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TYPHOON AND AGRICULUTURAL PRODUCTION PORTFOLIO EMPIRICAL EVIDENCE FOR A DEVELOPING ECONOMY

THI XUYEN TRAN

Department of Economics
Fächergruppe Volkswirtschaftslehre

Autoren / Authors

Thi Xuyen Tran
Helmut-Schmidt-University Hamburg
Department of Economics
Holstenhofweg 85, 22043 Hamburg
tranx@hsu-hh.de

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Zusammenfassung / Abstract

In this paper, we investigate whether and how households adjust their agricultural practices such as cultivation and livestock to adapt to a severe typhoon. We, therefore, make use of a natural experiment coming from the strong typhoon Ketsana in 2009. We apply the difference-in-differences approach using micro-data on household level and spatial data of this severe typhoon. Our empirical findings suggest that households alter their agricultural activities in response to a strong typhoon. While they decrease the crops-planted area, they tend to purchase more livestock in the short term and in the medium term. Our paper not only indicates the adjustment to the crop-livestock system as an adaptation strategy to a severe typhoon, but it also is a warning about the contraction of crops production in the aftermath of this type of event.

Schlagworte / Keywords: Typhoon, Agriculture, Crops, Livestock, Vietnam
JEL-Klassifikation / JEL-Classification: O12, O13, Q12, Q15, Q54

1 Introduction

Global warming is one of the most difficult challenges we are facing today. It also increases the frequency and the severity of some types of natural disasters (Hirabyashi et al. 2013; Leng, Tang and Rayburg 2015). Natural disasters have impacted negatively on agriculture, especially in developing countries. The losses from the agricultural sector in those countries from 2003 to 2013 amount to 22 percent of the total economic losses damaged by natural hazards, in which crop and livestock activities are the most affected subsectors (FAO 2015).

Typhoons belong to the most frequent natural disasters since they account for 42 percent of all events that occurred in 2018.[1] This type of hazard is also responsible for almost 23 percent of crop damage and losses in developing countries in the period between 2003 and 2013 (FAO 2015). The losses in crop yields are caused mainly by strong winds, heavy precipitation, flooding and their combination (Tani 1966; Coomes et al. 2016). Typhoons also decrease livestock activities (Mohan 2017; Morris et al. 2002; Jakobsen 2012). Moreover, the future warming will most likely increase the typhoons' severity (Emanuel 2005; Christensen et al. 2007; Bender et al. 2010; Knutson et al. 2010; Callaghan and Power 2011; Dell, Jones and Olken 2014) and change their tracks (Murakami and Wang 2010), which could damage the crop-livestock system even more. In detail, theory and high-resolution dynamical models project that by the end of the 21st Century the globally averaged intensity of tropical cyclones will be shifted towards stronger storms, whose intensity increases by 2-11 percent. Moreover, the higher resolution modeling studies predict that the precipitation rate within 100 km of the storm center will be increased by 20 percent (Knutson et al. 2010).

The mixed crop-livestock system is the main livelihood of millions of households and plays a crucial role in food security in developing countries (Tarawali et al. 2011; Thornton and Herrero 2014). Moreover, agricultural activities on the household level will be more affected by the natural disasters than on the industrial level (Nardone et al. 2010). Therefore, it is vitally important to understand whether and how households adjust their agricultural production portfolio to mitigate the negative effects of extreme events such as typhoons.

However, the existing literature about the adjustment to the agricultural practices in the aftermath of severe typhoons has not shown a clear picture. A few studies suggest that households do change their agricultural production portfolio in response to a strong typhoon (Van den Berg 2010; Avila-Foucat and Martínez 2018). However, other studies find that households continue their work as usual without any proper adaptation strategy (Huigen and Jens 2006; Hilvano et al. 2016). Moreover, to the best of our knowledge, there has been no evidence of the effect of typhoons on area planted. The existing studies have evaluated the agricultural damages from typhoons mostly through yields and harvested areas without taking into account the area planted (Iizumi and Ramankutty 2015; Aragón et al. 2019).

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[1]Munich Re NatCatSERVICE report, available at https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/the-natural-disasters-of-2018-in-figures.html

This approach would estimate inaccurately the real loss in agricultural output if households adjust their land use factor to adapt to natural disasters (Aragón et al. 2019).

This paper aims to fill the gap in the literature by studying the effect of an extreme event such as a strong typhoon on cultivation and animal husbandry. We test the hypothesis that farmers adjust their crop-livestock system to adapt to the typhoon. Since animal husbandry is perceived relatively more accessible than agricultural land (Rapsomanikis and Maltsoglou 2005) and the negative effect of typhoons on crop is considered larger and more lasting than on livestock (Mohan 2017), we expect that affected households are more likely to decrease area planted and purchase more livestock in comparison with non-affected households.

We thereby focus on Vietnam, a developing country which is, due to its geographical location, highly vulnerable to tropical typhoons. Moreover, the agricultural sector plays a crucial role in the Vietnamese economy. We investigate a natural experiment stemming from Typhoon Ketsana in 2009. We combine the data from the Thailand Vietnam Socioeconomic Panel on the household level and the spatial data about the typhoon from the International Best Track Archive for Climate Stewardship (IBTrACS version 04) dataset of tropical cyclones. We apply the difference-in-differences method to compare the behavior of households in the treatment group with households in the control group before and after the shock. Our findings suggest that households do change their agricultural production portfolio in the aftermath of a severe typhoon. They decrease their crops-planted area (field crops and horticultural crops), while they tend to increase their livestock size in the short term and in the medium term. On the one hand, this adaptation strategy complements other coping strategies such as migration (Gröger and Zylberberg 2016), income diversification (Jacoby and Skoufias 1998), micro-credit (Arouri, Nguyen and Youssef 2015), but on the other hand it predicts the contraction of crop production and export, which could affect millions of people and animals in developing countries (Iizumi and Ramankutty 2015; Sakamoto et al. 2006; Kotera et al. 2014).

The paper is organized as following: Section 2 delivers an overview of the literature on the impact of typhoons on agricultural production. Section 3 provides information about Typhoon Ketsana. Section 4 presents the agriculture in Vietnam. Section 5 describes the employed data and defines central variables, the treatment group and the control group. Section 6 outlines the estimation approach and reports the main estimation results. Section 7 reports robustness checks and section 8 concludes.

2   Related Literature

The existing studies on whether and how households change their agricultural production portfolio to attenuate the damages caused by typhoons are limited and have not reached a consensus.[2]

Some studies show that households modify their agricultural practices in the aftermath of hurricanes

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[2]The literature about the effect of climate change and other kinds of natural disasters on cropping and animal husbandry are summarized in Escarcha, Lassa and Zander 2018; Iizumi and Ramankutty (2015); Helgeson, Dietz and Hochrainer - Stigler (2013); Murray-Tortarolo and Jaramillo (2019); Karimi, Karami, and Keshavarz (2018); Kazianga and Udry (2006); Aragón et al. (2019).

(Van den Berg 2010; Avila-Foucat and Martínez 2018). Van den Berg (2010) studies the effect of the hurricane Mitch in 1998 on the household income strategy in rural Nicaragua. The paper uses the Living Standards Measurement Surveys data for Nicaragua in three waves 1998, 2001 and 2005 and applies cluster analysis to classify households into seven or eight livelihood strategies. These strategies are based on the shares of land and labor used in different types of productive activities. He observes that there was a difference in cropping and raising livestock between 1998 and 2005. More farmers were engaged in growing perennial crops or livestock production in 2005, seven years after the occurrence of hurricane Mitch. The results from Avila - Foucat and Martínez (2018) also support the findings by Van den Berg (2010). They consider the influence of hurricanes on households' resilience at coastal communities of Oaxaca - a Pacific coastal state of Mexico. Their qualitative analysis is based on 11 in-depth interviews with key informants and their descriptive statistic results are based on a survey of a total of 212 households in Oaxaca. They conclude that the accumulation of livestock to sell is one method for households to improve their situation after being affected by the hurricanes.

