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The Economic Impacts of Extreme Rainfall Events on Farming Households: Evidence from Thailand

by

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October 2016

Discussion Paper

No. 45

The Economic Impacts of Extreme Rainfall Events on Farming Households: Evidence from Thailand

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Abstract

We investigate how rainfall shocks, in terms of floods and droughts, affect income, consumption, and coping responses of farming households in Thailand. We draw on a province pseudo-panel, combining household-level information from repeated cross-sectional farm household surveys over the period of 2006-2010 and provincial-based measures of annual rainfall shocks. These rainfall shock variables are constructed from high frequency rainfall time series, identifying the incidence of excessive and deficit rainfall events. We find that crop income falls sharply as a results of rainfall shocks, while there is evidence of income smoothing through asset transactions and off-farm employment in response to excessive rainfall but not deficit rainfall. This suggests that deficit rainfall events are more difficult to insure against as droughts not only reduce crop income but also limit households' opportunities to smooth income. On average, households seem to be able to smooth their consumption when affected by floods or droughts, although we do see a reduction in spending on luxury and miscellaneous items in case of droughts in order to maintain necessary consumption. Dissaving and asset sales are prevalent strategies for consumption smoothing. Finally, our findings emphasise wealth-differentiated effects of rainfall shocks as landless households seem more vulnerable to rainfall shocks than landholding households due to their limited ability to smooth income and consumption.

Key words: Natural disasters, extreme rainfall, income shocks, consumption smoothing, coping strategies, Thailand

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We would like to thank Sommarat Chantarat, Huy Nguyen Quynh, and seminar participants at the Australian National University, the 2014 Australasian Development Economics Workshop in Perth, the 2014 Australian Conference of Economists and Econometric Society Australasian Meeting in Tasmania, and the 2015 workshop on "Analysing Extreme Weather Events from a Microeconomic Perspective" at the German Institute for Economic Research in Berlin for useful comments and feedback. All errors are our own.
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1. Introduction

Economic risk from the natural environment and its effects on livelihoods of households in developing countries, especially for the resource-constrained poor, has been well documented in the economic literature. With the expectation of increasing frequency and intensity of adverse natural events as a result of global warming (Parry, 2007), the provision of safety nets and measures to protect the vulnerable population have received growing attention in economic development and public policy. This is no less pertinent in Thailand, where, due to the country's tropical monsoon climate in conjunction with a lacking irrigation system, variation in rainfall has long been a prominent source of risk facing farming households.[1] A recent well-known example is the flood in 2011, which was recorded as the largest flood to have hit Thailand in over the past 50 years in terms of the damage caused and the number of affected people (Poapongsakorn and Meethom, 2012).[2] In addition to major catastrophic events, farming households in Thailand are also exposed to extreme rainfall conditions that can result in either local floods or droughts. These types of adverse rainfall events cause less severe damage but do occur more frequently than the national disasters. Specifically, the incidence of excessive and deficit rainfall events potentially involves agricultural production loss, resulting in a reduction of household income and consumption expenditure. Moreover, the Emergency Events Database (EM-DAT) recently revealed that the incidence of hydrological disasters such as floods and droughts has been increasing over time, especially in Asia and the Pacific region (Cavallo and Noy, 2010).

Agriculture has long been the mainstay of the Thai economy, employing roughly 40 percent of the total labour supply. The variability of rainfall conditions therefore potentially affects the income and livelihoods of a substantial part of the population. Excessive and deficit rainfall events are likely to have negative implications for farming households, especially if households are unable to insure their income and consumption against those shocks. This paper evaluates the welfare impacts of extreme rainfall events

[1] The Office of Agricultural Economics of Thailand reports that in 2011, 80 percent of farmland was non-irrigated, with 20 percent of irrigated farm areas, concentrated in the central region.

[2] The 2011 flood began in late July 2011 and receded in mid-December 2011, inundating 9.1 percent of total land area, affecting approximately 13 million people, with 800 deaths, and causing loss and damage of US$ 46.5 billion or 14 percent of the gross domestic product (GDP). Damaged areas were dispersed across 69 provinces in every region, with the 19 provinces most severely inundated located in the Chao Phraya and Tha Chin River basins, including industrial and residential areas in Bangkok and the adjacent provinces to the north and west of Bangkok.

on farming households and investigates their risk-coping responses. We assess how the incidence of extreme rainfall affects household income and consumption expenditure, and which coping mechanisms households adopt in response to rainfall shocks.

The relationship between household welfare and rainfall shocks has been explored extensively in the literature, addressing the variations in adverse natural events and measures of shocks. A number of studies have examined the welfare impacts of major disasters (see, for example, Morris et al., 2002; Carter et al., 2007; Van den Berg and Burger, 2008; Jakobsen, 2012), while another strand of literature considers the variability of rainfall conditions. A range of rainfall shock variables has been applied in the literature, for example the use of subjective measures of rainfall shocks (Dercon et al., 2005; Kurosaki, 2013) or simple rainfall deviations from the long-term trend (Asiimwe and Mpuga, 2007). Recent studies tend to apply more explicit measures of rainfall shocks by using information from the distribution of rainfall time series to capture the incidence of specific adverse rainfall events (Thomas et al., 2010; Skoufias et al., 2011; Porter, 2012). There are a few studies for the case of Thailand, but these are limited in the scope by either focussing on a specific province (Felkner et al., 2009) or a particular event (Poapongsakorn and Meethom, 2012). This is no evidence of the impacts of extreme rainfall events on the larger population of Thai farming households' welfare, despite the implementation of nationwide policies to compensate farming households for disaster damages.

This paper is the first rigorous study for Thailand that evaluates the potential welfare impacts of adverse rainfall events on farming households. The analysis applies explicit measures of shocks in order to capture the occurrence of extreme rainfall events. Following Skoufias et al. (2011) and Porter (2012), we define the incidence of excessive and deficit rainfall based on the variability of local rainfall conditions, using solely information on rainfall distribution – rather than the personal perceptions and recollection of survey respondents. The measures of rainfall shocks are constructed from high frequency rainfall time series at the province level, obtained from the Meteorological Department of Thailand. The empirical analysis further relies on a farm household socio-economic survey conducted by the Office of Agricultural Economics of Thailand. The advantage of this nationwide survey is that it is representative of farming households at the province level and that is of sufficient size to capture heterogeneity by key farm characteristics and wealth status.

The repeated cross-sectional farm household surveys are used to construct a pseudo-panel for provinces covering the period of 2006-2010, which is combined with provincial-based measures of rainfall shocks in each year. We then investigate how the incidence of excessive and deficit rainfall affects various measures of household income, consumption expenditure, and coping responses as well as how these effects differ by initial household endowment. The estimation results show that crop income is highly sensitive to the incidence of rainfall shocks compared to other sources of income. Farming households are likely to smooth income earned from off-farm employment and asset transactions when affected by excessive rainfall shocks. Deficit rainfall shocks, on the other hand, affect both farm and non-farm earnings. The incidence of deficit rainfall causes a significant reduction in household spending on miscellaneous and luxury goods. However, there is no significant effect of rainfall shocks on total household consumption expenditure, thus providing some evidence of consumption smoothing. Landless households are more affected by rainfall shocks as they have fewer opportunities to smooth income compared to relatively better-off households. Dissaving and selling assets are the main coping mechanisms in response to rainfall shocks.

The remainder of this paper is organised as follows. The next section provides a selective review of the related literature. Section 3 describes the socio-economic dataset and how we construct the objective measures of rainfall shocks. Section 4 outlines the empirical strategies used in identifying the welfare impacts of extreme rainfall events, while section 5 presents the estimation results. Finally, conclusions and policy implications are drawn in section 6.

2. Related literature

A large body of literature has been investigating the economic impacts of rainfall shocks on household socio-economic outcomes and how the affected households manage to deal with those shocks.[3] We focus here on two strands. The first evaluates the direct effects of

[3] Another set of literature examines macroeconomic effects of natural disasters. Using cross-country data, the impacts of natural disasters on the economy in terms of various outcomes such as national income, employment, and inflation in the short or long run have been assessed (see, for example,

adverse rainfall events on different measures of household welfare. The second investigates the relationship between rainfall shocks and household responses.

