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Building Business Resilience to Disasters

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Abstract

This paper studies the impacts of natural disasters on corporate disaster risk management. Using unique plant-level data from Thailand collected after the 2011 floods, we find that inundation/direct loss experience stimulates flood risk awareness and encourages plants to develop a business continuity plan (BCP), but indirect loss experience does not. We also find evidence consistent with the existence of nonnegligible fixed costs in BCP development. Furthermore, subscription to flood insurance amongst plants with inundation/direct loss experience dropped after the floods, suggesting that a BCP acts as a critical substitute for insurance as part of disaster risk management strategies. (98 words)

KEY WORDS: Business continuity plan (BCP); disaster; insurance; risk awareness, risk management.
JEL Code: D22, G22, H84, Q54

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1 Introduction

Disasters have increasingly been causing severe damage to both households and businesses alike. Most households are considered risk and/or ambiguity averse, and are supposed to take precautionary measures, both physical and financial, against disasters. However, the large empirical literature on household demand for insurance consistently reports low take-up of disaster insurance when subscription is voluntary (Kunreuther et al., 1978; Browne and Hoyt, 2000; Kriesel and Landry, 2004; Bin et al., 2008; Michel-Kerjan, 2010; Botzen and van den Bergh, 2012; Gallagher, 2014; Gallagher and Hartley, 2017; Mol et al., 2020; Wagner, 2022). Such an empirical finding that is apparently contrary to risk diversification motives for insurance subscription triggered the search for theoretical explanations, but no consensus has been reached yet.

By contrast, risk diversification motives for corporate insurance subscription are generally rejected in the corporate finance literature, since investors can diversify risk cheaper than businesses themselves do (e.g., Mayers and Smith, 1982). Instead, one possible corporate motive for risk prevention and resilience building is bankruptcy costs, since the damage a business incurs may be severe enough to lead to its bankruptcy. Hence, it is worthwhile to study corporate behaviors related to disaster resilience building, yet the literature on the issue is limited.

While purchasing disaster insurance is a common way for businesses to improve their resilience to disasters, there is a growing emphasis on the adoption of business continuity management (BCM) practices as an important corporate disaster risk management strategy in the past decades (Herbane, 2010). At the heart of BCM is the development of a business continuity plan (BCP), which outlines the processes and procedures that the business is going to follow during and after business disruptions. A business develops a BCP so as to minimize losses from disasters or other emergencies and restore its business activities quickly. When the supply of disaster insurance is limited, developing a BCP can act as an important substitute for insurance. However, the BCP development rate remains low, despite its potential benefits (ASEAN, 2011).[1] It is, therefore, imperative to understand how

[1] Outside the economics literature, there are some, but few studies on BCP (Kato and Charoenrat, 2018; Ono and Anbumozhi, 2020; Păunescu and Argatu, 2020).

businesses would build resilience to disasters by developing a BCP and/or by subscribing to disaster insurance.

This paper attempts to address this important issue by analyzing how business resilience to disasters may be built by focusing on the effects of past disaster experiences. Specifically, we investigate the impacts of the 2011 Thailand floods. This provides a natural experimental setting that fits our purpose. First, it was reportedly the worst flooding in Thailand in fifty years, occurring on an unexpectedly large scale. Second, the floods affected a major portion of large industrial estates housing a variety of establishments or plants. Third, whether a plant was inundated during the floods can be defined clearly by its location. These features enable us to identify the impacts of inundation experience per se, as opposed to that of possible changes in the flood risk, by using the difference-in-differences strategy. Specifically, in our identification strategy, we compare changes in corporate disaster risk management strategies before and after the 2011 floods between plants that were inundated and those that were not.

One challenge in empirically analyzing corporate disaster risk management is that typical datasets of businesses lack information related to a company's risk management practices, such as the development of BCPs and insurance subscription. To overcome this challenge, we conducted an original survey of about 300 plants operating in central Thailand between October 2013 and January 2014 as part of a research project at the Research Institute of Economy, Industry and Trade (RIETI) of Japan.[2] The unique feature of the dataset collected through this survey is that it contains a rich set of information on both plants' past flood experiences and their flood risk management practices. Most importantly, it provides the year and month when each respondent developed a BCP, as well as information about their flood insurance subscription status before and after the 2011 floods. This enables us to construct retrospective panel data that track plants' disaster risk management practices before and after the 2011 floods.