However, some other studies find either contradictory or weak evidence of this propensity. Huigen and Jens (2006) examine the effect of the super typhoon Harurot (Imbudo) that occurred in 2003 on socio-economic losses and coping strategies of farmers in San Mariano, Isabela, Philippines. The paper uses data from the Land Use Transition Modeling Project, which contains information on 151 farm households before, during and after the occurrence of the typhoon Harurot. They also performed semi-structured interviews with traders, middlemen and government officials. Their descriptive statistics results indicate that the majority of households (78 percent) did not change their agricultural activities and continued their work as usual in the aftermath of the super typhoon. Only 17 percent of the sample reported that they changed some of their crops. Four percent of the respondents stopped their farming. Moreover, households could not build up livestock since they could hardly afford for it. This lack of adaptation strategy in the aftermath of a powerful typhoon is also due to the cultural and social structure of households and their traders in the Philippines. In this country, farmers could receive crop investment from the traders. Hence, it is not necessary for them to change their agricultural practices to mitigate the damages. The traders also do not encourage farmers to produce another crop, since it is not easy for them to adapt their business to other products. Moreover, the findings from Hilvano et al. (2016) indicate that the capital assets such as livestock ownership after the typhoon and the person in charge of house reconstruction related weakly to moderately (0.17 to 0.26) to a household's income recovery. These results are derived from the analysis of how households in Manicani Island, Guiuan, Eastern Samar, Philippines coped with the super Typhoon Haiyan (Yolanda), which occurred in 2013.

Moreover, to the best of our knowledge there is yet no study that investigates the effect of extreme events such as typhoons on input use, particularly area planted, that is urgently necessary (Iizumi and Ramankutty 2015). Most existing studies have estimated the agricultural damages from typhoons through yields and harvested areas without considering the adjustment to the area planted (Iizumi and Ramankutty 2015; Aragón et al. 2019). If the land use is unchanged, this method is accurate, otherwise

the real loss in agricultural output will be inaccurately evaluated (Aragón et al. 2019). To the best of our knowledge, the only existing evidence for how subsistence farmers adjust their input use to mitigate the losses from extreme heat is from Aragón et al. (2019). Their analysis is based on a panel data approach and micro-data from Peruvian households. They suggest that households increase input use, in particular land use, to cope with extreme temperatures. Their findings confirm that households change input factors such as land use and labor use as a productive adaptation strategy to a negative shock (Benjamin 1992; Taylor and Adelman 2003; Aragón and Rud 2016; Aragón et al. 2019). However, in the case of typhoons less is known about this coping mechanism.

Therefore, our paper contributes to the literature by providing empirical evidence using a difference-in-differences method to show whether and how households alter their area planted and livestock husbandry after being affected by a strong typhoon.

3   Typhoon Ketsana in Vietnam

Vietnam is a long narrow country with a 3200 kilometers coastline, located at the tropical monsoon belt in South East Asia. Therefore, it is ranked as one of the most vulnerable countries to natural disasters, especially typhoons (Global Facility for Disaster Reduction and Recovery 2011). Over the period from 1987 to 2016 Vietnam was directly affected by 124 tropical storms (Berlemann and Tran 2020). These typhoons originate mainly from the East Sea and the Western Pacific Ocean, where tropical storms occur most frequently around the world. Provinces in the north and middle are the most affected areas since a large number of typhoons has made landfall in these regions (Institute of Strategy and Policy on Natural Resources and Environment of Vietnam 2009; Takagi 2019). Moreover, over the last century, Vietnam observed an increase in the number of heavy typhoons and a longer typhoon season (Ministry of Natural Resources and Environment of Vietnam 2016). The typhoons have caused enormous damage for Vietnam, which is estimated to about 4.5 billion USD (Global Facility for Disaster Reduction and Recovery 2011). These events also decreased household income and expenditure (Arouri, Nguyen and Youssef 2015; Thomas et al. 2010; Gröger and Zylberberg 2016), intensified poverty and increased inequality in Vietnam (Bui et al. 2014).

Ketsana is one of the strong typhoons, that caused the most damage to Vietnam, particularly the provinces in the middle. Ketsana was originally a tropical depression, that was formed about 860 km to the northwest of Palau on 23rd September, 2009. However, this depression quickly developed further. On 26th September 2009, it made landfall in the northern Philippines and brought lethal rainfall, resulting in devastating flooding and mudslides that affected more than 4.9 million people and caused a total estimated damage of around 237.5 million USD in this country (Guha-Sapir, Below, and Hoyois 2015).

After devastating the Philippines, Typhoon Ketsana then strengthened rapidly, gained peak wind speeds and made a second landfall in the province Quang Nam (adjacent province of Thu Thien Hue) in

the middle of Vietnam at around 2 p.m. local time on the 29th September 2009. Ketsana was a category 2 typhoon with maximum sustained winds of roughly up to 150 kilometers per hour when it landed in the country. This typhoon is known as the most destructive typhoon landed in Vietnam since 1990 (Guha-Sapir, Below, and Hoyois 2015; Gröger and Zylberberg 2016). It brought extremely heavy rains and strong wind gusts that caused a severe flood in Thua Thien Hue and other coastal provinces. Gröger and Zylberberg (2016) provide detailed information about local inundation and precipitation intensity.

Although the Central Committee for Flood and Storm Control announced several typhoon warnings and a strategy to cope with the landfall of Typhoon Ketsana and the Vietnamese Prime Minister released an urgent telegraph to command potentially affected provinces to evacuate their inhabitants living at the riskiest areas to safer places, these actions could not be accomplished. They could not prevent the grievous damage. In detail, as stated by Guha-Sapir, Below, and Hoyois (2015) Typhoon Ketsana killed 182 people, injured 860 people, made 109000 people homeless and affected 2.4 million other people in Vietnam. This typhoon also severely destroyed the infrastructure, production and environment, that lead to a total estimated economic loss of 785 million USD.

Thua Thien Hue is a province located in the key economic region in the middle of Vietnam. However, it is also noticeably prone to natural disasters such as typhoons. This province was reported as one of the most affected provinces damaged by Typhoon Ketsana. The Decision 1088/QD-UBND issued on 15th June 2015 by the People's Committee of Thua Thien Hue reports that Ketsana was the strongest typhoon that struck this province since 1990. The loss in the aftermath of this typhoon in this province was also recorded the highest. Figure 1 shows the affected area in province Thua Thien Hue by Typhoon Ketsana, that is within a radius of 100 km from the typhoon's trajectory.

