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Thriving in the rain: natural shocks, time allocation, and women's empowerment in Bangladesh

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ABSTRACT

In low- and middle-income countries, differences between men and women in their time use patterns represent a major source of gender inequality. Among other factors, natural shocks can affect these differences. This paper examines the impact of the 2017 flood in Bangladesh on men's and women's time use patterns and women's empowerment. Using georeferenced and longitudinal data, we find that the flood decreased women's time spent on domestic work while increasing their engagement in income generating activities and empowerment. In contrast, men spent less time at work and increased their participation in domestic work to substitute for women's. These responses to the shock are confirmed only for those individuals who were exposed to another flooding event that occurred in 2014. To better understand the underlying mechanisms, we look at the long-term impact of the 2014 flood on women's empowerment and on their engagement in income generating activities, and we find that the shock still positively affects both variables. These results suggest that when an increase in empowerment naturally occurs within the household, it persists over time and influences reactions to subsequent shocks.

1. Introduction

Gender differences in time use represent a major source of gender inequality worldwide: women tend to work more than men when both domestic and market activities are considered (Anxo et al., 2011; Ferrant et al., 2014); they tend to be more time-poor than men, i.e., lack the time for rest and leisure after considering the time spent at work, whether in the labour market or at home (Solotaroff et al., 2019); and they are usually responsible for the overall management of the household (Dean et al., 2022).

In low- and middle-income countries, such inequalities are even more exacerbated, and they are shaped by several factors, including natural shocks and climate change (Halliday, 2012; Garg et al., 2020). In the aftermath of a natural shock, women may engage more in paid activities to contribute to the household's increased economic expenses, reallocating their time from domestic work to market and leisure activities (Canessa and Giannelli, 2021; Lee et al., 2021). By increasing women's labour supply, exogenous negative shocks can lead to long-term changes in women's economic position within the household, and they can shape prevailing social norms through the disruption of the traditional replication of gender roles within the household (Bradshaw and Fordham, 2013). Indeed, while women engage more in paid activities as a risk-coping mechanism (Canessa and Giannelli, 2021), the social acceptability of women's employment may grow, followed by a more gender-equal division of time spent within the household (Moreno and Shaw, 2018).

Understanding these mechanisms is critical for designing better policies that encourage a gender-driven response to adaptation to climate change, especially when considering that natural disasters are not gender-neutral and that women tend to be more vulnerable to them than men are (Jost et al., 2016; Rao et al., 2019). This paper examines whether and to what extent extreme weather shocks impact women's and men's time allocation, time poverty, and women's empowerment. Specifically, by combining detailed panel data with high-precision satellite data, this study seeks to assess the impact of a severe flood that occurred in Bangladesh in 2017 on the reallocation of time by men and women, and on women's engagement in income generating activities. Then, this paper aims to deepen our understanding of the long-term impact of natural shocks on women's economic autonomy and empowerment. Building upon a recent paper showing that the flood that

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occurred in 2014 in Bangladesh led to an increase in women's earning capacity and their empowerment (Canessa and Giannelli, 2021), this study asks whether this increase persists over time and whether it leads men and women to react differently to the shock in 2017.

For the analysis, georeferenced data from NASA satellites are used to measure the impact of the flood as the share of inundated areas for each sampled household (Gröger and Zylberberg, 2016; Giannelli and Canessa, 2022). We match these data with the Bangladesh Integrated Household Survey (BIHS), a panel dataset representative of rural Bangladesh that was collected by the International Food Policy Research Institute (IFPRI) in 2012, 2015, and 2018. These data are particularly suited for this study for three reasons. First, they allow us to conduct the analysis of time allocation in the aftermath of both shocks. Indeed, the second and third waves were collected in a period ranging from three to nine months from the occurrence of the flood, depending on the month of the interview. Second, they include an extensive module on time use that was administered to both spouses in a household. Third, they allow us to include both shocks in the analysis.

The identification strategy relies on a difference-in-difference approach. Following the recent literature (De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021), we first assess the relevance of the documented problems of staggered adoption and heterogeneous treatment effects in our context. We compute the negative weights in our sample as suggested by De Chaisemartin and d'Haultfoeuille (2020), and we find positive evidence for using standard linear techniques. The treatment variable is the share of inundated areas in 2017 around each sampled household. Thanks to the nature of the data, we are able to conduct an in-depth analysis of the impact of repeated shocks on time use. Indeed, we estimate distinct equations at the individual level for men and women to assess the impact of the flood. Since the potential spillover effects of the flood in 2014 may affect the results on the impact of the flood in 2017, we then conduct the analysis on two subsamples of the population: those individuals who were exposed to the flood in 2014 and those who were not. We then test as potential contributing mechanism whether the documented increase in women's empowerment induced by the flood in 2014 persists in 2018, employing as a treatment variable the share of inundated areas around each sampled household in 2014. It is worth noting that the empirical analysis is conducted using only the waves in 2015 and in 2018, as we are mostly interested in analysing the impact of each shock separately.[1]

The results indicate that the 2017 flood had a significant impact on time allocation for both men and women. Women spent less time on domestic work and more time on leisure activities, while men devoted more time to domestic chores, rendering them more time-poor. Additionally, the flood prompted women to engage more in income generating activities, namely, work that provides own earnings, while other market-related activities, such as household farm work, typically remain unpaid. Through this shift, women experienced an increase in empowerment, as measured by the Women's Empowerment in Agriculture Index (WEAI).

When we disentangle these impacts for individuals who experienced the flood in 2014 and those who did not, we find that these results are driven by households who experienced both shocks. Within this group, women also experienced a significant reduction in time poverty. Conversely, among households exclusively affected by the 2017 flood, women allocated more time to domestic chores, leading to an increase in time poverty, and they spent less time on household farm work, but did not engage in more income generating activities. Men also decreased their involvement in household farm activities, likely attributable to the damage caused by the flood.[2]

Regarding the long-term impact of natural shocks on women's engagement in income generating activities and empowerment, we find that the 2014 flood led to a persistent increase in engagement in paid activities, in women's empowerment, and in women's economic autonomy (measured using the two WEAI sub-indexes of "control over use of income" and "decision-making power over productive resources"). These findings highlight the importance of women's contributions to household economy when adapting to and coping with natural disasters. Additionally, they emphasize the importance of promoting women's economic autonomy, as the positive effects tend to persist over time once they enter the workforce.

This work contributes to the literature in two ways. First, it is one of the first studies to investigate the gender-specific impact of natural shocks on time use and time poverty. Time use data are particularly useful for conducting in-depth analyses of individual and social behaviours, as well as for gaining a better understanding of policy impacts on women, men, and children (Floro and King, 2016). This research expands on the use of such data to better understand how people react to recurrent climatic shocks. Extreme weather occurrences are becoming more common as a result of climate change, particularly in low- and middle-income countries (Guiteras et al., 2015). To build more effective, gender-differentiated, and informed policies, it is necessary to have a thorough understanding of how households respond to shocks and how such shocks influence the daily activities of men and women differently.

Second, this study provides quantitative estimates of the long-term influence of natural shocks on women's empowerment and employment. Building on recent research that shows that the 2014 flood in Bangladesh led to an increase in women's income generating activities and empowerment in the short term (i.e., in 2015, right after the shock) (Canessa and Giannelli, 2021), this analysis corroborates and expands on these findings by demonstrating that such changes persist over time. Indeed, by using the third wave of the panel and georeferenced data at the household rather than at the village level, this research examines the long-term impact of the 2014 flood on women's empowerment and shows that the increase in women's empowerment brought about by this flood has persisted over time, leading women to engage more in paid than in reproductive work. These findings have far-reaching implications, as they demonstrate that when an increase in women's engagement in paid activities and empowerment occurs endogenously within the household irrespective of participation in affirmative policies and programs, their economic autonomy persists over time and leads to long-term changes in women's and men's behaviours within the household.

The paper proceeds as follows: Section 2 presents the theoretical framework; Section 3 describes the context of the study; Section 4 presents the data employed for the study; Section 5 explains the empirical methodology adopted for the analysis; Section 6 introduces the results; Section 7 provides robustness checks; and Section 8 concludes.

2. Theoretical framework

Our study examines the shifts in women's time allocation following a climate shock, with a particular emphasis on the time dedicated to income generating activities. We aim to explore the potential implications of these changes for women's economic roles and autonomy within the household. We utilize the conceptual framework depicted in Figure 1 as a basis for presenting our empirical analysis. The analysis encompasses three temporal points (T0, T1, and T2) involving repeated weather shocks. Starting in the left-hand corner of the framework (in T0 before the shock), in rural settings households are involved in cultivating crops on their farms. This involvement serves both subsistence needs and the

[1] We are interested in understanding the impact of the shock on time allocation between men and women in the short term (i.e., right after the 2017 flood), and the impact on women's empowerment in the long term (i.e., four years after the occurrence of the 2014 flood).

[2] Unfortunately, detailed data on alternative labor market engagements for men are not available in the survey.

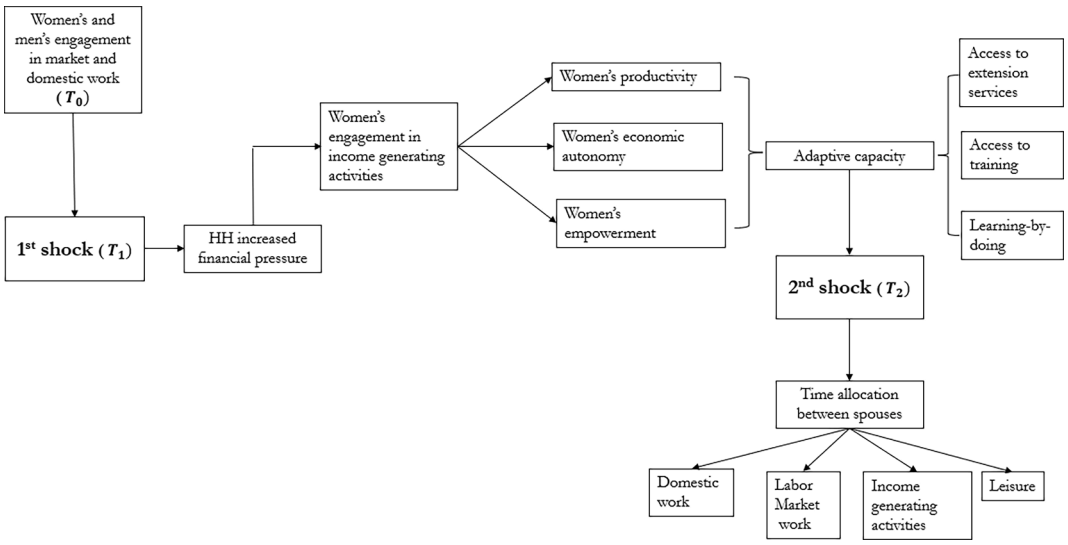

Figure 1. Theoretical framework.

production of crops and goods for sale in the market (market work).[3] Typically, both men and women participate in these activities, although women predominantly bear the additional responsibility of domestic work.