To preview the results, we first provide evidence that the inundation experience during the 2011 flooding increased flood risk awareness. Specifically, we show that due to inunda-

[2] A research project titled "Post-disaster Recovery Policies and Insurance Mechanisms against Disasters: Case studies on earthquakes in Japan and floods in Thailand" was conducted from April 2012 to March 2014.

tion experience, a plant's flood risk awareness increased by 20.1 percentage points, from an average baseline rate of 25.9 percent to 46.0 percent. This suggests that first-hand inundation experience heightens risk awareness and possibly motivates plants to engage in disaster risk management.

Our main estimation results show that inundation and direct loss experience prompted plants to develop a BCP. Specifically, we find that inundated plants are 18.8 percentage points more likely to develop a BCP after the floods compared to non-inundated plants. Not surprisingly, most newly developed BCPs include an action plan for floods. The magnitude of the impact is sizable, considering that the pre-flood BCP development rate was only 3.8 percent. The quarter-by-quarter estimates indicate that inundated plants developed a BCP within a year after the outbreak of the floods and the effects of inundation experience persist and remain significant for two years after the floods. We also find that direct loss experience led to BCP development but indirect loss experience through supply chain disruptions did not. Furthermore, we find that the impact on BCP development is larger among larger plants. This finding suggests that fixed costs in BCP development hinder smaller plants from developing a BCP, indicating a size effect on BCP development.

In contrast to the effects on BCP development, we find that inundation experience has *negative* impacts on flood insurance subscription, both for property damage and for business interruption. According to our estimates, the likelihood of subscribing to flood insurance decreases by 26.2 percentage points for property damage and by 18.3 percentage points for business interruption, due to the floods. While the results may appear counter-intuitive, we argue that the negative impact on insurance take-up is likely caused by the supply side's responses. That is, (re)insurers reduced the supply of flood insurance to the inundated plants. This result is indicative of a missing market, i.e., a market failure à la Rothschild and Stiglitz (1976).

Finally, to reconcile the results of BCP development and insurance subscription, we investigate how these two different risk management practices relate to each other. Our findings suggest that BCPs served as a substitute for flood insurance for inundated plants: Since flood insurance became unavailable to inundated plants after the floods due to the reduction in the supply, plants turned to BCPs as an alternative disaster risk management strategy. Consistent with this view, we find that the effect of inundation experience on BCP development is entirely explained by the reduction in flood insurance subscription. By contrast, the increase in flood risk awareness from inundation experience alone does not explain the positive impact on BCP development.

Taken together, the findings of this paper suggest that direct disaster experience prompts businesses to enhance their disaster risk management, notably through adopting business continuity management. However, such responses are contingent on external factors like the market availability of insurance. In addition, the size effect on BCP development underscores the need for policy intervention to support small businesses in developing effective risk management practices that enhance their resilience to disasters.

This study contributes to three strands of literature. First, it adds to the rapidly growing literature on the impacts of natural disasters on businesses. This literature includes works that study the impacts of disasters on business activities such as business performance (Carvalho et al., 2021; Elliott et al., 2019; Hsu et al., 2018; Leiter et al., 2009; Pan and Qiu, 2022; Tanaka, 2015; Zhou and Botzen, 2021), business survival and technology upgrading (Okazaki et al., 2019), and production network (Hayakawa et al., 2015). A few studies identify factors that enhance business resilience to natural disasters, such as relief aid and access to capital (De Mel et al., 2012) and diversified production networks (Todo et al., 2015). However, little is known about what induces businesses to invest in building disaster resilience. We fill this critical gap by analyzing the impacts of disaster experience using a unique plant-level micro data set from Thailand.

The current study also contributes to the economics literature on business management practices. While existing studies show wide variations in management practices across firms and their determinants (Bloom and Van Reenen, 2007, 2010), little is known about how businesses manage catastrophe risks and how they make decisions concerning corporate risk management practices.[3] Our study complements this literature by investigating how past exposure to disaster shapes corporate risk management practices.

[3] An exception is Grover and Karplus (2021), which shows that structured management practices mitigate the impact of the COVID-19 crisis. The literature in operation research has also investigated a variety of operational measures for managing the risk of supply chain disruption (Bakshi and Kleindorfer, 2009; Parlar and Perry, 1996; Tomlin, 2006; Yang et al., 2009).