Studies that consider specific natural catastrophic events generally find evidence of asset loss as well as an important role of assets in smoothing consumption. Morris et al. (2002) find that Hurricane Mitch in Honduras caused a significant reduction in the current income of the rural poor, mainly due to crop loss and a depletion of assets. Negative effects on asset loss were more critical for the poorest households since they were likely to have fewer assets to start with. Van den Berg and Burger (2008) take a step further by examining the consumption reactions to Hurricane Mitch of rural Nicaraguan households and show that asset-poor households reduced consumption in response to transitory income loss in order to maintain their limited asset holdings. Carter et al. (2007) and Jakobsen (2012) conclude that natural disasters have significant impacts on household asset portfolios through the presence of poverty traps. Asset loss due to destruction or transaction could hamper a household's long-term livelihood through a slow pace of asset recovery. It may also result in a temporary or permanent income shortage and reduced consumption. Asset-poor households seem to forego their consumption in response to income shocks, while the wealthier households may resort to using their assets to stabilise consumption.

Apart from major natural disasters, the variability of rainfall conditions can also have negative implications on production outcomes, and hence household income, which in turn can translate into consumption fluctuation (Morduch, 1995; Dercon, 1996). Using self-reported measures of shocks, Dercon et al. (2005) find negative and persistent effects of droughts on household consumption in Ethiopia. These effects were higher among female-headed households, households with an uneducated head, and households with small land holdings. Asiimwe and Mpuga (2007) show that higher than average rainfall in the main planting and harvesting seasons in Uganda significantly lowered household income and consumption. Kurosaki (2013) relies on self-reported information on floods and droughts of rural households in Pakistan and finds that household consumption was

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Skidmore and Toya, 2002; Raddatz, 2007; Loayza et al., 2009; Noy, 2009; Cavallo et al., 2010; Sawada et al., 2011). A general conclusion is that natural disasters have negative impacts on the economy's short-term economic growth. These negative effects are more dramatic for developing and smaller economies. However, the evidence for the long-run effects of natural disasters on the economy's long-term growth remains inconclusive.

not sensitive to droughts. However, the negative effects of floods were especially large and these impacts were even larger among those households with relatively few asset holdings.

Several studies apply explicit measures of rainfall shocks in order to capture the incidence of adverse rainfall events, rather than using subjective measures of rainfall shocks or simply deviations from rainfall average. Thomas et al. (2010) create natural disaster maps for droughts, excessive rainfall, riverine floods, and cyclones in Vietnam using meteorological data and find substantial loss of household consumption from both of riverine floods and cyclones. Skoufias et al. (2011) conclude that consumption of rural rice-farming households in Indonesia was affected by a shortfall of rain during the monsoon season, but not by a delay of rain in the onset of the monsoon. Porter (2012) also finds that deficit rainfall resulted in a significant reduction of crop income and consumption expenditure of households in rural Ethiopia.

When facing shocks, households can choose to engage in *ex-ante* risk-management or *ex-post* risk-coping strategies to insulate their consumption. Alderman and Paxson (1992) point out that risk management is related to actions undertaken to reduce the variability of income prior to the occurrence of shocks. This may involve a variety of diversification strategies regarding crop portfolio choices, off-farm activities, or migration decisions. In contrast, risk-coping mechanisms do not target the exposure to shocks but rather aim to mitigate the subsequent effects of income shocks on household consumption. In the absence of complete insurance, affected households may rely on informal risk-sharing arrangements or resort to self-insurance in order to maintain consumption. Risk-sharing networks can be formed through family ties, livelihood groups, or communities. If full risk-sharing exists, then households should be able to completely smooth their consumption against idiosyncratic shocks. An extensive body of literature has tested the full risk-sharing hypothesis and finds that group-based risk-sharing arrangements are partly effective in insuring against idiosyncratic shocks, although complete consumption insurance tends to be rejected (see, for example, Townsend, 1994 and 1995; Deaton, 1997; Grimard, 1997; Goldstein, 1999; Morduch, 2004; Chiappori et al., 2006).

The role of self-insurance as risk-coping mechanisms can be achieved by drawing on savings, selling assets, or seeking non-farm income. Deaton (1991) highlights the benefit of savings as self-insurance in the absence of a complete credit market. Paxson (1992) provides supporting evidence for the role of savings by examining saving behaviour of the Thai farming households and finds that savings were used to buffer consumption from transitory income shocks. When considering the timing of shocks and saving behaviour of households in Zimbabwe, Ersado et al. (2003) conclude that the use of savings was partly limited in the post-drought period, but that precautionary savings could not be maintained afterwards. As for the role of assets, Udry (1994) shows that after being hit by shocks, agrarian households in Nigeria reduced savings through a disaccumulation of assets. Dercon (1996) explores the relationship between crop portfolio decisions and asset holdings in Tanzania and finds that liquid assets helped provide consumption security. Constrained households who own small liquid assets ended up growing low-risk crops, with the cost of low returns. Fafchamps et al. (1998) and Kazianga and Udry (2006) find the marginal role of livestock as buffer stocks to insulate consumption from income shocks when facing droughts in West Africa and Burkina Faso, respectively. Hoddinott (2006) shows that the incidence of droughts in Zimbabwe was associated with a rise in the sale of livestock and that asset-poor households were less likely to sell assets as they had low assets at the pre-shock stage. Other sources of income can be another possible risk-coping option when compensating for income loss. Porter (2012) finds that crop shocks stimulated non-farm earnings by an equivalent amount as they negatively affected farm income.

Despite a growing body of literature on the direct effects of rainfall shocks on household welfare, there are few examples for the case of Thailand. Using household panel surveys from the Townsend Thai Project, Felkner et al. (2009) examine the potential impacts of climate change on rice yields of farmers in four villages in Sisaket, a province in the rural north-eastern part of Thailand. The results suggest that in an extreme climate change scenario, rice-farming households were less able to prevent yield loss, while most of these households may gain some benefits from a moderate increase of rain in a milder scenario. Poapongsakorn and Meethom (2012) compare the effects of the large flood in Thailand in 2011 on household income and expenditure by using satellite radar images to specify flooded and non-flooded subdistricts and find that the flood had significant negative impacts on money income and wage income of households. In addition, the flood also caused a significant reduction of expenditure for households in non-flooded areas, indicating the inter-dependence between families in urban and rural areas.

3. Data

The economic impacts of extreme rainfall events on household welfare are examined using information from the farm household socio-economic surveys, together with primary rainfall statistics. The combined dataset contains household-level information on income, expenditure, financial status, asset holdings, demographic characteristics, and province-level constructed measures of rainfall shocks. Table 1 reports the mean and standard deviation of all variables included in the analysis.[4]

3.1 Socio-economic data

Household-level information is drawn from five rounds of the Thai Agricultural Household Socio-Economic Survey between 2006 and 2010, collected by the Office of Agricultural Economics under the Ministry of Agriculture and Cooperatives of Thailand. This survey contains nationwide representative farming households, which are defined as households that commit to allocating some resources to agricultural production activities. The surveys are canvassed annually in accordance with the agricultural year, that runs from the beginning of May until the end of April in the following year. The survey takes place near the end of agricultural year, starting from February to March. Using a stratified two-stage sampling approach, each year between 6,000-12,000 farming households are randomly selected from 1,500-3,000 sampled villages. After pooling the sample from five repeated cross-sectional surveys and dropping some observations with incomplete rainfall data, there remain 40,684 farming households in 68 provinces.[5] The main advantage of this survey is that it includes comprehensive information on agricultural production including in-depth data on land use and characteristics, production outcomes, product distribution, and production cost. The survey also has extensive modules of household earnings from various sources, consumption expenditure on a range of goods and services, asset holdings, financial status, and household demographics.

