Weather Shocks and Income Inequality*

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Abstract

Governments and nongovernmental organizations (NGOs) rely on economic models to identify at-risk communities when addressing the issues of income inequality because resources are scarce. However, models developed to date neglect the impact of weather shocks. Because climate change is predicted to increase the frequency and severity of weather shocks that destroy crops, in this paper, we study the impact of weather shocks on household welfare and how it exacerbates household income inequality via increasing crop income inequality. We first recognize the limitations of existing measures of weather shocks and propose an absolute measure of weather shocks that does not depend on the length of weather samples obtained. Next, we study the impact of the newly constructed weather shocks on household welfare measured by different income sources and different types of consumption. The findings suggest that weather shocks have a significant negative impact on crop revenue and that the impact varies across households with different characteristics. Next, we consider how this diverse impact of weather shocks impacts household income inequality. The Gini decomposition of income sources suggests that crop income contributes to reducing income inequality in the provinces. Because weather shocks reduce income from crops, they contribute to increasing income inequality. Our model can assist governments and NGOs to identify at-risk communities to best target resources.

Keywords: Weather Shocks, Income Inequality, Gini Decomposition

JEL Classification: D63, O13, O18

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1 Introduction

Growing income inequality has become a major concern for governments and policymakers over the last few decades due to its impact on the economy, democracy and justice systems. First, societies with high levels of income inequality do not function efficiently, and their economies are neither stable nor sustainable in the long run (Stiglitz, 2012). Second, an increase in income inequality lowers consumption because rich people tend to consume a smaller proportion of their income than do the poor (Dynan et al., 2004); this leads to more unemployment in the short run, because total demand is lower than what the economy is capable of supplying. Thus, for example, if governments wish to stimulate the economy during a recession, giving money to the rich, who consume a smaller portion of their income, is ineffective.

At the household level, if economic status is associated with a given outcome, then an increase in economic inequality will lead to an increase in inequality in that outcome (Neckerman and Torche, 2007). For example, if higher income means people are happier, then higher income inequality would result in a wider gap in happiness measures. The negative association between income inequality and happiness is reported not only in advanced economies, but in emerging ones (Oishi et al., 2011; Tran et al., 2018). Furthermore, high income inequality is associated with high prevalences of mental illness and drug misuse in rich societies (Pickett and Wilkinson, 2010). Hence, reducing income inequality by redistributing income to those for whom it is more efficacious may improve many important social outcomes, such as health and education.

Attempts have been made to identify key factors that drive income inequality to assist governments in developing targeted programs to reduce inequality. A crucial factor is technological change, which disproportionately raises the demand for skilled labour over low-skilled and unskilled labour. Technological change eliminates many routine jobs via automation or by requiring higher skill levels to attain or remain in jobs (Acemoglu, 1998; Card and DiNardo, 2002). Thus, new information technology has driven up the skill premium, resulting in an increase in labour income inequality. Other factors have been identified as contributing to increased income inequality, including international trade, the flow of foreign direct investment from advanced to emerging economies, and changes in labour market institutions (Feenstra and Hanson, 1996, 2001; Figini and Görg, 2011).

Weather shocks are likely to be a cause of income inequality, but there is little investigation of the impact of such shocks on income inequality in the existing literature. If weather shocks drive income inequality, there is a strong case for governments to rectify their impacts because this is inequality due to different circumstances rather than different effort levels (Roemer, 1998). Governments need to know if weather shocks contribute to increasing income inequality and how to identify the affected communities to intervene effectively. To my knowledge, the only study that attempts to establish a link between weather shocks and income inequality is Marx (2018). However, Marx only shows that the impact of local temperatures on income varies by income deciles, and does not draw any conclusions about whether global warming increases income inequality. In this paper, we study the impact of weather shocks on different layers of household welfare, including income and consumption, and examine how it might exacerbate income inequality, which in turn has implications for households' happiness and fulfillment.

Although many studies show that natural disasters (including weather shocks) reduce household income and consumption and increase poverty (Nguyen et al., 2020b), the focus has been on the poor versus the non-poor. Poor households suffer more from shocks than wealthier households because their livelihoods are highly dependent on natural conditions, and their stocks of assets (which are often small) are more vulnerable (Tran, 2015). Furthermore, wealthier households can sell assets to smooth consumption, whereas poorer households may have to suffer falls in consumption when facing weather shocks (Hoddinott, 2006). When the poor experience economic stress, they eat less or take their children out of school (Banerjee and Duflo, 2007). In regions where marriage payments are customary and female children are considered tradeable assets, households might cope with temporary aggregate income shocks by marrying off their daughters earlier (Corno et al., 2020). Overall, it appears that weather shocks widen the gap between the poor and the wealthy, leading to a reduction in life satisfaction.

Some might argue that people could protect themselves from the financial impacts of weather shocks by buying insurance or hedging using weather derivatives. However, such a trading market for weather derivatives does not exist in many emerging economies; for instance, Vietnam lacks such a market (Tran and Otake, 2020). Furthermore, even when an insurance market exists, the cost might be too high for poor households, which may source their income from growing crops on small family plots; thus, take-up rates are low (King and Singh, 2020). In addition, households in rural areas might not be capable of understanding and participating in such complex financial contracts.

Given the above background, this chapter aims to address the following four research questions. (1) What are the impacts of weather shocks on the income sources of rural households? This is of interest because different households might have different strategies to diversify their income sources. Poor households might not have access to credit and thus, struggle to escape the poverty trap. (2) How do weather shocks affect households' consumption? This is relevant to inequality because households which lack assets to offset lost income may be forced to lower their consumption. Then, the question is, what do they stop consuming – entertainment, education, or medical treatment? If they have to take their children out of school or marry off their daughters early (depending on the culture), then weather shocks have an indirect but significant negative impact on their children's lives and intergenerational mobility. (3) How do the impacts of weather shocks vary for households with different characteristics? Specifically, we will examine households that derive their income predominantly from agriculture, and also examine characteristics including crop area, ethnicity, and household size. As this indicates, my focus is on households in rural villages. If all household incomes are altered by the same proportion, then relative inequality would stay the same even though absolute inequality might rise sharply. How can we capture both relative and absolute measures of inequality? (4) How do weather shocks exacerbate income inequality? This final research question recognises that weather shocks are likely to have doubly negative impacts on household welfare, both reducing income and increasing income inequality, making some households worse off.

In investigating these research questions, we use Vietnam's economy as a case study. Vietnam makes a useful case study because it is quite vulnerable to weather shocks. Although Vietnam has been experiencing rapid economic change,[1] more than half of its workforce remains employed in agriculture (Quyen, 2019), which is increasingly affected by extreme weather conditions, such as storms, floods and droughts. Vietnam experiences various types of natural disasters due to its location in a tropical monsoon region and its diverse and complex topography. As shown in Figure 1, which was constructed using Emergency Events Database (EM-DAT) data,[2] much of

[1] Vietnam has transformed from one of the world's poorest nations into a low middle-income country over the last 30 years.

[2] EM-DAT is an international disaster database developed and maintained by the Centre for Research

the country suffers from natural disasters, particularly floods and storms, with the three studied areas experiencing a high number of natural disasters over the 20-year period 2001-20.

As economic growth continues, average income rises, and the social impact of inequality is increasingly understood, there is increasing interest in analysing why some groups are falling behind. Although Vietnam has witnessed a significant reduction in poverty over the last few decades,[3] without a sustainable source of income, many families are likely to fall back into poverty following shocks. Most of Vietnam's remaining poor tend to be ethnic minorities living in mountainous areas. Poor households are often characterised by large household size, low education, a lack of supporting infrastructure, and high dependency on agriculture (Quyen, 2019). Because this group is at greater risk from weather shocks than other households, a focus of this study is understanding how weather shocks might affect farmers, ethnic minority groups, and large households differently.

My main contributions in conducting this research are to propose a new measure of weather shocks and to establish a link between weather shocks and income inequality. First, we recognise the limitations of existing measures of weather shocks, which tend to be dependent on the length of time over which weather samples are observed, and propose an absolute measure to overcome this limitation. This measure is defined as the total number of days with rainfall of at least 100 mm where there is also at least two such days in a row in the period that coincides with the household survey. Apart from being an absolute measure that does not depend on the period of weather data observations, this measure also provides a more accurate indication of weather shocks for short data series. Furthermore, weather shocks are likely to destroy crops and reduce the income of rural households, with the reduction varying between households with different characteristics; therefore, such shocks may exacerbate income inequality in locations where an increase in crop income would otherwise contribute to reducing income inequality. The results of this study will help governments and NGOs identify at-risk communities and design more effective and equitable assistance programs.

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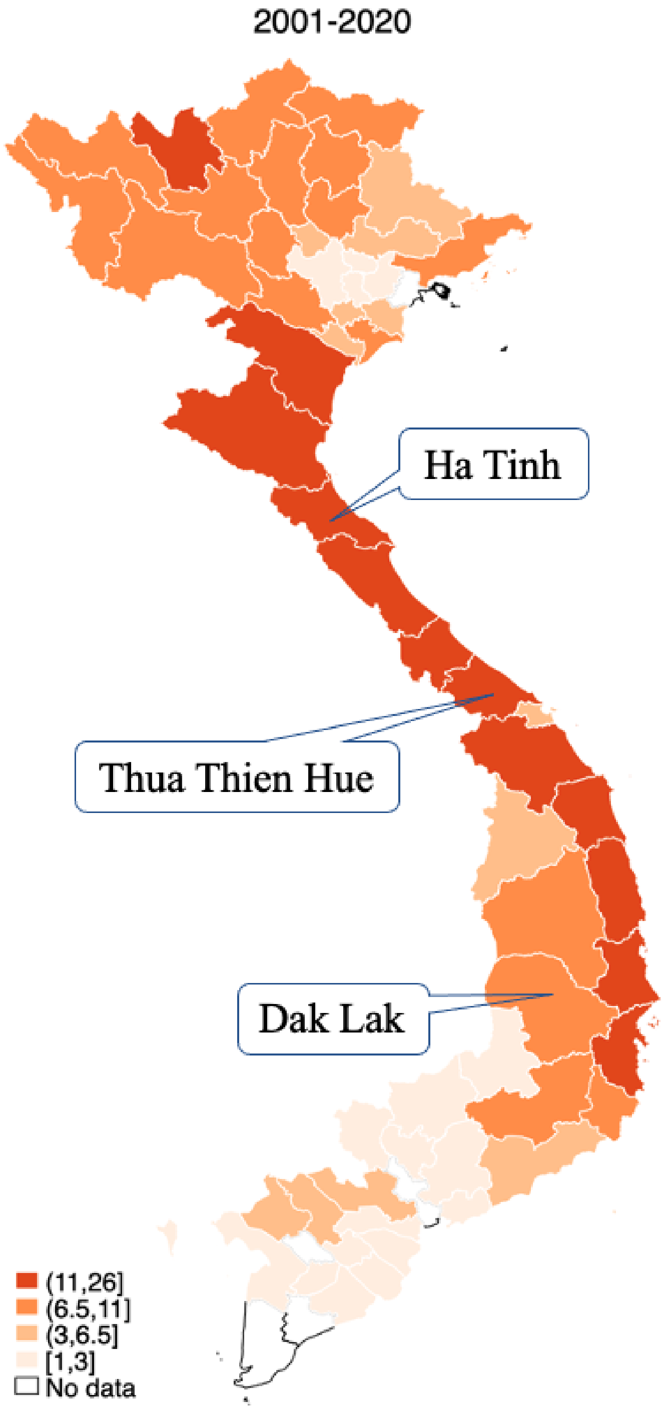
[3]The earliest survey conducted in Vietnam in 1992 indicated that about 64% of the population was considered poor, as measured by their income being below the international poverty line of $1.25 per day. Twenty years later, less than 3% of the population was considered poor by the same standard (Vu, 2015).

Figure 1: Number of natural disasters in provinces of Vietnam, 2001-20



Disaster Type	
Flood	69
Storm	67
Drought	4
Epidemic	6
Landslide	2
Wildfire	1
Total	149

Note: EM-DAT defines a disaster as "a situation or event which overwhelms local capacity, necessitating a request to the national or international level for external assistance, or is recognized as such by a multilateral agency or by at least two sources, such as national, regional, or international assistance groups and the media". Accordingly, an event is considered a disaster if there are (i) 10 or more people reported killed and/or (ii) 100 or more people reported affected and/or (iii) calls for international assistance/declaration of a state of emergency.

2 Data

2.1 Household Data

This study uses data collected in two research projects funded by the German Research Foundation (DFG) (Nguyen et al., 2020a), entitled *Impact of shocks on the vulnerability to poverty: Consequences for development of emerging South-East Asian Economies* (DFG FOR 756/1) and *Poverty dynamics and sustainable development: A long-term panel project in Thailand and Vietnam* (DFG FOR 756/2) (Do et al., 2021).[4] The researchers have collected data from rural areas of Thailand and Vietnam since 2007, with the purpose of examining and comparing the economic dynamics and vulnerability of rural households to poverty in these countries. The Thailand Vietnam Socio Economic Panel (TVSEP) panel dataset covers many important aspects of rural households' lives, including demography, income, expenditure and shocks experienced. The average attrition rate across the panel is below 5% (Parvathi et al. 2019, as cited in Do et al. (2021)). In this study, we focus on three rural provinces of Vietnam, Ha Tinh, Thua Thien Hue (Hue), and Dak Lak, shown in Figure 1. These provinces were chosen for their high incidence of poverty and high dependence on agriculture, which is increasingly being affected by extreme weather events.[5] As can be seen from Figure 1, these three provinces suffer frequent natural disasters, with from 11 to 26 natural disasters for Ha Tinh and Thua Thien Hue, and 6.5 to 11 for Dak Lak in the period between 2001 and 2020. Although Dak Lak does not experience weather shocks of the severity of those in Ha Tinh and Thua Thien Hue, observations from Dak Lak are included in the analysis because some variation in the treatment helps us estimate the coefficients of interest more accurately.

We include around 6,000 households in the main specification, which covers three years (2008, 2010, and 2013) because of the short span of weather data and the fact that only Thua Thien Hue was surveyed in 2011. The year here refers to the year when the household survey was completed; they often begin in May of the previous year and finish in April of that year.[6] The

[4]For more information, see `https://www.tvsep.de/`. Household and village questionnaires can be downloaded free of charge from this page.

[5]For details about the sampling procedure, please refer to Do et al. (2021)

[6]Some sections of the survey (e.g., self-reported shocks) cover the period from the last survey until the current survey.

panel includes a section for village heads in some years. However, because the village head survey was not implemented in 2008, we do not include village-level variables as controls. The numbers of households interviewed in each year in each province are similar, as indicated in Table 2.1.