Finally, this study is also related to the empirical studies on corporate insurance (Aunon-Nerin and Ehling, 2008; Hoyt and Khang, 2000; Cole and McCullough, 2006; Mayers and Smith, 1982; Michel-Kerjan et al., 2015; Yamori, 1999). Past studies have examined various determinants of corporate demand for insurance, but no studies thus far have investigated how past experience of disasters influences the demand. Adachi et al. (2023), our companion paper, uses the same data set as ours and finds empirical evidence for market failure in corporate insurance markets, both adverse selection and moral hazard. This underscores the importance of independent efforts by businesses to build resilience to disasters.

The remainder of the paper is structured as follows: Section 2 discusses the 2011 Thai floods and corporate disaster risk management strategies. Section 3 introduces the data used in this study and outlines our empirical methodology. Section 4 presents the estimation results, and the paper concludes with Section 5.

2 Background

2.1 The 2011 Thailand Floods

In 2011, Thailand witnessed one of the most catastrophic flood events in recent history. The floods, precipitated by intense monsoon downpours and further exacerbated by successive typhoons, inundated a large part of the country's central region from July to December. The two maps in Figure 1 show the geographical spread of the inundated areas: Panel (a) exhibits the inundated areas in the whole of Thailand, while panel (b) focuses on the inundated area in the lower Chao Phraya River basin, the main focus of our study, where particularly severe inundation took place in October 2011. The economic impacts were profound: numerous industrial estates found themselves underwater, leading to significant disruptions in both national and international supply chains. This calamity resulted in a loss of over 800 lives, displacement of thousands of people, and an estimated economic loss of approximately 46.5 billion US dollars, with the manufacturing sector most severely affected (World Bank, 2012).

2.2 Corporate Disaster Risk Management

While firms can employ numerous strategies to protect themselves from natural disasters, it is vital within management practices to proactively devise strategies that prevent or mitigate damage. This includes creating response and recovery manuals for potential emergencies and creating a culture that is deeply ingrained within the organization so that the methods specified in the manuals will be carried out accordingly through awareness training and verification drills. Such a holistic management approach, termed Business Continuity Management (BCM), has grown in significance in the last two decades due to escalating disaster risks (Herbane, 2010).[4]

Central to BCM is the development of a Business Continuity Plan (BCP), which is a detailed action plan that specifies the procedures and instructions that a business should follow in the event of a disruption. This involves accurately identifying critical business functions, analyzing potential threats to those functions, and formulating processes to maintain or rapidly restore operations. In tandem with BCM, a BCP serves to make businesses more resilient to potential risks, enabling them to quickly recover from interruptions. We therefore treat BCP development as our primary measure of corporate disaster risk management in our empirical analysis.

Developing a BCP requires specialist knowledge in areas such as risk assessment, business impact analysis, and regulatory compliance. If such specialist knowledge is not possessed within the business, it is common to hire external consultants to develop a BCP. This suggests that a lack of knowledge, in addition to financial and time costs, may act as a barrier to BCP development. Indeed, many Thai businesses cite a lack of knowledgeable personnel and financial resources as reasons for not developing a BCP (Kato and Charoenrat, 2018). This in turn points to the existence of economies of scale in BCP development, which is consistent with another finding by Kato and Charoenrat (2018) that larger businesses are more likely

[4]ISO 22301, Security and resilience – Business continuity management systems – Requirements, was the world's first International Standard for implementing and maintaining effective business continuity management when it was first published in 2012. ISO 22301 was last updated in 2019.

to develop a BCP.[5]

Alongside BCM/BCP, insurance can also play a critical role in promoting business resilience to disasters (Kousky, 2019). Disaster insurance products offered to businesses include property damage (PD) insurance, which covers physical losses or damages to the properties of the insured, and business interruption (BI) insurance, which covers the loss of earnings or profits due to business interruptions caused by disasters. By transferring financial risks to insurance markets, businesses can focus on post-disaster recovery and continuity, thereby enhancing their resilience. As mentioned earlier, however, the corporate motive for insurance subscription is different from that of households' (Mayers and Smith, 1982; Hoyt and Khang, 2000), and it does not include risk diversification. One main corporate motive arises from bankruptcy costs, which include various agency costs and opportunity costs of lost techniques and know-how. Businesses therefore try to protect themselves financially against extreme events that could lead to bankruptcy by subscribing to insurance.

When access to either type of formal disaster insurance policies is limited, adopting BCM can be particularly important to improve the resilience of businesses. In such a case, BCPs can serve as a substitute for insurance. However, setting aside the possible issues of insurance supply, Dong and Tomlin (2012) shows theoretically that business interruption insurance and BCP can be complements under certain conditions.