Figure 1: Affected area in province Thua Thien Hue by Typhoon Ketsana
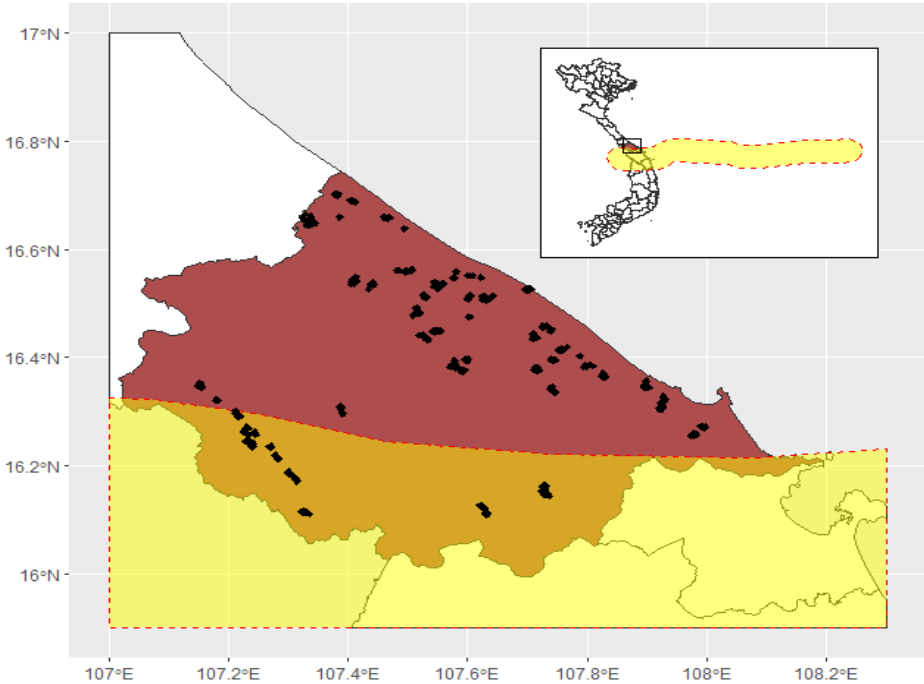
Source: International Best Track Archive for Climate Stewardship (IBTrACS version 4)

4 Agriculture in Vietnam

Agriculture plays a crucial role in the Vietnamese economy. According to the General Statistics Office of Vietnam (2019), roughly 70 percent of the population is living in rural areas, where agricultural activities are principal. Around 44 percent of the population at the age of fifteen years or above was working in this sector in 2015. Although there has been substantial industrialization in Vietnam, the labor force in agriculture still accounted for more than one-third of the population at labor age in 2019. As a result, agriculture's share of Gross Domestic Product (GDP) in Vietnam accounted for 17 percent in 2015. Particularly, in the period during and after the financial crisis of 2007-2008, the contribution of the agriculture sector to GDP in Vietnam had increased steadily, while other sectors had decreased in the contribution (General Statistics Office of Vietnam 2019).

Moreover, Vietnamese agricultural products contribute considerably to international food security. Vietnam is well known for being one of the three largest rice exporters in the world. The rice exported volume in 2018/19 was around 6581 thousand metric tons and had a value of 2.8 billion USD (United States Department of Agriculture 2020). Furthermore, Vietnam is also famous for other exportation commodities such as pepper, fishery products, coffee, tea and rubber.

Besides that, agricultural activities contribute significantly to the national food security, poverty reduction and livelihood opportunities to local inhabitants in Vietnam (Nguyen 2017). Since the population in Vietnam has grown substantially, from 83.1 million in 2005 to 93.4 million in 2015, food demand has increased rapidly (Dinh 2017). Therefore, most rural households own land for cultivation and livestock husbandry (Rapsomanikis and Maltsoglou 2005). Moreover, income from these agricultural activities in households in rural areas makes up the largest share in their total income, which is from 41 percent to 70 percent depending on the regions (Rapsomanikis and Maltsoglou 2005).

In Vietnam, access to the agricultural land is influenced by the land law system. According to the law 24-L/CTN enacted on 14th July 1993 and the law 45/2013/QH13 enacted on 29th November 2013, depending on the scale of cultivated land in each region, each household or individual engaged in agricultural production was allocated an agricultural land quota and land use rights for this quota by the state. The term for this land allocation is fifty years. Vietnamese households and individuals were allocated agricultural land in 1993 under the instructions from Decree No. 64-CP passed on 27th September 1993. Therefore, there has been a large number of citizens born after 1993 without agricultural allocation land, although they belong to engaged agricultural households.

If farmers seek more land for their agricultural production, they have the opportunity to apply for the cultivated land available for lease in the land fund managed by People's Committees in the region. However, this fund is limited and only a small number of applications is approved by the authorities. Moreover, the lease term could be up to fifty years. On the one hand this long-term lease facilitates the recovery of invested capital for the renters, but on the other hand it prevents new land seekers from successfully accessing this limited agricultural land fund. Land users also have the possibility

to exchange, transfer, lease or sublease the land use rights and consider the land use rights as capital. However, the transaction of the land use rights must meet the condition of the allocation quota that is prescribed depending on specific conditions in each locality and in each period by the government. Therefore, in Vietnam agricultural land ownership is also considered relatively less easy to access than raising livestock (Rapsomanikis and Maltsoglou 2005).

5   Data

5.1   Household Data

The Thailand Vietnam Socio Economic Panel (TVSEP)[3] is a repeated household survey for Thailand and Vietnam conducted during the period from 2007 to 2019.[4] As discussed above, in this paper, we focus on data for Vietnam. There are around 2200 households in 3 provinces, Ha Tinh, Thua Thien Hue and Dak Lak, in which people were asked about: demographics, agriculture, livestock, income, expenditures, insurance, shocks and other issues. The reference period is twelve months, from April in the year of the data collection on back to the previous May. For instance, the reference period for the survey in 2008 reaches from May 2007 to April 2008. [5]

Since all three provinces were heavily affected by the strong typhoon Nari that occurred in October 2013, we drop the data that was collected since 2014. Due to the fact that Typhoon Ketsana occurred in September 2009 and the data in 2010 contains the households' information in the period from May 2009 to April 2010, that was not entirely a period ex post, we thus exclude data, that was surveyed in 2010. Moreover, in 2011, the data was only collected in the province Thua Thien Hue. As described earlier, this province was also intensely hit by Typhoon Ketsana. Therefore, we only investigate the sample in this province. Doing so enables us to obtain a dataset with four periods 2007, 2008, 2011 and 2013, that allows us to study the effect in the short term and in the medium term post treatment. We construct a balanced panel dataset, that is the sample of the households in province Thua Thien Hue, repeatedly taking part in all waves from 2007 to 2013. Our main results are derived from this balanced panel. In order to show that the small attrition rate in the panel does not affect the main results, we also create an unbalanced panel, that contains all households in this province available in the dataset from 2007 to 2013. We present the robustness tests using this unbalanced panel in Section 7.

We are interested in the effect of a severe typhoon on the agricultural portfolio. Since cultivation and livestock are the most important sectors in the agricultural production, we examine these two fields in our paper. From the dataset, we construct two dependent variables. The first dependent variable is a numeric variable that indicates on how many 1000 m^2 each household planted crops over the last twelve months. The term crops includes field crops and horticultural crops. We denote this variable is "Area

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[3]The website https://www.tvsep.de/overview-tvsep.html provides more information about the project and the sample collection process.

[4]In 2007, 2008, 2010, 2011, 2013, 2016, 2017 and 2019.

[5]The reference period for the data in 2013 is from April 2012 to March 2013.

planted". In terms of cultivation, we focus on land use, in particular area planted, since this input factor is considered the most important capital in agriculture. The second left-hand-side variable is a count variable, that gives information about the number of livestock was purchased by each household. The livestock group comprises buffalos, beef cattles, pigs and goats. We define this variable as "Purchased livestock".

The TVSEP data also provides numerous variables on household level that can be used as explanatory variables. [6] First, we have information on the age of the household head. Since agricultural work requires physical strength, the older the household head is, the less engaged in farming he is. Secondly, we expect that a household with a highly educated household head is less likely to engage in agricultural activities. We construct a dummy variable that takes the value of 1 if the household head obtains high education and zero otherwise. Thirdly, we use information on the number of working-age members as an indicator of human resource in the household. According to the Vietnamese labor law, the labor age starts at fifteen years. Therefore, we consider those members who were in the corresponding age on the survey date. Besides, if the households have a property insurance, they can be more confident of their financial situation. The insurance variable is a dummy variable that takes the value of 1 if the household bought a property insurance and zero otherwise. We also add in the control variable group a dummy variable that indicates whether the households received remittances from absent members. We expect that if the households could receive this transfer, they would have the ability to invest more in agricultural production. Finally, we use the savings measured in 2005 PPP $ as a proxy for the household's wealth. We expect that if the households increase their savings, they are more likely to invest more in production.

