these results, for on-farm labor, we find that longer working time may worsen the negative effects of past rainfall and current rainfall shocks on the WAZ score. First, negative coefficients of interaction terms between farm activities and negative past rainfall shock suggest that when rainfall is insufficient for agricultural production the previous year, an increase in maternal on-farm labor time may harm the nutritional status of their child. This is because if a household does not have enough food due to poor harvests, they must buy food. However, longer working time in farm labor leads to shorter working hours in off-farm labor, which reduces household income. As a result, labor should be shifted away from the farm. Second, negative coefficients of interaction terms between on-farm activities and positive current rainfall shock suggest that when disease prevalence is higher due to higher rainfall, an increase in maternal on-farm labor time may harm their child's nutritional status. Once children have a disease, parents must take care of them in person while purchasing appropriate medical supplies to support them. If mothers work longer on farms, they are more likely to spend longer time with 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. Therefore, this result implies that the negative impact of increasing farm labor exceeds the positive impact of increasing farm labor.

In summary, with regard to maternal labor time, our findings suggest that while a longer working time of on-farm labor itself has a 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 to off-farm labor. Given that longer working hours in off-farm labor are directly associated with lower child nutritional status due to time constraints, it is essential to provide mothers with adequate off-farm opportunities as well as childcare supports during their work as an ex-post strategy following a rainfall shock. In addition, we conducted the same analysis with the labor time at the household level as well as the 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 consider 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 the Rabi season is because the survey was conducted mainly during the Rabi season and recall periods of much information in our data set are included in the Rabi season. Although specific survey timing (e.g., survey month) may be related to our findings, we do not have complete survey timing information. As a result, we were unable to control for it, which is our limitation.

Bangladesh has another cropping season called Kharif 1, which runs from March to June. Using Equation 11, we investigate the impacts of rainfall shock during the Kharif season in the survey year as well as the year before the survey. We find that the past Kharif rainfall shock has a trend similar to the past Rabi rainfall shock. That is, more rainfall in the previous year than the historical average rainfall significantly increases the WAZ score at the 1% level (Column (1) in Table A9). The results show that current rainfall shocks during the Kharif season are not significantly associated with the WAZ score. This is most likely due to the time lag between Kharif season and survey date. Because diarrhea prevalence is sensitive to current rainfall, rainfall during Kharif season would have no effect on the prevalence of diarrhea during the survey (Column (4) in Table A9), resulting in insignificant impacts of Kharif season rainfall shocks on child nutritional status.

6.5. Robustness check

To confirm the robustness of our findings, we performed an additional analysis. First, we analyze the association between rainfall shocks and the WAZ score by using five different methods: the pooled ordinary least square (OLS) model with covariates, the pooled OLS model with household fixed effect, the household fixed effect model without singleton observations, the individual fixed effect model, and the correlated random effect (CRE) model. This validates the robustness of our empirical strategy. Second, we use an alternative definition of rainfall shocks and reanalyze the rainfall impacts to rule out measurement error. We create a dummy variable that equals one if survey year rainfall exceeds historical average rainfall. In addition, we define flood and drought variables to account for extreme rainfall shocks. Third, to overcome our limitation of unavailable survey date information, we only focus on the first months of the Rabi season and compare the rainfall impacts with the impacts of the whole Rabi season rainfall. Then, instead of reallocating labor, we investigate other coping strategies such as change in total labor time, migration, and livestock sale after rainfall shocks. Finally, we study the impacts of rainfall shocks on child malnutrition as measured by other indicators such as underweight, wasting, and stunting.

7. Conclusions

Children's undernutrition remains a major issue in developing countries' rural areas. To achieve household food security in the face of weather shocks, rural households must properly allocate their labor among farm and off-farm activities. Identifying how each type of labor reduces the effect of weather shock on child nutritional status would assist farmers in selecting appropriate labor allocation to cope with weather shocks.

Using data from the three-wave panel survey in Bangladesh, we investigate the 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 disease. In addition, we find significant mitigating impacts of maternal off-farm self-employment. That is, a longer working time for maternal off-farm self-employed labor mitigates the negative association between previous year's rainfall shortage and WAZ score. However, an increase in maternal on-farm labor supply may exacerbate the negative effect of insufficient previous rainfall on WAZ score. It implies that on-farm labor does not play a role in coping with rainfall shocks, so mothers should shift their labor to off-farm labor if rainfall was scarce the previous year. Furthermore, findings show that maternal labor has consistent mitigating impacts in the case of extreme rainfall shocks (i.e., flood and drought).