Extreme weather shocks will expose the affected households to unforeseen and substantial income losses, creating financial pressures that could significantly influence the allocation of time between men and women in various ways. At T1, when the first shock hits, women may engage more in paid activities, contributing to the household's income through their own earnings, shifting their focus from domestic work to income generating activities and leisure (Canessa and Giannelli, 2021; Lee et al., 2021). The central part of Figure 1 illustrates this strategy, which is the focus of our study.

When women actively engage in activities that grant them direct access to their earned income, it is expected that this will enhance productivity, increase their economic autonomy within the household, and bring about positive changes in empowerment and gender roles (Moreno and Shaw, 2018). Both partners recognize the advantages of women's active participation in the household economy, as highlighted by Anderson and Eswaran (2009). This increased involvement in paid activities has the potential to prompt positive, enduring changes that impact responses to subsequent shocks and reshape the allocation of time for both men and women.

These positive changes require a period of adjustment, and the time between T1 and T2 serves as an "adjustment" phase during which adaptive capacity develops. Women increasingly participate in income generating activities, enhancing their autonomy within the household, and both spouses increasingly accept their involvement in paid employment. At the same time, adaptive capacity is nurtured through access to training and extension services, often provided by external aid sources (upper right-hand side of Figure 1).[4] These services also promote a learning-by-doing process, equipping households to respond more effectively to subsequent shocks (Sarma et al., 2023).

This dynamic concept of adaptation highlights the importance of learning, exchanging information, and sharing knowledge to anticipate, forecast, and respond effectively to future weather shocks. The involvement of women becomes pivotal in adapting to natural shocks as they engage in alternative livelihood activities alongside their regular household responsibilities (Azad and Pritchard, 2023). In such scenarios, women may find themselves taking on new roles in disaster preparedness, ensuring food security, and managing farms, all tasks for which they are often unprepared. In T2, when the second shock occurs, both men and women are expected to respond more promptly and replicate the adaptation strategy implemented between T1 and T2 at an accelerated pace. Adopting roles where women have an active earning capacity within the household, women are anticipated to engage more in income generating activities as a productive coping strategy, reallocating their time from domestic to paid activities and leisure activities. At the same time, men may take over part of their wives' domestic responsibilities. This change is aimed at granting women more time to participate in productive work. The lower section of Figure 1 indicates the process of reallocating time between partners.

In our study, the available data enables us to draw evidence regarding the evolution of the adaptation strategy across the three periods. This is achieved by differentiating between households that experienced a single impact from those affected twice by flooding. We make predictions by observing the distinct reactions of these two groups to the most recent flooding event. The group impacted only in T2 is expected to exhibit an emergency strategy, indicative of unpreparedness. On the other hand, the group impacted twice should manifest the effects of women's adaptive capacity leading to resilience, as depicted in the graph. More specifically, the nature of the data enables us to examine whether the period after the first shock has prepared women to shift their time from domestic to paid activities after the second shock. Men, in turn, may substitute women increasing their time spent in domestic chores, a shift that, in the Bangladeshi context, primarily entails increased involvement in market activities for shopping.

3. The context: Gender norms and time allocation in Bangladesh

Bangladesh is a patriarchal society where men control property, income, and women's labour (Cain et al., 1979). Women in rural Bangladesh find themselves trapped in a circle that sees their role changing from daughter to wife to mother with little possibility of expressing independent goals or aspirations (Solotaroff et al., 2019). Patriarchy generates a system in which men feel allowed to claim power over women's lives. A major example of such control is "purdah" (i.e., seclusion), a common practice that confines women's sphere of activities within the homestead, limiting their access to economic and social opportunities (Solotaroff et al., 2019). For instance, the strict application of purdah prevents women from cultivating land themselves or from going to the market, and all these tasks must be interceded by male household

[3] For the definition of market work used in this paper refer to Section 4.2.

[4] Note that this part of the graph is only suggestive as our data do not allow us to test for access to these services.

members (Solotaroff et al., 2019). Purdah also hinders women's access to the labour market, as they have to engage in income-generating activities within the compound (Cain et al., 1979; Kabeer, 1988). These patriarchal norms have engendered a highly segregated labour market and a rigid division of labour that still persists today (Heintz et al., 2018; Kabeer et al., 2021).

Another common practice in rural Bangladesh is exogamy, i.e., marrying one's daughter to a man living in another village (Cain et al., 1979; Kabeer, 1988). The application of exogamy makes women vulnerable and powerless. Indeed, when they marry, women move to the village where their husband lives, weakening their ties with their family of origin (Cain et al., 1979). Once married, women's autonomy is particularly limited because they are subjected to the will and supervision not only of their husband but also of their mother-in-law, who plays an essential role within the family (Solotaroff et al., 2019). More generally, the practice of exogamy makes parents invest less in their daughter's education, as she leaves the household at an early stage of her life (Solotaroff et al., 2019). In addition, women tend to not claim their land inheritance because they live away from their father's property and have to rely on others to represent their interests (Kabeer, 1988).

These norms define a strict division of labour within the household. Women employ most of their time in domestic work, to which men mainly contribute by shopping for consumer goods since purdah severely limits women's ability to go to the market (Cain et al., 1979). While men specialize in the stage of agricultural production that is carried out in public space, women engage in activities that are carried out within the home (Kabeer et al., 2021). Consequently, women tend to specialize in activities that keep them close to the homestead, such as food processing and preparation, animal husbandry, and household maintenance (Cain et al., 1979). For agricultural work, while men specialize in harvest and preharvest activities, women specialize in postharvest activities (Cain et al., 1979). Women's peak periods of agricultural activity are in December-January and June-July, while they engage more in income earning activities during February-March, which is a busy period for garden cultivation, hut repair, and handicrafts (Cain et al., 1979).

These well-defined gender roles make women particularly vulnerable to negative shocks (Islam et al., 2017; Solotaroff et al., 2019). Indeed, they are not only at higher risk of being physically injured by disasters such as floods (Cannon, 2002), but their coping strategies are also less effective because they lack access to crucial productive assets and resources (Solotaroff et al., 2019). Women are usually denied access to land (Solotaroff et al., 2019; Kabeer et al., 2021), and even if they are legally entitled to part of an inheritance, they usually trade this right with their kin in exchange for support in times of potential distress (Kabeer, 1988; Kabeer et al., 2021). Since land is usually not registered in their names, women cannot claim any compensation for any crop loss caused by regular flooding and erosion (Solotaroff et al., 2019). During floods, women have to plan and implement measures to mitigate disasters and risks. These measures include but are not limited to activities such as preserving fuels and storing food, preparing portable mud stoves for future use, collecting and storing firewood in dry places, and storing fodder for domestic animals (Khandker, 1988). In the aftermath of the shock, women mitigate the household risk induced by the flood by participating in food processing and selling in local markets, rearing cattle and poultry, doing small business, and saving for children's education (Khandker, 2007).

4. Data

4.1. GIS data and floods

Between 2011 and 2018, Bangladesh experienced two severe flooding events in 2014 and 2017. From mid-August 2014 until the end of September 2014, heavy rains and overflows from the Brahmaputra and Ganges rivers caused severe flooding that affected almost 3 million people, with an estimated 275,000 individuals displaced. The flood was particularly intense in the northeastern part of the country, where more than 10,000 acres of crops were inundated and more than 600 schools remained closed. This event was registered as the worst event to affect the country since the flood in 2007.[5]

From August 2017 to mid-September 2017, Bangladesh was hit again by a dramatic flood that was recorded as one of the worst flooding events in recent history, affecting almost 7 million people and 9,000 villages. The overflows of the Brahmaputra and Ganges rivers led to the inundation of 31 districts in the northern part of the country. The flood caused significant damage to housing and infrastructures, particularly schools, roads, and railways, which resulted in the inundation of additional areas that otherwise would have been protected. In particular, the flood damaged the agricultural sector, causing losses in food crops (including the main staple, rice) and livestock and fish stocks.[6]

The treatment is defined as the households' exposure to the inundations. Following the literature (Gröger and Zylberberg, 2016; Giannelli and Canessa, 2022), we adopt georeferenced data to build the treatment variable. More specifically, we adopt the NASA Flooding Map, a product composed of 250-mt resolution images, that defines flooded areas as water observations falling outside normal water levels.[7] As in Giannelli and Canessa (2022), we adopt a composite image for an interval of 15 days, in which an area is defined as flooded if it is recognized as such for at least 2 days. This time span of the composite image overcomes the issue of cloud coverage, thus providing more detailed data. We construct two treatment variables for the analysis, one for each flood. To decide which reference period to consider for the flood, we follow the information reported in the Official Reports in 2014 and in 2017 of the Bangladesh Water Development Board of the National Government. In 2014, the report stated that the flood reached its highest peak at the end of August and during the first 10 days of September, while in 2017, the highest peak was reached during the last two weeks of August.

The units of analysis for the shock are the 6,500 sampled households, which are nationally representative of the country's rural areas. While Giannelli and Canessa (2022) define their treatment at the village level, for this study, we had access to the georeferenced coordinates of the households, which were released with the Harmonized Bangladesh Integrated Household Survey in September 2017. The treatment variable is then defined as the share of pixels identified as "flooded" in a 5-km radius for each household in the sample. As robustness checks, we repeat the analysis for 2- and 10-km radiuses. The 5 km radius should include the areas of agricultural activities of rural households (Gröger and Zylberberg, 2016; Canessa and Giannelli, 2021). Indeed, data in Table 1 show that the average distance of the land from the homestead is approximately 0.5 km.

For 2017, with the treatment specification of the 5-km radius, the mean share of inundated areas corresponds to 9 percent, with the maximum reaching 93 percent. In normal times (i.e., the first two weeks of July 2017), the mean share is very low, approximately 1 percent, while the maximum reaches 22 percent. Figure 2 shows the average share of flooded areas for selected intervals before (1st to 14th of July 2017), during landfall (16th to 29th of August 2017), and in two periods after landfall (29th to 11th of September 2017 and 15th to 30th of September 2017). The figure shows that 9 percent of the median household is inundated during the last two weeks of August. This number reaches 98 percent for the most affected households. It is important to note that after one month, approximately 7 percent of the households are still inundated, probably because of differences in soil absorption. This may differently impact time allocation among

[5] https://reliefweb.int/sites/reliefweb.int/files/resources/a-i7876e_0.pdf
[6] https://reliefweb.int/disaster/fl-2014-000117-bgd
[7] All data are publicly available at the following link: https://floodmap.modaps.eosdis.nasa.gov/index.php

Table 1
Descriptive statistics at baseline (2015).