Various measures of household income and consumption expenditure are extracted in order to account for the sensitivity of income sources and types of spending to rainfall shocks. Crop income is measured by the total value of crop production minus production

[4] A brief description of the variables is provided in the supplemental appendix.
[5] Although this survey is conducted in all 76 provinces of Thailand, only farming households from 68 provinces are compiled into the sample. This exclusion is due to the unavailability of daily rainfall data in eight provinces used in constructing the objective measures of excessive rainfall events.

cost. Likewise, livestock income is the aggregate value of livestock and fishery products minus their input cost. Apart from crop and livestock income, farm income also includes earnings from other farm activities and returns from providing farm labour and services. Non-farm income is mainly comprised of profits from trading goods and services, wage and salary from non-farm employment, earnings from renting or selling non-farm land and assets, and remittances. Total household income combines total farm and non-farm income, plus any transfers from the government given as natural disaster relief. Total consumption expenditure is the sum of household spending on food and non-food items. Food expenditure includes food purchases, consumption of own-produced agricultural products, and food received as gifts. Non-food expenditure captures spending on housing and utilities, education, medical care, durable goods, and miscellaneous items such as luxury goods, gambling, entertainment, recreation, and special occasions.

The survey also provides information on coping responses, such as dissaving, borrowing, selling assets, and selling last-year stocks of crop and livestock products. The module on the farming household's financial status records savings and borrowings, assets, and stock holdings at the start and end of the year. We use this information to construct binary variables indicating the propensity to engage in each of the coping strategies, irrespective of shocks. Dissaving is defined as a reduction in a household's financial savings during a year. Borrowing involves loans from both formal and informal lenders in the last year to finance farm and non-farm transactions. A reduction of asset and stock holdings of at least 20 percent of the initial value measured at the beginning of the year is applied to indicate the sale of farm and non-farm assets and farm stocks.[6]

There are four sets of control variables used in the empirical analysis, which are farm characteristics, asset holdings, household characteristics, and market prices. The first three sets control for any observed heterogeneity across the sampled households in which households differ by production practices, endowments, and livelihoods. Farm characteristics include farm size and an irrigation dummy. Asset holdings are measured by the total value of household financial and physical assets, evaluated at the beginning of

[6] It is not straightforward to identify the sale of assets and farm stocks. Farming households were asked to report the total value of assets and farm stocks they held at the beginning and at the end of agricultural year in each survey. Unfortunately, one cannot identify the cause of a reduction in the total value of asset and stock holdings – as it could be due to depreciation or selling assets. To address this asset valuation issue, the threshold is arbitrarily set at 20 percent, above which we interpret a reduction as selling.

each year. Demographic characteristics contain information on gender, age, and the highest education level of the household head and members. Furthermore, indicators for social capital and non-farm earnings are included to control for households' heterogeneous livelihood factors. Finally, village-level average prices of 12 major crops are also included in the regressions in order to control for market conditions at the village level.[7] These price controls help explain the change of household income conditioning on the supply side of the market environment. The control of crop prices in expenditure equations captures indirect effects of rainfall shocks on household consumption choices, especially on food items, on the demand side.

[Table 1 here]

3.2 Constructed rainfall shock variables

We use primary rainfall time series and apply standard definitions of flood and drought events to identify the incidents of extreme rainfall, rather than relying on self-reported events. This avoids any influence of the personal perceptions or past experience with regard to shocks. The main objective is to define rainfall shock variables that best track the prospect of extreme excessive and deficit rainfall events. These measures are constructed from daily and monthly rainfall data available at the province level obtained from the Thai Meteorological Department.[8] However, there are several limitations to this approach. First, sampled households that are in the same province are assigned to be in proximity of the same rainfall station, and therefore assumed to be similarly affected by rainfall shocks. Second, only rainfall data is used in defining the incidence of excessive and deficit rainfall, disregarding physical factors such as river water levels and flows, soil types, and moisture content. Finally, the production cycles of crops are not taken into account.

In defining incidents of extreme rainfall as having too much and too little rain, some admittedly arbitrary decisions need to be made regarding the formation process in order to define rainfall shocks. Crucially, the triggers of floods and droughts differ in critical

[7] These 12 crops are rice, maize, cassava, sugarcane, rubber, and selected fruit trees of which the sampled households produce the most.
[8] General information about rainfall patterns in Thailand is given in the supplemental appendix.

rainfall thresholds and the duration for which these thresholds need to be exceeded. The thresholds are here defined as rainfall patterns that are beyond normal conditions such that these events can be considered as extreme, with the threshold values set at two standard deviations above and below the mean of rainfall distribution for excessive and deficit rainfall, respectively. To justify these choices, the cut-off points are compared with standard meteorological measures of extreme excessive and deficit rainfall. In addition, the results are robust to changes to the cut-off points. The rainfall shock variables are derived from the daily and monthly rainfall data by identifying excessive and deficit rainfall spells, and then expressing these spells as annual cumulative measures at the province level. Figure 1 shows the spatial and temporal differences of the incidence of excessive and deficit rainfall in 68 provinces during 2006-2010.

The measure of excessive rainfall events is constructed from daily rainfall data.[9] The rationale behind the use of high frequency daily statistics is the fact that flooding is a fast-onset type of event, which can be formed when there is an excessive amount of rain over a short period of consecutive rainy days. The incidence of excessive rainfall spells is counted when the rainfall total in each day exceeds a given threshold for any three days in a row. The use of a three-day period in identifying excessive rainfall events can be linked to the actual occurrence of flash floods caused by tropical storms in the early monsoon season as summarised in Poapongsakorn and Meethom (2012).[10] The excessive rainfall threshold values are computed for each province separately by taking the 95th percentile of the daily rainfall time series over five years. The amount of rain at the 95th percentile recorded across provinces and time periods in this study is approximately 48 millimetres on average, with a minimum of 34 millimetres. This corresponds closely to the definitions for the amount of daily rainfall applied by the Thai Meteorological Department that classify rainfall of more than 35 millimetres per day as 'heavy rain'.[11]

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[9] Daily rainfall data is not available in eight provinces, including seven provinces in the central area (Uthai Thani, Samut Sakhon, Samut Songkhram, Nonthaburi, Ang Thong, Nakhon Sawan, and Sing Buri) and one in the west (Prachuap Khiri Khan).

[10] Examples are *Haima depression* in June 2011 (rainfall in five days greater than 150 millimetres); *Nok Ten depression* in July 2011 (rainfall in three days greater than 150 millimetres); *Hai Tang storm* in September 2011 (rainfall in three days greater than 180 millimetres); *Nesard storm* in October 2011 (rainfall in two days greater than 120 millimetres); and *Nalkae storm* in October 2011 (rainfall in three days greater than 180 millimetres).

[11] The Meteorological Department of Thailand applies the criteria for measuring the amount of rain in a 24-hour period based on typical rainfall conditions of the tropical monsoon climate as follows: '*unnoticeable*' when the amount of rain is less than 0.1 millimetres, '*light rain*' between 0.1 and 10

The excessive rainfall shock variable is constructed by counting the number of excessive rainfall spells in each province on a daily basis over a year, with a spell defined as three consecutive days of heavy rain:

$$F_p^t = \sum_{j=1}^{J} f_{j,p}^t \quad \text{when} \quad f_{j,p}^t = 1 \;\; \text{if} \;\; r_{j-i,p}^t > \tau_p \; ; \;\; \forall i = \{0,1,2\} \qquad [1]$$

$$\text{and} \quad f_{j,p}^t = 0 \quad \text{otherwise}$$

where the indicator $f_{j,p}^t$ reports the incidence of excessive rainfall spells occurring in province *p* on day *j* in year *t*, by taking value 1 for any *j* if the third consecutive day on which the amount of daily rainfall, $r_{j,p}^t$, exceeds the provincial-specific threshold, τ_p, and taking value 0 otherwise. The excessive rainfall shock variable, F_p^t, then sums $f_{j,p}^t$ over the total number of days in a year, *J*.