Table 2.1: Estimated populations of the three studied Vietnamese provinces in 2020 and numbers of observations by year

Province	Population (million)	2008	2010	2013
Ha Tinh	1.5	713	701	659
Thua Thien Hue	1.3	696	683	648
Dak Lak	2.1	735	715	703
Total observations		2144	2099	2010

Most of the 6,000 households in the study are dependent on agriculture, with 67% of household heads (about 30% of all household members) reporting agricultural activities as their main occupation. The kernel densities of the log of total income and crop revenue per capita for the three provinces are approximately normal, as shown in Figure 2. Table 2.2 shows descriptive statistics for the three provinces in 2013. Similar statistics for 2008 and 2010 can be found in Appendix A.

Welfare measures such as income and consumption are recorded at the household level in TVSEP dataset; most studies using this data set to study the impact of natural disasters on household welfare use the household-level data, controlling for household heads' characteristics. We also do this, and the results are presented in Appendix B. However, household heads might change over time and thus, variables such as gender or ethnicity are not time-invariant for household heads. Presenting a fixed-effect model from which supposedly time-invariant variables like gender or ethnicity do not drop out may appear peculiar. Therefore, we use the individual-level data to investigate the impact of weather shocks on household welfare measures such as income or consumption.

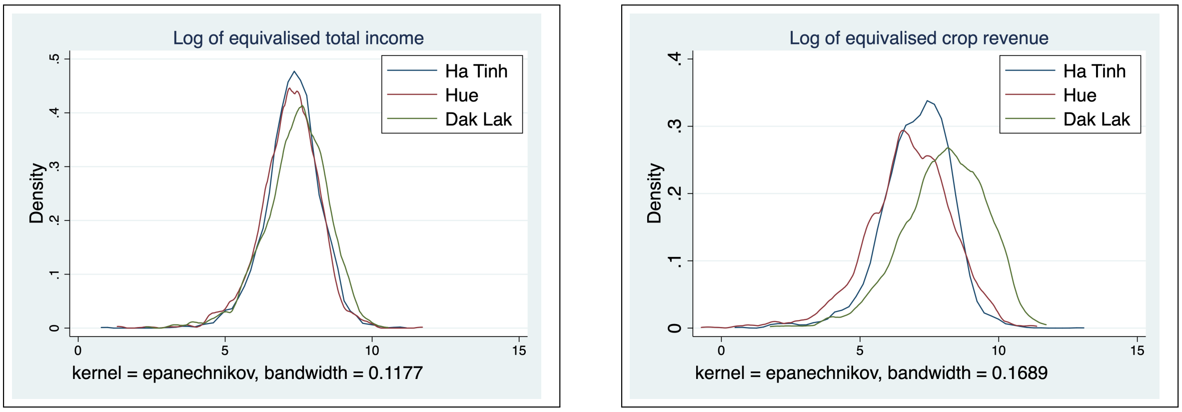
Descriptive statistics of the variables of interest are presented in Table 2.2, and tests for the significance of differences between selected statistics for the three provinces are presented in Table 2.3. The variables are divided into four groups: demographic variables, income variables, consumption variables and household asset variables. With regard to demographic variables, the average household size in all three provinces is between five and six members. With ethnicity as a dummy variable that equals 1 if the individual belongs to the ethnic majority (Kinh), we observe that most of Ha Tinh's population are from an ethnic majority, as is the case in Thua Thien Hue (76%). The population of Dak Lak is more heterogeneous, with many indigenous ethnic minorities, which account for about 40% of the province's population. Around two thirds of the population in these three provinces has not been educated beyond primary school level. Many individuals (mostly men) are members of socio-political organisations; Ha Tinh has the highest percentage of adult women who are members of socio-political organisations, at 6%.[7]

To calculate the equivalised income, we use the OECD-modified scale,[8] following the formula

$$\text{Equivalised income} = \frac{\text{Total household income}}{1 \times \text{first adult} + 0.5 \times \text{additional adults} + 0.3 \times \text{children}}.$$

With regard to consumption, we follow the convention and use consumption per capita. The gap between equivalised total income and per capita total consumption is mostly due to saving. All monetary values are converted to 2005 PPP USD using the appropriate consumer price index (CPI) ratios and PPP factors, as noted in the TVSEP documentation.

Figure 2: Kernel density of log of total income and crop revenue per capita



The main sources of income for individuals in these three provinces are crops; livestock; hunting,

[7] It would be interesting to know whether having more women as members of socio-political organisations means those women receive more support from such organisations and thus, cope better with weather shocks (in terms of not having to reduce consumption). However, the low percentage of women as members of such organisations casts doubt on the meaningfulness of such an analysis.

[8] https://www.oecd.org/els/soc/OECD-Note-EquivalenceScales.pdf

Table 2.2: Descriptive statistics for the three studied Vietnamese provinces, 2013 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Demographic variables				
Household size	6.42	5.85	6.69	6.64
Number of children	1.20	1.01	1.19	1.36
Gender (Female=1)	0.51	0.52	0.51	0.50
Age	32.60	35.28	32.82	30.18
Ethnicity (Kinh=1)	0.77	1.00	0.76	0.59
Marital status (Married=1)	0.37	0.38	0.35	0.37
Education: Primary school	0.63	0.51	0.69	0.66
Education: Secondary school	0.22	0.29	0.18	0.20
Education: High school	0.10	0.13	0.09	0.09
Education: Bachelor or higher	0.05	0.07	0.04	0.04
Farmer	0.29	0.29	0.23	0.35
Member of socio-political organization	0.52	0.75	0.44	0.40
Percentage of socio-political women	0.04	0.06	0.04	0.03
Income variables (2005 PPP USD)				
Equivalised total income	2277.54	2115.61	2492.99	2212.92
Equivalised crop income	410.30	228.98	201.29	754.35
Equivalised crop revenue	3822.11	2384.74	2466.19	6271.12
Equivalised livestock income	265.50	417.68	198.89	200.59
Equivalised hunting income	149.11	16.14	393.06	34.05
Equivalised off-farm employment income	588.86	543.10	671.76	550.25
Equivalised remittance: family/friends	314.27	492.94	338.98	142.87
Consumption variables (2005 PPP USD)				
Per capita total consumption	1080.36	979.62	1061.89	1181.20
Per capita food consumption	539.43	466.89	551.96	588.17
Per capita non-food consumption	403.03	372.15	390.94	439.89
Per capita education consumption	72.61	68.81	65.61	82.24
Per capita health consumption	44.86	50.28	35.63	48.90
Per capita rent	20.93	21.88	18.90	22.02
Household asset variables				
Household crop area ($1000m^2$)	0.74	0.35	0.85	0.98
Number of tractor	1.12	1.12	1.18	1.10
Number of vehicle	1.68	1.44	1.83	1.74
Number of phones	2.52	2.19	2.74	2.59

Table 2.3: Socioeconomic differences between the three studied Vietnamese provinces, 2013

	Ha Tinh - rest	Hue - rest	Dak Lak - rest
Demographic variables			
Household size	-.8141119***	.406581***	.3497069***
Number of children	-.2685711***	-.0134565	.2577007***
Gender (Female=1)	.0136682	.00404	-.0163351*
Age	3.835651***	.3254035	-3.807105***
Ethnicity (Kinh=1)	.3293522***	-.0175743**	-.2832281***
Marital status (Married=1)	.0135882	-.0173986*	.004398
Education: Primary school	-.1650105***	.0984696***	.0553921***
Education: Secondary school	.1001762***	-.0625314***	-.0309744***
Education: High school	.0343458***	-.0195402***	-.0124511**
Education: Bachelor or higher	.0304885***	-.016398***	-.0119666***
Farmer	-.0029924	-.0966232***	.095912***
Member of socio-political organization	.3294881***	-.1199909***	-.1785348***
Percentage of socio-political women	.0270043***	-.0052199***	-.0195723***
Income variables (2005 PPP USD)			
Equivalised total income	-231.8806***	324.2421***	-101.4152
Equivalised crop income	-259.6334***	-314.5641***	539.9511***
Equivalised crop revenue	-2058.205***	-2040.655***	3843.493***
Equivalised livestock income	217.9126***	-100.247***	-101.8825***
Equivalised hunting income	-190.4079***	367.1408***	-180.5777***
Equivalised off-farm employment income	-65.53534***	124.7558***	-60.601***
Equivalised remittance: family/friends	255.8448***	37.19047**	-268.994***
Consumption variables (2005 PPP USD)			
Per capita total consumption	-144.2566***	-27.80083	158.2589***
Per capita food consumption	-103.8827***	18.84862***	76.48033***
Per capita non-food consumption	-44.21805***	-18.19427	57.83859***
Per capita education consumption	-5.439925**	-10.53138***	15.11356***
Per capita health consumption	7.756018***	-13.89236***	6.330759**
Per capita rent	1.36322***	-3.057096***	1.706155***
Household asset variables			
Household crop area (1000m^2)	-.5683911***	.1517686***	.3878979***
Number of tractor	.0004655	.0635427***	-.0248924*
Number of vehicle	-.3433091***	.2135484***	.0948823***
Number of phones	-.4725952***	.3364408***	.1116995***

Note: The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

collecting, and logging in the forests; off-farm employment activities; and remittances from family members and friends. Of the three sources of income that are most likely to be affected by weather shocks (crop, livestock and hunting income), each province has one that dominates. Crop income contributes more to total household income in Dak Lak in both relative and absolute terms in all three years. Livestock yields more income to households in Ha Tinh, and hunting in Hue in all three years. Compared to statistics of previous years (see Appendix A), remittances from family members have been increasing consistently in Ha Tinh and Hue, but not Dak Lak. It is possible that household members in the former two provinces have pursued migration as a deliberate strategy in response to weather shocks, as Imbert et al. (2018) suggest. It would be interesting to determine whether receiving remittances helps households to smooth consumption when facing adverse weather conditions.

Regarding consumption, it appears that individuals in Dak Lak spends more on main consumption categories such as food, nonfood items and education than individuals in Ha Tinh and Hue. They also have larger crop areas and more phones per household.

2.2 Weather Data

The rainfall data used in this study come from the Tropical Rainfall Measuring Mission (TRMM), a joint space mission between the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency. TRMM relies on a satellite designed to measure the interactions between water vapor, clouds and precipitation, which are central to regulating the Earth's climate. TRMM was in operation between 1997 and 2015. It officially ended on April 15, 2015 after the spacecraft depleted its fuel reserves.[9] This data source provides 642,840 observations of daily rainfall, covering 220 villages in the three provinces of interest from 2007 to 2014. However, to construct the weather shocks variable so that its time span matches that of the household surveys, we use only data from May of the previous year to April in each year of interest. For this reason, we do not have enough weather data to construct weather shocks for the year 2007 (because it would require data from May 2006 to April 2007), or the lags of weather shocks, and thus focus my analysis on the years 2008, 2010 and 2013.

[9]For more information, see https://gpm.nasa.gov/missions/trmm

3 Data Analysis

3.1 Identifying Dependent and Independent Variables

When analysing the impacts of weather shocks on rural households' welfare, the dependent variable is often household consumption or household income (Nguyen et al., 2020b). Although consumption might be more closely related to household wellbeing, it tends to be smoothed over time. Because the choice of wellbeing measure matters empirically, we use both income and consumption as welfare indicators to examine the impacts of weather shocks (Decanq and Neumann, 2016). This allows me to cross-check the results for errors in measuring household income and consumption.

In the Vietnamese households under study, household income includes farm income, off-farm income, and remittances. Farm income comes mainly from crops, livestock and hunting, whereas off-farm income is derived from employment and self-employment. Household income could be negative as a result of income losses from investing in crops, livestock, or nonfarm self-employment. The numbers of households with income less than or equal to zero across provinces are shown in Table 3.1. Because the households with zero or negative incomes are small in number and appear to be randomly distributed across provinces, we drop such values and transform the remaining values into the logarithmic form to symmetrise the residuals and reduce potential outliers, as shown in Figure 2.

Table 3.1: Households with nonpositive income by province and year

Province	2008	2010	2013	Total
Ha Tinh	6	12	20	38
Thua Thien Hue	10	2	13	25
Dak Lak	19	43	45	107
Total	35	77	78	170

As Table 2.2 shows, household consumption includes food and nonfood items, education, health services and rent, with the largest share spent on food. We analyse the log values of consumption for the same reason as for income. As explained in Section 2.1, the dependent variables include equivalised income and per capita consumption for all individuals and for farmers specifically.

Farmers are classified as such because their main occupation is growing crops, fishing, hunting or collecting, or because they are permanently employed in agriculture. We did not use the proportion of income derived from agricultural activities to distinguish farmers from nonfarmers, because this percentage is likely to be low when households face weather shocks. Therefore, the share of income derived from agriculture activities does not accurately reflect the relative importance of farming income and other income sources. Based on this classification, nonfarming households may still engage in agricultural activities, but the income generated from these activities is not their main income source.

The identification of explanatory variables for regression models is based on the sustainable livelihoods framework, in which a livelihood is defined as the capabilities, assets and activities of a means of living (Nguyen et al., 2020b). Control variables include demographic variables such as household size, number of children, age, education level, whether an individual is a member of a socio-political organisation, and household assets.

3.2 Constructing Measured Weather Shocks

The current literature measures the exposure to weather shocks using two approaches. The first approach, "self-reported weather shocks", involves directly asking households to report whether they have experienced weather shocks. Under the second approach, "measured weather shocks", the times and places at which the shocks occurred are traced using weather data, which are matched with the locations of the surveyed households.

The limitations of using self-reported data to study the impacts of extreme weather events have been well documented. There is evidence that perception of shocks is endogenous to a household. People experience similar shocks differently and tend to adapt to their average environment Guiteras et al. (2015). Households affected by the same weather shocks might report the shocks differently depending on their level of engagement in agricultural activities and their perceived resilience, which depends on their application of coping strategies (Nguyen and Nguyen, 2020; Lohmann and Lechtenfeld, 2015). The TVSEP asks households if they had experienced any major shocks since the last survey. In the first survey, in 2007, households were asked to recall events over the previous five years, which is likely to result in inaccuracies.