Variables	Obs	Mean	Std. Dev.	Min	Max
Women Time spent on domestic work (minutes)	2704	429.381	165.223	0.000	1140.000
Time spent on market work (minutes)	2704	151.925	154.738	0.000	1050.000
Time spent on leisure activities (minutes)	2704	191.233	132.526	0.000	840.000
Time poverty	2704	0.382	0.486	0.000	1.000
WEAI	2704	0.414	0.139	0.090	0.900
Engagement in income generating activities (IGA)	2704	0.786	0.411	0.000	1.000
Work place (=1 homestead, 0 outside)	2124	0.7504	0.432	0.000	1.000
Age	2704	38.515	10.533	15.000	73.000
Men Time spent on domestic work (minutes)	2704	65.581	113.159	0.000	855.000
Time spent on market work (minutes)	2704	511.731	248.279	0.000	1530.000
Time spent on leisure activities (minutes)	2704	197.674	169.082	0.000	1035.000
Time poverty	2704	0.443	0.497	0.000	1.000
Age	2704	46.557	12.217	22.000	105.000
GIS data Flood 16 Aug. – 29 Aug. 2017	5408	0.090	0.189	0.000	0.982
Flood 1 July – 14 July 2017	5408	0.009	0.040	0.000	0.532
Flood 28 Aug. – 10 Sept. 2014	5408	0.080	0.187	0.000	0.978
Flood 1 July – 14 July 2014	5408	0.037	0.113	0.000	0.854
Flood – dummy variable	1164	0.148	0.355	0.000	1.000
Household asset Number of electric iron owned by	5408	0.072	0.281	0.000	4.000
Number of metal pots owned by hh	5408	14.195	9.404	1.000	126.000
Number of stove owned by hh	5408	0.053	0.264	0.000	5.000
Number of tv owned by hh	5408	0.329	0.516	0.000	4.000

Note: the reported variables are, respectively: the time measured in minutes spent in domestic work, market work, and leisure activities for both men and women; a dummy variables equals to 1 if the respondent worked more than 10.5 h the day prior to the interview for both men and women; the Women's Empowerment in Agriculture Index measured following Alkire et al. (2013); a dummy equals to 1 if the woman reported engaging in income generating activities at the time of the interview; the age of the respondent; the incidence of the flood between August 16 and August 29, 2017; between July 1 and July 14, 2017; between August 28 and September 10, 2014; between July 1 and July 14, 2014; a dummy variables equals to 1 if the respondent reported being exposed to a flood in the 5 years preceding the interview; the number of electric irons owned by the household; the number of metal pots owned by the household; the number of stoves owned by the household; and the number of televisions owned by the household.

household members. Figure 4 in the appendix shows the incidence of the flood during the last 2 weeks of August 2017.

4.2. BIHS data

The Bangladesh Integrated Household Survey is a panel dataset that was collected by IFPRI in three rounds, the first in 2011 (October 2011 – June 2012), the second in 2015 (January – June 2015), and the third in 2018 (November 2017 – March 2018). The survey is nationally representative of the rural areas in all seven divisions of the country, and it follows approximately 6,500 households over the three waves. The attrition rate at the household level is 4.4 between the first and second waves and 6.7 between the second and third waves. Importantly, the nature of the data allows for analysing both the short and long term impacts of the 2014 and 2017 flooding events. As illustrated in Figure 5 in the appendix, when we look at the impact of the 2017 flood on the outcomes of interest in 2018, we refer to the short term, and when we look at the impact of the 2014 flood on the outcomes of interest in 2018, we refer to the long term.

The data provide detailed information at the household and individual level about socioeconomic characteristics, as well as agricultural production and practices, dietary intake, anthropometric measurements, and data to measure the Women's Empowerment in Agriculture Index (WEAI). One of the modules of the WEAI covers time use and was administered to both the head of the household and their spouse. The data were collected using time diaries, in which respondents were asked to recall the time spent on activities in the 24 h prior to the interview, starting at 4:00 am of the day before the interview. Thanks to their sequential nature paired with a very short recall period (i.e., 15 min), time-use diaries are more likely than stylized questions to avoid recall bias because they help respondents accurately remember their daily activities (Seymour et al., 2020). The main threat of time-use diaries in agricultural settings is that a 24-hour recall does not adequately consider all factors of time allocation. For instance, time-use diaries do not capture seasonal variations or account for festivities – if the day prior to the interview was a holiday, the data may not capture the actual dimension of individuals' workload (Alkire et al., 2013; Seymour et al., 2020). To account for the former concern, we add dummy variables to control for the month of the interview in the analysis. Regarding the latter concern, in the sample, only 6 percent of the respondents reported that the day before the interview was a holiday.

Our sample consists of 16,230 observations at the individual level, specifically, 2,705 women and 2,705 men per year. Because gender roles within the household are particularly strict in Bangladesh and they greatly influence women's and men's time allocation, to have more accurate information on our outcomes of interest, we decided to focus only on household heads and spouses, and we included in the sample only individuals who were present in all three waves and who reported being the household head or the spouse in the time-use module.[8] In this way, approximately 20 percent of the observations from the original sample are dropped. As aforementioned, the aim of this study is to analyse the impact of the two floods on women's and men's time use patterns, their time poverty, women's probability of engaging in income generating activities and, finally, on women's empowerment as measured with the WEAI. Thus, the outcome variables for time use patterns are the time measured in minutes, spent on domestic work, market work, and leisure activities in the last 24 h.

To construct our time use variables, we follow Seymour et al. (2020) and we exploit the time allocation module of the WEAI questionnaire. Our Domestic Work variable corresponds to the sum of the categories listed in module as "domestic work", "caring for children and elderly individuals", "cooking and cleaning", and "shopping and or obtaining services". Note that "domestic activities", not otherwise specified, are recorded separately from the more typical household chores of urban or more developed areas. Women in rural areas, spanning various age groups, dedicate a significant portion of their day to unpaid domestic responsibilities such as gathering water and firewood, travelling and transporting materials (Bardasi and Wodon, 2006). Our Market Work

[8] Moreover, the time-use module is supposed to be administered to the main respondents of the household.

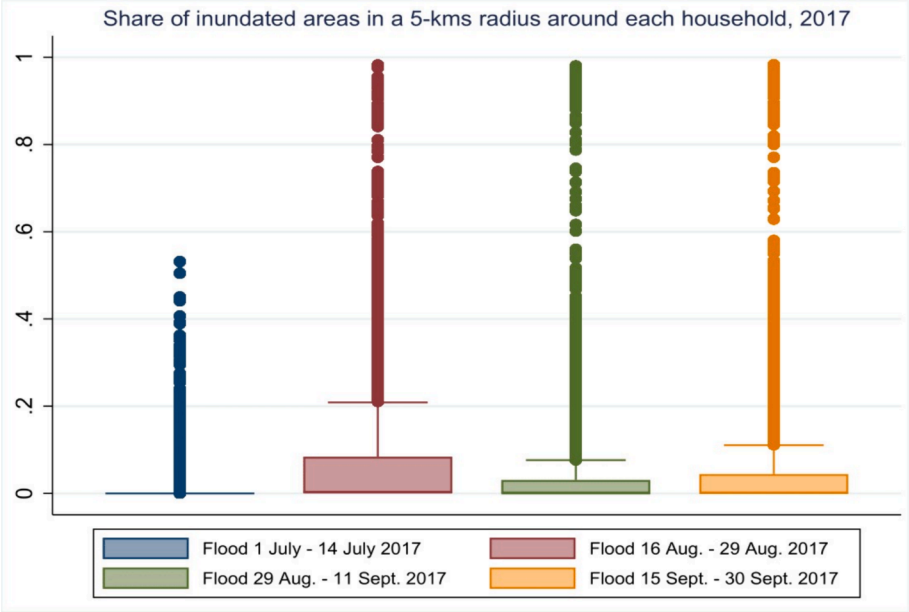

Figure 2. Share of inundated areas, 2017.

variable corresponds to the sum of the categories "working as employed or in one's own business", "farming and/or fishing", "working in construction", and "commuting". Our Leisure variable is the sum of "watching TV, listening to the radio, reading", "exercising", "sitting with family", engaging in "social" and "religious activities". The Time Poverty dummy is defined following Alkire et al. (2013) and Bardasi and Wodon (2006): an individual is time-poor if she worked more than 10.5 h in the day prior to the interview.

Note that the purpose of the WEAI time use module is to assess whether respondents, particularly women, have an excessive workload based on their time allocation to market and non-market activities (Seymour et al., 2020). Consequently, the module does not collect information on whether market activities generate income. Then, our Market Work variable does not imply that women participate in occupations where they earn an income directly accessible to them. In rural areas of low- and middle-income countries, women predominantly engage in unpaid work within the family farm or business, as "contributing family workers" who, as per ILO definition, "work in a market-oriented establishment operated by a related person living in the same household. They cannot be regarded as partners because their degree of commitment to the operation of the establishment is not at a level comparable to that of the head of the establishment".[9]

Therefore, our market work variable is a proxy of contributing family work. To overcome this limitation and directly measure women's engagement in income generating activities, we build a dummy variable that is equal to 1 if the woman answers positively to the following question: "Are you currently involved in any work or business that generates income, provides extra food, or helps you build assets for your household?". In this way, we are able to distinguish between paid and contributing family work and examine whether the floods had an impact on women's likelihood of engaging in income generating activities (IGA) (Canessa and Giannelli, 2021). Formulated in this way, the question, particularly its final segment, suggests that such resources accrue to the respondents, allowing them to decide their allocation. Importantly, as shown in Table 1, 75 percent of the women in the sample reported engaging in these activities at home, whereas 15 percent reported doing so outside or a in a combination of the two locations. Empowerment is measured through the WEAI, a survey-based index used to assess women's empowerment in agricultural settings, following Alkire et al. (2013). The index is composed of two subindexes: the five domains of empowerment (5DE) and the Gender Parity Index (GPI), which are weighted at 90 and 10 percent, respectively, in the final index. The 5DE score is a weighted average of 10 indicators grouped into the following five domains: (1) decisions about agricultural production, (2) access to and decision-making power over productive resources, (3) control over the use of income, (4) leadership in the community, and (5) time allocation (Alkire et al., 2013). Women are considered adequate on each indicator if their score is equal to or higher than a specified threshold for each domain (Alkire et al., 2013). We then exploit the two sub-indexes "control over use of income" and "decision-making power over productive resources" to proxy women's economic autonomy within the household.