The current paper therefore addresses the following questions. (a) Does (in)direct disaster experience stimulate risk awareness of businesses? (b) Does (in)direct disaster experience lead businesses to develop a BCP? (c) Do the above effects vary depending on plant size? (d) How do disasters affect the subscription to insurance products such as property damage insurance and business interruption insurance? (e) Can a BCP serve as a substitute for

[5] Similar patterns can be found in other countries. For example, in Japan, a questionnaire by the Tokyo Chamber of Commerce and Industry in 2022 provides evidence similar to this (Tokyo Chamber of Commerce and Industry, 2022). It reports that about one third of respondents had a BCP overall, and it indicates that size matters - over half of large businesses and fewer than one quarter of small and medium businesses developed one. Also, amongst businesses with a BCP, the average time spent to develop a BCP was between 3 and 6 months, while those without a BCP indicated that the longest period they could spend was also between 3 and 6 months on average. Furthermore, just over one fifth of businesses with a BCP hired external consultants to develop a BCP, and the use of external consultants is increasing in the size of the business. The subsequent questionnaire by the Tokyo Chamber of Commerce and Industry in 2023 also reports that about half of the respondent businesses raised costs as a major obstacle in developing a BCP, and also two fifths listed the lack of personnel (Tokyo Chamber of Commerce and Industry, 2023).

property damage/business interruption insurance?

3 Data and Empirical Strategy

3.1 Data

We use the data set of plants and establishments (henceforth plants) operating in central Thailand collected through the "RIETI Survey of Industrial Estates/Parks and Firms in Thailand on Geographic and Flood Related Information" (the RIETI survey hereafter), which was commissioned to the Teikoku Data Bank Ltd. (TDB) and implemented between October 2013 and January 2014.

The RIETI survey comprises two modules: (1) an industrial estates/parks module and (2) a plant module. The plant module targets Thai subsidiaries of Japanese companies and local domestic businesses that satisfy the three criteria: (1) annual turnover is at least two billion yen, (2) number of employees is at least 50, and (3) present in Thailand. In this paper, we only use the data from the plant module. The data were collected through a postal survey in Japan (for Japanese parent companies of the Thai subsidiaries) and postal and interview surveys in Thailand, conducted in cooperation with the Industrial Estate Authority of Thailand (IEAT). The postal questionnaire in Japan was sent to 842 plants selected from the TDB's database. The survey in Thailand mostly focused on plants operating in one of the 34 major industrial estates/parks in central Thailand.[6]

We obtained valid responses from a total of 314 plants, which constitute the sample for our analysis. Among them, 129 responses were collected through the postal questionnaire sent to head offices of the parent companies in Japan, and 185 responses were collected from the survey in Thailand, of which 39 responses were collected through postal questionnaires, 102 by face-to-face interviews, and 45 by telephone interviews.

[6]The 34 industrial estates/parks are: Saha Rattana Nakorn, Hi-Tech, Bangpa-in, Rojana-Ayutthaya, Factory Land (Wangnoi), Nava Nakorn-Pathum Thani, Bangkadi, Bangchan, Lad Krabang, Bangpoo, Bangplee, Gateway City, Wellgrow, 304 IP II, Amata Nakorn, Pinthong, Hemaraj Chonburi, 304 Industrial Park (IP) I, Kabinburi, Rojana-Prachinburi, Laem Chabang, Eastern Seaboard (Rayong), Hemaraj Eastern Seaboard, Siam Eastern, Amata City, Rojana-Rayong, Hemaraj Rayong Industrial Land, Rayong Industrial Park, Asia Industrial Estate Mapta Phut, Hemaraj Eastern, Padaeng, Hemaraj Saraburi Industrial Land, Kaeng Khoi, and Nong Khae.

Importantly, the data set includes not only plants that were inundated during the 2011 floods but also those that were not inundated. Furthermore, it is a unique data set that contains detailed information on plants' disaster risk management and perception of disaster risk, along with basic information on plant characteristics (such as location, plant size, and operation history) and business conditions. We describe our key variables below.