5.2 Storm data

Our treatment is based on the natural experiment that a typhoon affects some regions in province Thua Thien Hue, Vietnam. Therefore, we employ spatial data for Typhoon Ketsana, that is available in the International Best Track Archive for Climate Stewardship (IBTrACS version 04) dataset.[7] This dataset is collected by the National Oceanic and Atmospheric Administration (NOAA).[8] This dataset provides information on the typhoon's position (geographic coordinates of the typhoon's eyes) and maximum wind speed (in knots) in three-hourly storm intervals.

We use the described storm data to identify affected households and non-affected households. We also have the survey data on the household level, which contains the commune of residence for each household. In order to be able to combine these two sorts of data we use a Vietnamese shapefile on the commune level.[9] The following subsection describes the definition of the treatment group and the control group.

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[6]The selected explanatory variables are based on Sarker, Alam and Gow (2013)

[7]For more detailed information on cyclones see e.g. Berlemann (2016); Berlemann and Wenzel (2018); Yang (2008) or Keller and DeVecchio (2016).

[8]The IBTrACS version 04 data were downloaded from: https://www.ncdc.noaa.gov/ibtracs/index.php?name=ib-v4-access on 10.01.2020.

[9]The shapefiles were downloaded from https://gadm.org on 06.05.2018.

5.3 Definition of Treatment and Control Group

We identify households in treatment group and households in the control group based on whether Typhoon Ketsana hit their location or not. Firstly, we connect the eyes of Typhoon Ketsana's intervals to construct it's trajectory. Then we create a buffer around the trajectory. Since typhoons can heavily affect regions within a distance of 100 km (Holland, Belanger and Fritz 2010; Knutson et al. 2010), we choose all households living within a radius of 100 km from the typhoon's trajectory as the treatment group. The control group must contain households that were neither affected by the typhoon nor suffered directly from this event. Therefore, when we identify the control households, we exclude those living closer than 25 km to the treatment area. This means our control group consists of households that lived outside the 125 km distance buffer from the typhoon's trajectory. Figure 1 presents the households in affected areas. Moreover, we want to explore whether the effect remains when we consider households living within the radius of 125 km from the typhoon's trajectory as treated households. We call this treatment the broad treatment and the robustness test results using the broad treatment are reported in subsection 7.2.

Among 638 households in the balanced panel, the treatment group contains 205 households and the control group consists of 213 households. In the unbalanced panel, there were 684 households that were surveyed in 2008, in which 229 households in the treatment group and 230 households in the control group. The attrition rate in the treatment group and the control group of this panel is relatively low, which is not more than 10 percent per wave. The estimation results in the robustness checks in section 7 do not show any difference in household's behavior between two specifications. Table 1 reports the descriptive statistics for households in the balanced panel by groups in the pre-disaster wave 2008.

Table 1: Descriptive statistics by groups in 2008

	Treatment group (205 obs)				Control group (213 obs)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Working-age members	3.41	1.71	1	10	3.79	1.72	1	10
Age of household head	45.46	14.59	23	92	51.28	14.09	23	90
Education of household head (1-yes, 0-No)	0.15	0.36	0	1	0.15	0.35	0	1
Insurance (1-yes, 0-No)	0.03	0.17	0	1	0.04	0.20	0	1
Remittances from absent members (1-yes, 0-No)	0.07	0.25	0	1	0.16	0.37	0	1
Savings (PPP US$)	151.45	1099.89	0	14496	143.06	631.12	0	5602.70
Area planted (1000 m^2)	0.33	0.60	0	5.37	0.44	0.52	0	3.8
Purchased livestock (units)	0.75	2.68	0	30	1.56	4.87	0	42

In the ex ante wave 2008, on average, the households in the treatment group had fewer working-age labors, had a younger household head, bought less property insurance, received fewer remittances from absent members, planted fewer crops and raised fewer livestock than the households in the control group.

In detail, the average household in our treatment group has 3.41 working-age members, whereas the average household in the control group has 3.79 members at the labor age. Moreover, the household head at the average household in the treatment group is 45.46 years old, roughly six years younger than the one in the control group. However, concerning education, 15 percent of households in the treatment group have a household head with a high school degree or a higher educational level, which is the same figure in the control group. Furthermore, there are 3 percent of households in the treatment group reported to have bought property insurance, which is slightly smaller than in the control group. Regarding remittances from absent members, 16 percent of households in the control group got this transfer, which is nearly two-and-a-half times the proportion in the treatment group (7 percent). Regarding savings, on average the sparing money in the treatment group is slightly larger than in the control group. Concerning the agricultural production, the average household in the control group planted 440 m^2 crops in the last twelve months, which is 110 m^2 more than in the treatment group. Likewise, on average, the households in the control group bought 1.56 livestock, whereas the households in the treatment group purchased 0.75 animals.

6 Empirical Analysis

6.1 Estimation Approach

Our primary aim is to study whether and how households adjust their agricultural productive activities after suffering from a strong typhoon. For this purpose, we make use of a natural experiment coming from Typhoon Ketsana. We conduct an empirical analysis comparing treated and non-treated households, before and after the natural disaster. Our investigation is based on the difference-in-differences (DiD) approach with the pretreatment period 2008 and posttreatment periods 2011 and 2013. Data in 2007 is used only for placebo estimations, that are described in subsection 6.2. Since we have two post-disaster waves, we apply DiD with multiple periods, following Angrist and Pischke (2009). This estimation approach is described in the following equation:

$$A_{i,h,t} = \alpha + \lambda * Treatment_i + \sum_{j=2011}^{2013} \gamma_j * Year_{j,t} + \sum_{j=2011}^{2013} \delta_j * Year_{j,t} * Treatment_i + \beta X'_{i,t} + \epsilon_{i,h,t} \tag{1}$$

where $A_{i,h,t}$, the dependent variable, is Area planted/Purchased livestock for household i living in commune h at time t with $t \in \{2008, 2011, 2013\}$. $Treatment_i$ is a time-constant dummy variable, indicating the treatment status of the household i. It takes the value of 1 if the household belongs to the treatment group and zero otherwise. Since we have observations for two post-disasters, we include the time dummy variables $Year_{j,t}$ taking the value of 1 whenever $j = t$, with $j \in \{2011, 2013\}$. For instance, $Year_{2011,t}$ takes the value of 1 for observations in 2011 and zero otherwise. We are interested in the parameters δ_j with $j \in \{2011, 2013\}$, which correspond with the interactions between time and the treatment. These

parameters reveal the causal effect of the treatment on the outcome in 2011 and 2013. $X_{i,t}$ is a vector of control variables on the household level such as working-age members, age of household head, education of the household head, insurance, remittances from absent members and savings. Finally, $\epsilon_{i,h,t}$ stands for the unexplained residual. One may suspect that some serial correlation in our treatment may exist, we solve this problem by calculating the standard errors clustered on the household level (Bertrand, Duflo and Mullainathan 2004).

We estimate the equation (1) via OLS using the balanced panel dataset. The estimation results are presented in subsection 6.3 and subsection 6.4. In order to show that our main results remain unchanged, although there is a small attrition rate in the panel data, we estimate (1) for the unbalanced panel. We report the estimation result in subsection 7.1 as a robustness check.

Since Purchased livestock is a count variable, we estimate the equation (1) using the Poisson regression model to compare differences in pre- and post-treatment measures of the number of livestock purchased as a robustness test. The interaction coefficient of the DiD term δ_j also estimates the effect of the treatment on the outcome (Kondo et al. 2015). In the following subsections, we present and discuss the identification assumption in DiD approach and the estimation results, respectively.