Unlike flooding, the occurrence of drought is a slow-onset event and unlikely to occur within a short period of time. We therefore determine the occurrence of deficit rainfall based on the notion of meteorological drought, which is measured by rainfall deficiencies over a three-month period.[12] The incidence of deficit rainfall is defined as a shortfall of three-month cumulative rainfall that is below a given threshold. The objective measure of deficit rainfall is constructed from monthly rainfall time series data over the 30-year period from 1981 to 2010. The threshold values are set for each province separately at the 5th percentile of the monthly rainfall records for each of every three consecutive months in comparison with the same three-month period over 30 years. This approach is in line with the interpretation of the standardised precipitation index (SPI) − a widely used index in defining meteorological droughts.[13] To confirm this, the provincial rainfall data for the

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millimetres, '*moderate rain*' between 10.1 and 35 millimetres, '*heavy rain*' between 35.1 and 90 millimetres, and '*very heavy rain*' beyond 90.1 millimetres.

[12] According to Wilhite and Glantz (1985), there are four main types of drought phenomenon which are meteorological, hydrological, agricultural, and socio-economic. The first three deal with the physical occurrence, while the last one defines drought in terms of supply and demand in tracking the effects of a water shortfall as it ripples through socio-economic systems. Meteorological drought is usually defined as the degree of abnormal dryness with respect to normal conditions or the long-term average amount of precipitation for a specific period of time.

[13] Pioneered by McKee et al. (1993), SPI is a widely used index used to characterise the occurrence of meteorological drought on a range of timescales. The calculation of SPI requires only precipitation data, but using long-term records (30 to 50 years recommended). SPI is expressed as the number of standard deviations that the observed amount of rain deviates from the long-term mean of a standard normal distribution. Negative values of SPI thus reflect the degree of dryness in terms of deviation from mean

months where the three-month moving total is below the 5th percentile threshold yields an average value of the three-month SPI of -2.10.[14] This suggests that the measure of deficit rainfall spells indeed reflects periods of extremely dry conditions.

The deficit rainfall shock variable is constructed by counting the number of deficit rainfall spells on a monthly basis over a year:

$$D_p^t = \sum_{k=1}^{K} d_{k,p}^t \quad \text{when} \quad d_{k,p}^t = 1 \quad \text{if} \quad \sum_{h=k-2}^{k} m_{h,p}^t < \omega_p \qquad [2]$$

$$\text{and} \quad d_{k,p}^t = 0 \quad \text{otherwise}$$

where the indicator $d_{k,p}^t$ reports the incidence of deficit rainfall spells occurring in province *p* in month *k* of year *t*, by taking value 1 for any *k* if the cumulative amount of rain over three consecutive months, $\sum_{h=k-2}^{k} m_{h,p}^t$, is less than the provincial-specific threshold, ω_p, and taking value 0 otherwise. The deficit rainfall shock variable, D_p^t, then sums $d_{k,p}^t$ over the total number of months in a year, *K*.

[Figure 1 here]

4. Empirical strategy

To examine how the incidence of extreme rainfall events affects household income and consumption and how farming households respond to shocks, the empirical analysis relies on reduced-form regressions applied to pooled repeated cross-sectional household datasets that form a pseudo-panel at the province level. The strategy uses provincial variation of rainfall shock variables to explain the variation of outcome variables of the average household in those provinces:

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conditions, with the classification '*near normal condition*' when the SPI is between -0.99 and 0.99, '*moderately dry*' between -1.49 and -1.00, '*severely dry*' between -1.99 and -1.50, and '*extremely dry*' less than -2.00.

[14] The standard three-month SPI is often used to capture seasonal variations of rainfall conditions which could happen within or between the seasons. The idea behind the three-month SPI is similar to comparing monthly rainfall total from any specific three-month period with the rainfall total from the same three-month period over years included in the historical records. The scale of three months reflects short- and medium-term moisture conditions.

$$Q_{idpt} = \mathbf{W}'_{pt}\boldsymbol{\beta} + \mathbf{H}'_{idpt}\boldsymbol{\theta} + \gamma_d + \delta_t + \varepsilon_{idpt} \quad [3]$$

where Q_{idpt} represents the outcome variables of household i that lives in district d of province p in year t. The outcome variables of interest are various measures of household income and consumption expenditure per adult equivalent expressed in log form and binary variables for risk-coping responses. Next, $\mathbf{W}_{pt}$ is a vector of provincial-based measures for the incidence of excessive and deficit rainfall spells, $\mathbf{H}_{idpt}$ is a vector of control variables including weather and farm characteristics, asset holdings, average market prices of 12 major crops at the village level, household demographics and livelihood characteristics. The model includes district dummies, γ_d, and time fixed effects, δ_t, to control for unobserved heterogeneity across locations and over time. The random error ε_{idpt} is assumed to follow a standard normal distribution. Robust standard errors are clustered at the province level.

The use of index-based measures of rainfall shocks helps avoid potential endogeneity bias, which could arise when applying subjective or self-reported information on shocks in the absence of household panel data. However, the effects of rainfall shocks on household welfare in each location cannot be assumed to be random as the occurrence of extreme rainfall events in a locality is likely correlated with household behaviour, which could in turn affect their earnings and spending habits. For example, households who are more exposed to floods would be more accustomed to dealing with floods, compared to those who rarely experience floods. To resolve this problem, district fixed effects are included to control for unobserved district-specific factors.[15] In addition to the explicit measures of rainfall shocks, the estimation equation includes long-term average rainfall over 30 years to control for normal rainfall patterns in each province. The rainfall shock variables therefore capture the incidence of adverse rainfall events with an intensity beyond the province's typical rainfall conditions and farmer expectations.

The estimate of $\boldsymbol{\beta}$ yields the average effects of extreme rainfall events on the outcome variables by assuming that households living in the same province are similarly affected. The coefficient can be interpreted as a percentage change of household income and

[15] District is an administrative unit in Thailand which is smaller than a province but larger than a county (or subdistrict). Sampled households are from 821 districts over five years.

consumption expenditure or a percentage point change in the probability of engaging in coping mechanisms when the number of excessive or deficit rainfall spells changes by one in a year. Summary statistics show that the average number of excessive and deficit rainfall spells is less than one, occurring once in 10 and 5 years, respectively.

Since the incidence of excessive and deficit rainfall is most likely to have negative consequences for agricultural production, and hence on farm outcomes, the estimate of **β** on crop income is expected to be negative. Farming households that earn a living from non-farm activities may also rely on their non-farm earnings to compensate for crop income loss since non-farm income is likely to be affected less severely by rainfall shocks. The estimate of **β** on non-farm income would then be positive. In case of risk aversion, households may prefer a smoothed consumption path, even when their income fluctuates as a result of unexpected events. If farming households are able to smooth their consumption against negative income shocks, the effect of rainfall shocks on consumption expenditure should be lower than that on income.

5. Estimation results

5.1 Rainfall shocks and income smoothing

Table 2 summarises the estimation results from OLS regressions on the average effects of rainfall shocks on the household income portfolio. The top panel shows that, for the full sample, there is imperfect smoothing of crop income with respect to both floods and droughts. Crop income falls by 33.77 percent and 20.49 percent on average in response to excessive and deficit rainfall shocks, respectively.[16] However, there is a positive association between livestock income and the incidence of extreme rainfall, although the estimates are not precise. An explanation could be that livestock is usually kept as asset, which can be sold and turned into cash when needed. Excessive rainfall events cause a substantial decline in other farm income, but increases household income from farm labour and services. This suggests that farming households can supply their labour or provide services to other farms in compensation when their own farm is affected by excessive rainfall shocks. On the other hand, there is no such evidence for the case of

[16] We also test the sensitivity of the results to different threshold values for defining excessive and deficit rainfall shocks in the supplemental appendix. The results appear robust in the sense that the conclusions remain qualitatively similar for different threshold values, although, as expected, the magnitude of the coefficients decreases gradually as we lower the threshold for defining rainfall shocks.

deficit rainfall events, suggesting that when affected by droughts, it is more difficult for farming households to find another source of income from off-farm activities since other farms nearby might also be affected. Droughts typically have a larger geographic coverage and last longer than excessive rain or flash floods. Earnings from renting or selling non-farm land and assets are also used to smooth household income in case of excessive rainfall shocks, but not deficit rainfall shocks.