Researchers construct weather shocks using the measured weather shocks approach in several ways. The first way is to define a "rain shocks" variable as equal to one if the annual rainfall is above the 80^{th} percentile for the district, as zero if it is between the 80^{th} and 20^{th} percentiles, and -1 if it is below the 20^{th} percentile (Jayachandran, 2006; Shah and Steinberg, 2017; Kaur, 2019). This measure is appropriate for India, where more rain often benefits crops. However, Vietnam often has too much rain. Using only one categorical variable to identify a rain shock becomes problematic when interpreting the results in different contexts. For instance, a negative coefficient for the rain shock variable would mean more rain reduces income even if the country is currently experiencing drought. Conversely, a positive coefficient would mean that a hurricane that destroys all crops would increase income if the country is currently experiencing normal weather. To rectify these issues, we create two dummies for weather shocks: one for too much rain (flood) and one for too little rain (drought). This construction shows that drought is almost 12 times more frequent than flood, which is inconsistent with the EM-DAT data used in constructing Figure 1. EM-DAT data record no droughts for Ha Tinh and Hue during 2001-2020, and only one drought in Dak Lak – in 2015, which is outside my period of analysis. Because most of the natural disasters experienced by the three provinces from 2007 to 2014 are storms and floods, we focus on identifying incidents of too much rain as weather shocks for the remainder of the paper.[10]

The second way of identifying weather shocks in the existing literature is to count the number of times that monthly rainfall is three standard deviations away from the mean (see, e.g., Nguyen and Nguyen, 2020). The drawback of this approach is its dependence on the duration of the sample, meaning that the identification of shocks could vary from sample to sample. A month could be counted as including shocks using one sample, but be considered a normal month using a different sample. Another way to identify weather shocks is to use the deviation of yearly rainfall from the norm of the location, which is calculated as the natural log of a year's rainfall

[10] Although Quiñones et al. (2021) use TVSEP and show significant impacts of drought, their paper combines provinces of Vietnam and Thailand and covers a longer period from 2007 to 2017. They also state that exceptional dry spells fell occurred in 2007, 2013 and 2016, which mostly fall outside my period of analysis.

minus the natural log of mean annual rainfall in a given village (Maccini and Yang, 2009). Again, this measure is dependent on the mean, which varies depending on the duration of the sample observed. Therefore, we sought to identify an absolute measure, defined by the absolute amount of rainfall, that conveys the level of severity of the rainfall events.

Initially, we considered a weather shock as at least two consecutive days with rainfall of more than 100 mm.[11] However, this measure has two issues. First, if there are two days of continuous rainfall above the cutoff, followed by one day below the cutoff, then another two days above the cutoff, using this measure would result in counting two flood incidents, whereas it is actually one. Second, the measure does not reflect the level of severity accurately. For example, it cannot distinguish between a three-day rainy incident and a 100-day rainy incident.

To resolve these issues, we construct the weather shocks variable as the total number of days with rainfall of at least 100 mm where there was also at least two such days in a row in the period that coincides with the household survey. Table 3.2 presents the frequency of this constructed weather shocks variable across the three provinces in three years. As mentioned in Section 2.1, the year in this table refers to the year in which the household survey was undertaken, which often covers the period from the previous May through to April of the reference year. As can be seen from Table 3.2, of the three provinces, Hue experienced the most severe rain shocks.

3.3 Model Specification

We use econometric regressions to estimate the effects of independent variables, including weather shocks, on dependent variables (welfare outcome variables). Following the livelihood framework, the basic form of the econometric model is:

$$Y = f(S, H), \tag{1}$$

where Y denotes the outcome (dependent) variables, S represents the shocks that the individual faced, and H is a vector representing the individual characteristics and household assets as controls.

[11] This cutoff was used based on information from the official website of the Thua Thien Hue meteorology department.

Table 3.2: The frequency of the weather shocks variable

	2008			2010			2013		
	Ha Tinh (713)	Hue (696)	Dak Lak (735)	Ha Tinh (701)	Hue (683)	Dak Lak (715)	Ha Tinh (659)	Hue (648)	Dak Lak (703)
0	175	10	735	334	39	656	39	477	703
2	0	370	0	367	46	59	620	171	0
3	538	0	0	0	0	0	0	0	0
4	0	0	0	0	347	0	0	0	0
5	0	153	0	0	0	0	0	0	0
6	0	163	0	0	0	0	0	0	0
10	0	0	0	0	251	0	0	0	0

Note: The number in the far left column is the total number of days across the year where there was both at least 100 mm of rain and at least two such days in a row. Thus, a frequency of 6 could indicate three instances of two continuous days with rainfall of at least 100 mm, or two instances of three such days continuously, or one instance of two continuous days together with another instance of four continuous days. The numbers in the remaining columns indicate the number of households in the province experiencing these adverse rain events. The total number of households in each province in each survey is given in parentheses under each province name to provide an understanding of how widespread the shocks are.

The advantage of the model is that weather shock can be treated as an exogenous variable and thus, its causal interpretation is clear. However, several econometric challenges need to be taken into account. First, because we use panel data, either fixed effects or random effects regressions can be chosen. Hausman tests indicated that a fixed effects regression is the appropriate specification. Furthermore, to control for econometric heteroscedasticity, the standard errors are clustered at the village level. Thus, the model is further specified as follows:

$$y_{ivt} = \sigma_i + \gamma_t + \mathbf{h}_{ivt}^{'}\boldsymbol{\beta} + s_{vt}\theta + \epsilon_{ivt}, \tag{2}$$

where y_{ivt} is a welfare measure of individual i in village v in year t; σ_i is individual fixed effects; γ_t is the year fixed effects; $\mathbf{h}_{ivt}$ is a vector capturing individual characteristics and household assets; s_{vt} is the weather shock faced by village v in year t; $\boldsymbol{\beta}$ and θ are the corresponding coefficients; and ϵ_{ivt} is the error term.

Although it is possible that severe weather shocks might have impacts on households lasting for several years, we do not include lag of weather shocks in the model because we do not have household-level data for every single year. Sometimes there are two or three-year gaps between the surveys, as explained in Section 3.1.

3.4 Effect of Crop Income on Household Income Inequality

As Table 2.2 shows, crops are one of the most important income sources of rural households. As a result, changes in crop income lead to changes in total income and income inequality among households. Many measures have been used to quantify income inequality, including the Gini coefficient, Atkinson index and Theil index. In this paper, we use Gini coefficient, one of the most well-known inequality measures to capture both relative and absolute inequality (Kakwani and Son, 2016). To determine the contribution of crop income to overall income inequality in each province, we employ the Gini decomposition method proposed by Shorrocks (1982) and later extended by Lerman and Yitzhaki (1985).

In the Gini decomposition method, the Gini coefficient (G) is written as:

$$G = \sum_{k=1}^{K} S_k G_k R_k, \tag{3}$$

where S_k refers to the share of income source k, G_k is the Gini coefficients of income source k, and R_k is the Gini correlation of income source k with the distribution of total income.

There are different ways to calculate S_k in (3). For example, one could use total crop income divided by total income. In this paper, we follow Stark et al. (1986) and compute $S_k = \bar{Y}_k/\bar{Y}$, where $\bar{Y}_k$ is the mean of income source k and $\bar{Y}$ is the mean of total income. $R_k =$Cov$[Y_k, F(Y)]/$Cov$[Y_k, F(Y_k)]$, where $F(Y)$ and $F(Y_k)$ are the cumulative distributions of total income Y and of income source k (Y_k).

An important issue arises when calculating the Gini coefficient for distributions such as crop income that include negative values. The Gini coefficient is defined by:

$$G = \frac{S}{2(M-1)(T_a - T_n)}, \tag{4}$$

where M is the number of observations, S denotes the sum of absolute differences,

$$S = \sum_{i=1}^{M} \sum_{j=1}^{M} |Y_i - Y_j|,$$

T_a is the sum of positive values, and T_n is the sum of absolute negative values.

When dealing with negative values, the original Gini coefficient can be greater than one and is no longer a concentration index, making interpretation troublesome. We follow De Battisti et al. (2019) in computing the G_a by dropping all the negative values. When disaggregating overall income distributions into their sources, the number of negative values may no longer be considered a negligible phenomenon, and the G_p that is a normalised version of the original Gini should be computed. G_p can be evaluated from the original Gini coefficient using the following transformation:

$$G_p = G \cdot \left[\frac{T_a - T_n}{T_a + T_n}\right]. \tag{5}$$

Following Stark et al. (1986), the partial derivative of G with respect to a 1% change (e) in income source k is:

$$\frac{\partial G}{\partial e} = S_k(G_k R_k - G), \tag{6}$$

and therefore the marginal percentage change of income source k in income inequality is:

$$\frac{\partial G/\partial e}{G} = S_k\left(\frac{G_k R_k}{G} - 1\right). \tag{7}$$

There are three channels through which an income source could contribute to total income inequality, as shown in equation (7). First, if an income source accounts for a large share of total income (large S_k), it is likely to have a large effect on inequality. Second, if that income source is unequally distributed (large G_k), it may increase or decrease inequality, depending on where the households earning that income source are on the income distribution. Third, inequality could increase if the income source is unequally distributed and skewed toward those at the top of the income distribution (large positive R_k).

The fact that weather shocks amplify inequality can be illustrated by a simple model. Let X be the hypothetical income random variable in the absence of weather shocks. The realized income is:

$$Y = \begin{cases} X + c \text{ with probability } 1/2 \text{ if weather is good} \\ X - c \text{ with probability } 1/2 \text{ if weather is bad,} \end{cases}$$

where c is a positive scalar. It is easy to see that $\text{Var}Y = \text{Var}X + c^2$, so that even shocks of neutral quality could amplify inequality. A natural question to ask is why Vietnamese farmers do not use hedging to lower c and reduce inequality. We will return to this question after showing that weather shocks reduce households' income in Section 4.3.

We note that if weather shocks reduce the income of all households by the same amount (proportion), they would have no impact on absolute (relative) inequality. Although these two cases almost never coincide, we will check if income loss is the same for all households. After confirming that weather shocks have differential impacts on households with different characteristics, we apply the Gini decomposition method to evaluate the impact of weather shocks on income inequality.

4 Results and Discussion

4.1 Impact of Weather Shocks on Household Welfare

As described in Section 3.1, the impacts of weather shocks on household welfare are measured by considering the effects on income and consumption. The impact of weather shocks varies depending on income sources, as indicated in Table 4.1. Annual equivalised income from hunting is most affected, with a decrease of approximately 5.53% on average if households experience one more day of rain with at least 100 mm, given that they have already experienced at least two continuous days of rain of similar magnitude. This result is consistent with Le (2020), who found that hunting and aquaculture income were most affected when a village is flooded. One reason for this large reduction in annual hunting income could be that households that hunt rely more on available natural resources.

If a household has already experienced at least two continuous days of rain with rainfall of at least 100 mm, then having one more day of such rainfall reduces equivalised remittances by about 3.63%, and average annual equivalised crop revenue by approximately 2.91%. It can be seen that the coefficient of crop income is of smaller magnitude compared with that of crop revenue, at 2.45% on average. We expect that this is because households adjust their input costs. For example, in response to a weather shock, they might reduce the amount of fertilisers used on crops or spend less time harvesting. Although the percentage reductions in crop revenue and crop income are smaller than those for remittances and hunting income, it is worth emphasising that crop income makes up a larger share of total income. Hence, a small percentage reduction could mean a larger value in absolute terms. On average, having an additional day of heavy rain after the first two days reduces the annual equivalised total income by about 0.65%.

Table 4.1: Impact of weather shocks on equivalised income (ln)

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain shock	-0.0065	-0.0248	-0.0295***	-0.0008	-0.0569***	0.0175	-0.0369**
	(0.0070)	(0.0155)	(0.0107)	(0.0117)	(0.0145)	(0.0118)	(0.0162)
Household size	-0.1346***	-0.1155*	-0.1366***	-0.2072***	0.0075	-0.0898	0.0118
	(0.0360)	(0.0592)	(0.0329)	(0.0702)	(0.0503)	(0.0783)	(0.0778)
Number of children	0.0364	0.1141***	0.0482*	0.1483**	-0.0075	0.0819	-0.0298
	(0.0276)	(0.0433)	(0.0275)	(0.0636)	(0.0505)	(0.0528)	(0.0887)
Age	0.0006	-0.0053	0.0016	0.0143	0.0150**	0.0033	-0.0210
	(0.0040)	(0.0062)	(0.0043)	(0.0088)	(0.0062)	(0.0132)	(0.0159)
Marital status (Married=1)	0.0841**	-0.0478	0.0242	0.0587	0.2081***	-0.1644	0.1354
	(0.0393)	(0.0489)	(0.0369)	(0.0784)	(0.0713)	(0.1040)	(0.0900)
Education (ref: Primary school)							
Education: Secondary school	0.0662*	-0.0041	0.0443	0.0651	-0.0769	0.0232	0.0436
	(0.0393)	(0.0545)	(0.0432)	(0.0836)	(0.0616)	(0.0691)	(0.1062)
Education: High school	0.0523	-0.0591	0.0072	-0.0580	-0.1113	0.0653	-0.3237***
	(0.0385)	(0.0662)	(0.0518)	(0.0780)	(0.0759)	(0.0762)	(0.1097)
Education: Bachelor or higher	-0.0513	-0.1888**	-0.1288	-0.1247	-0.1404	-0.2145*	-0.1500
	(0.0526)	(0.0827)	(0.0785)	(0.1186)	(0.1855)	(0.1096)	(0.1467)
Member of socio-political organization	0.0015	0.0008	0.0069	0.0070	0.0842**	0.0159	-0.2810***
	(0.0211)	(0.0383)	(0.0290)	(0.0578)	(0.0398)	(0.0478)	(0.0678)
Household crop area (1000m^2)	0.0232	0.0184	0.0676	-0.0679	0.0180*	0.0040	0.0125
	(0.0161)	(0.0161)	(0.0474)	(0.0574)	(0.0105)	(0.0074)	(0.0220)
Number of tractor	0.0933***	0.0388	0.1212***	0.1353**	-0.0297	0.0480	-0.2285**
	(0.0336)	(0.0505)	(0.0438)	(0.0660)	(0.0797)	(0.0835)	(0.0992)
Number of vehicle	0.1633***	0.0716	0.0503	0.1431**	-0.0236	0.1033**	-0.1071*
	(0.0257)	(0.0480)	(0.0368)	(0.0627)	(0.0548)	(0.0461)	(0.0632)
Number of phones	0.0439***	-0.0157	0.0282	0.0411	-0.0100	0.0425	0.0492
	(0.0141)	(0.0277)	(0.0175)	(0.0271)	(0.0329)	(0.0304)	(0.0441)
Constant	7.6402***	6.1974***	7.9656***	5.3981***	3.0306***	6.4220***	6.2521***
	(0.2451)	(0.4082)	(0.2566)	(0.5046)	(0.3325)	(0.5689)	(0.7369)
Observations	29994	24179	27507	20480	16831	17865	14262
R^2	0.0355	0.1135	0.4754	0.0208	0.0427	0.3323	0.0268
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

The impact of weather shocks on individuals whose main occupations are related to agricultural activities can be expected to be larger. The larger absolute values of coefficients of the rain shocks on crop income, crop revenue, livestock, and hunting, as shown in specification (2) to (5) of Table 4.2, reaffirm this expectation. If a farmer has already experienced at least two continuous days of rain with rainfall of at least 100 mm, then having one more day of such rainfall reduces equivalised crop revenue by about 3.6% on average, an increase of 0.7% compared with the impact on an individual on average. The reduction of weather shocks on equivalised hunting income is also stronger for farmers, at 6.2%, than for a general individual, at 5.53%. However, the magnitude of weather impacts on remittance income is smaller for farmers compared with general households (and not statistically significant). This is plausible, because farmers may have fewer family members working away from home who send remittances. Rainfall shocks also reduce income from off-farm employment activities for farmers, possibly due to higher input prices or shortages of inputs, as Grabrucker and Grimm (2021) suggest.