6.2 Identification Assumption

The most important assumption in the DiD method is that the treatment group and the control group must have parallel trends in the absence of the treatment. Therefore, we need to verify that both households in the treatment group and households in the control group experienced the same trend in planting crops and animal husbandry in the absence of Typhoon Ketsana. In order to test this assumption, we apply two different methods. First, we calculate the mean of the outcome variables by groups and draw the graphs that visually show these trends over time. Figure 2 clearly presents the parallel trends of the area planted and purchased livestock in the treatment group and the control group ex ante.

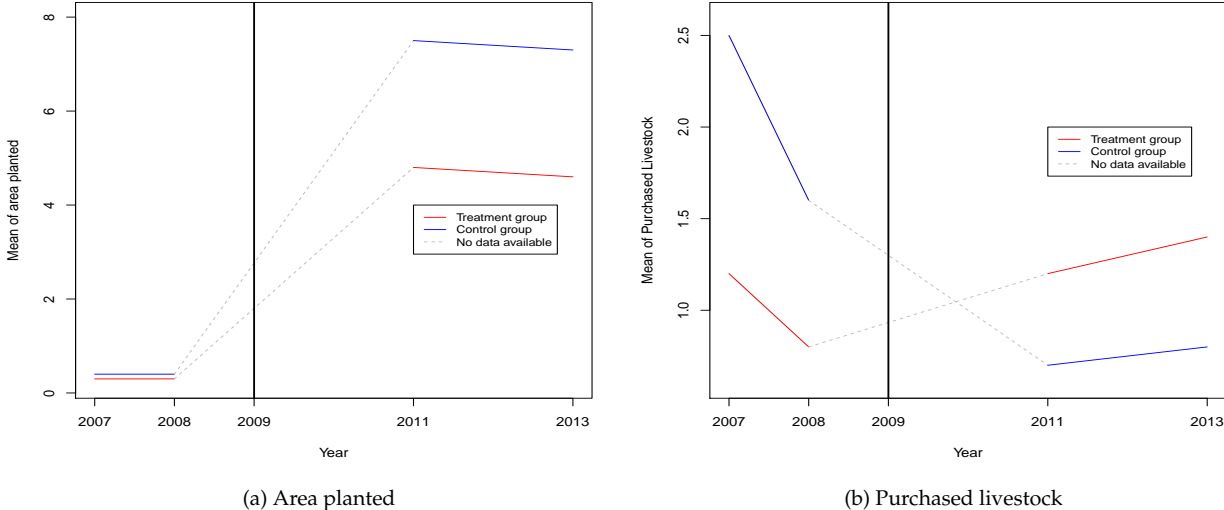(a) Area planted

(b) Purchased livestock

Figure 2: Parallel Trends

Secondly, we provide quantitative evidence for the parallel trends by conducting placebo tests. In order to run the tests, we restrict our sample to the pre-treatment 2007 and 2008 and we replicate our benchmark strategy as if Typhoon Ketsana hit Vietnam in September 2007, two years before the actual occurrence. [10] We estimate the equation (1) using this restricted sample. That means we compare the area planted and purchased animals between the affected group and the non-affected group before and after the occurrence of placebo Typhoon Ketsana. The results from Table 2 show that the coefficients of our placebo treatment in all regressions turn out to be statistically insignificant. These results confirm the graphical results from the first method, which indicate the equal trends in planting crops and raising livestock in treated households and non-treated households before Typhoon Ketsana occurred. Therefore, we can apply DiD technique to our analysis.

Table 2: Placebo estimations using the balanced panel

	Dependent variable:	
	Area planted	*Purchased livestock*
	(1)	(2)
Treatment	−0.158***	−1.295***
	(0.043)	(0.372)
Year 2008	0.00001	−0.965**
	(0.048)	(0.464)
DiD 2008	0.050	0.541
	(0.069)	(0.532)
Constant	0.516***	2.845***
	(0.070)	(0.547)
Household's characteristics	Yes	Yes
Observations	836	836
R^2	0.059	0.040
Adjusted R^2	0.049	0.030
Residual Std. Error	0.494 (df = 826)	3.935 (df = 826)
F Statistic	5.804*** (df = 9; 826)	3.835*** (df = 9; 826)

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

6.3 Typhoon and Crop

As the first step in our empirical analysis, we investigate how households adapt their crops to the powerful typhoon Ketsana. We estimate equation (1) using the balanced panel. The corresponding results are reported in Table 3.

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[10]We follow the strategy described in Gröger and Zylberberg (2016).

Table 3: Typhoon and area planted

	Dependent variable:
	Area planted
	(1)
Treatment	−0.384**
	(0.157)
Year 2011	6.775***
	(0.582)
Year 2013	6.849***
	(0.651)
DiD 2011	−2.543***
	(0.715)
DiD 2013	−2.595***
	(0.720)
Constant	1.888***
	(0.552)
Household's characteristics	Yes
Observations	1254
R^2	0.233
Adjusted R^2	0.226
Residual Std. Error	6.035 (df = 1242)
F Statistic	34.2*** (df = 11; 1242)

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

After the typhoon Ketsana occurred, we observe a strong and statistically significant difference in area planted between the two groups in the short term and in the medium term. Our estimate predicts that in 2011 an average affected household reduced 2543 m^2 area planted compared to an average non-affected household. Two years later, this effect is still existent with a reduction of 2595 m^2 in the average treated household in comparison with the average control household. Therefore, our estimate suggests that the strong typhoon decreases the land use among the exposed households in the short run and in the medium run.

Land use is considered the most important agricultural input. However, as discussed earlier, to the best of our knowledge, there is no evidence so far on the effect of typhoons on the area planted. Our finding, that is based on the extreme typhoon Ketsana, indicates that a typhoon has a significant negative effect on the size of field crops and horticultural crops. Our result supports the result from the standard production model, that households are more likely to reduce area planted in responding to a negative shock (Benjamin 1992). Moreover, our finding suggests a decreasing trend in planting field crops and horticultural crops ex post complements the result from Van den Berg (2010), which shows the increase in planting perennial crops in the aftermath of the strong typhoon. However, our findings are not in line with the findings of Huigen and Jens (2006) that households did not alter their agricultural activities to cope with a strong typhoon. As stated above, due to the strongly dependent relationship between farmers and traders in the Philippines, it is not necessary for farmers to change the cultivation of crops

to adapt to the strong typhoon. This is not the case in Vietnam, where households are responsible for their own agricultural practices.

6.4   Typhoon and Livestock

In the next step of our analysis, we consider the effect of Typhoon Ketsana on the household's animal husbandry. We again estimate the equation (1) using the balanced panel data. The referring estimation results are reported in Table 4.

Table 4: Typhoon and Purchased livestock (OLS regressions)

	Dependent variable:	
	Purchased livestock	
	OLS	*Poisson Regression*
	(1)	(2)
Treatment	−0.819**	−0.730**
	(0.398)	(0.338)
Year 2011	−0.920**	−0.842***
	(0.374)	(0.310)
Year 2013	−0.821**	−0.713**
	(0.381)	(0.310)
DiD 2011	1.218***	1.170***
	(0.460)	(0.427)
DiD 2013	1.328***	1.198***
	(0.470)	(0.418)
Constant	1.977***	0.889**
	(0.491)	(0.366)
Household's characteristics	Yes	Yes
Observations	1254	1254
R^2	0.018	
Adjusted R^2	0.01	
Residual Std. Error	3.1(df = 1242)	
F Statistic	2.0** (df = 11; 1242)	
Log Likelihood		−2878
Akaike Inf. Crit.		5780

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

The estimation result from column (1) in Table 4 indicates that there is a positive and statistically significant difference in investing in livestock between the two groups ex post. The coefficient of the variable *DiD* 2011 is positive and statistically significant. This result indicates that the average household in the treatment group increased 1.2 purchased livestock compared to the average household in the control group ex post. Moreover, the estimated effect in the medium term (in 2013) is more pronounced than in the short term. On average, the treated households tend to raise their livestock's size by 1.3 in comparison to the control household. Therefore, our results suggest that households in the treatment group are more engaged in raising livestock in the aftermath of a strong typhoon.