Table 1 presents the summary statistics of the sample at baseline (2015). Notably, women spend disproportionately more time than men in domestic work, while men are mostly engaged in market work. Men are also more likely to be time-poor than women, and they spend almost the same amount of time on leisure activities. Hence, the issue is about the gendered division of labour and its consequences for women and, more generally, for households' livelihoods.

Table 8 in the appendix reports summary statistics of households' socio-economic characteristics at baseline (2015). Households in our sample have an average of 4.7 members, 1.5 members under the age of 15, 47 percent of the household heads have never attended school, followed by 41 percent of the spouses. The average age difference between the household head and the spouse is 8 years, while the female quota within the household is 49 percent. Approximately 40 percent of the sample's households have access to electricity, and the average number of livestock held is 78, with a median of 60. The average number of televisions owned by households is 0.3, electric irons are 0.07, metal plots are 14, and stoves are 0.05. The minimum distance between the plot and the house is 0.13 km, the average soil type is sand, and the average flood depth is 2.67 feet. Figure 6 in the appendix also reports the distribution of livestock at baseline.

[9] https://webapps.ilo.org/wcmsp5/groups/public/—dgreports/—integration/documents/publication/wcms_229374.pdf

5. Empirical methodology

5.1. Impact of the flood in 2017 on time use, IGA and women's empowerment

The identification strategy relies on the assumption that the flood, given its exogenous nature, is not correlated with other omitted determinants of time allocation within the household. To estimate the impact of flooding on the time use patterns of men and women, we adopt a difference-in-difference methodology, controlling for time-invariant unobserved individual characteristics of the respondents.[10] The treatment is a continuous variable for the share of inundated areas in 2017 in a range of 5 km around each sampled household. We estimate the following specification for men and women separately:

$$Y_{ihrt} = \beta_0 + \beta_1(T_h{*}t = 2018) + \beta_2(P_h{*}t = 2018) + \beta_3 W_{rt} + \beta_4 X_{iht} + \beta_5 D_t + \beta_6 Z_{ht} + \alpha_i + \varepsilon_{ihrt}$$

where Y_{ihrt} are the outcome variables for each individual i in household h residing in region r at time t; T_h is the treatment variable, i.e., the share of inundated pixels in a buffer of 5-km for each household; t is the time variable; and β_1 is the difference-in-difference coefficient of the treatment, which gives the difference in the outcome of interest after the flood between the treatment and the control group. Following the literature (Gröger and Zylberberg, 2016; Giannelli and Canessa, 2022), P_h is the household propensity to be inundated in normal times, measured by the percentage of water coverage in a buffer of 5-km for each household during the first two weeks of July 2017. This control is used to identify changes in time allocation due to the treatment for those households that have the same propensity to be inundated in normal times. W_{rt} are interactions between wave and region fixed effects to account for changes in regional characteristics over time; D_t are the dummy variables of the month of interview, taking January as a reference to avoid any problem of collinearity. X_{iht} are individual and household socioeconomic characteristics that may shape time-use patterns, namely, the number of members under the age of 15 and the age and education of both spouses. We also control for households' durable, agricultural, and livestock assets, as measured by principal component analysis. We control for the level of wealth rather than for yearly income or expenditure estimates because the latter are usually prone to recall bias, which makes the available information less accurate (Arthi et al., 2016). Z_{ht} is a set of control variables that may influence the home production function, i.e., the number of electric irons owned by the household, the number of gas stoves, the number of cooking stoves, and access to electricity. Since individuals seem to spend most of their time for leisure activities watching television, we also added the number of televisions owned by the household as a control. To control for the household's probability of being inundated, we also control for the distance from the house to the plot, the soil slope, and the soil type. The fixed effects at the individual level are α_i, and ε_{ihrt} is the error term. For the heterogeneity analysis, the identification strategy is the same, but we repeat the analysis separately for men and women for two subsamples of the population, i.e., those individuals who experienced the flood in 2014 and those who did not.

Recent literature has suggested that when the treatment effects are heterogeneous across time and places, the estimation of the average treatment on treated (ATT) may be biased (Callaway and Sant'Anna, 2021; De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021). To assess the extent to which this is the case in our context, we follow De Chaisemartin and d'Haultfoeuille (2020) and we estimate the share of negative weights in our sample. Table 9 in the appendix reports the share of negative weights in the sample and their relevance (i.e., the share of their sum). The share is less than 2 percent, and their relevance is less than 5 percent, suggesting that the bias in our sample is small enough for us to adopt the aforementioned methodology.

5.2. Long-term impact of the flood in 2014 on IGA and women's empowerment

The panel nature of the data allows us also to dig deeper into the mechanisms at play and examine whether the impact of the 2014 flood on women's engagement in IGA and empowerment persists over time. Our long-run period is four years, spanning the time between the flood in 2014 and the endline data collecting in 2018. We examine whether the flood in 2014 still affects women's engagement in IGA and their empowerment, and then we look separately at differences between women who experienced both shocks (i.e., 2014 and 2017), and those who experienced only the 2014 shock. We estimate the same identification strategy as before, employing the engagement in IGA, the WEAI, and the two economic subindexes of the WEAI, i.e., control over the use of income and input in productive decisions, as dependent variables and the share of inundated areas around each sampled household in 2014 as the treatment variable. We control for the same variables at the individual and household levels as in the main time allocation analysis. We estimate the following specification:

$$Y_{ihrt} = \beta_0 + \beta_1(T_h{*}t = 2014) + \beta_2(P_h{*}t = 2014) + \beta_3 W_{rt} + \beta_4 X_{iht} + \beta_5 D_t + \beta_6 Z_{ht} + \alpha_i + \varepsilon_{ihrt}$$

6. Results

This section presents the estimated effects of the flood on the time allocation of men and women, on time poverty, on the likelihood of women engaging in IGA, on their empowerment as measured by the WEAI. We first present the results of the impact of the flood that occurred in 2017, and we then present the results of the heterogeneity analysis, and last, we report the results for the long-term impact of the shock in 2014 on women's engagement in IGA and empowerment.

6.1. The impact of the flood in 2017 on time allocation

As shown in Table 2, the flood in 2017 has significant effects on our variables of interest. Time allocation changes significantly for both men and women who have been impacted by the flood. Indeed, while women engage in 55 fewer minutes in domestic work (around 13 percent less than the baseline value), men increase their time spent in it by 73 min (around 37 percent more than the baseline value). Both women's and men's market work do not change significantly, while women's leisure increases by 94 min (around 50 percent more than the baseline value) while men's leisure does not change significantly. Men's increased engagement in domestic work makes them 17 percentage points more likely to experience time poverty than men who did not experience the flood.

Although market work seems to be unaffected by the flood, as shown in Table 3, the shock significantly increases women's likelihood of engaging in IGA by 37 percentage points and women's empowerment at the 10 percent level. Figure 7 in the appendix reports the impact of the 2017 flood on each activity of our Market Work Variable for women. We find no significant effect on any single activity of the variable. As previously stated, our market work variable for women mostly includes activities related to contributing family work that do not necessarily generate an income directly available to them. We find that women reallocate their time from family towards IGA, and we posit that men's and women's reallocation of time is due to the increased engagement of women in income generating activities as a risk coping strategy. As predicted by Anderson and Eswaran (2009), women engage more in paid activities, reduce their time spent in domestic work and increase

[10] We estimate an Ordinary Least Square (OLS) model for time use variables and the WEAI, while a Linear Probability Model (LPM) when looking at the engagement in IGA.

Table 2
Impact of the flood of 2017 on time use variables for women and men.

	Women				Men			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Domestic work	Market work	Leisure time	Time poverty	Domestic work	Market work	Leisure time	Time poverty
Year 2018	3.631	10.65	38.15***	0.043	-3.681	-18.33	35.14***	-0.010
	(13.90)	(10.22)	(9.587)	(0.0295)	(7.278)	(15.05)	(11.52)	(0.0318)
Treat	-55.55**	-12.42	93.65***	-0.063	73.49***	-61.68	-28.63	0.171**
	(26.86)	(27.29)	(22.47)	(0.084)	(20.13)	(37.57) (25.19)	(0.0828)	
Year#July 2017	203.6*	-46.09	-157.8	0.279	-19.31	-136.3	-91.98	-1.076***
	(106.8)	(99.40)	(97.93)	(0.364)	(92.51)	(154.2)	(109.4)	(0.412)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,352	4,997	5,352	5,352	5,352	5,240	5,352	5,352
R-squared	0.061	0.077	0.091	0.033	0.018	0.013	0.034	0.010
Number of id	2,684	2,680	2,684	2,684	2,684	2,684	2,684	2,684

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported time use variables denote the minutes spent in domestic work, in market work, in leisure activities and time poverty, defined as a dummy equal to 1 if the individual worked more than 10.5 h in the previous day. Control variables are those reported in Section 4.2.

Table 3
Impact of the flood of 2017 on women's engagement in IGA and empowerment.

	(1)	(2)
	IGA	**WEAI**
Year 2018	0.102***	−0.033***
	(0.022)	(0.010)
Treat	**0.373*** **	**0.035***
	(0.060)	**(0.026)**
Year#July 2017	−0.455*	−0.009
	(0.247)	(0.114)
Control	Yes	Yes
Observations	5,352	5,352
R-squared	0.090	0.033
Number of id	2,684	2,684

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The dependent variables are defined as a dummy equal to 1 if the woman reported being engaged in IGA, and the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013). Control variables are those reported in Section 4.2.

their time spent in leisure activities. Consequently, men reallocate their time towards increased engagement in domestic work to substitute for women's. Importantly, men's increased engagement in domestic work is mainly related to the activity "shopping/getting services": when we disentangle the effect for each activity, we find that men reduce their time spent in childcare while substantially increasing the time spent in getting services (Figure 7 in the appendix). This implies that men spend more time outside of the home running domestic-related errands while women engage themselves in IGA within the homestead. These results resonate with qualitative studies analysing the role of women during flooding events in Bangladesh: in-depth qualitative interviews reveal that after these shocks women contribute to family income through livelihood diversification, which usually includes poultry and livestock farming while men during the day go to the market (Azad and Pritchard, 2023).