Table 4.2: Impact of weather shocks on equivalised income (ln) for farmers

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain shock	-0.0041	-0.0357**	-0.0367***	-0.0115	-0.0641***	-0.0043	-0.0281
	(0.0100)	(0.0156)	(0.0128)	(0.0140)	(0.0187)	(0.0157)	(0.0213)
Household size	-0.1220***	-0.1305*	-0.1501***	-0.2150***	-0.0087	-0.0328	0.0790
	(0.0458)	(0.0722)	(0.0347)	(0.0816)	(0.0549)	(0.0983)	(0.0839)
Number of children	0.0320	0.1534***	0.0884***	0.1806***	-0.0173	0.0512	0.0891
	(0.0331)	(0.0518)	(0.0304)	(0.0683)	(0.0536)	(0.0744)	(0.1131)
Age	0.0091	0.0057	0.0124	0.0171	0.0319	0.0132	-0.0343
	(0.0138)	(0.0197)	(0.0105)	(0.0278)	(0.0228)	(0.0278)	(0.0343)
Marital status (Married=1)	0.0552	-0.1310	-0.0262	0.2754	0.1409	-0.1317	-0.2172
	(0.0871)	(0.1095)	(0.0843)	(0.2324)	(0.1057)	(0.2218)	(0.2370)
Education (ref: Primary school)							
Education: Secondary school	0.0733	0.0176	0.0816	0.0886	-0.1476	-0.1365	-0.0853
	(0.0881)	(0.1073)	(0.0818)	(0.1924)	(0.1307)	(0.1750)	(0.1940)
Education: High school	0.1473	0.1589	0.1316	0.0006	-0.2521	0.0151	-0.6442**
	(0.1257)	(0.2242)	(0.1836)	(0.2488)	(0.2517)	(0.2531)	(0.2907)
Education: Bachelor or higher	0.1888	0.3457	0.0957	0.0604	0.8614***	-0.7494	-0.2185
	(0.1950)	(0.3477)	(0.2601)	(0.3924)	(0.2815)	(0.4680)	(0.5133)
Member of socio-political organization	0.0580	0.0037	-0.0193	-0.0357	0.1705***	-0.0727	-0.2943**
	(0.0378)	(0.0528)	(0.0466)	(0.1092)	(0.0639)	(0.0907)	(0.1368)
Household crop area ($1000m^2$)	0.0243	0.0119	0.0462	-0.0554	0.0163*	0.0065	0.0021
	(0.0161)	(0.0114)	(0.0356)	(0.0701)	(0.0086)	(0.0079)	(0.0123)
Number of tractor	0.0813**	0.0097	0.0928*	0.1243*	-0.0663	-0.0032	-0.1558
	(0.0373)	(0.0526)	(0.0501)	(0.0694)	(0.0865)	(0.1059)	(0.1103)
Number of vehicle	0.1452***	0.1081**	0.0694*	0.0647	-0.0154	0.0655	-0.0691
	(0.0326)	(0.0511)	(0.0364)	(0.0643)	(0.0600)	(0.0625)	(0.0839)
Number of phones	0.0307	-0.0158	0.0309	0.0585*	-0.0055	0.0157	0.0705
	(0.0187)	(0.0296)	(0.0195)	(0.0315)	(0.0358)	(0.0489)	(0.0642)
Constant	7.0184***	5.9895***	7.6967***	5.2072***	2.8206***	4.3237***	6.3703***
	(0.6630)	(1.0019)	(0.4840)	(1.2091)	(0.8827)	(0.9789)	(1.5289)
Observations	10404	9184	10410	7603	6776	6034	4616
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Regarding the impact of lost income on household consumption, it appears that households employ some coping mechanisms to smooth consumption when facing adverse events, as indicated in Tables 4.3 and 4.4. Food, nonfood and education consumption are not reduced by statistically significant amounts when the households experience weather shocks. However, an additional day of heavy rain after at least two consecutive days reduces annual health consumption per capita by about 3.3% for an individual on average, and by about 3.63% for farmers. It may be that heavy rains result in rivers flooding and transportation disruptions, making it more difficult for people to obtain medical treatment, which may have long-term negative consequences. However, an additional day of heavy rain after at least two consecutive days results in an increase in annual rent consumption per capita by about 2.2%. This is probably due to the floods displacing people from their homes, forcing them to seek shelter elsewhere.

It is important to note that the impact of weather shocks is different for households with different characteristics, as indicated in Table 4.5. First, ethnic majorities appear to fare better than minority groups when facing weather shocks, possibly because the latter face greater disadvantages in accessing formal credit, which limits their ability to diversify income sources, as Nguyen et al. (2020a) suggest. Second, the impact of weather shocks on annual equivalised crop revenue is stronger for larger households and for farmers. Furthermore, Thua Thien Hue and Dak Lak are statistically more vulnerable to weather shocks than Ha Tinh. As discussed in Section 2.1, it is possible that Ha Tinh residents already employ strategies to diversify their income sources, such as migration of some family members, or diversifying away from crops to raising livestock.

As noted above, it has been observed that households employ mechanisms to smooth consumption when experiencing weather shocks. A natural question is why Vietnamese households do not employ some strategies to "smooth" income, such as buying insurance against bad weather or using weather derivatives. The first reason is that there are no active trading markets for weather derivatives in Vietnam or other developing countries (Tran and Otake, 2020). Second, agricultural practices in Vietnam, where farmers grow crops on small family-run paddy fields, could explain why Vietnamese farmers do not think investment in insurance is worthwhile. Vietnamese farmers tend to use private transfers as a substitute for agricultural insurance. The individual riskiness and lack of trust in insurers have been found to contribute to the low take-up

Table 4.3: Impact of weather shocks on per capita consumption (ln)

	Total	Food	NonFood	Education	Health	Rent
	(1)	(2)	(3)	(4)	(5)	(6)
Rain shock	0.0003	0.0033	-0.0004	0.0090	-0.0330**	0.0244***
	(0.0030)	(0.0036)	(0.0039)	(0.0084)	(0.0135)	(0.0048)
Household size	-0.0876***	-0.0882***	-0.0804***	-0.2762***	-0.0670	-0.1425***
	(0.0148)	(0.0171)	(0.0183)	(0.0390)	(0.0508)	(0.0182)
Number of children	-0.0308**	-0.0003	-0.0614***	0.1219***	-0.0227	-0.0240
	(0.0154)	(0.0166)	(0.0189)	(0.0350)	(0.0458)	(0.0174)
Age	0.0016	0.0015	0.0008	0.0091	0.0011	0.0018
	(0.0020)	(0.0023)	(0.0026)	(0.0059)	(0.0079)	(0.0031)
Marital status (Married=1)	-0.0041	0.0171	-0.0019	-0.1138**	-0.0116	-0.0026
	(0.0185)	(0.0180)	(0.0259)	(0.0540)	(0.0592)	(0.0238)
Education (ref: Primary school)						
Education: Secondary school	-0.0185	-0.0101	0.0154	-0.2420***	-0.0304	0.0151
	(0.0179)	(0.0190)	(0.0217)	(0.0429)	(0.0651)	(0.0243)
Education: High school	-0.0173	0.0146	0.0377*	-0.3872***	0.0441	-0.0129
	(0.0160)	(0.0185)	(0.0205)	(0.0527)	(0.0662)	(0.0226)
Education: Bachelor or higher	-0.0590**	-0.0112	-0.0253	-0.4087***	0.0664	0.0261
	(0.0246)	(0.0274)	(0.0372)	(0.0898)	(0.0885)	(0.0434)
Member of socio-political organization	0.0203**	0.0010	0.0497***	0.0307	-0.0559	-0.0084
	(0.0096)	(0.0098)	(0.0133)	(0.0269)	(0.0383)	(0.0158)
Household crop area ($1000m^2$)	0.0080	0.0079**	0.0076	0.0254	0.0450	-0.0204***
	(0.0055)	(0.0035)	(0.0083)	(0.0178)	(0.0478)	(0.0055)
Number of tractor	0.0754***	0.0720***	0.0809***	0.0518	0.0522	0.0846***
	(0.0174)	(0.0182)	(0.0251)	(0.0452)	(0.0588)	(0.0281)
Number of vehicle	0.1483***	0.0981***	0.2636***	0.0249	-0.0028	0.0233
	(0.0134)	(0.0145)	(0.0200)	(0.0345)	(0.0461)	(0.0200)
Number of phones	0.0402***	0.0250***	0.0633***	0.0574***	0.0403	0.0136
	(0.0070)	(0.0083)	(0.0088)	(0.0213)	(0.0282)	(0.0111)
Constant	7.0168***	6.4099***	5.6013***	5.4992***	3.0724***	3.5092***
	(0.1058)	(0.1199)	(0.1396)	(0.2973)	(0.4107)	(0.1561)
Observations	29986	29986	29986	22021	26588	29933
R^2	0.1577	0.0669	0.1861	0.1645	0.0116	0.0903
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Table 4.4: Impact of weather shocks on per capita consumption (ln) for farmers

	Total	Food	NonFood	Education	Health	Rent
	(1)	(2)	(3)	(4)	(5)	(6)
Rain shock	0.0001	0.0005	0.0042	0.0063	-0.0370**	0.0221***
	(0.0040)	(0.0046)	(0.0053)	(0.0120)	(0.0157)	(0.0067)
Household size	-0.0821***	-0.0802***	-0.1008***	-0.2511***	-0.0209	-0.1452***
	(0.0195)	(0.0230)	(0.0226)	(0.0470)	(0.0685)	(0.0212)
Number of children	-0.0333*	-0.0067	-0.0439*	0.1550***	-0.0283	-0.0350*
	(0.0194)	(0.0208)	(0.0227)	(0.0465)	(0.0493)	(0.0199)
Age	0.0100	0.0102	0.0127*	0.0027	0.0093	0.0003
	(0.0061)	(0.0082)	(0.0067)	(0.0170)	(0.0184)	(0.0070)
Marital status (Married=1)	0.0351	0.0489	0.0130	0.1433	0.0359	-0.0050
	(0.0389)	(0.0388)	(0.0469)	(0.1068)	(0.1152)	(0.0400)
Education (ref: Primary school)						
Education: Secondary school	0.0469	0.0824**	0.0042	-0.0104	-0.1435	-0.0499
	(0.0324)	(0.0339)	(0.0434)	(0.0775)	(0.1221)	(0.0418)
Education: High school	0.1289***	0.1593***	0.0899	-0.1838	0.2007	-0.1184*
	(0.0481)	(0.0486)	(0.0784)	(0.1387)	(0.1771)	(0.0688)
Education: Bachelor or higher	0.1481	0.1447	0.1134	-0.2357	0.7829**	-0.1564
	(0.1044)	(0.1089)	(0.1517)	(0.3354)	(0.3820)	(0.1383)
Member of socio-political organization	0.0276*	0.0136	0.0762***	0.0610	-0.0607	0.0088
	(0.0163)	(0.0192)	(0.0229)	(0.0460)	(0.0687)	(0.0243)
Household crop area ($1000m^2$)	0.0092**	0.0137***	0.0065	0.0193	0.0831	-0.0200***
	(0.0044)	(0.0040)	(0.0056)	(0.0156)	(0.0617)	(0.0050)
Number of tractor	0.0783***	0.0648***	0.0840***	0.0876	0.0912	0.0652*
	(0.0200)	(0.0233)	(0.0293)	(0.0571)	(0.0690)	(0.0355)
Number of vehicle	0.1411***	0.0872***	0.2727***	0.0193	-0.0145	0.0235
	(0.0154)	(0.0164)	(0.0237)	(0.0465)	(0.0532)	(0.0228)
Number of phones	0.0517***	0.0342***	0.0772***	0.0598***	0.0706**	0.0129
	(0.0088)	(0.0107)	(0.0114)	(0.0226)	(0.0347)	(0.0140)
Constant	6.4311***	5.8347***	5.0056***	4.3014***	2.2730**	3.5198***
	(0.2610)	(0.3446)	(0.3121)	(0.6494)	(0.9204)	(0.3349)
Observations	10537	10537	10537	7073	9386	10513
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Table 4.5: Heterogeneity tests

	Crop Revenue				
	(1)	(2)	(3)	(4)	(5)
Rain shock	-0.0353**	-0.0264**	0.0680***	0.0123	-0.1418***
	(0.0143)	(0.0108)	(0.0210)	(0.0288)	(0.0367)
Household crop area (1000m^2)	0.0645	0.0673	0.0663	0.0668	0.0626
	(0.0469)	(0.0474)	(0.0462)	(0.0473)	(0.0450)
Rain shock × Household crop area (1000m^2)	0.0138				
	(0.0190)				
Number of children	0.0465*	0.0487*	0.0518*	0.0511*	0.0537**
	(0.0280)	(0.0276)	(0.0274)	(0.0279)	(0.0272)
Marital status (Married=1)	0.0245	0.0210	0.0270	0.0254	0.0246
	(0.0369)	(0.0371)	(0.0368)	(0.0369)	(0.0373)
Education: Secondary school	0.0453	0.0376	0.0383	0.0442	0.0496
	(0.0434)	(0.0429)	(0.0431)	(0.0431)	(0.0432)
Education: High school	0.0090	-0.0004	0.0077	0.0055	0.0049
	(0.0519)	(0.0527)	(0.0519)	(0.0517)	(0.0513)
Education: Bachelor or higher	-0.1293	-0.1321*	-0.1225	-0.1292	-0.1162
	(0.0785)	(0.0786)	(0.0783)	(0.0785)	(0.0779)
Member of socio-political organization	0.0072	0.0061	0.0121	0.0081	0.0074
	(0.0289)	(0.0289)	(0.0293)	(0.0290)	(0.0288)
Number of tractor	0.1209***	0.1213***	0.1326***	0.1209***	0.1209***
	(0.0437)	(0.0438)	(0.0437)	(0.0439)	(0.0438)
Number of vehicle	0.0498	0.0505	0.0516	0.0492	0.0540
	(0.0369)	(0.0369)	(0.0368)	(0.0369)	(0.0372)
Number of phones	0.0282	0.0281	0.0294*	0.0273	0.0298*
	(0.0175)	(0.0175)	(0.0174)	(0.0173)	(0.0173)
Farmer=1 × Rain shock		-0.0103			
		(0.0083)			
Thua Thien Hue × Rain shock			-0.1131***		
			(0.0266)		
Dak Lak × Rain shock			-0.2391***		
			(0.0557)		
Rain shock × Household size				-0.0069	
				(0.0045)	
Ethnicity (Kinh=1)=1 × Rain shock					0.1233***
					(0.0373)
Observations	27507	27507	27507	27507	27507
Individual FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Note: Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

rates (King and Singh, 2020).