[Table 2 here]

Extreme rainfall events reduce total household income by about 17 percent, on average. The negative effects of excessive rainfall shocks on aggregate income are slightly smaller than that of deficit rainfall shocks. This is in contrast to the results for crop income, which is more affected by excessive rainfall spells, suggesting that farming households are more able to smooth their income earned from off-farm employment and asset transactions when affected by excessive rainfall shocks. Deficit rainfall shocks seem to have negative implications on a wider range of income sources, thereby reducing the ability to smooth not only farm but also non-farm income. Perhaps surprisingly, there is no positive correlation between receipt of government assistance through natural disaster relief and the rainfall shock variables. Thailand's compensation scheme for natural disasters is mainly based on self-reported claims of the victims in the absence of effective loss and damage assessment of local authorities. Our results suggest that these self-reported claims are not in line with actual damage of extreme rainfall.

The lower panels show the estimates of rainfall shocks by land ownership. Landholding households constitute the majority of the sample. Those who do not own land but rent land for agricultural production are classified as landless households. The overall results indicate that the negative effects of extreme rainfall events are significantly larger for landless farming households. Since land holdings are positively correlated with asset holdings and household income, these findings emphasise the wealth-differentiated effects of rainfall shocks. In addition, we find that only landholding households smooth their income by increasing earnings from livestock, labour supply, renting or selling non-farm land and assets.

5.2 Rainfall shocks and consumption smoothing

The reduced-form effects of rainfall shocks on household consumption expenditure are presented in Table 3. The estimation results provide no statistically significant evidence of any impact of extreme rainfall events on average food and non-food consumption expenditure, suggesting that on average farming households are able to smooth their consumption when farm income is affected by floods or droughts. But we do see a statistically significant reduction of miscellaneous expenses in response to the incidence of deficit rainfall, suggesting that farming households are more likely to spend less on unnecessary items when affected by droughts in order to maintain their necessary consumption.

[Table 3 here]

However, we do observe some heterogeneity in the ability to smooth consumption, as landless farming households are more vulnerable to the incidence of rainfall shocks when compared to the wealthier landholding households. While landholding households are able to smooth consumption, the results show negative and significant effects of deficit rainfall shocks on food and non-food consumption expenditure among landless households. This corresponds to the findings for household income, as landowners are able to smooth away the negative effects of rainfall shocks on crop income by relying on other income sources, whereas landless households cannot.

5.3 Rainfall shocks and coping responses

Table 4 presents the estimation results obtained from linear probability regressions of four types of risk-coping strategies: dissaving, borrowing, selling assets, and selling farm stocks. The estimated coefficients reflect the percentage point increase in the propensity of engaging in a particular option in coping with the incidence of excessive and deficit rainfall. Dissaving is found to be the most common strategy in coping with rainfall shocks in both situations. Farming households may resort to their own savings when their income is negatively affected by shocks in order to maintain consumption. In contrast with dissaving, households in general seem not to incur more debt by taking out new loans when they are affected by rainfall shocks. This could reflect farming households reducing investments in farming activities when the negative effects of rainfall shocks are substantial. As for the role of physical assets, there is statistically significant evidence that farming households are likely to sell their non-farm assets to buffer the negative effects of deficit rainfall spells. While affected by excessive rainfall events, they would rather resort to selling their stocks of crop and livestock.

[Table 4 here]

6. Summary and conclusions

The combination of a tropical monsoon climate and the country's lacking irrigation system leaves Thai farming households being exposed to rainfall variability and the associated risk to agricultural production and earnings. Yet the evidence regarding welfare impacts of extreme rainfall events for Thai farming households is scant.

This paper evaluates the potential welfare impacts of extreme rainfall events on farming households, as well as the strategies that affected households may adopt in response to rainfall shocks. We draw on a province pseudo-panel, combining household-level information from annually repeated cross-sectional farm household surveys over the period of 2006-2010 and provincial-based measures of annual rainfall shocks. The rainfall shock variables are constructed from primary high frequency rainfall time series, identifying the incidence of excessive and deficit rainfall events.

The estimation results are consistent with the existing literature as they show evidence of imperfect income smoothing. Crop income falls significantly, with the negative effects of excessive rainfall shocks being slightly larger than that of deficit rainfall shocks. The evidence further suggests that farming households supply labour or provide services to other farms to compensate for own farm income reductions due to excessive rainfall shocks. However, we find no evidence of income smoothing against deficit rainfall shocks, as droughts seem to have negative implications for a wider range of income sources.

In general, our findings support the notion that farming households manage to smooth their consumption and insure against temporary income loss from floods and droughts. The most prominent smoothing strategy is to spend down savings, but we also see evidence of selling assets, farm stocks, and livestock products. However, the results do show heterogeneity by initial wealth level, expressed in terms of land ownership. Landholding households are able to smooth both income and consumption by renting or selling non-farm land and assets in response to excessive rainfall shocks, while income and consumption smoothing is rejected for households who do not own any land.

Finally, the results suggest that the provision of public assistance for dealing with extreme rainfall events seems to be mistargeted and households are therefore not fully insured against flood and drought loss. In comparison to excessive rainfall events, the incidence of deficit rainfall shocks has greater impacts on farming households by affecting both farm and non-farm income, as well as consumption, especially for the least wealthy. However, the public safety net program through disaster compensation scheme is predominantly focussed on flooding, which sometimes tends to be exaggerated in the absence of an effective local loss and damage assessment. Only a small fraction of funds is allocated to compensate farmers for drought loss. Even though the occurrence of drought is not apparent for the compensation, farming households do suffer from negative effects of drought and they are also less able to cope with. The Thai government should therefore develop a more accurate system for assessing drought loss and provide support to the farmers through an effective assessment procedure.

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Table 1: Summary statistics

Variable	N	Mean	SD
Measures of household income per adult equivalent:			
Farm income (baht)	40,684	58,120.59	107,305.90
− Crop income (baht)	40,684	38,993.39	85,734.11
− Livestock income (baht)	40,684	11,057.73	40,014.83
− Other farm income (baht)	40,684	2,652.01	30,937.41
− Farm labour and services (baht)	40,684	6,065.57	30,212.13
Non-farm income (baht)	40,684	32,200.89	59,898.08
− Trade and business (baht)	40,684	5,340.55	26,585.31
− Wage and salary (baht)	40,684	18,401.46	41,145.50
− Renting or selling assets (baht)	40,684	407.11	11,472.17
− Remittances (baht)	40,684	5,162.36	20,773.02
− Other non-farm income (baht)	40,684	2,889.42	22,896.83
Disaster relief (baht)	40,684	1,851.46	4,703.75
Total income (baht)	40,684	91,600.64	124,105.00
Measures of household consumption expenditure per adult equivalent:			
Food consumption expenditure (baht)	40,684	16,216.40	10,037.80
Non-food consumption expenditure (baht)	40,684	27,680.99	38,725.36
− Household items (baht)	40,684	15,274.56	25,068.46
− Education and health care (baht)	40,684	4,644.57	10,360.13
− Durable goods (baht)	40,684	2,178.17	13,649.77
− Miscellaneous expense (baht)	40,684	5,583.68	14,396.54
Total consumption expenditure (baht)	40,684	43,897.38	42,816.75
Risk-coping options:			
Reduction of savings (=1)	40,684	0.24	0.42
Borrowing in total (=1)	40,684	0.60	0.49
Borrowing for farming purposes (=1)	40,684	0.42	0.49
Borrowing for non-farming purposes (=1)	40,684	0.30	0.45
Reduction of assets in total (=1)	40,684	0.23	0.41
Reduction of farm assets (=1)	40,684	0.14	0.35
Reduction of non-farm assets (=1)	40,684	0.13	0.33
Reduction of farm stocks (=1)	40,684	0.15	0.35
Weather characteristic and constructed measures of rainfall shocks:			
Mean annual rainfall (millimetres)	40,684	1,412.13	513.03
Excessive rainfall − F_{pt} (the number of spells per year)	40,684	0.10	0.36
Deficit rainfall − D_{pt} (the number of spells per year)	40,684	0.22	0.52
Farm characteristics:			
Farm size (rai)	40,684	24.81	26.70
Irrigation dummy (=1)	40,684	0.28	0.45
Asset holdings per household:			
Own land (baht)	40,684	1,145,584.00	4,685,331.00
Productive assets (baht)	40,684	144,293.50	857,419.30
Durable assets (baht)	40,684	367,905.80	454,570.80
Farm stocks (baht)	40,684	28,496.63	93,522.69
Savings (baht)	40,684	37,074.45	160,584.50
Household characteristics:			
Head's age (years)	40,684	54.56	11.67
Male head (=1)	40,684	0.83	0.37
Highest education of household head:			
− Under primary school or self-learning (=1)	40,684	0.06	0.24
− Primary school (=1)	40,684	0.77	0.42
− Secondary school (=1)	40,684	0.13	0.34
Number of males aged < 18 years	40,684	0.56	0.75
Number of males aged > 65 years	40,684	0.18	0.39
Number of females aged < 18 years	40,684	0.53	0.73
Number of females aged > 65 years	40,684	0.18	0.39
Number of males aged 18-65 years classified by highest education level:			
− Under primary school or self-learning	40,684	0.05	0.23
− Primary school	40,684	0.87	0.76
− Secondary school	40,684	0.47	0.67
− Postsecondary or higher education	40,684	0.23	0.50
Number of females aged 18-65 years classified by highest education level:			
− Under primary school or self-learning	40,684	0.07	0.27
− Primary school	40,684	0.94	0.67
− Secondary school	40,684	0.37	0.60
− Postsecondary or higher education	40,684	0.25	0.53
Social capital dummies:			
− [SC]-BAAC (=1)	40,684	0.50	0.50
− [SC]-Farmer and cooperative group (=1)	40,684	0.16	0.37
− [SC]-Saving group (=1)	40,684	0.08	0.26
Non-farm participation dummies:			
− [NF]-Retail and business owner (=1)	40,684	0.12	0.33
− [NF]-Full-time employment (=1)	40,684	0.13	0.34