6.2. Heterogeneity analysis

If the flood in 2014 led to an increase in women's engagement in IGA and empowerment, its effect may influence the reaction to the flood of 2017. To check for this effect, we conduct a heterogeneity analysis on two subsamples of the population, i.e., inundated/not inundated individuals in 2014. The results show significant and opposite effects for the two groups for both women and men.

As shown in Tables 4 and 5, and according to our theoretical framework, the sign of the impact of the flood of 2017 on time use is confirmed only for women who experienced the 2014 flood. Those women significantly decrease their time spent in domestic work by 100 min and increase their leisure by 122 min, while no significant effect on market work is detected. As a result, their likelihood of being time-poor decreases by 21 percentage points. In contrast, women who did not experience the flood in 2014 show the opposite reaction to the flood in 2017. They disproportionately increase their time spent in domestic work and decrease their time spent in market work by 277 min, thus being very likely to be time-poor.

Table 5 confirms the positive and significant impact on women's engagement in IGA, although when disentangling the effect of the flood for these two groups, it appears that only women who were flooded in 2014 are affected, becoming more likely to engage in IGA by 20 percentage points. The effect on the WEAI, already significant at the 10 percent level in the whole sample, is no longer significant for both groups.

Table 10 in the appendix reports results between men who have and have not experienced the flood in 2014: men who were inundated in 2014 increase their time spent in domestic activities by 52 min and decrease their time spent in market activities by 106 min, substituting for the decrease in domestic work of their female counterpart. In contrast, for men who did not experience the flood in 2014, the results show a significant impact only in the reduction of time spent on market work.

The results in Table 2 are consequently driven by the group of households who had previously undergone a significant flooding event a few years earlier. The estimates of men and women who experienced both shocks reflect the effect of the adaptation period mentioned in the theoretical framework, whereas for households that experienced only the second shock we observe the direct impact of the 2017 flood. Both men and women decrease their time spent in market work, most likely because of the disruption caused by the flood to the plots and the household farm, and women increase the time spent in domestic work.[11] It is also interesting to note the differences in the impact of the control variable for "normal times". As previously explained, women in Bangladesh usually engage in specific activities to prepare for floods, such as collecting firewood, storing food, and securing the household.

[11] To further support the interpretation of the results and make sure that they are not driven by unobservable factors, we look at the impact of the 2014 flood on women's time allocation in 2018. As per our theoretical framework, one should expect the 2014 flood to have no effect on women's time allocation in 2018, reflecting the time they need to adapt between the first and second shock. Figure 8 in the appendix shows that the 2014 flood has no significant effect on women's time use in 2018.

Table 4
Impact of the flood of 2017 on time use variables, heterogeneity analysis – women.

	Flood 2014 = yes				Flood 2014 = no			
	(1) Domestic work	(2) Market work	(3) Leisure time	(4) Time poverty	(5) Domestic work	(6) Market work	(7) Leisure time	(8) Time poverty
Year 2018	13.47	39.77***	37.09***	0.158***	26.51*	43.14***	32.50***	0.162***
	(18.44)	(13.83)	(13.26)	(0.0384)	(15.10)	(15.36)	(12.50)	(0.0461)
Treat	**-100.1*** **	**-14.76**	**122.4*** **	**-0.213** **	**466.2*** **	**-277.1** **	**-73.77**	**0.711***
	(30.41)	**(31.89)**	**(26.47)**	**(0.0934)**	**(155.2)**	**(152.3)**	**(126.2)**	**(0.506)**
Year#July 2017	236.7**	-79.50	-185.7*	0.242	-445.7	370.6	-298.4	3.90
	(109.6)	(99.84)	(99.35)	(0.360)	(1986.2)	(1855.3)	(1583.15)	(7.44)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,152	2,908	3,152	3,152	2,202	2,091	2,202	2,202
R-squared	0.085	0.142	0.099	0.057	0.068	0.148	0.081	0.060
Number of id	1,582	1,578	1,582	1,582	1,103	1,103	1,103	1,103

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported time use variables denote the minutes spent in domestic work, in market work, in leisure activities, and time poverty, defined as a dummy equal to 1 if the individual worked more than 10.5 h in the previous day. Control variables are those reported in Section 4.2.

Table 5
Impact of the flood of 2017 on women's engagement in IGA and empowerment, heterogeneity analysis – women.

	Flood 2014 = yes		Flood 2014 = no	
	(1) IGA	(2) WEAI	(3) IGA	(4) WEAI
Year 2018	0.0864***	−0.0268**	0.163***	−0.0505***
	(0.030)	(0.013)	(0.033)	(0.013)
Treat	**0.204*** **	**0.0250**	**0.214**	**−0.142**
	(0.069)	**(0.029)**	**(0.377)**	**(0.132)**
Year#July 2017	−0.459*	0.003	−9.606**	0.004
	(0.244)	(0.115)	(4.761)	(1.432)
Control	Yes	Yes	Yes	Yes
Observations	3,152	3,152	2,200	2,200
R-squared	0.153	0.028	0.081	0.054
Number of id	1,582	1,582	1,102	1,102

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The dependent variables are defined as a dummy equal to 1 if the woman reported being engaged in IGA, and the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013). Control variables are those reported in Section 4.2.

This preparation is reflected in the impact that the control variable for normal times has on the time spent in domestic work, which increases by 236 min for women who experienced the flood in 2014. For the other group, the effect is not significant, and in contrast, the time women spend in domestic work is reduced. The same results are valid for leisure activities: women exposed to the 2014 flood engage less in leisure activities in July 2017, while for those who were not exposed, there is no significant effect. Additionally, women who already experienced the shock reduced their time spent in market activities, while for those who did not experience the shock in 2014, their time spent in productive work increased, even if not significantly. The only similar effects are found in the probability of engaging in IGA, which decreases for both groups in normal times before flooding. These results suggest the presence of an adaptive capacity to climate change, which translates into a learning-by-doing adaptation strategy (Adger et al., 2003; Davidson-Hunt and Berkes, 2003).

6.3. Mechanisms

Overall, these findings suggest that the 2014 flood still holds effects in 2018, leading individuals to react differently to the 2017 shock. As developed in the theoretical framework, we posit that during the period between the two shocks an adaptation mechanism took place during which women who suffered from the 2014 shock and started working to cover the increased household expenses became more productive while implementing adaptation capacity strategies that led both spouses to be more prepared to the second shock. In this section, we test for this contributing mechanism by looking at the long-term impact of the 2014 flood on women's engagement in IGA, empowerment, and on the two economic subindexes of the WEAI (i.e., control over use of income, and decision-making power on productive resources).

As shown in Figure 3, the results are in line with our theoretical framework. The 2014 flood still positively impacts both women's likelihood of engaging in IGA, their empowerment, their control over the use of income, decision-making power in productive decisions, suggesting that its occurrence brought by positive changes in gender roles within the household that would have not occurred otherwise.

When we distinguish between women exposed to the 2017 shock and those who were not, we notice that that the results are mainly driven by those who experienced both shocks. For this subgroup of the sample, women's economic autonomy within the household still holds a positive and significant coefficient, while engagement in IGA and the WEAI are no longer statistically significant. Even though engagement in IGA and the WEAI are not significant anymore, the size of the coefficients and standard errors that are very similar to those of the whole sample suggest that empowerment may continue to increase and that engagement in IGA did not decrease either. Conversely, for the group not hit by the 2017 shock, the level of empowerment in 2018 appears to be unaffected by the 2014 shock. However, these women are less likely to engage in IGA. This difference in outcomes suggests that the 2014 flood, in the absence of a subsequent shock, may not be sufficient to drive sustained changes in empowerment levels or engagement in IGA.

7. Robustness checks

7.1. Attrition

We perform an attrition analysis to address the problem of potential bias due to the correlation between the occurrence of flooding and the failure to track individuals in the following wave because of the displacement of the households or changes in the composition of the family (e.g., men may have migrated to find work in urban areas or women may have become widowers).[12] To account for attrition, we run the analysis for the balanced as well as unbalanced samples and compare the coefficient estimates (Wooldridge, 2010): as shown in Table 11 in the appendix, the coefficients are very similar for the 2017 shock in the

[12] It is worth noticing that widows constitute 5.5 percent of the unbalanced sample and 4.3 percent of the balanced sample, and the attrition rate for widows in the sample is 2.11 percent.

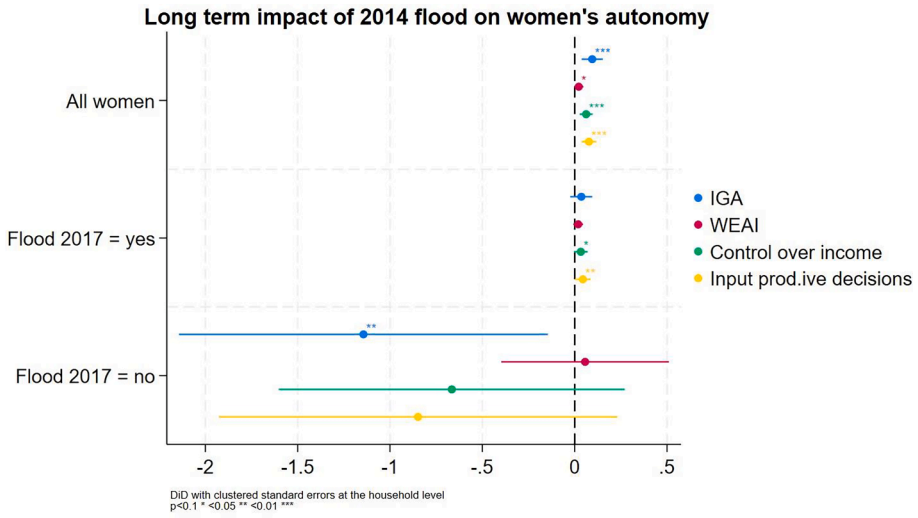

Figure 3. Impact of the 2014 flood on women's autonomy.

balanced and unbalanced samples, thus ruling out the possibility that attrition, in this case, may be selective.

When we look at the impact of the 2014 shock on women's empowerment in 2018 (Table 12), the coefficients between the balanced and unbalanced samples are similar but not the same: in the unbalanced sample, the impact of the flood is no longer significant. The effect on the economic subindexes, instead, is still significant and goes in the same direction as in the balanced sample.

These results may raise concerns about a potential sample composition effect: women who experienced the 2014 flood and were interviewed only at baseline may have dropped out of the sample because they did not survive the shock (i.e., they were less empowered). To check for this concern, we look at differences in the mean empowerment at baseline between attritors and non-attritors. Table 6 shows that there are no significant differences, suggesting that the reason for dropping out from the survey was not linked to their empowerment levels.