4.2 Robustness Check

We use two alternative weather shock variables to check the validity of the newly constructed weather shock variables described in Section 3.2 and used to produce the results in Section 4.1.

4.2.1 Three standard deviations away from the mean

The first alternative is to construct the weather shock variable as the number of times that monthly rainfall is three standard deviations away from the mean, as in Nguyen and Nguyen (2020). We refer to this variable as “Rain month”; the results of my analysis on the impact of “Rain month” on household welfare are presented in Tables 4.6 and 4.7.

Table 4.6: Impact of weather shocks on equivalised income (ln) – Rain month

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain month	-0.1058***	0.0410	-0.1670***	-0.0297	-0.3710***	0.1585***	-0.3377***
	(0.0366)	(0.0546)	(0.0537)	(0.0658)	(0.0611)	(0.0598)	(0.0849)
Household size	-0.1318***	-0.1164**	-0.1346***	-0.2065***	0.0032	-0.0939	0.0142
	(0.0364)	(0.0588)	(0.0329)	(0.0703)	(0.0513)	(0.0769)	(0.0772)
Number of children	0.0367	0.1129**	0.0493*	0.1485**	0.0046	0.0811	-0.0317
	(0.0276)	(0.0434)	(0.0270)	(0.0636)	(0.0502)	(0.0522)	(0.0875)
Age	0.0000	-0.0043	0.0022	0.0142	0.0150**	0.0049	-0.0211
	(0.0040)	(0.0062)	(0.0042)	(0.0087)	(0.0059)	(0.0131)	(0.0155)
Marital status (Married=1)	0.0824**	-0.0486	0.0204	0.0584	0.1961***	-0.1554	0.1461
	(0.0395)	(0.0488)	(0.0371)	(0.0787)	(0.0683)	(0.1016)	(0.0901)
Education (ref: Primary school)							
Education: Secondary school	0.0698*	-0.0084	0.0486	0.0662	-0.0669	0.0143	0.0307
	(0.0393)	(0.0546)	(0.0433)	(0.0840)	(0.0615)	(0.0695)	(0.1039)
Education: High school	0.0576	-0.0638	0.0136	-0.0574	-0.0989	0.0526	-0.3122***
	(0.0382)	(0.0667)	(0.0512)	(0.0778)	(0.0785)	(0.0763)	(0.1072)
Education: Bachelor or higher	-0.0425	-0.2009**	-0.1297*	-0.1238	-0.1371	-0.2300**	-0.0661
	(0.0527)	(0.0837)	(0.0782)	(0.1186)	(0.1828)	(0.1097)	(0.1441)
Member of socio-political organization	0.0072	-0.0044	0.0134	0.0092	0.0934**	0.0049	-0.2664***
	(0.0208)	(0.0380)	(0.0282)	(0.0570)	(0.0408)	(0.0476)	(0.0674)
Household crop area ($1000m^2$)	0.0207	0.0201	0.0646	-0.0698	0.0134	0.0066	0.0092
	(0.0147)	(0.0174)	(0.0460)	(0.0567)	(0.0117)	(0.0072)	(0.0203)
Number of tractor	0.0927***	0.0331	0.1167***	0.1350**	-0.0233	0.0467	-0.2260**
	(0.0332)	(0.0512)	(0.0437)	(0.0661)	(0.0783)	(0.0828)	(0.0968)
Number of vehicle	0.1623***	0.0756	0.0502	0.1426**	-0.0223	0.1095**	-0.0988
	(0.0257)	(0.0478)	(0.0366)	(0.0626)	(0.0551)	(0.0465)	(0.0622)
Number of phones	0.0417***	-0.0133	0.0279	0.0404	-0.0060	0.0477	0.0436
	(0.0138)	(0.0277)	(0.0169)	(0.0270)	(0.0322)	(0.0300)	(0.0430)
Constant	7.6409***	6.1457***	7.9121***	5.4004***	3.0342***	6.3955***	6.2143***
	(0.2451)	(0.4038)	(0.2535)	(0.5035)	(0.3268)	(0.5642)	(0.6408)
Observations	29994	24179	27507	20480	16831	17865	14262
R^2	0.0395	0.1121	0.4774	0.0209	0.0615	0.3349	0.0368
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: "Rain month" is measured by the number of times monthly rainfall is three standard deviation away from the mean. Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Table 4.7: Impact of weather shocks on per capita consumption (ln) – Rain month

	Total	Food	NonFood	Education	Health	Rent
	(1)	(2)	(3)	(4)	(5)	(6)
Rain month	-0.0475***	-0.0362**	-0.0597***	-0.0701*	-0.1582***	0.1313***
	(0.0145)	(0.0177)	(0.0191)	(0.0364)	(0.0493)	(0.0257)
Household size	-0.0871***	-0.0880***	-0.0797***	-0.2767***	-0.0619	-0.1456***
	(0.0146)	(0.0169)	(0.0181)	(0.0383)	(0.0499)	(0.0179)
Number of children	-0.0302*	0.0004	-0.0608***	0.1239***	-0.0270	-0.0236
	(0.0153)	(0.0166)	(0.0188)	(0.0349)	(0.0456)	(0.0171)
Age	0.0013	0.0010	0.0004	0.0076	0.0018	0.0015
	(0.0020)	(0.0022)	(0.0026)	(0.0057)	(0.0079)	(0.0031)
Marital status (Married=1)	-0.0048	0.0167	-0.0027	-0.1116**	-0.0120	-0.0002
	(0.0185)	(0.0180)	(0.0257)	(0.0549)	(0.0591)	(0.0235)
Education (ref: Primary school)						
Education: Secondary school	-0.0163	-0.0081	0.0180	-0.2388***	-0.0289	0.0121
	(0.0176)	(0.0188)	(0.0216)	(0.0430)	(0.0649)	(0.0244)
Education: High school	-0.0153	0.0161	0.0402*	-0.3845***	0.0494	-0.0191
	(0.0160)	(0.0183)	(0.0206)	(0.0522)	(0.0663)	(0.0225)
Education: Bachelor or higher	-0.0544**	-0.0068	-0.0197	-0.4027***	0.0688	0.0206
	(0.0245)	(0.0273)	(0.0369)	(0.0908)	(0.0885)	(0.0432)
Member of socio-political organization	0.0232**	0.0037	0.0533***	0.0382	-0.0512	-0.0125
	(0.0095)	(0.0097)	(0.0131)	(0.0266)	(0.0389)	(0.0160)
Household crop area ($1000m^2$)	0.0065	0.0066**	0.0058	0.0230	0.0342	-0.0178***
	(0.0047)	(0.0032)	(0.0072)	(0.0162)	(0.0467)	(0.0057)
Number of tractor	0.0755***	0.0725***	0.0810***	0.0509	0.0514	0.0878***
	(0.0172)	(0.0181)	(0.0248)	(0.0446)	(0.0588)	(0.0281)
Number of vehicle	0.1474***	0.0973***	0.2626***	0.0228	-0.0034	0.0243
	(0.0133)	(0.0145)	(0.0199)	(0.0348)	(0.0461)	(0.0201)
Number of phones	0.0391***	0.0239***	0.0621***	0.0545**	0.0407	0.0137
	(0.0069)	(0.0083)	(0.0087)	(0.0214)	(0.0282)	(0.0111)
Constant	7.0267***	6.4267***	5.6113***	5.5571***	2.9956***	3.5568***
	(0.1042)	(0.1191)	(0.1384)	(0.2931)	(0.4066)	(0.1519)
Observations	29986	29986	29986	22021	26588	29933
R^2	0.1613	0.0685	0.1891	0.1656	0.0125	0.0959
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: "Rain month" is measured by the number of times monthly rainfall is three standard deviation away from the mean.
Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

The results using the number of times that monthly rainfall is three standard deviations away from the mean tell the same story as the main results presented in Tables 4.1 and 4.3. The impacts of "Rain month" on annual equivalised income have the same sign and are of the same relative magnitude as the main results, with the percentage of hunting income most reduced, followed by remittance income and crop revenue. Spending on health is the type of consumption most reduced when households experience a month of heavy rain. In addition, an additional month with rainfall three standard deviations away from the mean would result in an increase in rent spending. These results are all consistent with the main results presented in Tables 4.3 and 4.4.

It should be noticed here that the absolute magnitudes of the impact using the Rain month variable are larger than those using the weather shocks variable constructed by counting the number of heavy rain days. This is plausible, because a month of heavy rain is likely to be more disastrous than a few days of heavy rain.

4.2.2 Rainfall deviation

Another way to construct the weather shock variable is to use "Rainfall deviation", defined by the natural log of the year's rainfall minus the natural log of mean annual rainfall in a given village, as used in Maccini and Yang (2009). The results presented in Tables 4.8 and 4.9 show the same direction of impacts of rainfall deviation on different income sources. However, the results should only be used to support the main findings because of the short span of the weather data, which cover only the period from 2007 to 2014. The deviation from the mean for such a short period of time might not be a good indicator of weather shocks.

Table 4.8: Impact of weather shocks on equivalised income (ln) – Rainfall deviation

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall deviation	-0.0720	-0.4681**	-0.0138	0.2178	-0.8345**	-0.3559	-0.3882
	(0.1456)	(0.2194)	(0.2202)	(0.2603)	(0.3236)	(0.2527)	(0.3140)
Household size	-0.1354***	-0.1225**	-0.1363***	-0.2032***	-0.0019	-0.0936	0.0091
	(0.0359)	(0.0588)	(0.0325)	(0.0705)	(0.0514)	(0.0787)	(0.0775)
Number of children	0.0371	0.1203***	0.0472*	0.1436**	-0.0103	0.0906*	-0.0282
	(0.0276)	(0.0430)	(0.0275)	(0.0638)	(0.0512)	(0.0530)	(0.0891)
Age	0.0006	-0.0065	0.0028	0.0157*	0.0153**	-0.0029	-0.0202
	(0.0039)	(0.0063)	(0.0042)	(0.0088)	(0.0063)	(0.0136)	(0.0157)
Marital status (Married=1)	0.0839**	-0.0476	0.0236	0.0589	0.1990***	-0.1614	0.1345
	(0.0393)	(0.0489)	(0.0369)	(0.0785)	(0.0698)	(0.1053)	(0.0901)
Education (ref: Primary school)							
Education: Secondary school	0.0658*	-0.0030	0.0424	0.0640	-0.0730	0.0300	0.0405
	(0.0393)	(0.0546)	(0.0437)	(0.0836)	(0.0611)	(0.0686)	(0.1057)
Education: High school	0.0525	-0.0607	0.0058	-0.0580	-0.0992	0.0726	-0.3247***
	(0.0385)	(0.0657)	(0.0523)	(0.0779)	(0.0774)	(0.0770)	(0.1103)
Education: Bachelor or higher	-0.0498	-0.1733**	-0.1374*	-0.1347	-0.1168	-0.1925*	-0.1535
	(0.0527)	(0.0815)	(0.0779)	(0.1179)	(0.1872)	(0.1114)	(0.1469)
Member of socio-political organization	0.0011	0.0024	0.0049	0.0046	0.0849**	0.0246	-0.2847***
	(0.0211)	(0.0383)	(0.0287)	(0.0580)	(0.0404)	(0.0480)	(0.0679)
Household crop area ($1000m^2$)	0.0231	0.0168	0.0693	-0.0657	0.0161	0.0019	0.0109
	(0.0163)	(0.0167)	(0.0490)	(0.0574)	(0.0098)	(0.0077)	(0.0234)
Number of tractor	0.0932***	0.0396	0.1177***	0.1314*	-0.0307	0.0602	-0.2257**
	(0.0336)	(0.0506)	(0.0440)	(0.0671)	(0.0819)	(0.0841)	(0.0990)
Number of vehicle	0.1633***	0.0732	0.0520	0.1439**	-0.0173	0.1036**	-0.1099*
	(0.0258)	(0.0481)	(0.0370)	(0.0628)	(0.0552)	(0.0464)	(0.0629)
Number of phones	0.0441***	-0.0167	0.0311*	0.0438	-0.0102	0.0370	0.0498
	(0.0139)	(0.0274)	(0.0173)	(0.0273)	(0.0335)	(0.0305)	(0.0437)
Constant	7.6195***	6.1266***	7.8920***	5.3828***	2.7833***	6.5413***	6.1137***
	(0.2445)	(0.4072)	(0.2575)	(0.5103)	(0.3538)	(0.5744)	(0.7302)
Observations	29994	24179	27507	20480	16831	17865	14262
R^2	0.0353	0.1139	0.4732	0.0211	0.0368	0.3323	0.0238
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: “Rainfall deviation” is measured by the natural log of the year rainfall minus the natural log of mean annual rainfall in a given village. Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Table 4.9: Impact of weather shocks on per capita consumption (ln) – Rainfall deviation

	Total	Food	NonFood	Education	Health	Rent
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall deviation	-0.1557**	-0.1579**	-0.0852	-0.4967***	0.1063	0.1586
	(0.0649)	(0.0795)	(0.0892)	(0.1585)	(0.2232)	(0.1162)
Household size	-0.0900***	-0.0908***	-0.0817***	-0.2815***	-0.0638	-0.1416***
	(0.0144)	(0.0168)	(0.0182)	(0.0379)	(0.0513)	(0.0182)
Number of children	-0.0281*	0.0027	-0.0600***	0.1283***	-0.0272	-0.0248
	(0.0154)	(0.0167)	(0.0187)	(0.0348)	(0.0460)	(0.0174)
Age	0.0009	0.0006	0.0005	0.0055	0.0033	0.0012
	(0.0020)	(0.0023)	(0.0026)	(0.0055)	(0.0081)	(0.0032)
Marital status (Married=1)	-0.0046	0.0168	-0.0021	-0.1096**	-0.0134	-0.0016
	(0.0184)	(0.0179)	(0.0258)	(0.0545)	(0.0595)	(0.0236)
Education (ref: Primary school)						
Education: Secondary school	-0.0173	-0.0086	0.0160	-0.2367***	-0.0341	0.0171
	(0.0178)	(0.0190)	(0.0216)	(0.0427)	(0.0657)	(0.0246)
Education: High school	-0.0174	0.0144	0.0376*	-0.3830***	0.0458	-0.0133
	(0.0160)	(0.0184)	(0.0206)	(0.0517)	(0.0660)	(0.0226)
Education: Bachelor or higher	-0.0515**	-0.0027	-0.0213	-0.3820***	0.0536	0.0256
	(0.0241)	(0.0266)	(0.0371)	(0.0898)	(0.0878)	(0.0441)
Member of socio-political organization	0.0215**	0.0027	0.0503***	0.0380	-0.0623	-0.0056
	(0.0096)	(0.0098)	(0.0133)	(0.0266)	(0.0386)	(0.0162)
Household crop area ($1000m^2$)	0.0071	0.0068**	0.0072	0.0215	0.0535	-0.0210***
	(0.0054)	(0.0034)	(0.0082)	(0.0167)	(0.0485)	(0.0056)
Number of tractor	0.0775***	0.0746***	0.0820***	0.0580	0.0482	0.0859***
	(0.0173)	(0.0181)	(0.0251)	(0.0445)	(0.0587)	(0.0282)
Number of vehicle	0.1476***	0.0973***	0.2633***	0.0207	0.0004	0.0228
	(0.0134)	(0.0145)	(0.0200)	(0.0346)	(0.0461)	(0.0201)
Number of phones	0.0389***	0.0234***	0.0627***	0.0526**	0.0446	0.0121
	(0.0070)	(0.0084)	(0.0088)	(0.0213)	(0.0281)	(0.0112)
Constant	7.0134***	6.4155***	5.5976***	5.5094***	2.9733***	3.5880***
	(0.1049)	(0.1193)	(0.1400)	(0.2837)	(0.4142)	(0.1562)
Observations	29986	29986	29986	22021	26588	29933
R^2	0.1597	0.0684	0.1864	0.1680	0.0089	0.0826
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: "Rainfall deviation" is measured by the natural log of the year rainfall minus the natural log of mean annual rainfall in a given village.
Standard errors (in parentheses) are clustered at the village level. The symbols ***, ** and * denote p<0.01, p<0.05 and p<0.10, respectively.