However, it is also important to consider the direct impact of working hours on child health. Our empirical results find that, while longer maternal off-farm labor time is associated with a lower WAZ score, longer maternal on-farm labor time significantly improves WAZ score, most likely due to differences in working environments. Since people who engage in farm labor in developing countries mainly work on their own family farm or the places that are relatively close to their home, farm labor can be easier to balance work and childcare practices (Debela et al., 2021). Lastly, we find heterogeneous labor-mitigating impacts among household members. In contrast to maternal labor, we find no significant mitigating impacts of household-level labor or labor by household members other than mothers. Therefore, we conclude that maternal labor allocation plays an important role in coping with rainfall shocks in the context of child health.

The current paper adds to the literature by demonstrating the various impacts of different types of labor under the same conditions. Considering the possibility of further increasing extreme weather in the near future, it is even more important for households to adapt to the fluctuation of rainfall through reallocation of labor. Our findings can guide rural households to make their labor decision after experiencing rainfall shocks. Furthermore, by comparing labor impacts 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. While we undertook various robustness checks supporting our findings, we acknowledge that there is still a potential endogeneity problem caused by simultaneous decision making of labor time. We therefore interpret our results as associations and do not claim causality.

Bangladesh still suffers from the problem of child undernutrition, despite the substantial efforts to improve food and nutrition in recent decades. Specific projects, such as social safety nets or money transfers, are, of course, effective ways for rural households to deal with income shocks, but their recipients are limited (Branco and Féres, 2021). However, labor reallocation in response to shocks can be adapted by any household. As a result, our results of off-farm self-employment labor-mitigating impact point to the importance of policies that provide off-farm labor opportunities to mothers in rural settings in order for them to cope with rainfall shocks. A variety of off-farm labor opportunities allows mothers to select a more suitable job based on their circumstances, resulting in a higher rate of working mothers with children away from home. Furthermore, such a policy should take into account maternal time constraints. Supporting mothers who work and care for children is another crucial role of these policies. Possible ways include the introduction of childcare spaces in a work place, the adoption of kindergartens in rural areas, and the implementation of babysitter services.