BCP Development The RIETI survey asks respondent plants whether they have developed a BCP by the time of the survey, and if so, the year and month it was developed. Using this information, we construct plant-level two-period panel data that track the BCP development status before and after the 2011 floods. We also construct quarterly panel data covering 2009 - 2013 to investigate the trend in BCP development at a more granular frequency.[7]

One may be concerned whether BCP development is a relevant measure that accurately represents plants' risk management practices. To examine this, we compare the fraction of plants that have their own disaster mitigation measures between plants with and without a BCP in Figure 2. The data on disaster mitigation measures are also collected in the RIETI survey. While 28.5% of plants without a BCP have their own disaster mitigation measures, the fraction is doubled among those with a BCP (56.3%). This corroborates that BCP development is positively correlated with plants' broader risk management practices.

While the accuracy of self-reported information on BCP development may be a potential issue, we believe that the measurement error is minimal. First, the date of BCP development should typically be documented within the business's internal records. Second, whether a plant is ISO-certified for BCP development (ISO 22301) is verifiable by the government or by relevant authorities. Thus there should be little incentive for a business to misreport its BCP development status.

Flood Insurance Subscription Flood insurance policies may include coverage for direct property damage or losses (i.e., property insurance) and for lost earnings due to business

[7] The number of observations in the quarterly panel data is slightly smaller than in the two-period panel data because a few plants do not report the specific month in which they developed a BCP, making inclusion to the quarterly panel data inappropriate.

interruptions (i.e., business interruption insurance). The RIETI survey includes data on the subscription status for property damage and business interruption insurance, both at the time of the 2011 floods and at the time of the survey. Using this information, we separately construct two-period panel data for property damage and business interruption insurance to track subscription status before and after the 2011 floods.[8]

Flood Experience We use two sets of variables to measure each plant's experience with the 2011 floods. The first is a dummy variable indicating whether the plant was inundated during the 2011 floods. The second set consists of two dummy variables indicating whether the plant incurred direct and indirect losses through its supply chains.

Risk Awareness The RIETI survey asks whether respondents considered their industrial estate to be in a flood-prone area before the 2011 floods and at the time of the survey, with responses being "yes" or "no". For each question, we construct a dummy variable that takes on a value of one if the response is "yes", utilizing these as indicators of flood risk awareness. We also have the subjective probability of future flood occurrences, which we use in the analysis presented in Appendix C.4.

Other Plant Characteristics We also use several plant characteristics in our regression analyses. This includes plant age, the number of stories in the plant's building, lot size, employment levels, subsidiary status, and business sentiment before the 2011 floods. Regarding business sentiment, the RIETI survey asks whether a plant's overall business performance, sales, and profits improved (increased), worsened (decreased), or remained unchanged in the first half of 2011 compared to 2010. From these responses, we construct two dummy variables for each business condition measure to indicate whether it improved or worsened in 2011 compared to 2010.

Finally, to augment the RIETI survey data with geographic information, we manually geo-reference each plant using the plant address provided in the survey. When the survey-provided address information was inaccurate or missing, we referred to the plants' websites

[8]Unfortunately, we do not have specific information on the specific year and month when businesses first subscribed to flood insurance.

and Google Maps for correct addresses. Figure 1 shows the spatial distribution of plants in the sample. Using the coordinates of each plant, we calculate the straight-line distance from the Chao Phraya River.

Summary Statistics and Balance Test Summary statistics for the variables used in our analysis are presented in Table 1. Table 2 compares plant characteristics and outcome variables between inundated and non-inundated plants. As shown in panel A, inundated plants are located closer to the Chao Phraya River and have a longer operation history than their non-inundated counterparts, whereas other observed characteristics appear to be well-balanced between the two groups.

3.2 Empirical Strategy

We examine the impacts of the 2011 floods on corporate disaster risk management (BCP development and flood insurance subscription) by using the difference-in-differences strategy. Specifically, we compare the change in corporate disaster risk management before and after the 2011 floods between plants that were inundated and those that were not. The main estimation equation is as follows:

$$Y_{it} = \beta \cdot Flood_i \cdot Post_t + X'_{it}\theta + \gamma_i + \delta_t + \varepsilon_{it}, \quad (1)$$

where the dependent variable Y_{it} is BCP development and flood insurance subscription of plant i in period t. $Flood_i$ is a dummy variable indicating the inundation or loss experience. When we use loss experience, we include two dummy variables for the direct loss and indirect loss. $Post_t$ is equal to one if period t is after the 2011 floods, and zero otherwise. X_{it} is a vector of plant characteristics. As shown in 2, the inundation experience is correlated with the distance to the Chao Phraya River and plant age in the baseline. Therefore, we control for these two variables, with each being interacted with the post-flood dummy. γ_i and δ_t are plant and time period fixed effects, respectively. The coefficient of interest is β, which identifies the effect of inundation experience on outcome variables under the parallel trend assumption that the outcome variables would have changed similarly between the inundated and non-inundated plants in the absence of the floods. To control for serial correlations, we cluster standard errors at the plant-level throughout the analysis.