As described earlier, the left-hand-side variable is a count variable. We thus estimate DiD using the Poisson regression as a robustness test. The referring estimation results are summarized in column (2) of Table 4. We also find a positive and statistically significant difference between households in the treatment group and households in the control group in purchasing livestock before and after the treatment. Therefore, our results remain qualitatively under the different modeling approach.

Our findings support those found by Van den Berg (2010) and Avila-Foucat and Martínez (2018) that households do choose investing in animal husbandry as an adaptation strategy in the aftermath of a strong typhoon. This is due to the fact that hurricanes do not affect all agricultural products in the same way. The negative effect of typhoons on crops is relatively larger and remains in a longer period of time than the effect on livestock (Mohan 2017). Moreover, investment into livestock also ranks as the most frequently reported coping strategy for natural disasters (Helgeson, Dietz and Hochrainer-Stigler 2013) since it results in a relatively high return as well as is relatively liquid to use as a buffer for future incidents (Dercon 1998). However, our results do not fit the results from Huigen and Jens (2006) and Hilvano et al. (2016). As explained earlier, the lack of adaptation in the case of the super typhoon in the Philippines comes from the close relationship between the farmers and the traders. The farmers' decision in agricultural activities in this country is influenced by the traders, that does not exist in other countries. Altogether, we might conclude that households tend to invest in accumulating livestock in order to cope with the losses from a powerful typhoon.

7 Robustness Tests

7.1 Unbalanced Panel

In the first stability check, we test the main results by using the unbalanced panel dataset. To do so, we first check whether the treatment group and the control group in the unbalanced panel have parallel trends in the absence of the treatment. We follow the strategy described in subsection 6.2. As we expected, Figure 3 demonstrates the parallel trends of the quantity of land used and purchased livestock in the treated households and the control households in the unbalanced panel ex ante. Moreover, the results from the placebo tests using the unbalanced panel, that are reported in Table 8 in Appendix, again confirm the findings using the balanced panel. We find that all coefficients of the interaction effects are not significantly different from zero. That means the households in the treatment group and households in the control group in the unbalanced panel also experienced the same trends in land use and buying livestock before the occurrence of the treatment.

Since the parallel trend assumption holds with our unbalanced panel, we estimate equation (1) using this sample. We test whether households in our unbalanced panel change their crop-livestock system in the aftermath of Typhoon Ketsana. The results in Table 5 indicate that the treated households significantly decreased their area planted and increased purchased livestock in comparison with control households

in the short time and in the medium time. The coefficients of all the variables show a relatively equivalent effect as in the case using the balanced sample. That means, the small attrition rate in the panel does neither affect the results quantitatively nor qualitatively.
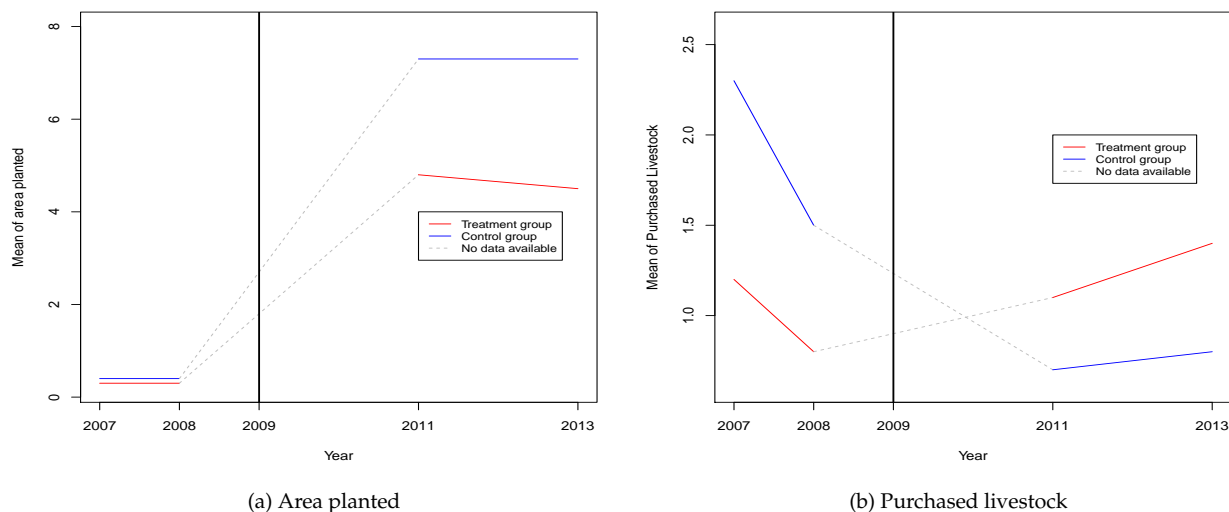

(a) Area planted   (b) Purchased livestock

Figure 3: Parallel trends using the unbalanced panel

Table 5: Estimation results using the unbalanced panel

|	Dependent variables:		
	Area planted	*Purchased livestock*	
	OLS	*OLS*	*Poisson Regression*
	(1)	(2)	(3)
Treatment	−0.308**	−0.795**	−0.736**
	(0.143)	(0.367)	(0.322)
Year 2011	6.539***	−0.880**	−0.834***
	(0.556)	(0.349)	(0.302)
Year 2013	6.806***	−0.763**	−0.676**
	(0.642)	(0.360)	(0.303)
DiD 2011	−2.251***	1.174***	1.173***
	(0.696)	(0.427)	(0.411)
DiD 2013	−2.685***	1.297***	1.199***
	(0.709)	(0.444)	(0.404)
Constant	1.682***	1.934***	0.866**
	(0.534)	(0.458)	(0.351)
Household's characteristics	Yes	Yes	Yes
Observations	1332	1332	1332
R^2	0.230	0.018	
Adjusted R^2	0.223	0.01	
Residual Std. Error	5.975 (df = 1320)	3.1 (df = 1320)	
F Statistic	35.8*** (df = 11; 1320)	2.1** (df = 11; 1320)	
Log Likelihood			−2983
Akaike Inf. Crit.			5990

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

7.2 Broad treatment

In the second step of the robustness check, we test our hypothesis using the broad treatment. We consider all households living within a distance of 125 km from Typhoon Ketsana's trajectory as affected households. Our control group contains households that lived outside the 125 km distance buffer from the typhoon's trajectory. Figure 4 presents the households in province Thua Thien Hue hit by Typhoon Ketsana.