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Tables and Figures

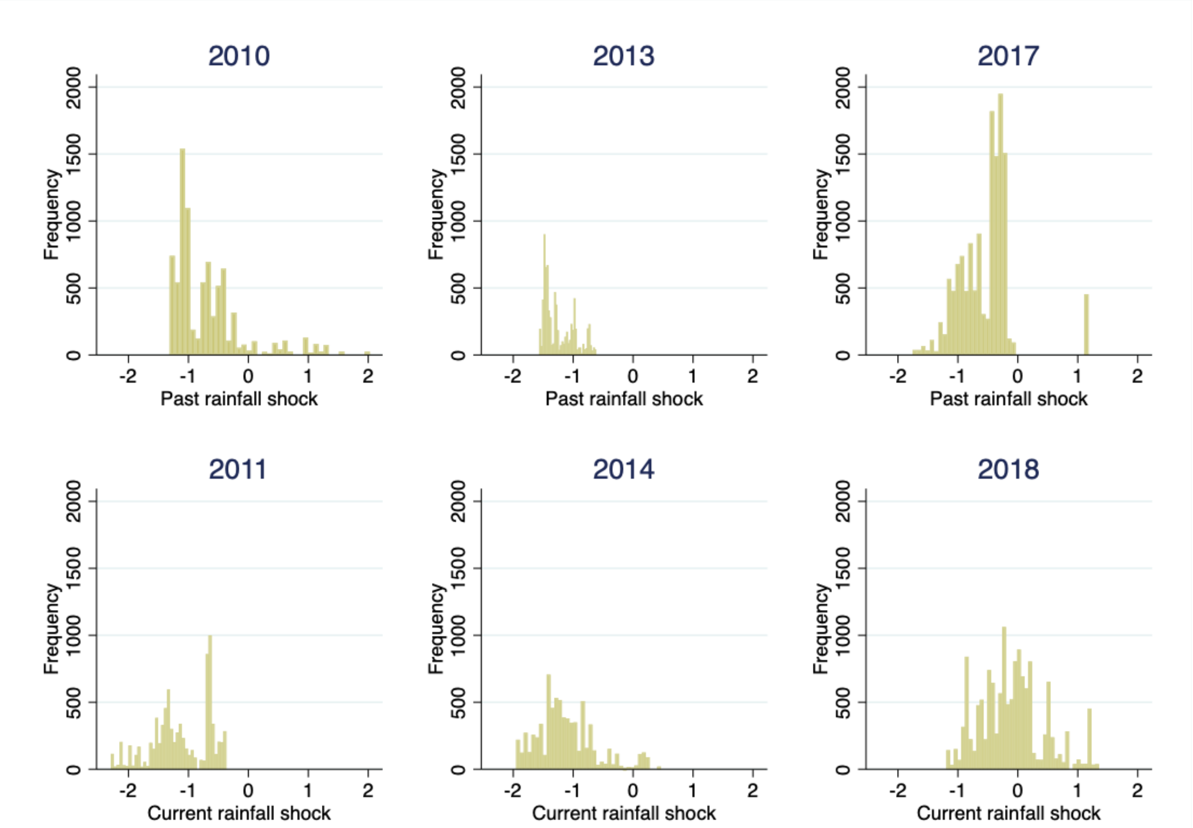

Figure 1: Histogram of rainfall shocks during Rabi season for each year

Note: Calculation by authors.

Table 1: Summary Statistics – Main Variables

	Round 1		Round 2		Round 3	
A. Main variables of interest	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)
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)
B. Climate variables	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Rainfall						
Past rainfall shock	-0.650	(0.605)	-1.242	(0.247)	-0.724	(0.345)
Positive past rainfall shock	0.083	(0.276)	0.000	(0.000)	0.000	(0.000)
Negative past rainfall shock	0.733	(0.409)	1.242	(0.247)	0.724	(0.345)
Current rainfall shock	-1.170	(0.481)	-1.157	(0.427)	-0.218	(0.487)
Positive current rainfall shock	0.000	(0.000)	0.006	(0.038)	0.101	(0.230)
Negative current rainfall shock	1.170	(0.481)	1.163	(0.408)	0.319	(0.346)
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)
Temperature	0.138	(0.013)	-0.693	(0.065)	-0.004	(0.036)
Past temperature shock						
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	

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

	(1)	(2)
Past		
Past rainfall shock	0.203*	
	(0.107)	
Positive past rainfall shock		0.360*
		(0.216)
Negative past rainfall shock		-0.151
		(0.119)
Current		
Current rainfall shock	-0.166***	
	(0.059)	
Positive current rainfall shock		0.042
		(0.205)
Negative current rainfall shock		0.181***
		(0.062)
Controls		
Past temperature shock	0.523	0.972
	(0.893)	(1.059)
Current temperature shock	-1.013*	-1.259**
	(0.574)	(0.642)
Historical rainfall CV	0.043	-2.514
	(3.166)	(3.945)
Historical temperature CV	-172.489	-182.524
	(122.219)	(120.469)
Historical average rainfall (mm)	0.024	0.012
	(0.019)	(0.022)
Historical average temperature (°C)	-1.430	-1.505
	(1.219)	(1.132)
Year FE	Yes	Yes
HH FE	Yes	Yes
N	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.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HH	HH	HH	HH	HH	HH	HH	HH
	Off, Self-emp.	Off, Emp.	On, Self-emp.	On, Emp.	Off, Self-emp.	Off, Emp.	On, Self-emp.	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.

Table 5: Mitigating impacts of mother's labor time

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	Off, Self-emp.	Off, Self-emp.	Off, Emp.	Off, Emp.	On, Self-emp.	On, Self-emp.	On, Emp.	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.

A Appendix

A.1 Supplementary tables

Table A1: Summary Statistics – Other Varibales

	Round 1		Round 2		Round 3	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
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)
Observations	1244		2385		1879	

Table A2: Labor change in response to prior and current rainfall shocks: Household members except mothers

	(1) Off, Self-emp.	(2) Off, Emp.	(3) On, Self-emp.	(4) 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 A3: 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 A4: 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 A5: 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.

Table A6: 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 restricted 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 A7: 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 A8: 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.

Table A9: The effect of rainfall shock: Different definitions

Outcome	(1) WAZ	(2) WAZ	(3) WAZ	(4) Diarrhea	(5) Diarrhea	(6) 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 coefficient of this term is dropped. The coefficient is also dropped in CRE model.

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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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