Table 2: Effects of rainfall shocks on household income

Independent variables	Farm income				Non-farm income				Total farm income	Total non-farm income	Disaster relief	Total income
	Crop income	Livestock income	Other farm income	Farm labour & services	Trade & business	Wage & salary	Renting/ selling assets	Remittances				
Full sample (N=40,684)												
Excessive rainfall (F_{pt})	-0.3377*	0.3454	-0.4234*	0.7384**	-0.1138	0.2506	0.0760*	0.2552	-0.1536	0.0407	-0.4224	-0.1691*
	(0.1806)	(0.2918)	(0.2425)	(0.2920)	(0.1344)	(0.3285)	(0.0426)	(0.2623)	(0.1236)	(0.2415)	(0.3979)	(0.0874)
Deficit rainfall (D_{pt})	-0.2049*	0.2093	-0.0466	0.0185	-0.2343	-0.4263	-0.0083	-0.4373	-0.1705*	-0.8511	-0.5465	-0.1731
	(0.1220)	(0.1754)	(0.2659)	(0.4334)	(0.2245)	(0.5945)	(0.0228)	(0.4284)	(0.0970)	(0.8842)	(0.3982)	(0.1412)
R^2	0.1727	0.3746	0.0700	0.1058	0.1769	0.1365	0.0390	0.2067	0.0892	0.1520	0.3500	0.0864
Landholding households (N=31,075)												
Excessive rainfall (F_{pt})	-0.3420**	0.4605*	-0.4075	0.7388*	-0.1332	0.3111	0.1040**	0.3015	-0.1254	0.0554	-0.5136	-0.1146
	(0.1485)	(0.2742)	(0.2789)	(0.3423)	(0.1633)	(0.3689)	(0.0493)	(0.2832)	(0.1037)	(0.2771)	(0.4460)	(0.0740)
Deficit rainfall (D_{pt})	-0.1413	0.3385	0.0047	-0.0111	-0.2532	-0.4615	-0.0040	-0.5033	-0.0647	-0.9725	-0.5478	-0.1583
	(0.1387)	(0.2043)	(0.3107)	(0.4441)	(0.2587)	(0.6612)	(0.0282)	(0.4713)	(0.0860)	(0.9792)	(0.4227)	(0.1358)
R^2	0.1330	0.3868	0.0793	0.1097	0.1782	0.1430	0.0472	0.2073	0.1126	0.1638	0.3610	0.0936
Landless households (N=9,609)												
Excessive rainfall (F_{pt})	-0.4938	0.0371	-0.4153	0.6389	0.1106	0.0076	-0.0155	0.1911	-0.3253	0.3676	-0.3588	-0.5105**
	(0.4658)	(0.4294)	(0.2784)	(0.4038)	(0.3150)	(0.4444)	(0.0429)	(0.3688)	(0.2981)	(0.4390)	(0.3666)	(0.2162)
Deficit rainfall (D_{pt})	-0.5433**	-0.2310	-0.0935	0.0547	-0.2902	-0.3424	-0.0403	-0.1992	-0.6018***	-0.5340	-0.4928	-0.2734
	(0.2666)	(0.3194)	(0.2629)	(0.4884)	(0.2713)	(0.5030)	(0.0517)	(0.3858)	(0.2259)	(0.6533)	(0.4339)	(0.1900)
R^2	0.3660	0.4074	0.1500	0.1938	0.2520	0.1981	0.0966	0.2678	0.1941	0.1985	0.3920	0.1542

Notes: The table shows OLS estimates on various measures of household income in log forms by allowing the error terms to be correlated across equations for the full sample and population subgroups. Sampled households are divided into landholding and landless households using information on their own land. Other covariates included, but omitted from the table, include weather and farm characteristics, asset holdings, household characteristics, village-level price controls, district, and time fixed effects. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively; robust standard errors are in parentheses.

Table 3: Effects of rainfall shocks on household consumption expenditure

Independent variables	Total food consumption expenditure	Non-food consumption expenditure				Total non-food consumption expenditure	Total consumption expenditure
		Household items	Education & health care	Durable goods	Miscellaneous expense		
Full sample (N=40,684)							
Excessive rainfall (F_{pt})	-0.0106	-0.0088	0.2129	0.3197	0.0093	-0.0250	-0.0196
	(0.0218)	(0.0201)	(0.1999)	(0.3801)	(0.1124)	(0.0189)	(0.0178)
Deficit rainfall (D_{pt})	-0.0371	0.0083	-0.1166	0.3304	-0.1904***	-0.0007	-0.0147
	(0.0265)	(0.0183)	(0.1543)	(0.3429)	(0.0733)	(0.0191)	(0.0181)
R^2	0.3513	0.2947	0.2075	0.1898	0.2425	0.3759	0.4063
Landholding households (N=31,075)							
Excessive rainfall (F_{pt})	-0.0043	-0.0041	0.2159	0.4242	0.0602	-0.0233	-0.0168
	(0.0202)	(0.0193)	(0.1956)	(0.3893)	(0.1175)	(0.0189)	(0.0163)
Deficit rainfall (D_{pt})	-0.0348	0.0067	-0.0257	0.4641	-0.1950**	0.0064	-0.0084
	(0.0282)	(0.0216)	(0.1544)	(0.3237)	(0.0853)	(0.0224)	(0.0202)
R^2	0.3655	0.2993	0.2080	0.1936	0.2613	0.3809	0.4130
Landless households (N=9,609)							
Excessive rainfall (F_{pt})	-0.0126	-0.0105	0.3294	0.1847	-0.1597	-0.0163	-0.0131
	(0.0428)	(0.0397)	(0.3270)	(0.6548)	(0.2072)	(0.0328)	(0.0320)
Deficit rainfall (D_{pt})	-0.0487*	-0.0074	-0.5141*	-0.3229	-0.2346**	-0.0432*	-0.0469**
	(0.0284)	(0.0230)	(0.2694)	(0.5132)	(0.0915)	(0.0239)	(0.0219)
R^2	0.3797	0.3916	0.2900	0.2710	0.3129	0.4430	0.4622