Figure 4: Affected area in province Thua Thien Hue by the broad treatment
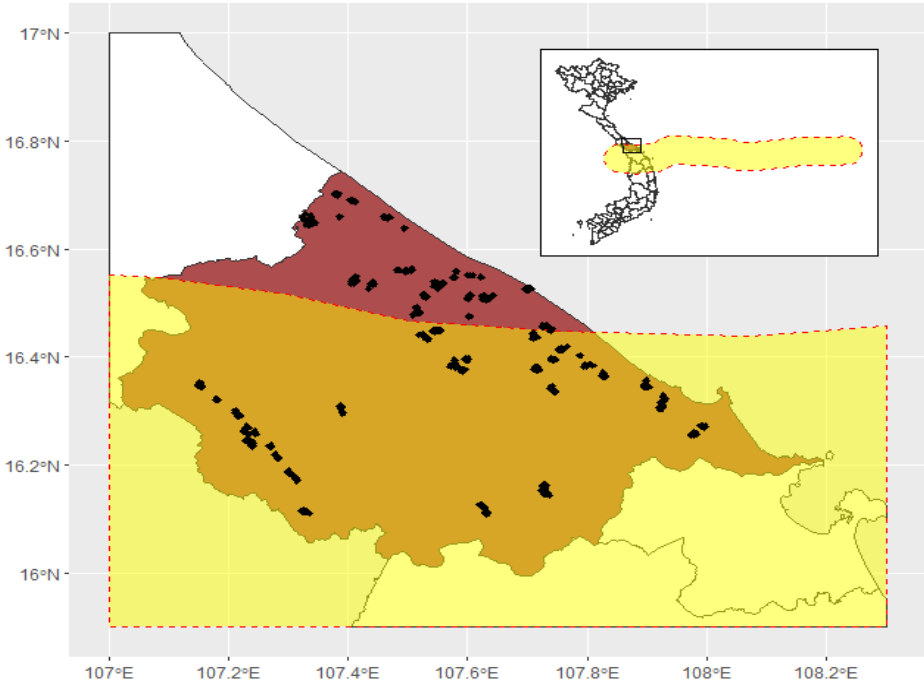
Source: International Best Track Archive for Climate Stewardship (IBTrACS version 4)

When we use this treatment, among 638 households in the balanced panel there are 425 households in the treatment group and 213 households in the control group. Table 9 in Appendix reports the descriptive statistics of these groups in 2008.

We replicate the estimation strategy described in section 6. We estimate equation (1) using two specifications, that are the balanced panel and the unbalanced panel. We also find the parallel trends in planting crops and purchasing livestock of the treatment group and the control group ex ante. Figure 5 and Figure 6 clearly present these parallel trends.
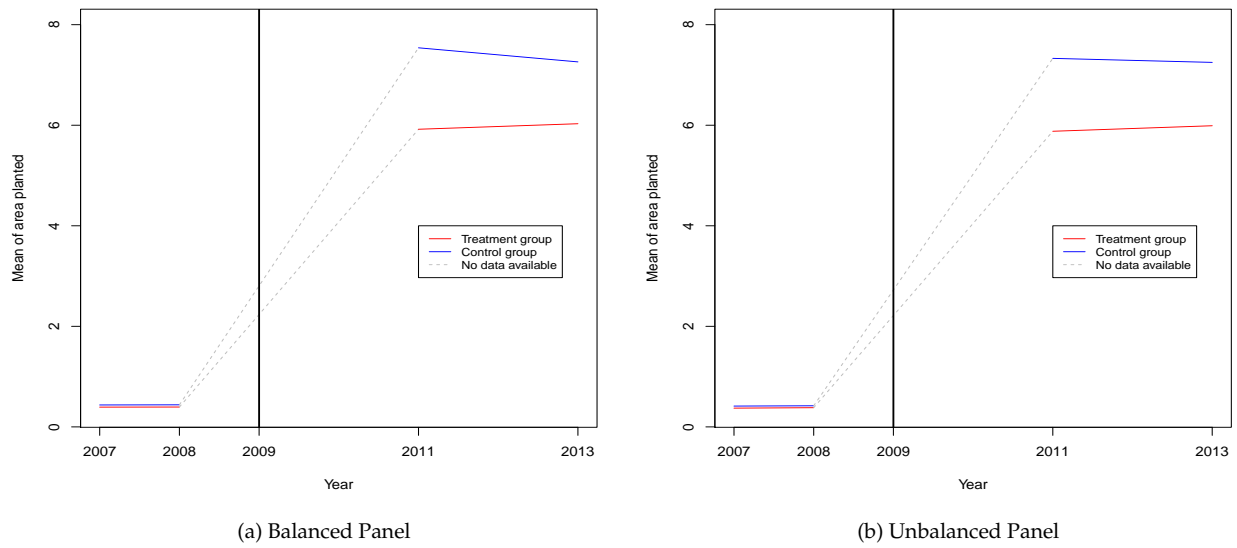
(a) Balanced Panel

(b) Unbalanced Panel

Figure 5: Mean of Area planted (Broad treatment)

(a) Balanced Panel

(b) Unbalanced Panel
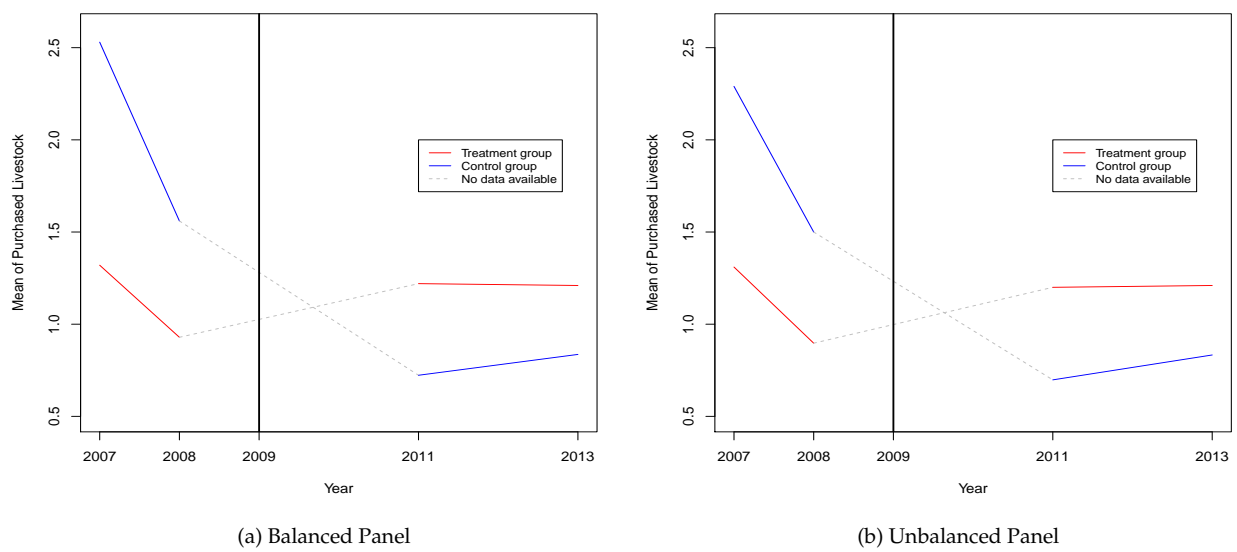
Figure 6: Mean of Purchased livestock (Broad treatment)

Moreover, as expected, the placebo estimation results using the placebo broad treatment also confirm that there is no difference in the agricultural activities between the two groups in the pre-disaster periods. These estimation results are reported in Table 10 in Appendix.

Since the identification assumption holds under the broad treatment circumstance, we estimate the equation (1) via OLS. Table 6 reports results with area planted in the left-hand side.

Table 6: Typhoon and Area planted (Broad treatment)

	Dependent variable:	
	Area planted	
	Broad Treatment	
	Balanced Panel	Unbalanced Panel
	(1)	(2)
Treatment	−0.071	−0.057
	(0.119)	(0.111)
Year 2011	6.787***	6.566***
	(0.594)	(0.569)
Year 2013	6.384***	6.361***
	(0.644)	(0.636)
DiD 2011	−1.423**	−1.234*
	(0.690)	(0.666)
DiD 2013	−1.099	−1.141
	(0.718)	(0.709)
Constant	1.361**	1.185**
	(0.554)	(0.534)
Household's characteristics	Yes	Yes
Observations	1914	2013
R^2	0.211	0.213
Adjusted R^2	0.206	0.208
Residual Std. Error	6.4 (df = 1902)	6.277 (df = 2001)
F Statistic	46.1*** (df = 11; 1902)	49.1*** (df = 11; 2001)

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

The coefficients of the variable *DiD* 2011 in columns (1) and (2) of Table 6 turn out to be statistically significant. That means, there was a significant difference in cropping between the two groups ex post. The households in the treatment group on average declined 1423 m^2 area planted in the aftermath of Typhoon Ketsana compared to the control households. However, this effect turns out to be statistically insignificant in 2013 over three years after the incident. That means these treated households did not change their cropping activity in the medium term ex post. Since the losses in households living further from the storm's eyes are likely to be smaller than in households living close to the eyes of the strong typhoon, it is no surprise that the negative effect of the severe typhoon on these treatment households remains only in the short time. Therefore, our findings suggest that the affected households by Typhoon Ketsana are less engaged in planting crops ex post in comparison with the non-affected households.