7.1.1. Different definitions of the treatment

As a first robustness check of the results, we repeat the analysis with the treatment defined as the share of inundated areas in a radius of 2 and 10 kms around each sampled household. As shown in Tables 13 and 14 in the appendix, results are confirmed with both buffers, suggesting that they are robust across different definitions of the treatment.

7.2. Self-reported data

As an additional robustness check, we also repeat the analysis using as a treatment variable the self-reported information of having been inundated or not in the year preceding the survey. The data provide detailed information on the shocks that the household experienced over the past 5 years. As an alternative treatment, we employ a dummy variable equal to 1 if the household reported loss of crops, livestock, productive assets, and consumption assets due to floods in the year prior to the survey of 2018. Results are shown in Tables 15 and 16 in appendix. Women decrease their time spent in domestic work by 110 min, and they are 33 percentage points less likely to be time poor and 12 percentage points less likely to have any input in production decisions.

Table 6
Mean differences in WEAI between attritors and non-attritors at baseline.

	Non attritors	Mean	Attritors	Mean	Diff.	St. Err.	P-value
WEAI	4010	.534	2262	.53	.004	.004	.346

In contrast, for men, there is no significant impact, even though the sign of the effect of the self-reported shock is consistent with the treatment variable derived from GIS data.

These results confirm that adopting GIS data to study the impact of weather events leads to more accurate, precise, and reliable results. Indeed, self-reported data are subject to several forms of cognitive biases, such as recall error and reference dependence (Guiteras et al., 2015). This last bias is of particular concern when studying the impact of flooding because people may set the average exposure conditions as a reference point and then consider deviations from that specific average. This can translate into different perceptions and, consequently, different reports of the magnitude of the shock between households that are frequently exposed to floods and those that are not (Guiteras et al., 2015).

7.3. Parallel trends

To check for ex-ante correlation between the treatment and the trends of our variables of interest, we follow Gröger and Zylberberg (2016) and Giannelli and Canessa (2022) by performing a balance test at baseline (i.e., 2015) to check for mean differences between treated and untreated individuals before the occurrence of the shock. Table 17 in the appendix reveals that the treatment variable is correlated with some of the outcomes of interest. To ensure that such correlations are not driven by the flood that occurred in 2014, we repeat the analysis in 2011. As shown in Table 17, except for the time spent in leisure activities for men and the likelihood of being time poor for women, the results are not significant, suggesting that in the absence of the shock, the treatment and the control group would have followed the same path. To directly test for the presence of the parallel trend assumption, we then run a placebo test between the first two waves, those in 2011 and 2015. We replicate the benchmark strategy as if the flood hit in 2015, and we estimate the following specification:

$$Y_{ihrt} = \beta_0 + \beta_1(T_h{*}t = 2015) + \beta_2(P_h{*}t = 2015) + \beta_3 W_{rt} + \beta_4 X_{iht} + \beta_5 D_t + \beta_6 Z_{ht} + \alpha_i + \varepsilon_{ihrt}$$

The results are reported in Table 7. For women, the hypothesis of parallel trends seems to be confirmed except for one outcome variable, i.e., the probability of engaging in market work. Since this variable is likely to reflect the persistent impact of the flood in 2014, we add as a control variable the share of inundated areas in 2014. The results show that the impact of the treatment on the outcome is no longer significant. For men, the hypothesis of ex ante correlations between the outcomes of interest and the treatment seems to be insignificant except for two

Table 7
Placebo test with the first two waves on the impact of the flood in 2015.

	Women	Men
	Year 2015#Flood 2017	Year 2015#Flood 2017
(1) Domestic work	14.38	−115.7***
	(30.36)	(39.73)
(2) Market work	44.89	21.71
	(27.89)	(66.67)
(3) Leisure time	−22.60	40.35
	(17.72)	(41.26)
(4) Time poverty	0.0954	−0.297**
	(0.0980)	(0.121)
(5) WEAI	0.0170	
	(0.041)	
(6) IGA	−0.217**	–
	(0.0844)	
Control for flooding in 2014 (7) IGA	0.121	
	(0.144)	
(8) Domestic work		−28.25
		(55.77)
(9) Time poverty		−0.427**
		(0.175)
Number of observations	4,944	4,335
Number of id	2,678	2,676

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables are the minutes spent in domestic work, in market work, in leisure activities, and time poverty, defined as a dummy equal to 1 if the individual worked more than 10.5 h in the previous day; the Women's Empowerment in Agriculture Index, as measured in Alkire et al. (2013), and a dummy equal to 1 if the woman reported being engaged in IGA. Control variables are those reported in Section 4.2.

variables, i.e., the time spent in domestic work and the probability of being time poor. As before, to check whether such results are also driven by the impact of the flood that occurred in 2014, we add as a control variable the share of inundated areas in 2014. While the impact of the flood in 2017 on the time spent in domestic work is no longer significant, it is still significant for the variable capturing time poverty.

8. Discussion and policy implications

Social and cultural norms highly influence time use differences between men and women. In low- and middle-income countries, while men usually engage in productive activities, women are in charge of reproductive work, which includes domestic activities such as cleaning, cooking, and caring for children and agricultural work in household farming. Climate change and extreme weather events risk increasing this disparity in time allocation in both the short and long term. While shocks such as droughts lead women to spend more time in activities such as fetching water or collecting firewood, in the aftermath of flooding, women risk finding themselves overloaded by their engagement in both market and reproductive activities. Although a large body of literature has focused on time use patterns in such contexts, gender-specific responses to weather shocks in time allocation have not yet received much attention.

This study assesses the impact of a dramatic flood that hit Bangladesh in 2017 on the time allocation of women and men and on women's empowerment. As the data allow for including another dramatic flood that occurred in 2014 (Giannelli and Canessa, 2022), we also analyse the heterogeneous impact of the flood in 2017, distinguishing between individuals who had been previously inundated and those who had not. The use of GIS satellite data and panel data allows for the identification of the impact of the flood while controlling for unobserved time-invariant characteristics.

One of the strengths of this study is the use of georeferenced data, which is employed to construct both the treatment and control variables. As shown in the robustness checks, GIS data provide more robust and reliable results than self-reported data, which are usually prone to cognitive biases such as recall bias. In addition, the results seem to hold using an additional definition of the treatment variable. Finally, the use of the first and second waves as a placebo test confirms that the parallel trend assumption holds for this analysis.

The results of the difference-in-difference estimation suggest that after the shock, women's time allocation shifts towards paid activities and leisure activities, while their time spent in domestic work decreases. On the other hand, men seem to engage less in market activities while substituting for women in domestic work, their leisure decreases, and they become more time-poor. These results are in line with the cross-sectional analysis by Anderson and Eswaran (2009), according to which women's autonomy in Bangladesh increases as their engagement in IGA outside the household does and men start contributing more to domestic work. The heterogeneity analysis sheds light on the mechanisms underlying such changes in time allocation. The results show that individuals exposed to the 2014 flood react differently from those that were not, suggesting the existence of an adaptive capacity to climate change. Indeed, it seems that individuals adopted a "learning-by-doing" mechanism that in the long term can help them reduce the damages of natural shocks and extreme weather events.

The 2014 shock leads to a persistent increase in women's engagement in IGA, their empowerment, and their economic autonomy which affect the reaction to the 2017 shock. These results are particularly important as they show that, in a patriarchal context with well-defined gender roles, women's engagement in IGA and their economic autonomy within the household depends on the occurrence of repeated exogenous shocks that require them to work more as a coping strategy to contribute to the increased household expenses. When gender roles are challenged endogenously, positive, long-term changes occur that could affect both spouses behaviours and beliefs.

From a policy perspective, the findings of this study could have important implications from different points of view. First, this study shows that women's and men's time use patterns react differently to weather shocks and are influenced by two factors: women's level of empowerment and individuals' adaptive capacity to climate change. Both of these factors are important targets for the attainment of the Sustainable Development Goals (SDGs), especially SGD 5 (i.e., "Achieve gender equality and empower all women and girls") and SGD 13 (i.e., "Take urgent action to combat climate change and its impact").[13] As already stated, women are more vulnerable than men to natural shocks because they lack access to and control over financial resources and extension services and because of the gender norms limiting their spheres of activity (Jost et al., 2016). Gender-specific development interventions should be designed to increase women's ability to cope with shocks and enhance their adaptive capacity.

Adaptive capacity, as considered in its dynamic perspective, could be boosted by skills development programs and farmer-to-farmer extension services (Jost et al., 2016). Importantly, such programs should target both spouses, or at least a male and a female member of the household, to overcome women's mobility restrictions that are linked to the practice of purdah and to increase their participation in such programs. Another important element to consider is information: improving women's access to weather and climate information, particularly seasonal weather forecasts (Diouf et al., 2020), could significantly improve their flood preparedness. In rural Bangladesh, information is primarily accessed via radio, but access via television could significantly improve understanding of the information itself (Jost et al., 2016).

Microcredit could be an effective instrument for enhancing women's access to resources to cope with natural shocks (Attanasio et al., 2015;

[13] https://sdgs.un.org/goals

Akhter and Cheng, 2020). These microcredit programs can shape local social norms and power dynamics between spouses, leading to an increase in women's decision-making within the household (Field et al., 2021). Group-based lending has been proven to have long-lasting positive effects on female decision-making within the household (Holvoet, 2005). Additionally, aside from increasing access to financial resources and savings, group-based lending could boost women's confidence and awareness of their rights. This increase in confidence and awareness may lead to greater acceptability of working women, thereby permanently increasing their engagement in income-generating activities.

Lastly, women's empowerment has been the target of gender-driven policies and programs in many low- and middle-income countries. This study provides important results for such programs. It shows that an increase in women's engagement in income-generating activities, economic autonomy, and empowerment persists only when they face multiple negative shocks that require them to challenge existing gender roles as a coping strategy for the household. Policies and programs aimed at promoting women's empowerment should consider the temporality and cumulative nature of these changes. It is crucial to recognize that gender norms, and consequently women's empowerment, may evolve gradually, particularly in the aftermath of repetitive shocks. This highlights the need for tailored interventions that acknowledge the dynamics of adaptation and change over time.