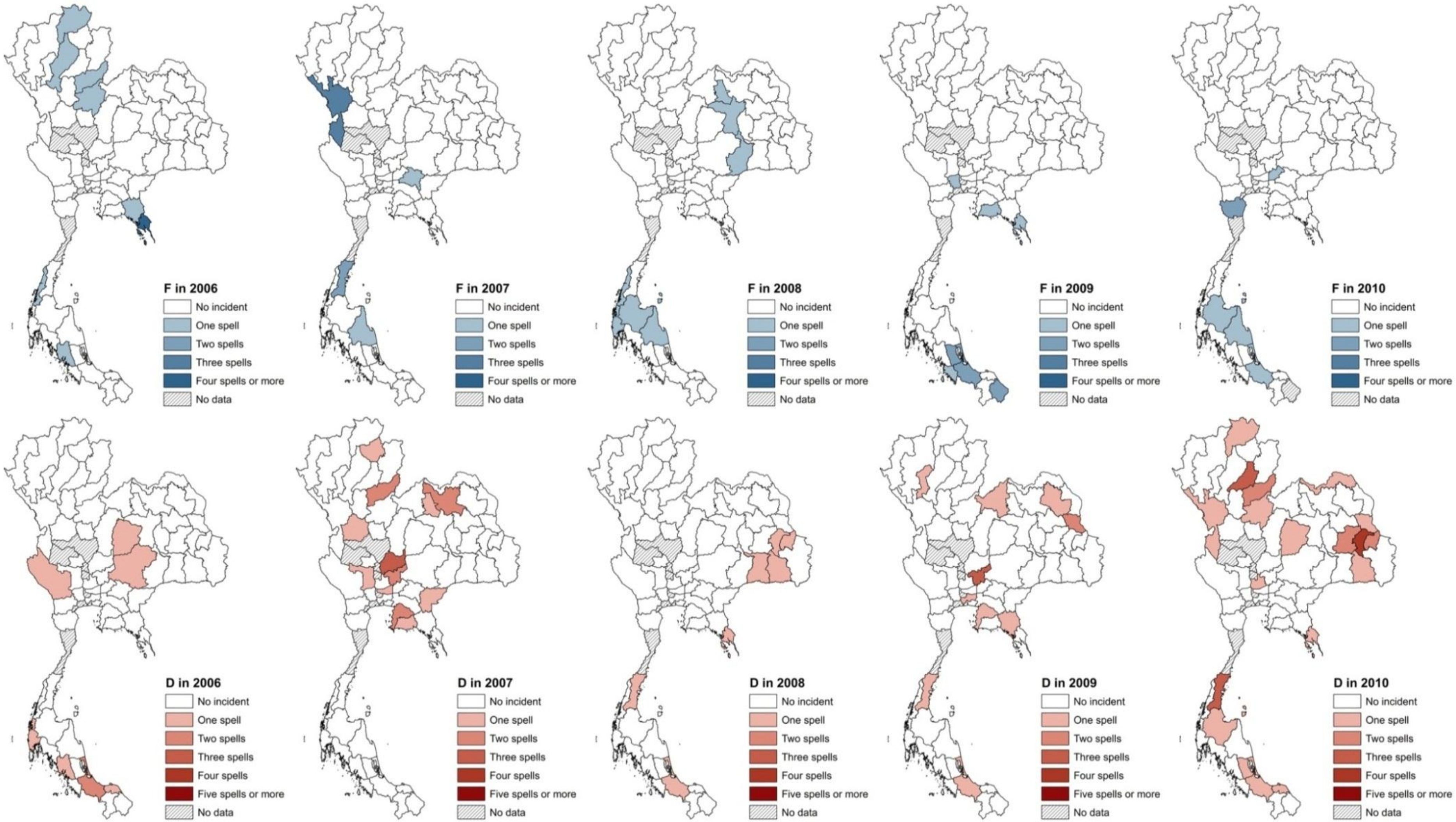
Notes: The table shows OLS estimates on various measures of household consumption expenditure in log forms by allowing the error terms to be correlated across equations for the full sample and population subgroups. Sampled households are divided into landholding and landless households using information on their own land. Other covariates included, but omitted from the table, include weather and farm characteristics, asset holdings, household characteristics, village-level price controls, district, and time fixed effects. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively; robust standard errors are in parentheses.

Table 4: Effects of rainfall shocks on risk-coping responses

Independent variables	Reduction of savings	Borrowing			Reduction of assets			Reduction of farm stocks
		Total	Farming purposes	Non-farming purposes	Total	Farm assets	Non-farm assets	
Full sample (N=40,684)								
Excessive rainfall (F_{pt})	0.0414**	-0.0176	-0.0078	-0.0282**	0.0081	0.0046	0.0069	0.0197**
	(0.0183)	(0.0145)	(0.0148)	(0.0124)	(0.0149)	(0.0102)	(0.0107)	(0.0080)
Deficit rainfall (D_{pt})	0.0258*	-0.0062	-0.0291**	0.0165	0.0145	-0.0033	0.0170*	0.0058
	(0.0152)	(0.0159)	(0.0127)	(0.0162)	(0.0124)	(0.0080)	(0.0098)	(0.0050)
R^2	0.1100	0.2401	0.2188	0.1460	0.1161	0.0969	0.0904	0.1503

Notes: The table shows estimates from the linear probability model for risk-coping responses observed from the change of household's savings, borrowings, and asset holdings within a year. Other covariates included, but omitted from the table, include weather and farm characteristics, asset holdings, household characteristics, village-level price controls, district, and time fixed effects. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively; robust standard errors are in parentheses.

Figure 1: Constructed measures of excessive and deficit rainfall spells



Supplemental Appendix (not for publication, but available online)

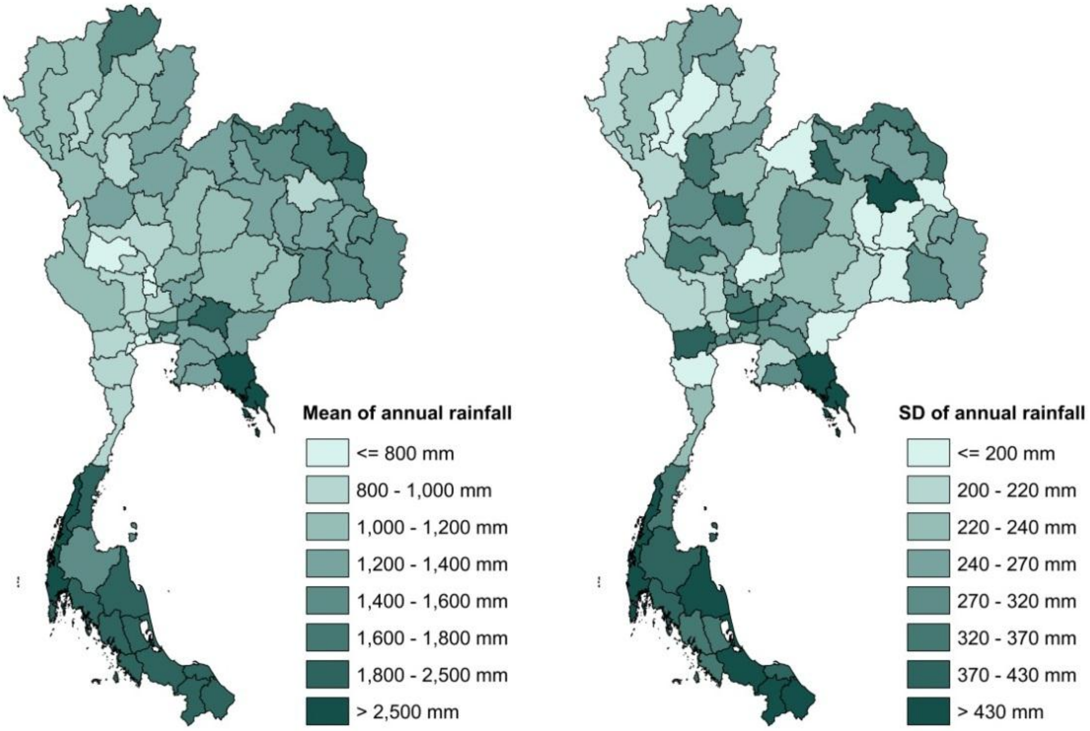
Appendix Table A.1: Definitions of key socio-economic variables