In the final step, we estimate the equation (1) via OLS and Poisson with Purchased livestock as the dependent variable. The estimation results are reported in Table 7.

	Dependent variable:			
	Purchased livestock			
	OLS		Poisson Regression	
	Balanced Panel	Unbalanced Panel	Balanced Panel	Unbalanced Panel
	(1)	(2)	(3)	(4)
Treatment	−0.649*	−0.627*	−0.541**	−0.541**
	(0.358)	(0.334)	(0.255)	(0.246)
Year 2011	−0.947**	−0.912***	−0.861***	−0.858***
	(0.371)	(0.347)	(0.307)	(0.299)
Year 2013	−0.851**	−0.796**	−0.731**	−0.698**
	(0.376)	(0.356)	(0.303)	(0.296)
DiD 2011	1.143***	1.116***	1.062***	1.074***
	(0.411)	(0.386)	(0.350)	(0.341)
DiD 2013	0.994**	0.970**	0.879**	0.878***
	(0.419)	(0.397)	(0.346)	(0.338)
Constant	2.023***	1.972***	0.951***	0.924***
	(0.440)	(0.413)	(0.314)	(0.302)
Household's characteristics	Yes	Yes	Yes	Yes
Observations	1914	2013	1914	2013
R^2	0.019	0.019		
Adjusted R^2	0.013	0.014		
Residual Std. Error	3.0 (df = 1902)	3.0 (df = 2001)		
F Statistic	3.3*** (df = 11; 1902)	3.5*** (df = 11; 2001)		
Log Likelihood			−4324	−4459
Akaike Inf. Crit.			8672	8943

Note: *p<0.1; **p<0.05; ***p<0.01

Standard errors are clustered on the household level and reported in parentheses.

The coefficients of the interaction variable between the treatment and time in 2011 and in 2013 turn out to be positive and statistically significant. The estimation result in the column (1) in Table 7 indicates that the average household in the affected group increased their livestock by 1.1 and 1.0 in comparison with the average household in the non-affected group in the short time and the medium time ex post, respectively. The estimation results using the unbalanced panel and Poisson model also confirm these findings. Our results suggest that households that are severely affected by the strong typhoon tend to invest more in livestock as a coping strategy.

8 Summary and conclusions

The increasing danger of climate-related natural disasters, in particular typhoons, keeps threatening farmers' livelihood in developing countries, which is based mainly on the mixed crop-livestock system. However, the existing literature about whether and how these households adjust their agricultural production in response to a severe typhoon remains understudied. To the best of our knowledge, there is also no paper yet that studies whether households make the adjustment to area planted in the

aftermath of a strong typhoon. The current studies have not taken into account the crops-planted area when evaluating the agricultural losses from typhoons. If this input factor changes, the shortcoming would evaluate incorrectly the real loss in agricultural output.

Our paper adds to the limited literature by investigating a natural experiment coming from the strong typhoon Ketsana in 2009. We combine micro-data on the household level and the spatial data on this typhoon. Our paper aims to compare households' behavior in the treatment group and the control group before and after the shock by applying a difference-in-differences approach. The households in the treatment group are identified by their location. All households living within a radius of 100 km from the typhoon's trajectory are in the treatment group as typhoons can severely damage regions within a distance of 100 km from the typhoon's eyes. Our control group consists of households that lived outside the 125 km distance buffer from the typhoon's trajectory to make sure that they were neither affected by Typhoon Ketsana nor suffered directly from this typhoon.

We find that households do adjust their agricultural production portfolio in the aftermath of a severe typhoon. They tend to reduce their field crops and horticultural crops planted area and increase purchased livestock in the short time and in the medium time. This behavior is considered as a productive adaptation strategy that complements other coping strategies such as migration, diversification of income sources, credit, savings.

Our paper helps policymakers to have a clear picture of the influence of the typhoon on the transformation in the crop-livestock system in a developing country. Our results are important to design policies for effective adaptation strategies to help farmers cope with the potential impact of extreme events such as typhoons. The reduction in crops production could raise the likelihood of lacking the basic food and threaten millions of people and animals in developing countries. Our results also suggest that future research estimating the damages to agriculture caused by natural disasters should take land use into account.

Acknowledgements

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Appendix

Table 8: Placebo estimations using the unbalanced panel

	Dependent variable:	
	Area planted	*Purchased livestock*
	(1)	(2)
Treatment	−0.152***	−1.068***
	(0.039)	(0.341)
Year 2008	0.00001	−0.791*
	(0.044)	(0.426)
DiD 2008	0.054	0.321
	(0.064)	(0.491)
Constant	0.474***	2.596***
	(0.063)	(0.479)
Household's characteristics	Yes	Yes
Observations	937	937
R^2	0.064	0.035
Adjusted R^2	0.055	0.025
Residual Std. Error	0.477 (df = 927)	3.812 (df = 927)
F Statistic	7.060*** (df = 9; 927)	3.711*** (df = 9; 927)

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

Table 9: Descriptive statistics by groups using the broad treatment in 2008

	Treatment group (425 obs)				Control group (213 obs)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Working-age members	3.53	1.73	1	10	3.79	1.72	1	10
Age of household head	48.31	14.47	23	92	51.28	14.09	23	90
Education of household head (1-yes, 0-No)	0.13	0.34	0	1	0.15	0.35	0	1
Insurance (1-yes, 0-No)	0.04	0.21	0	1	0.04	0.20	0	1
Remittances from absent members (1-yes, 0-No)	0.12	0.33	0	1	0.16	0.37	0	1
Savings (PPP US$)	95.16	823.66	0	14496	143.06	631.12	0	5602.70
Area planted (1000 m^2)	0.39	0.55	0	5.37	0.44	0.52	0	3.8
Purchased Livestock (units)	0.93	2.61	0	30	1.56	4.87	0	42

Table 10: Placebo test in the broad treatment

	Area planted		Purchased livestock	
	Balanced Panel	Unbalanced Panel	Balanced Panel	Unbalanced Panel
	(1)	(2)	(3)	(4)
Treatment	−0.038	−0.035	−1.181***	−0.961***
	(0.039)	(0.036)	(0.339)	(0.308)
Year 2008	−0.005	−0.004	−1.023**	−0.843**
	(0.047)	(0.044)	(0.463)	(0.424)
DiD 2008	−0.002	0.001	0.560	0.358
	(0.058)	(0.054)	(0.491)	(0.452)
Constant	0.454***	0.423***	2.756***	2.545***
	(0.060)	(0.055)	(0.466)	(0.414)
Household's characteristics	Yes	Yes	Yes	Yes
Observations	1276	1410	1276	1410
R^2	0.050	0.051	0.036	0.032
Adjusted R^2	0.043	0.045	0.029	0.025
Residual Std. Error	0.494 (df = 1266)	0.482 (df = 1400)	3.526 (df = 1266)	3.448 (df = 1400)
F Statistic	7.331*** (df = 9; 1266)	8.413*** (df = 9; 1400)	5.247*** (df = 9; 1266)	5.066*** (df = 9; 1400)

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered on the household level and reported in parentheses.

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