In estimating the effect of inundation experience on BCP development, we also estimate the following quarter-by-quarter difference-in-differences regression model:

$$Y_{it} = \sum_{\tau} \beta_\tau \cdot Flood_i \cdot \delta_\tau + X'_{it}\theta + \gamma_i + \delta_t + \varepsilon_{it}. \quad (2)$$

β_τ is the effect of the 2011 floods on BCP development at year-quarter τ. We use the third quarter of 2011 as the base period and normalize the coefficient for this period to be zero.

Figure 3a presents the preview of our main findings on BCP development by tracking the share of plants that have developed a BCP before and after the 2011 floods by inundation experience. Before the 2011 floods, approximately 4 percent of plants had developed a BCP. Importantly, the pre-flood trends in BCP development are similar between inundated and non-inundated plants, corroborating the parallel trend assumption. After the 2011 floods, however, we observe an increase in BCP development among inundated plants compared to their non-inundated counterparts, suggesting a positive impact of inundation experience on BCP development. Data also shows a sustained disparity in BCP development rates even two years after the floods, with non-inundated plants not showing significant catch-up.

A similar pattern can be observed when we divide the sample by the types of losses incurred during the floods, as shown in Figure 3b. While the pre-trends in BCP development are similar across different loss types, plants that experienced direct flood-related losses were more likely to develop BCPs afterward. Interestingly, indirect losses alone do not appear to drive BCP development significantly.

4 Estimation Results

4.1 Impacts on Flood Risk Awareness

Before showing the main results on disaster risk management practices, we first examine whether inundation experience affects plants' awareness of flood risk. Figure B.1a shows the change in flood risk awareness before and after the floods.[9] The pattern indicates that awareness of flood risk increased among all plants on average after the floods, but significantly more so among those that had experienced inundation. That is, the inundation experience positively affects flood risk awareness. To formally examine this relationship, we estimate our DID equation (1), using a dummy variable indicating whether a plant is aware of flood risk as the dependent variable.

Table 3 presents the results. Column (1) includes a dummy for inundation instead of plant fixed effects, and we find its coefficient is positive and statistically significant. This indicates that inundated plants were more likely to be aware of the flood risk before the 2011 floods. More importantly, the coefficient on the interaction term is also positive and statistically significant, indicating that inundation experience had a positive effect on flood risk awareness. We control for plant fixed effects in Column (2) to find a similar result. Column (3) shows that the result is robust to controlling for baseline plant characteristics, distance to the Chao Phraya River and plant age at the baseline, with each being interacted with the post-flood dummy. The estimate in Column (3) implies that inundation experience increases the chance that the plant is aware of the flood risk by 20.1 percentage points.[10]

These results suggest that first-hand inundation experience heightens risk awareness and possibly motivates the affected business to adopt in disaster risk management strategies. This is aligned with the existing literature, which shows that individuals' subjective beliefs of disaster risks tend to rise after disasters (Gallagher, 2014). In subsequent subsections, we investigate the impact of inundation or direct/indirect loss experience on BCP development and flood insurance subscription.

[9] Note that we observe risk awareness only at two points in time, before the floods (retrospectively) and at the time of the survey.

[10] In Appendix C.4, we further investigate the relation between the inundation experience and probabilistic beliefs about future flood events. Our cross-sectional analysis shows that inundated plants are more likely to form a probabilistic belief about future plants. However, among the plants that formed a probabilistic belief, the subjective probability of future flood events is very diverse and does not differ significantly by the inundation experience.

4.2 Impacts on BCP Development

Table 4 presents the main estimation results on the effects of the 2011 floods on BCP development. Column (1) estimates a model similar to equation (1), where instead of plant fixed effects γ_i, the inundation dummy $Flood_i$ is included to illustrate the pre-flood difference in the BCP development rate between inundated and non-inundated plants. The coefficient on the inundation dummy shows that, before the 2011 floods, there was no significant difference in the BCP development rate between the two groups of plants. However, the coefficient of the interaction term, β, is positive and statistically significant at the 1% level. This estimate suggests that the inundation experience during the 2011 floods increased the likelihood of a plant developing a BCP.