Variable	Description
Measures of household income:	
Farm income	
− Crop income (baht)	Value of total crop production minus total production cost of 320 types of crop within a year
− Livestock income (baht)	Value of current livestock holding and fishery products minus total input cost of 51 product items within a year
− Other farm income (baht)	Return from other farm-related activities, e.g. selling plant seeds, animal breeds, and processed agricultural products, renting or selling farmland and farm assets, etc.
− Farm labour and services (baht)	Return from offering farm labour and providing farm services
Non-farm income	
− Trade and business (baht)	Profit from trading goods and services from own business e.g. retail shop, handicraft, car repair, etc.
− Wage and salary (baht)	Cash income earned from non-farm jobs either full-time or part-time
− Renting or selling assets (baht)	Revenue from renting or selling non-farm land and assets
− Remittances (baht)	Money transferred from family members either onshore or offshore
− Other non-farm income (baht)	Money received from miscellaneous sources, e.g. interest, gambling, special occasions such as funerals, weddings, charity, etc.
Disaster relief (baht)	Money transferred from the government as natural disaster relief
Total income (baht)	Sum of total farm and non-farm income plus the government's transfers in case of natural disaster relief
Measures of household consumption expenditure:	
Food consumption expenditure (baht)	Cost of buying food supplies and cooked food, plus value of own-produced crop and livestock products and food received as gifts consumed by the household
Non-food consumption expenditure	
− Household items (baht)	Cash spending on housing (e.g. rent, property tax, repair cost, etc.), utilities, fuel, clothing and footwear, frequently purchased household and personal items (e.g. light bulbs, soap, shampoo, detergents, toothpaste, etc.), communication, and transportation
− Education and health care (baht)	Money spent on education and medical care
− Durable goods (baht)	Money spent on furniture and household equipment, transport equipment, and non-farm land including maintenance costs
− Miscellaneous expense (baht)	Money spent on luxury goods, gambling, entertainment, recreation, special occasions such as funerals, weddings, charity, etc.
Total consumption expenditure (baht)	Sum of food and non-food consumption expenditure
Farm characteristics:	
Farm size (rai)	Total area of farmland in rai (1 rai = 0.16 hectare)
Irrigation dummy (=1)	Dummy variable which equals one if the household has at least one plot of farmland located in irrigated areas
Asset holdings:	
Own land (baht)	Value of farm and non-farm land owned by the household
Productive assets (baht)	Value of productive assets owned by the household, e.g. storehouse, water tank, water pump, livestock and fishery facilities, tractor, truck, farm machines and equipment, etc.
Durable assets (baht)	Value of durable assets owned by the household, e.g. house excluding land, furniture, household electrical appliances, etc.
Farm stocks (baht)	Value of stocks of crop and livestock products carried from last year
Savings (baht)	Value of cash savings in financial institutions
Other household characteristics:	
Social capital dummies − BAAC (=1) − Farmer and cooperative group (=1) − Saving group (=1)	Dummy variables for social capital benefits which equal one if the household has at least one member aged 18 years and over who is a member of the Bank for Agriculture and Agricultural Cooperatives (BAAC), farmer or cooperative group, or informal saving group
Non-farm participation dummies − Retail and business owner (=1) − Full-time employment (=1)	Dummy variables for household's engagement in non-farm activities which equal one if the household has at least one member aged 18 years and over running own business or employed full-time

Rainfall patterns in Thailand

Located on the Indochinese Peninsula, Thailand is influenced by the south-west and the north-east monsoon over a year cycle. Under the influence of the south-west monsoon, the rainy season in Thailand usually begins in mid-May and lasts through October in most regions, except for the southern part where it lasts until December. During the rainy season, a significant amount of rain can be found in two non-consecutive periods in May-June and August-September. There is a slight decline in the amount of rain in the middle of the rainy season, starting from late June and possibly lasting from two to four weeks. The discontinuity of rainfall between June and July is driven by the temporary movement of the monsoon trough from northern Thailand towards southern China. This low pressure trough comes back to Thailand in late July, causing moderate to heavy rain until the end of the rainy season. Appendix Figure A.1 shows the spatial variation of rainfall conditions across 76 provinces in Thailand, represented by the long-term average and standard deviation of annual rainfall between 1981 and 2010. The amount of rain is moderate and differs slightly between the north and the north-east. Maximum average rainfall is found in the southern and eastern regions which are under the strong influence of the two monsoons throughout the year. The central flat plain and the western region have the lowest average rainfall compared with the other regions.

Appendix Figure A.1: Mean and standard deviation of annual rainfall



Sensitivity analysis of rainfall shock variables

The construction of rainfall shock variables involves an arbitrary decision on the threshold values. This appendix provides a sensitivity of the choice of threshold. Appendix Table A.2 shows the estimation results for four different threshold values. The estimates in scenario 3 are similar to the results in Table 2 using the 95th and the 5th percentile in defining the incidence of excessive and deficit rainfall, respectively. Scenario 1 presents a less extreme case with threshold values of P90 and P10 for excessive and deficit rainfall. The coefficients are smaller and less precise, yet the signs and interpretation are similar. This is not surprising, as the P90 and P10 thresholds also include some of the rainfall intensity within two standard deviations, which we can interpret as within the range of expectation of farmers. The amount of daily rain at P90 is 34 millimetres on average, classified as '*moderate rain*' using the Thai Meteorological Department's definition, while the cut-off at P10 corresponds to the average value of 3-month SPI at -1.70, indicating '*moderately dry condition*'. Smaller deviations from our preferred threshold values, with P94 and P6 in scenario 2 and P96 and P4 in scenario 4, give us qualitatively similar results. We cannot apply the sensitivity test to more extreme thresholds as we lack sufficient variation in deficit rainfalls shocks once we reach a threshold of P3.

Appendix Table A.2: Sensitively analysis of rainfall shocks on income

	Threshold	Crop income	Livestock income	Total farm income	Total non-farm income	Total income
Scenario 1						
Excessive rainfall (F_{pt})	P90	-0.0609	0.2212	0.0057	0.1848	0.0184
		(0.0778)	(0.1507)	(0.0658)	(0.1931)	(0.0434)
Deficit rainfall (D_{pt})	P10	-0.1181*	0.0599	-0.0820*	-0.2722	-0.0794
		(0.0633)	(0.0967)	(0.0436)	(0.2946)	(0.0489)
Scenario 2						
Excessive rainfall (F_{pt})	P94	-0.3479**	0.4184	-0.1275	-0.1464	-0.1124*
		(0.1477)	(0.2527)	(0.0856)	(0.2043)	(0.0564)
Deficit rainfall (D_{pt})	P6	-0.2042	0.2110	-0.1690*	-0.8586	-0.1703
		(0.1230)	(0.1791)	(0.0985)	(0.8929)	(0.1428)
Scenario 3 – Baseline results						
Excessive rainfall (F_{pt})	P95	-0.3377*	0.3454	-0.1536	0.0407	-0.1691*
		(0.1806)	(0.2918)	(0.1236)	(0.2415)	(0.0874)
Deficit rainfall (D_{pt})	P5	-0.2049*	0.2093	-0.1705*	-0.8511	-0.1731
		(0.1220)	(0.1754)	(0.0970)	(0.8842)	(0.1412)
Scenario 4						
Excessive rainfall (F_{pt})	P96	-0.3346	0.3964	-0.0305	0.1860	-0.0749
		(0.2428)	(0.3089)	(0.1745)	(0.2365)	(0.1093)
Deficit rainfall (D_{pt})	P4	-0.2013	0.2074	-0.1649*	-0.8468	-0.1682
		(0.1235)	(0.1773)	(0.0978)	(0.8926)	(0.1427)

Notes: The table shows OLS estimates of shocks on household income using multiple thresholds. *, **, *** indicate statistical significance at 10%, 5% and 1%, respectively; robust standard errors are in parentheses.