Overall, the two alternative variables, Rain month and Rainfall deviation, provide similar results to my main findings. However, the newly constructed weather shock variable has the advantage of being an absolute measure that does not depend on the duration of weather data observation, which makes it more suitable for situations when only a short period of rainfall data is available.

4.3 Impact of Weather Shocks on Income Inequality

The total level of household income inequality, as measured by the Gini indexes, was around 0.5 for all three provinces in the period of analysis (Table 4.10), which represents a high level of inequality (The World Bank, 2021). Although these Gini indexes are of similar magnitude to that for the six North Central region provinces, measured at 0.554 in 2016 (Nguyen and Tran, 2018), they are higher than those computed for rural Vietnam from 2002 to 2018 (Kang and Imai, 2012; Benjamin et al., 2017; Le and Nguyen, 2020). In addition, they are higher than the Gini index for Vietnam as a whole, which remained below 0.4 during the period 2002–2018 (The World Bank, 2021). This indicates a higher level of inequality in the three focus provinces than in the country as a whole. Moreover, the Gini indexes of the three provinces are higher than the world average Gini index of 0.47 and that of the United States, standing at 0.41 in 2021 (World Population Review, 2021). It is also important to note that the general trend was for the Gini indexes to increase with time, indicating a growing level of income inequality. Using G_p as an indicator, Ha Tinh, Thua Thien Hue and Dak Lak experienced increases of 14.65, 15.32 and 2.06 percentage points in their indexes from 2008 to 2013.

We computed G, G_a, and G_p to better evaluate the differences between distributions when dealing with negative values, following suggestions from De Battisti et al. (2019), as described in Section 3.4. The original Gini coefficient G is always higher than the one computed when the nonpositive values are dropped for all three provinces in all three years, which makes intuitive sense because there are households with nonpositive incomes in all those provinces in each year. However, the difference between G and G_a is not very large for years in which a province has a small number of households with nonpositive total income, as shown in Table 3.1. For example, the reduction from G to G_a is between 2 to 6 percentage points for Ha Tinh. The reduction tends to be larger for a province with a larger number of households with nonpositive income. For example, the reduction from G to G_a for Dak Lak is about 16.18 percentage points in 2010 and 13.37 percentage points in 2013. It is important to point out that the reduction from G to G_a depends not only on the number of households with negative incomes, but on the degree to which they are negative.

Although there is a drop from G to G_a when the nonpositive values are excluded, the G_p obtained by normalising G is higher than G_a, but smaller than G. The relative magnitudes of the three indexes are consistent for all provinces in all three years, with G the largest, followed by G_p in the second position, and G_a ranking the third.

Table 4.10: Gini coefficient of total income (at the household level)

	2008	2010	2013
Ha Tinh			
G	0.477	0.502	0.552
G_a (Dropping the ≤ 0 values)	0.463	0.487	0.520
G_p (the Raffinetti et al. normalization)	0.471	0.498	0.540
Thua Thien Hue			
G	0.545	0.520	0.577
G_a (Dropping the ≤ 0 values)	0.463	0.490	0.560
G_p (the Raffinetti et al. normalization)	0.496	0.512	0.572
Dak Lak			
G	0.541	0.550	0.576
G_a (Dropping the ≤ 0 values)	0.517	0.461	0.499
G_p (the Raffinetti et al. normalization)	0.533	0.511	0.544

The relative magnitude of G, G_p, and G_a also holds true for crop income Gini indexes as shown in Table 4.11. As expected, G_a are smaller than G, meaning that positive crop income reduces income inequality among rural households. More importantly, there is a higher level of inequality in crop income than in total income for all three provinces, as shown by larger Gini indexes in Table 4.11. The original Gini coefficient G for Thua Thien Hue in 2010 is greater than one (1.358), signalling there was either a significant proportion of sampled households with negative crop income or their crop income had become really negative. This is consistent with the frequency of the weather shocks variable constructed in Table 3.2, which show that about 50% of sampled households experiencing weather shocks at level 6 and 37% of sampled households experiencing weather shocks at level 10. By comparing the G_p of three provinces in three years, we see that crop income inequality is consistently higher for Thua Thien Hue – the province that experienced more severe weather shocks.

Table 4.11: Gini coefficient of crop income (at the household level)

	2008	2010	2013
Ha Tinh			
G	0.638	0.699	0.848
G_a (Dropping the ≤ 0 values)	0.596	0.601	0.621
G_p(the Raffinetti et al. normalization)	0.629	0.665	0.729
Thua Thien Hue			
G	0.753	1.358	0.998
G_a (Dropping the ≤ 0 values)	0.609	0.631	0.666
G_p (the Raffinetti et al. normalization)	0.713	0.809	0.796
Dak Lak			
G	0.694	0.870	1.010
G_a (Dropping the ≤ 0 values)	0.586	0.594	0.610
G_p (the Raffinetti et al. normalization)	0.658	0.713	0.759

In this dataset, weather shocks decrease household income by reducing income from crops, and the impacts are different for households with different characteristics, so the next question to answer is: What are the impacts on income inequality? We estimate the contribution of crop income to income inequality for the three provinces of interest, as shown in Table 4.12 – Owing to the small number of observations, we combine the three years of household data for each province. The top (bottom) half of the table presents the Gini decomposition when using the original Gini G (G_a).

Column 1 of Table 4.12 displays the income share from crops, showing that it plays an important role in rural Vietnamese household income. As described in Section 3.4, the income share is computed as the ratio of mean crop income to mean total household income. Therefore, when the means of crop income are often smaller when including negative values, the same applies to the contribution of crop income to total income when including negative values. Crop income makes up about 18.26%, 13.09%, and 45.52% of total income for households in Ha Tinh, Thua Thien Hue, and Dak Lak, respectively, when excluding negative values.

There are two important points to note about the Gini coefficient of crop income and total

Table 4.12: Gini decomposition by income source (at the household level)

	Income Share	Gini coefficient	Gini correlation with total income	Percentage change in Gini coefficient
Using G				
Ha Tinh				
Crop income	0.134	0.983	0.737	-0.008
Total income		0.768		
Hue				
Crop income	0.102	0.947	0.712	-0.010
Total income		0.747		
Dak Lak				
Crop income	0.382	0.873	0.839	0.004
Total income		0.726		
Using G_a				
Ha Tinh				
Crop income	0.183	0.612	0.660	-0.033
Total income		0.491		
Hue				
Crop income	0.131	0.637	0.524	-0.047
Total income		0.518		
Dak Lak				
Crop income	0.455	0.605	0.789	-0.022
Total income		0.461		

Note: The top (bottom) half of the table presents the Gini decomposition using the original Gini G (G_a).

income presented in column 2 (Table 4.12). First, there is more inequality in crop income than total income for each province. Second, Gini coefficients when dropping negative values are always smaller than those computed using all the values. This means that positive crop income and total income contribute to reducing the level of income inequality among rural households.

We see a high Gini correlation between crop income and total income, as indicated in column 3 (Table 4.12). The Gini correlation coefficients are generally higher when including all values than when excluding the negative values. When excluding negative values, this correlation ranges from 0.524 for Thua Thien Hue to 0.789 for Dak Lak. The high correlation coefficients reflect the importance of crop income to the overall Gini coefficient.

Column 4 (Table 4.12) shows the impact of a small change in crop income on the overall Gini coefficient. When including negative values, crop income contributes very little to reducing income inequality. An increase of one percentage point in crop income, holding other things constant, decreases the Gini coefficient by 0.008% for Ha Tinh and 0.01% for Thua Thien Hue. For Dak Lak, crop income even contributes to increasing income inequality when considering all negative values.

When considering only positive values, crop income contributes to reducing income inequality for all three provinces, and the reduction is larger than when negative values are included. An increase of one percentage point in crop income decreases the Gini coefficient by 0.033% for Ha Tinh and by 0.022% for Dak Lak. The magnitude is greatest for Thua Thien Hue at 0.047%. Because weather shocks reduce the crop income of rural households, they will contribute to increasing income inequality. The situation is worse in Thua Thien Hue, because this province experiences more severe weather shocks and crop income plays a more important role in reducing income inequality there.

5 Conclusion

In this paper, we assessed the impact of weather shocks on households' welfare and income inequality using a panel household dataset collected in three provinces of Vietnam. The necessity of identifying at-risk communities when addressing the issue of income inequality arises because resources are scarce. This paper provides governments and NGOs with the tools to identify such communities.

To evaluate the impact of weather shocks, we first proposed a new measure of weather shocks to overcome the limitations of existing measures. The weather shocks variable is defined as the total number of days with rainfall of at least 100 mm when there was also at least two such days in a row in the period that coincides with the household survey. This measure has the advantage of being an absolute measure that does not depend on the duration of weather samples observed. Then, we computed the Gini decomposition to identify the contribution of crop income to income inequality in the three provinces. We found that weather shocks have a significant negative impact on the income sources of rural households, particularly income from crops. In addition, weather shocks affect households with different characteristics differently. Farmers with larger crop areas are more severely affected, and ethnic minority groups and large households are also disproportionately impacted by weather shocks.

We found that crop income contributes to reducing income inequality in the three provinces by computing the Gini decomposition of income sources. Because weather shocks reduce income from crops, they contribute to increasing income inequality. The results from this paper should assist governments and NGOs to identify at-risk communities that are more prone to weather shocks to provide necessary support. In addition, it is important for governments in countries that are agriculturally intensive to create and facilitate a market for weather derivatives to mitigate the effects of unfavourable weather patterns.

This study has has several limitations that can potentially be improved with further research. First, it is important to investigate the mechanisms for which weather shocks are translated into income inequality. Is it the case that farmers are afraid of weather shocks so they stop growing crops or transition to other occupations? Second, although the Gini decomposition computed using the original G and G_a provides valuable information about the contribution of crop income to reducing income inequality, it would be interesting to see how the results change if using G_p. Future researchers might explore how to compute the Gini decomposition when using G_p, which is a good complementary index for the original G and G_a when a distribution includes negative values. Furthermore, the contribution of other income sources, such as livestock income or hunting income, could be added in the Gini decomposition to obtain a more complete picture. However, the number of households with negative livestock income might be different from the number of households with negative hunting income, in which case the current Gini decomposition method would not be useful. Thus, another direction for future research is to develop a decomposition method that is suitable for dealing with different numbers of negative values for different income sources.

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A Descriptive statistics

Table A.1: Descriptive Statistics by Provinces in 2008 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Demographic variables				
Household size	5.71	5.27	5.93	5.89
Number of children	1.54	1.18	1.67	1.74
Gender (Female=1)	0.51	0.52	0.51	0.50
Age	29.30	32.43	29.29	26.65
Ethnicity (Kinh=1)	0.77	1.00	0.76	0.59
Marital status (Married=1)	0.39	0.40	0.36	0.39
Education: Primary school	0.65	0.51	0.73	0.71
Education: Secondary school	0.23	0.33	0.18	0.20
Education: High school	0.11	0.15	0.08	0.09
Education: Bachelor or higher	0.01	0.01	0.01	0.01
Farmer	0.34	0.35	0.28	0.38
Member of socio-political organization	0.51	0.72	0.54	0.31
Percentage of socio-political women	0.05	0.07	0.06	0.03
Income variables (2005 PPP USD)				
Equivalised total income	2450.34	2256.36	1672.51	3352.06
Equivalised crop income	861.20	539.71	322.18	1652.95
Equivalised crop revenue	1368.49	746.36	511.62	2723.98
Equivalised livestock income	231.88	384.32	45.03	276.36
Equivalised hunting income	74.72	55.36	120.43	37.37
Equivalised off-farm employment income	282.38	262.55	287.27	296.58
Equivalised remittance: family/friends	181.95	291.71	102.50	161.06
Consumption variables (2005 PPP USD)				
Per capita total consumption	940.95	875.18	857.01	1079.87
Per capita food consumption	483.39	426.57	460.34	556.19
Per capita non-food consumption	345.83	316.30	314.36	401.68
Per capita education consumption	53.52	76.67	33.90	52.07
Per capita health consumption	34.03	34.22	24.05	43.43
Per capita rent	24.31	21.42	24.74	26.50
Household asset variables				
Household crop area ($1000m^2$)	0.74	0.40	0.47	1.26
Number of tractor	1.05	1.02	1.10	1.07
Number of vehicle	1.31	1.17	1.41	1.34
Number of phones	1.63	1.68	1.63	1.59