CRediT authorship contribution statement

Sveva Vitellozzi: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gianna Claudia Giannelli:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Figures

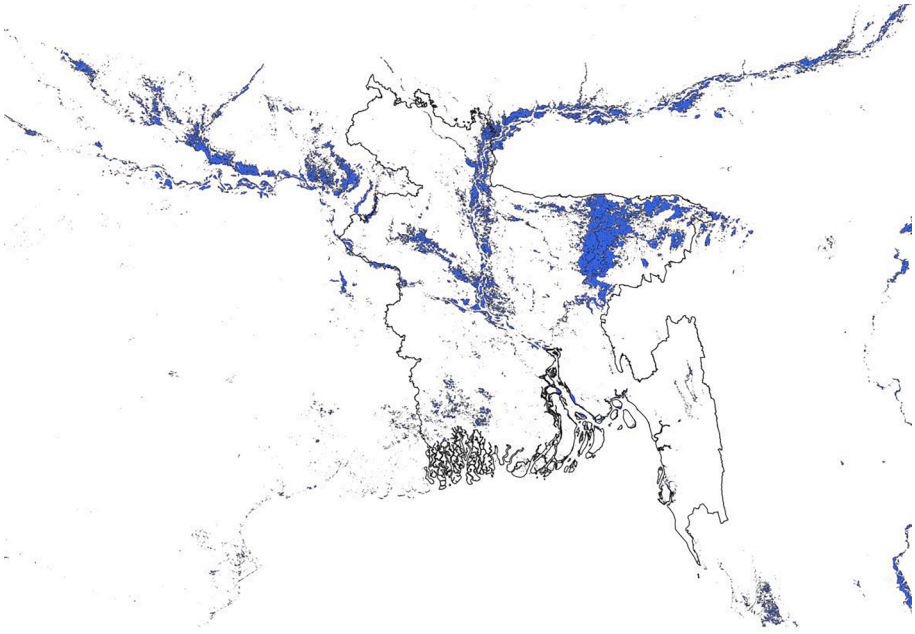

Figure 4. Incidence of the flood, 16–29 August 2017.

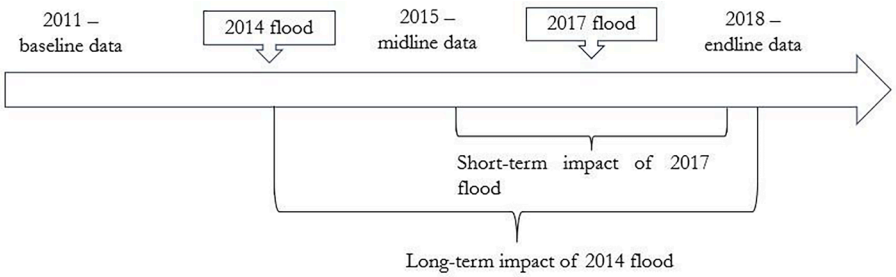

Figure 5. Timeline of shocks.

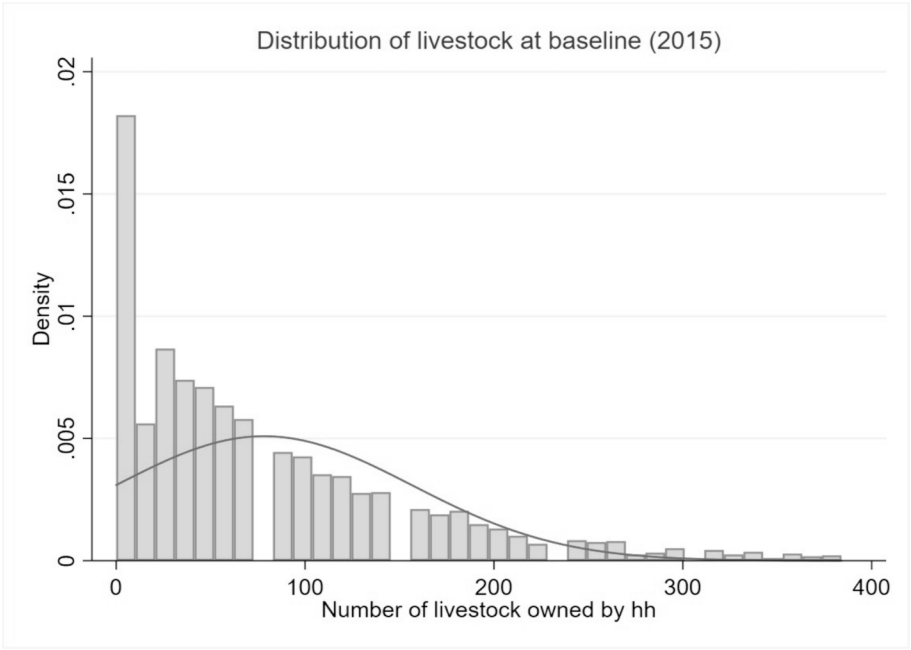

Figure 6. Livestock distribution at baseline (2015).

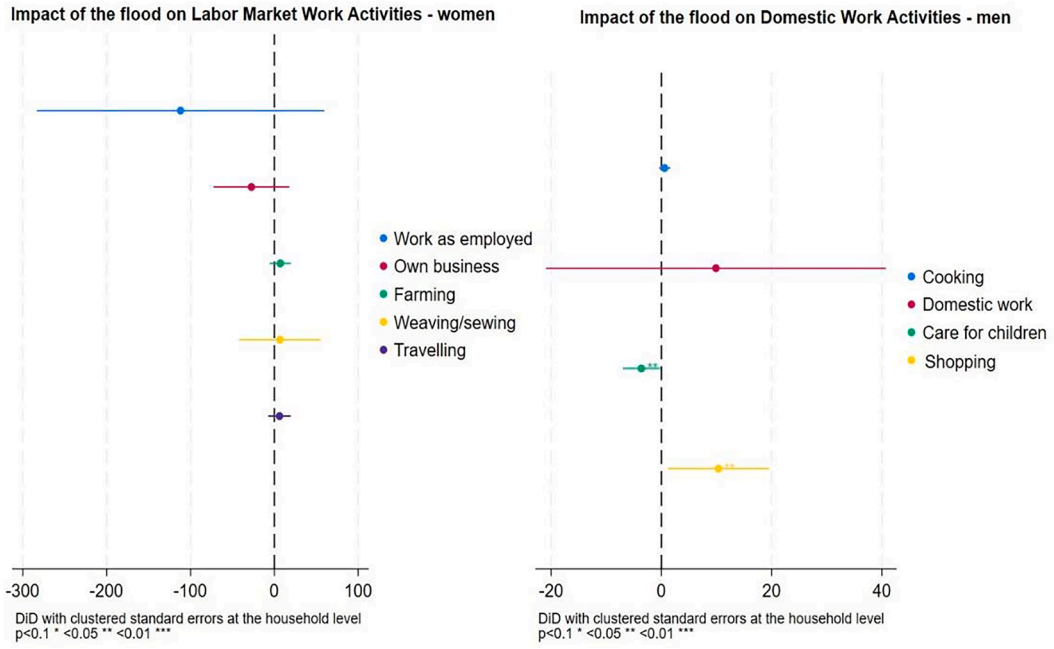

Figure 7. Impact of the flood on separate activities in market and domestic work for women and men.

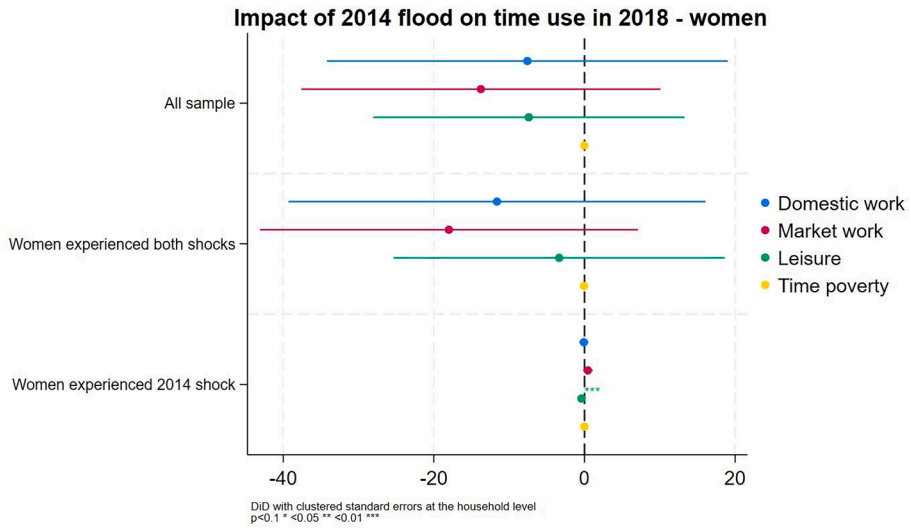

Figure 8. Impact of the 2014 flood on time use in 2018 – women.

Tables

Table 8
Summary statistics of control variables at baseline (2015).

	Mean	SD	Max	Min	Median	Var
Total HH members	4.780	1.579	14	2	5	2.493954
Members, age < 15	1.55	1.143	7	0	1.5	1.306
Household head age	46.49	12.23	105	22	45	149.5877
HH head – no school	0.4735	0.4993	1	0	0	0.2493462
Spouse – no school	0.4156	0.4928	1	0	0	0.2429324
Woman age	38.4501 10.5367		73	15	38	111.0236
Age difference btw spouses	8.0590	4.5284	54	−7	7	20.5072
Female quota hh	0.4944	0.1593	0.8571	0.1666	0.5	0.0253
Electricity	0.4080	0.4915	1	0	0	0.2415
Dur. asset − quintile	2.9205	1.354	5	1	3	1.8351
Prod. asset − quintile	3.178	1.348	5	1	3	1.817
Liv. asset − quintile	2.766	1.492	5	1	3	2.227
Number of livestock owned by hh	78.236	78.3681	384	0	60	6141.63
Number of tv owned by hh	0.3241	0.5106	4	0	0	0.2607
Number of electric iron owned by hh	0.0703	0.2770	4	0	0	0.07676
Number of metal pots owned by hh	14.1270	9.3527	126	1	12	87.4731
Number of stove owned by hh	0.05295	0.2628	5	0	0	0.06907
Distance from plot − km	0.13986	0.17883	1.7146	0	0.07974	0.03198
Soil type	3.9674	0.9908	5	1	4	0.9817
Flood depth	2.6796	3.3627	16	0	2	11.308

Note: the reported variables are, respectively: the total number of household members; the total number of household members under the age of 15; the age of the household head; a dummy equals to 1 if the household head did not go to school; a dummy equals to 1 if the spouse did not go to school; the age of the spouse; the age difference between the spouses; the share of female members in the household; a dummy equals to 1 if the household has electricity at home; the quintile distribution of durable assets; the quantile distribution of agricultural assets; the quantile distribution of livestock assets; the number of livestock owned by the household; the number of televisions owned by the household; the number of electric irons owned by the household; the number of metal pots owned by the household; the number of stoves owned by the household; the distance of the homestead from the closest plot in kms; the plot's soil type; and the usual flood depth of the plots during monsoon season.

Table 9
Two-way fixed effects weights.

	Flood 2017
Share of negative weights	0.0167
Share of sum of negative weights	0.0434

Table 10
Impact of the flood of 2017 on time use variables, heterogeneity analysis– men.

	Flood 2014 = yes				Flood 2014 = no			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Domestic work	Market work	Leisure time	Time poverty	Domestic work	Market work	Leisure time	Time poverty
Year 2018	23.45***	-9.600	40.72***	0.0809**	5.624	3.562	29.25*	0.0493
	-8.881	(20.02)	(13.27)	(0.0383)	-8.423	(20.55)	(17.06)	(0.0512)
Treat	**52.12** ** **-106.2** **	**2.566**	**0.00393**	**80.39**	**-461.9*** **	**12.77**	**-0.430**	
	(23.21)	**(43.40)**	**(29.30) (0.0923)**	**(71.14)**	**(167.2)**	**(132.8) (0.479)**		
2018 Year#July 2017	25.35	-183.5	-86.41	1.209***	-979.2	524.95	-128.26	3.13
	(76.39)	(149.8)	(110.4)	(0.404)	(843.4)	(2028.3)	(1705.8)	(5.567)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,152	3,085	3,152	3,152	2,202	2,156	2,202	2,202
R-squared	0.062	0.031	0.030	0.038	0.040	0.019	0.051	0.023
Number of id	1,582	1,582	1,582	1,582	1,103	1,103	1,103	1,103

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported time use variables denote the minutes spent in domestic work, in market work, in leisure activities, and time poverty, defined as a dummy equal to 1 if the individual worked more than 10.5 h in the previous day. Control variables are those reported in Section 4.2.

Table 11
Impact of the flood of 2017 on time use variables, unbalanced sample (attrition).

	Women				Men			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Domestic work	Market work	Leisure time	Time poverty	Domestic work	Market work	Leisure time	Time poverty
Year 2018	−3.380	10.79	48.18***	0.0346	−6.977	−11.68	37.79***	0.00653
	(9.545)	(8.798)	(8.002)	(0.0266)	(6.191)	(12.68)	(9.977)	(0.0295)
Treat	**−59.28** **	**−19.81**	**108.8*** **	**−0.0770**	**72.01*** **	**−61.76** *	**−19.96**	**0.105**
	(24.88)	**(25.71)**	**(21.14)**	**(0.0791)**	**(19.20)**	**(35.32)**	**(23.92)**	**(0.0795)**
July 2017	264.4***	−19.39	−242.2***	0.557*	−20.61	−62.42	−104.5	−0.697*
	(96.85)	(91.78)	(85.22)	(0.316)	(79.79)	(144.9)	(102.7)	(0.379)
Constant	246.9***	104.3**	294.1***	−0.163	−34.70	488.0*** 237.6***		0.531***
	(59.52)	(46.93)	(54.52)	(0.153)	(46.66)	(91.07)	(74.63)	(0.198)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,835	7,317	7,835	7,835	7,614	7,468	7,614	7,614
R-squared	0.063	0.074	0.089	0.031	0.016	0.014	0.031	0.008
Number of id	4,872	4,767	4,872	4,872	4,716	4,696	4,716	4,716

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities and time poverty, defined as a dummy equal to 1 if the individual worked more than 10.5 h in the previous day. Control variables are those reported in Section 4.2.

Table 12
Impact of flood 2014 on WEAI and engagement in IGA, unbalanced sample.

	(1) WEAI	(2) IGA	(3) *Control over* income	(5) Input prod.ive decisions
Year 2018	−0.035***	0.0799***	0.0212	−0.00592
	(0.008)	(0.0218)	(0.0152)	(0.00970)
Treat 2014	0.0432	0.218***	0.155***	0.0494**
	(0.0344)	(0.080)	(0.0486)	(0.0216)
July 2014	−0.0150	0.0788	−0.174*	−0.0883**
	(0.0555)	(0.138)	(0.0894)	(0.0411)
Constant	0.544***	0.499***	0.590***	0.989***
	(0.0551)	(0.136)	(0.0913)	(0.0681)
Control	Yes	Yes	Yes	Yes
Observations	7,835	7,835	7,835	7,835
R-squared	0.039	0.099	0.023	0.035
Number of id	4,872	4,872	4,872	4,872

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables are the Women's Empowerment in Agriculture Index, as defined in Alkire et al. (2013), a dummy equal to 1 if the woman reported being engaged in IGA, and two economic sub-indexes of the WEAI, control over use of income and input in productive decisions. Control variables are those reported in Section 4.2.

Table 13
Robustness check– buffer of 10 kms around each sampled household.

	Women Treatment 10 km	Men Treatment 10 km
(1) Domestic work	−64.07**	75.91***
	(30.10)	(21.29)
(2) Market work	−35.58	−75.78*
	(31.89)	(41.55)
(3) Leisure	97.21***	−19.64
	(0.0917)	(28.84)
(4) Time poverty	−0.189**	0.154*
	(0.0655)	(0.0921)
(5) WEAI	0.031	–
	(0.028)	
(6) IGA	0.442***	–
	(0.0454)	
Observations	5,354	5,353
Number of id	2,685	2,685

Note: Clustered standard errors at the household in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities, and time poverty, defined as a dummy equals to 1 if the individual worked more than 10.5 h in the previous day, the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013), and women's likelihood of engaging in IGA, defined as a dummy equal to 1 if the woman reported being engaged in IGA. Control variables are those reported in Section 4.2.

Table 14
Robustness check– buffer of 10 kms around each sampled household.

	Women Treatment 2 Km	Men Treatment 2 Km
(1) Domestic work	−34.91*	65.98***
	(24.10)	(17.48)
(2) Market work	−29.32*	−60.60*
	(22.56)	(33.64)
(3) Leisure	73.22***	−37.61*
	(20.80)	(22.24)
(4) Time poverty	−0.0803	0.0725
	(0.0748)	(0.0752)
(5) WEAI	0.034*	–
	(0.023)	
(6) IGA	0.388***	–
	(0.0548)	
Observations	5,354	5,354
Number of id	2,685	2,685

Note: Clustered standard errors at the household in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities and time poverty, defined as a dummy equals to 1 if the individual worked more than 10.5 h in the previous day, the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013), and women's likelihood of engaging in IGA, defined as a dummy equals to 1 if the woman reported being engaged in IGA. Control variables are those reported in Section 4.2.

Table 15
Robustness checks– impact of self-reported shock on outcome variables, women.

	(1) Domestic work	(2) Market work	(3) Leisure time	(4) Time poverty	(5) IGA	(6) WEAI
year = 2018	13.08	64.60*	24.69	0.113*	0.241***	0.0687**
	(20.71)	(35.29)	(16.17)	(0.0648)	(0.0419)	(0.0306)
year#flood 2017	**−110.8****	**−9.715**	**62.11**	**−0.333****	**−0.0683**	**−0.001**
	(48.41)	**(51.87)**	**(42.18)**	**(0.157)**	**(0.0959)**	**(0.051)**
year#july 2017	145.8	−59.44	−121.5	0.124	−0.134	−0.0523
	(116.1)	(109.6)	(113.0)	(0.376)	(0.213)	(0.0915)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,257	2,902	3,257	3,257	3,257	3,257

(*continued on next page*)

Table 15 (*continued*)

	(1) Domestic work	(2) Market work	(3) Leisure time	(4) Time poverty	(5) IGA	(6) WEAI
R-squared	0.073	0.163	0.113	0.107	0.124	0.038
Number of id	2,68	2,394	2,68	2,68	2,68	2,68

Note: Clustered standard errors at the household in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities, and time poverty, defined as a dummy equals to 1 if the individual worked more than 10.5 h in the previous day, the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013), and women's likelihood of engaging in IGA, defined as a dummy equals to 1 if the woman reported being engaged in IGA. Control variables are those reported in Section 4.2.

Table 16
Robustness checks – impact of self-reported shock on outcome variables, men.

	(1) Domestic work	(2) Market work	(3) Leisure time	(4) Time poverty
Year = 2018	20.41*	26.80	−0.185	0.131*
	(12.07)	(25.53)	(19.68)	(0.0679)
Year#flood	**65.46**	**13.04**	**–23.80**	**−0.0737**
	(40.65)	**(68.47)**	**(42.34)**	**(0.165)**
Year#july 2017	191.9**	−383.1**	−62.48	−1.053**
	(95.91)	(171.6)	(136.5)	(0.503)
Control	Yes	Yes	Yes	Yes
Observations	3,257	3,144	3,257	3,257
R-squared	0.062	0.048	0.053	0.074
Number of id	2,68	2,587	2,68	2,68

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities and time poverty, defined as a dummy equals to 1 if the individual worked more than 10.5 h in the previous day. Control variables are those reported in Section 4.2.

Table 17
Balance test at baseline, 2011 and 2015.

	OLS at baseline = 2011	OLS at baseline = 2015
	Flood 2017	Flood 2017
Women	29.96	–22.00
(1)Domestic work		
	(34.83)	(36.75)
(2)Market work	4.904	−15.92
	(27.25)	(21.79)
(3)Leisure time	5.080	22.49
	(18.82)	(55.46)
(4)Time poverty	0.237**	−0.242**
	(0.110)	(0.104)
(5)IGA	−0.0521	−0.0535
	(0.119)	(0.095)
(6)WEAI	0.052*	
	(0.033)	
Number of observations	2,277	2,674
Men	19.17	–22.00
(7)Domestic work		
	(53.73)	(36.75)
(8)Market work	50.54	–33.12
	(68.74)	(33.88)
(9)Leisure time	−72.12**	−92.21***
	(35.07)	(29.12)
(10) Time poverty	0.0926	−0.153
	(0.150)	(0.111)
Number of observations	1,661	2,674

Note: Clustered standard errors at the household level in parentheses.*, **, *** denote significance at the 10%, 5% and 1% levels respectively. The reported dependent variables denote the minutes spent in domestic work, in market work, in leisure activities and time poverty, defined as a dummy equals to 1 if the individual worked more than 10.5 h in the previous day, the Women's Empowerment in Agriculture Index (WEAI), as defined by Alkire et al. (2013), and women's likelihood of engaging in IGA, defined as a dummy equals to 1 if the woman reported being engaged in IGA. Control variables are those reported in Section 4.2.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2024.106684.

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