Table A.2: Difference of a province compared to the rest in 2008

	Ha Tinh - rest b	Hue - rest b	Dak Lak - rest b
Demographic variables			
Household size	-.6310284***	.3305689***	.2775994***
Number of children	-.514996***	.1918763***	.3035904***
Gender (Female=1)	.0127784	-.0003658	-.0113085
Age	4.428933***	-.096816	-4.185909***
Ethnicity (Kinh=1)	.3265955***	-.0242539***	-.2774715***
Marital status (Married=1)	.0251947**	-.0317376***	.0072697
Education: Primary school	-.2029865***	.1116412***	.0842031***
Education: Secondary school	.1378071***	-.0766749***	-.0554906***
Education: High school	.0664678***	-.0331023***	-.0315787***
Education: Bachelor or higher	-.0012883	-.001864	.0028662
Farmer	.01232	-.0832744***	.0701955***
Member of socio-political organization	.2937363***	.0424332***	-.3221531***
Percentage of socio-political women	.0303064***	.0057157**	-.0343227***
Income variables (2005 PPP USD)			
Equivalised total income	-282.526***	-1166.171***	1391.966***
Equivalised crop income	-471.9492***	-814.0819***	1216.866***
Equivalised crop revenue	-910.5426***	-1294.127***	2084.217***
Equivalised livestock income	216.9706***	-282.46***	65.94659*
Equivalised hunting income	-9.262661	86.3482***	-40.31587***
Equivalised off-farm employment income	-31.10103**	4.929441	19.63838
Equivalised remittance: family/friends	158.1308***	-119.1396***	-32.56432***
Consumption variables (2005 PPP USD)			
Per capita total consumption	-99.35057***	-129.8374***	210.6707***
Per capita food consumption	-84.63821***	-37.01687***	110.1112***
Per capita non-food consumption	-43.47534***	-47.90628***	85.56112***
Per capita education consumption	32.91468***	-29.83185***	-2.704931
Per capita health consumption	-.0295981	-15.2211***	14.24474***
Per capita rent	-4.306081***	.5162203	3.261614***
Household asset variables			
Household crop area (1000m^2)	-.5079192***	-.3894979***	.8300628***
Number of tractor	-.0607104***	.0565265***	.0424431***
Number of vehicle	-.1957382***	.1301457***	.0531462***
Number of phones	.0696343***	-.0080182	-.0631388**

Table A.3: Descriptive Statistics by Provinces in 2010 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Demographic variables				
Household size	6.00	5.53	6.20	6.21
Number of children	1.37	1.09	1.43	1.57
Gender (Female=1)	0.51	0.52	0.51	0.50
Age	30.49	33.54	30.47	27.85
Ethnicity (Kinh=1)	0.77	1.00	0.76	0.59
Marital status (Married=1)	0.45	0.47	0.42	0.46
Education: Primary school	0.58	0.45	0.65	0.62
Education: Secondary school	0.27	0.35	0.22	0.24
Education: High school	0.14	0.19	0.12	0.13
Education: Bachelor or higher	0.01	0.01	0.01	0.02
Farmer	0.34	0.35	0.27	0.41
Member of socio-political organization	0.59	0.79	0.55	0.47
Percentage of socio-political women	0.05	0.08	0.05	0.04
Income variables (2005 PPP USD)				
Equivalised total income	2031.76	2120.48	1902.35	2076.76
Equivalised crop income	408.47	304.27	146.99	746.46
Equivalised crop revenue	6059.02	3365.64	2619.98	11657.49
Equivalised livestock income	177.14	306.78	131.62	107.16
Equivalised hunting income	87.53	33.97	180.54	46.29
Equivalised off-farm employment income	458.26	391.44	506.84	470.58
Equivalised remittance: family/friends	235.27	378.14	251.96	94.97
Consumption variables (2005 PPP USD)				
Per capita total consumption	859.59	761.87	746.26	1051.89
Per capita food consumption	445.23	391.28	415.66	520.21
Per capita non-food consumption	305.67	265.45	253.10	390.42
Per capita education consumption	48.00	44.38	37.03	61.52
Per capita health consumption	39.46	38.81	17.92	60.38
Per capita rent	21.51	21.95	23.19	19.55
Household asset variables				
Household crop area (1000m^2)	0.74	0.38	0.49	1.25
Number of tractor	1.05	1.04	1.06	1.07
Number of vehicle	1.43	1.28	1.48	1.49
Number of phones	1.97	1.76	2.04	2.09

Table A.4: Difference of a province compared to the rest in 2010

	Ha Tinh - rest	Hue - rest	Dak Lak - rest
Demographic variables			
Household size	-.6757107***	.3125019***	.3262995***
Number of children	-.4158378***	.0910182***	.2994446***
Gender (Female=1)	.0134628	-.0014313	-.01117
Age	4.41816***	-.0263383	-4.097511***
Ethnicity (Kinh=1)	.3250459***	-.0247283***	-.2793219***
Marital status (Married=1)	.0260168**	-.0361086***	.0108805
Education: Primary school	-.1902702***	.1112675***	.0692208***
Education: Secondary school	.1220153***	-.0690105***	-.0466704***
Education: High school	.0661846***	-.0377975***	-.0249608***
Education: Bachelor or higher	.0020703	-.0044595*	.0024103
Farmer	.0049828	-.1143804***	.1067261***
Member of socio-political organization	.2898217***	-.0732716***	-.199052***
Percentage of socio-political women	.0304896***	-.0016994	-.0267991***
Income variables (2005 PPP USD)			
Equivalised total income	128.4749**	-194.7729***	69.76038
Equivalised crop income	-150.8903***	-393.5385***	524.0172***
Equivalised crop revenue	-3900.271***	-5175.876***	8679.776***
Equivalised livestock income	187.7419***	-68.51031***	-108.4954***
Equivalised hunting income	-77.55368***	139.9879***	-63.93563***
Equivalised off-farm employment income	-96.76249***	73.11678***	19.10532
Equivalised remittance: family/friends	206.8811***	25.11803*	-217.5258***
Consumption variables (2005 PPP USD)			
Per capita total consumption	-141.5035***	-170.567***	298.1422***
Per capita food consumption	-78.12055***	-44.50602***	116.2414***
Per capita non-food consumption	-58.24594***	-79.12374***	131.4023***
Per capita education consumption	-5.241266***	-16.50883***	20.96652***
Per capita health consumption	-.9351519	-32.41104***	32.43245***
Per capita rent	.6293584	2.519574***	-3.040731***
Household asset variables			
Household crop area ($1000m^2$)	-.5268732***	-.3563036***	.8198641***
Number of tractor	-.0249893***	.0081333	.0228368***
Number of vehicle	-.2077108***	.0799001***	.1080655***
Number of phones	-.3104237***	.1118478***	.1971398***

B Results Using Household Level Data

This section presents results when using household level data, controlling for household heads' characteristics. The information about age, gender, ethnicity, and education level is for the household head. Gender equals 0 if the household head is male, and 1 if female. Compared to statistics at individual level such as 2.2, we can see that household heads are predominantly males. Ethnicity is 1 if the household head belongs to an ethnic majority and 0 if from an ethnic minority. The poverty status is determined using the threshold value of income per capita of 1.90 USD/day adjusted using purchasing power parity (PPP) rates Nguyen et al. (2020b). The education dummy equals 1 if the household head has a university degree or higher. We observe a higher percentages of household heads holding a university degree or higher in year 2013 compared to previous years, though these numbers are still very low.

B.1 Summary statistics at the household level

Table B.1: Descriptive Statistics by Provinces in 2008 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Household demographics				
Number of females	2.53	2.38	2.59	2.61
Number of female children	0.73	0.56	0.76	0.85
Number of male children	0.73	0.56	0.78	0.84
Age	48.97	52.40	49.46	45.24
Gender	0.16	0.17	0.18	0.15
Ethnicity	0.79	1.00	0.76	0.63
Poverty	0.38	0.34	0.47	0.32
Education dummy	0.01	0.01	0.01	0.02
Household income (2005 PPP USD)				
Crop income	2315.76	1396.15	884.23	4576.02
Livestock income	628.39	996.63	128.36	749.63
Hunting income	200.60	142.37	326.80	104.45
Remittance from family members	342.05	544.03	117.69	358.25
Remittance from friends	181.14	245.52	192.88	108.55
Dwelling income	879.37	687.55	758.58	1184.62
Off-farm employment income	792.68	691.90	831.51	857.77
Total income	6714.53	5938.82	4700.86	9375.12
Household consumption (2005 PPP USD)				
Food consumption	2555.94	2125.88	2529.02	2986.24
Non-food consumption	1828.55	1576.16	1727.02	2156.66
Education consumption	282.99	382.06	186.23	279.57
Health consumption	180.19	171.31	132.13	233.15
Rent	128.53	106.77	135.92	142.28
Total consumption	4975.54	4362.17	4708.24	5797.90

Table B.2: Descriptive Statistics by Provinces in 2010 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Number of females	2.68	2.52	2.76	2.75
Number of female children	0.66	0.52	0.68	0.76
Number of male children	0.68	0.50	0.75	0.78
Age	50.73	54.15	50.95	47.19
Gender	0.17	0.18	0.19	0.15
Ethnicity	0.79	1.00	0.76	0.63
Poverty	0.43	0.42	0.47	0.41
Education dummy	0.01	0.01	0.01	0.02
Household income (2005 PPP USD)				
Crop income	1184.59	875.01	429.37	2209.51
Livestock income	518.36	851.35	387.68	316.72
Hunting income	249.43	94.82	527.67	135.22
Remittance from family members	324.83	630.93	253.24	93.10
Remittance from friends	390.96	445.13	535.94	199.36
Dwelling income	119.46	115.63	133.60	109.70
Off-farm employment income	1335.12	1065.37	1524.57	1418.61
Total income	5934.14	5891.37	5690.81	6208.50
Household consumption (2005 PPP USD)				
Food consumption	2463.81	2038.61	2399.58	2922.54
Non-food consumption	1691.50	1382.99	1461.11	2193.41
Education consumption	265.62	231.23	213.78	345.64
Health consumption	218.34	202.21	103.46	339.19
Rent	119.05	114.35	133.86	109.84
Total consumption	4756.76	3969.38	4308.09	5909.54

Table B.3: Descriptive Statistics by Provinces in 2013 (all values are annual means)

	All	Ha Tinh	Hue	Dak Lak
Household demographics				
Number of females	2.46	2.25	2.55	2.57
Number of female children	0.52	0.40	0.53	0.61
Number of male children	0.54	0.40	0.58	0.64
Age	53.49	56.28	54.22	50.20
Gender	0.19	0.20	0.20	0.18
Ethnicity	0.79	0.99	0.75	0.62
Poverty	0.43	0.46	0.42	0.43
Education dummy	0.05	0.06	0.04	0.05
Household income (2005 PPP USD)				
Crop income	1270.81	675.73	651.63	2399.37
Livestock income	830.01	1223.67	634.94	640.79
Hunting income	467.51	47.21	1285.56	107.44
Remittance from family members	580.03	1096.98	487.00	181.20
Remittance from friends	412.65	358.03	604.16	287.32
Dwelling income	117.63	113.14	110.55	128.36
Off-farm employment income	1839.37	1557.84	2189.31	1780.71
Total income	7102.03	6161.53	8031.68	7126.75
Household consumption (2005 PPP USD)				
Food consumption	3031.29	2413.78	3228.27	3428.59
Non-food consumption	2264.80	1924.01	2286.53	2564.23
Education consumption	408.00	355.73	383.72	479.38
Health consumption	252.11	259.95	208.41	285.04
Rent	117.63	113.14	110.55	128.36
Total consumption	6071.00	5064.59	6210.76	6885.60

B.2 Impact of weather shocks on rural household income

Table B.4: Impact of weather shocks on rural household per capita income (ln)

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain shock	-0.0188**	-0.0225	-0.0258**	-0.0065	-0.0869***	-0.0058	-0.0350*
	(0.0086)	(0.0164)	(0.0115)	(0.0136)	(0.0170)	(0.0144)	(0.0207)
Crop area	0.1006***	0.1253**	0.3081***	-0.0388	-0.0522	0.0241	0.1558
	(0.0308)	(0.0487)	(0.0440)	(0.0681)	(0.0549)	(0.0519)	(0.1176)
Age × Age	-0.0010***	-0.0007***	-0.0009***	-0.0003	0.0001	-0.0019***	-0.0006
	(0.0002)	(0.0003)	(0.0002)	(0.0005)	(0.0004)	(0.0005)	(0.0007)
Age	0.1095***	0.0772**	0.0887***	0.0197	-0.0336	0.1999***	0.0375
	(0.0272)	(0.0298)	(0.0261)	(0.0490)	(0.0491)	(0.0600)	(0.0706)
Gender	-0.4095***	-0.1673	-0.1587	-0.4855*	-0.4409	-0.0645	-0.0440
	(0.1376)	(0.2001)	(0.1911)	(0.2588)	(0.2748)	(0.2814)	(0.3441)
Ethnicity	-0.1673	-0.1261	0.2817	0.0274	-0.7212	0.2163	0.9011
	(0.2863)	(0.3664)	(0.4787)	(0.6234)	(0.6000)	(0.3664)	(1.4856)
Household size	-0.0976***	-0.1263***	-0.1461***	-0.1299***	-0.0404	-0.0478	-0.0717
	(0.0292)	(0.0477)	(0.0318)	(0.0491)	(0.0460)	(0.0635)	(0.0734)
Education dummy	0.0043	0.2110	-0.0597	0.0581	0.1350	0.0039	0.5989
	(0.1237)	(0.1869)	(0.1834)	(0.2505)	(0.5517)	(0.2021)	(0.4013)
Constant	4.8082***	4.3526***	4.2743***	5.4161***	5.5495***	-0.4129	3.8529*
	(0.8436)	(0.9686)	(0.8376)	(1.4256)	(1.6180)	(1.7805)	(2.3085)
Observations	4594	4045	4605	3371	2517	2655	2200
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE							

Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.5: Impact of weather shocks on rural household per capita income (ln) for farmers

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain shock	-0.0157	-0.0350*	-0.0415***	0.0069	-0.0754***	-0.0316*	-0.0204
	(0.0111)	(0.0191)	(0.0126)	(0.0176)	(0.0216)	(0.0190)	(0.0262)
Crop area	0.0944**	0.0907*	0.2996***	-0.0925	-0.0778	0.0366	0.1052
	(0.0373)	(0.0533)	(0.0480)	(0.0773)	(0.0555)	(0.0763)	(0.0956)
Age × Age	-0.0009**	-0.0012***	-0.0010***	0.0000	0.0000	-0.0035***	-0.0005
	(0.0004)	(0.0004)	(0.0003)	(0.0007)	(0.0006)	(0.0008)	(0.0009)
Age	0.0686*	0.0927**	0.0696**	-0.0186	-0.0847	0.2566***	-0.0024
	(0.0372)	(0.0410)	(0.0335)	(0.0636)	(0.0736)	(0.0897)	(0.0864)
Gender	-0.3480*	0.0146	-0.0822	-0.5424	-0.4963	-0.4749	0.1670
	(0.1936)	(0.2058)	(0.2119)	(0.3298)	(0.3254)	(0.3999)	(0.4164)
Ethnicity	-0.3191	-0.2669	0.0343	0.1836	-0.7700	0.3785	0.9532
	(0.3092)	(0.3360)	(0.4942)	(0.6654)	(0.8224)	(0.4767)	(1.4734)
Household size	-0.1177***	-0.1392**	-0.1702***	-0.0811	-0.0674	-0.0608	0.0241
	(0.0411)	(0.0645)	(0.0330)	(0.0582)	(0.0566)	(0.0961)	(0.0830)
Education dummy	-0.2097	0.2075	-0.5000*	0.0605	0.8109***	-1.6040***	0.9609**
	(0.1981)	(0.2280)	(0.2963)	(0.4756)	(0.2304)	(0.5823)	(0.4842)
Constant	6.6682***	4.9638***	5.8588***	6.0528***	8.1482***	0.0598	4.7972**
	(1.1461)	(1.1665)	(0.9666)	(1.7163)	(2.5698)	(2.6607)	(2.4114)
Observations	3390	3040	3455	2566	1981	1882	1596
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE							

Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

B.3 Impact of weather shocks on rural household consumption

Table B.6: Impact of weather shocks on rural household per capita consumption (ln)

	Total	Food	NonFood	Education	Health
	(1)	(2)	(3)	(4)	(5)
Rain shock	-0.0044	-0.0030	-0.0003	0.0078	-0.0300*
	(0.0038)	(0.0047)	(0.0047)	(0.0100)	(0.0156)
Crop area	0.0274*	0.0172	-0.0039	0.0805**	0.0015
	(0.0146)	(0.0154)	(0.0167)	(0.0324)	(0.0487)
Age × Age	-0.0002*	-0.0000	-0.0003***	-0.0009**	0.0004
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0004)
Age	0.0199*	0.0018	0.0316***	0.0855**	-0.0445
	(0.0114)	(0.0125)	(0.0120)	(0.0363)	(0.0433)
Gender	-0.0702	0.0030	-0.1104	0.0726	0.0581
	(0.0691)	(0.0695)	(0.0737)	(0.1877)	(0.2154)
Ethnicity	-0.0724	-0.0662	-0.1942	0.4446***	-0.2207
	(0.0796)	(0.1571)	(0.1303)	(0.1659)	(0.4429)
Household size	-0.1123***	-0.0995***	-0.1241***	-0.2588***	-0.1240***
	(0.0136)	(0.0157)	(0.0145)	(0.0426)	(0.0438)
Education dummy	0.0712	0.0498	-0.0200	-0.0585	0.2090
	(0.0764)	(0.0848)	(0.0749)	(0.1768)	(0.2108)
Constant	7.0598***	6.8038***	5.2974***	2.9087***	4.9213***
	(0.3381)	(0.4057)	(0.3469)	(0.9985)	(1.2450)
Observations	4597	4597	4597	3174	4127
Household FE	Yes	Yes	Yes	Yes	Yes
Wave FE					

Note: Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.7: Impact of weather shocks on rural household per capita consumption (ln) for farmers

	Total	Food	NonFood	Education	Health
	(1)	(2)	(3)	(4)	(5)
Rain shock	-0.0045	-0.0025	0.0051	0.0031	-0.0417**
	(0.0048)	(0.0056)	(0.0062)	(0.0137)	(0.0190)
Crop area	0.0204	0.0224	-0.0008	0.0801**	-0.0203
	(0.0166)	(0.0175)	(0.0199)	(0.0372)	(0.0638)
Age × Age	-0.0001	0.0002	-0.0001	-0.0012*	0.0004
	(0.0001)	(0.0002)	(0.0002)	(0.0006)	(0.0005)
Age	0.0166	-0.0154	0.0231	0.0951*	-0.0107
	(0.0157)	(0.0166)	(0.0186)	(0.0543)	(0.0538)
Gender	-0.1437	-0.0806	-0.1253	-0.3064	0.1584
	(0.0959)	(0.0868)	(0.1005)	(0.2071)	(0.2876)
Ethnicity	-0.1590**	-0.2121	-0.2322	0.6257***	-0.1680
	(0.0700)	(0.1488)	(0.1445)	(0.1735)	(0.5475)
Household size	-0.1181***	-0.1006***	-0.1362***	-0.2321***	-0.1331**
	(0.0174)	(0.0200)	(0.0179)	(0.0498)	(0.0519)
Education dummy	0.2398*	0.1530	0.1686	0.0456	0.5077
	(0.1254)	(0.1140)	(0.1224)	(0.3260)	(0.3626)
Constant	7.0875***	7.1164***	5.3622***	2.6782**	3.3350**
	(0.4509)	(0.5189)	(0.5075)	(1.3093)	(1.6650)
Observations	3409	3409	3409	2392	3062
Household FE	Yes	Yes	Yes	Yes	Yes
Wave FE					

Note: Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.8: Heterogeneity test for crop area, farmers, provinces, household size, and ethnicity

	Crop Revenue					Total Income				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rain shock	-0.0505***	-0.0444***	0.0538**	-0.0375	-0.2011***	-0.0176**	-0.0126	0.0122	0.0031	-0.1102***
	(0.0098)	(0.0149)	(0.0222)	(0.0236)	(0.0253)	(0.0082)	(0.0086)	(0.0182)	(0.0163)	(0.0199)
Crop area	0.5761***					0.2199***				
	(0.0251)					(0.0200)				
Rain shock × Crop area	-0.0292**					-0.0241**				
	(0.0132)					(0.0113)				
Farmer=1 × Rain shock		-0.0471***					-0.0334***			
		(0.0171)					(0.0110)			
Thua Thien Hue × Rain shock			-0.0917***					-0.0337*		
			(0.0249)					(0.0201)		
Dak Lak × Rain shock			-0.2312***					-0.1870***		
			(0.0831)					(0.0683)		
Rain shock × Household size				-0.0066					-0.0064**	
				(0.0040)					(0.0029)	
Ethnicity=1 × Rain shock					0.1400***					0.0853***
					(0.0263)					(0.0205)
Observations	4605	4798	4798	4798	4798	4594	5288	5288	5288	5288
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

B.4 Robustness Check

B.4.1 Three standard deviation away from the mean

Table B.9 and Table B.10 present the results when weather shock is defined as the number of times monthly rainfall is three standard deviation away from the mean.

B.4.2 Rainfall deviation

Table B.11 and Table B.12 present the results using rainfall deviation which equals the natural log of the year rainfall minus the natural log of mean annual rainfall in a given village.

Table B.9: Impact of weather shocks on rural household per capita income (ln) - Rain month

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain month	-0.1449***	0.0397	-0.1802***	-0.0675	-0.4011***	0.0903	-0.3808***
	(0.0406)	(0.0586)	(0.0546)	(0.0673)	(0.0799)	(0.0624)	(0.1035)
Crop area	0.0863***	0.1341***	0.2911***	-0.0442	-0.0717	0.0383	0.1151
	(0.0302)	(0.0495)	(0.0415)	(0.0669)	(0.0533)	(0.0508)	(0.1141)
Age × Age	-0.0011***	-0.0007***	-0.0010***	-0.0004	-0.0000	-0.0019***	-0.0008
	(0.0002)	(0.0003)	(0.0002)	(0.0005)	(0.0004)	(0.0005)	(0.0007)
Age	0.1175***	0.0749**	0.0996***	0.0225	-0.0208	0.1950***	0.0520
	(0.0276)	(0.0301)	(0.0260)	(0.0493)	(0.0488)	(0.0596)	(0.0704)
Gender	-0.3942***	-0.1842	-0.1375	-0.4798*	-0.3518	-0.0975	-0.0432
	(0.1365)	(0.2009)	(0.1922)	(0.2596)	(0.2604)	(0.2796)	(0.3350)
Ethnicity	-0.1343	-0.1358	0.3162	0.0378	-0.5677	0.1663	0.8910
	(0.2952)	(0.3540)	(0.4786)	(0.6227)	(0.6275)	(0.3434)	(1.5181)
Household size	-0.0966***	-0.1265***	-0.1455***	-0.1290***	-0.0413	-0.0475	-0.0680
	(0.0291)	(0.0477)	(0.0320)	(0.0492)	(0.0473)	(0.0632)	(0.0704)
Education dummy	0.0177	0.1929	-0.0485	0.0613	0.1459	-0.0237	0.6822*
	(0.1236)	(0.1842)	(0.1809)	(0.2510)	(0.5494)	(0.2025)	(0.4067)
Constant	4.6673***	4.3240***	4.0684***	5.3772***	5.3143***	-0.3733	3.7348
	(0.8542)	(0.9618)	(0.8336)	(1.4328)	(1.6357)	(1.7662)	(2.3107)
Observations	4594	4045	4605	3371	2517	2655	2200
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE							

Note: "Rain month" is measured by the number of times monthly rainfall is three standard deviation away from the mean. Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.10: Impact of weather shocks on rural household per capita consumption (ln) - Rain month

	Total	Food	NonFood	Education	Health
	(1)	(2)	(3)	(4)	(5)
Rain month	-0.0926***	-0.0885***	-0.0465**	-0.0738	-0.2217***
	(0.0174)	(0.0208)	(0.0212)	(0.0484)	(0.0630)
Crop area	0.0162	0.0063	-0.0099	0.0700**	-0.0252
	(0.0139)	(0.0153)	(0.0160)	(0.0315)	(0.0486)
Age × Age	-0.0002**	-0.0001	-0.0003***	-0.0010***	0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0004)
Age	0.0251**	0.0068	0.0342***	0.0894**	-0.0297
	(0.0115)	(0.0124)	(0.0121)	(0.0358)	(0.0437)
Gender	-0.0549	0.0183	-0.1015	0.0903	0.0750
	(0.0681)	(0.0687)	(0.0735)	(0.1835)	(0.2137)
Ethnicity	-0.0493	-0.0437	-0.1818	0.4524***	-0.1921
	(0.0891)	(0.1631)	(0.1345)	(0.1596)	(0.4256)
Household size	-0.1121***	-0.0993***	-0.1240***	-0.2588***	-0.1222***
	(0.0133)	(0.0155)	(0.0145)	(0.0422)	(0.0427)
Education dummy	0.0838	0.0625	-0.0125	-0.0304	0.2150
	(0.0745)	(0.0836)	(0.0744)	(0.1732)	(0.2061)
Constant	6.9819***	6.7319***	5.2627***	2.9014***	4.6242***
	(0.3396)	(0.4047)	(0.3491)	(0.9927)	(1.2357)
Observations	4597	4597	4597	3174	4127
Household FE	Yes	Yes	Yes	Yes	Yes
Wave FE					

Note: "Rain month" is measured by the number of times monthly rainfall is three standard deviation away from the mean.
Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.11: Impact of weather shocks on rural household per capita income (ln) - Rainfall deviation

	Total income	Crop income	Crop revenue	Livestock	Hunting	Off Farm	Remittance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall deviation	-0.1757	-0.4237*	-0.0320	-0.0102	-1.2857***	-0.5880**	-0.3559
	(0.1691)	(0.2417)	(0.2102)	(0.2719)	(0.4102)	(0.2506)	(0.3757)
Crop area	0.1023***	0.1241**	0.3140***	-0.0378	-0.0524	0.0141	0.1651
	(0.0313)	(0.0491)	(0.0444)	(0.0686)	(0.0568)	(0.0533)	(0.1175)
Age × Age	-0.0010***	-0.0007***	-0.0009***	-0.0003	0.0002	-0.0019***	-0.0006
	(0.0002)	(0.0003)	(0.0002)	(0.0005)	(0.0004)	(0.0005)	(0.0007)
Age	0.1068***	0.0705**	0.0879***	0.0195	-0.0395	0.1875***	0.0315
	(0.0272)	(0.0294)	(0.0261)	(0.0495)	(0.0490)	(0.0592)	(0.0702)
Gender	-0.4116***	-0.1565	-0.1738	-0.4893*	-0.4406	-0.0582	-0.0476
	(0.1373)	(0.2004)	(0.1896)	(0.2598)	(0.2689)	(0.2826)	(0.3419)
Ethnicity	-0.1749	-0.1368	0.2717	0.0275	-0.7102	0.2354	0.8973
	(0.2832)	(0.3660)	(0.4748)	(0.6230)	(0.6156)	(0.4057)	(1.4703)
Household size	-0.0991***	-0.1301***	-0.1460***	-0.1304***	-0.0586	-0.0530	-0.0767
	(0.0292)	(0.0477)	(0.0317)	(0.0492)	(0.0465)	(0.0635)	(0.0739)
Education dummy	0.0021	0.2201	-0.0714	0.0573	0.1268	0.0446	0.5862
	(0.1242)	(0.1867)	(0.1837)	(0.2509)	(0.5199)	(0.2064)	(0.4033)
Constant	4.8717***	4.5582***	4.2469***	5.4102***	5.7646***	0.0067	3.9873*
	(0.8481)	(0.9579)	(0.8281)	(1.4400)	(1.6381)	(1.7791)	(2.3085)
Observations	4594	4045	4605	3371	2517	2655	2200
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave FE							

Note: "Rainfall deviation" is measured by the natural log of the year rainfall minus the natural log of mean annual rainfall in a given village. Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.

Table B.12: Impact of weather shocks on rural household per capita consumption (ln) - Rainfall deviation

	Total	Food	NonFood	Education	Health
	(1)	(2)	(3)	(4)	(5)
Rainfall deviation	-0.2182***	-0.2443***	-0.1364	-0.6026***	0.3485
	(0.0713)	(0.0873)	(0.0882)	(0.1867)	(0.2576)
Crop area	0.0262*	0.0155	-0.0051	0.0693**	0.0100
	(0.0143)	(0.0152)	(0.0166)	(0.0316)	(0.0493)
Age × Age	-0.0001	0.0000	-0.0003**	-0.0009**	0.0003
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0004)
Age	0.0166	-0.0019	0.0295**	0.0795**	-0.0382
	(0.0114)	(0.0124)	(0.0118)	(0.0356)	(0.0436)
Gender	-0.0623	0.0130	-0.1039	0.0996	0.0321
	(0.0682)	(0.0685)	(0.0729)	(0.1848)	(0.2176)
Ethnicity	-0.0728	-0.0659	-0.1934	0.4424***	-0.2516
	(0.0808)	(0.1577)	(0.1312)	(0.1592)	(0.4410)
Household size	-0.1144***	-0.1018***	-0.1254***	-0.2626***	-0.1216***
	(0.0133)	(0.0152)	(0.0144)	(0.0415)	(0.0443)
Education dummy	0.0811	0.0620	-0.0123	-0.0322	0.1800
	(0.0752)	(0.0832)	(0.0738)	(0.1717)	(0.2108)
Constant	7.1755***	6.9376***	5.3753***	3.1844***	4.6619***
	(0.3360)	(0.4013)	(0.3419)	(0.9893)	(1.2387)
Observations	4597	4597	4597	3174	4127
Household FE	Yes	Yes	Yes	Yes	Yes
Wave FE					

Note: "Rainfall deviation" is measured by the natural log of the year rainfall minus the natural log of mean annual rainfall in a given village.
Standard errors (in parentheses) are clustered at the village level. The symbols ***, **, and * denote that p<0.01, p<0.05, and p<0.10, respectively.