Column (2) replaces the inundation dummy with plant fixed effects to estimate equation (1) and shows that the result is qualitatively unchanged. One may still be concerned whether the estimates are confounded by plant characteristics correlated with inundation during the 2011 floods. To mitigate this concern, column (3) controls for the baseline plant characteristics, distance to the Chao Phraya River and plant age at the baseline, with each being interacted with the post-flood dummy. Reassuringly, the estimate of the effect of inundation experience during the 2011 floods changes only slightly and is still statistically significant at the 1% significance level. The estimate implies that the inundation experience increased the BCP development rate by 18.8 percentage points, which is sizable compared to the pre-flooding BCP development rates, which are 4.1 percent for the inundated plants and 3.7 percent for the non-inundated (Table 2).

When an inundated plant develops a BCP to prepare for future floods, it is natural to expect that its BCP would contain action plans for handling flood events. To examine whether this is indeed the case, column (4) estimates the effects of the 2011 floods on the development of a BCP with a flood action plan (FAP). The dependent variable is a dummy variable which is equal to one if a plant has developed a BCP with a FAP and zero otherwise. The estimated effect is 0.166, which indicates that about 88 percent of the observed effect on BCP development in column (3) is driven by the development of BCPs with a FAP.

Appendix A provides further robustness checks of our results on BCP development as well as other outcomes. In Table A.1, we show that the effect is not driven by the differences in the survey respondents' characteristics.[11] Furthermore, in Table A.2, we show that the results are robust in probit estimation.

Figure 4a reports the estimation results of equation (2), which uses quarter-level panel data. The regression results echo and confirm the descriptive patterns presented in figure 3. First, we find no evidence of pre-trends: inundation during the 2011 floods is not associated with the trend in BCP development before the 2011 floods. This suggests that the parallel trend assumption is likely to be valid. Second, the effect of inundation during the 2011 floods on BCP development is rather immediate. The impact on BCP development was immediate after the floods, with most plants that developed a BCP doing so by the second quarter of 2012. Finally, the positive and significant effects persisted until the end of our study period, indicating minimal catch-up by non-inundated plants.

Direct and Indirect Losses During the 2011 floods, some plants, even though not directly subjected to inundation, incurred indirect damages via the supply chains. Does indirect loss experience also induce BCP development? Table 5 shows the effect of the 2011 floods on BCP development, using the loss status as the treatment variable. Column (1) shows that direct loss experience increases BCP development by 16.9 percentage points, which is similar to the results using inundation experience in Table 4. Interestingly, however, incurring indirect losses does not induce plants to develop a BCP. In column (2), we add an interaction term between direct loss, indirect loss, and the post-flood dummy to test whether incurring both direct and indirect losses has an additional effect on BCP development. However, the coefficient on the interaction term is negative and statistically insignificant. This suggests it is the experience of direct losses that primarily induces BCP development and that there are no additional effects due to indirect losses. Columns (3) and (4) estimate the effects on the development of a BCP with a FAP and show qualitatively similar results. Finally, the quarter-by-quarter estimates in Figure 4b also show similar patterns. Hereafter, we focus on the results using the inundation experience as the treatment variable because the results are

[11] Specifically, we control for whether the respondent is in an executive position and whether the survey was conducted in Japan as opposed to in Thailand, both being interacted with the post-flood dummy. We find the estimated effects on BCP development are almost unchanged by these controls.

qualitatively similar when we use the loss experience.

Heterogeneity As developing a BCP incurs fixed costs, the effect of inundation experience on BCP development can be larger for larger plants with a greater capacity and more resources to allocate to BCP development. To assess such size effects, we estimate the heterogeneous effect of inundation experience with respect to plant size, using four measures of plant size: (1) the number of employees, (2) the number of stories of the building in the plant, (3) the lot size, and (4) subsidiary status. We estimate equation (1) with a triple interaction term between $Flood_i \times Post_t$ and each measure.[12]

The estimation results are presented in Table 6. The coefficients on the tripe interaction terms are positive and statistically significant for all of the four plant size variables. That is, the effect of inundation experience on BCP development is larger for plants with more employees (Column 2), more building floors (Column 3), larger lots (Column 4) and for subsidiary plants than for non-subsidiaries (Column 5). These results suggest that there is indeed a size effect in BCP development and thus smaller plants are more likely to face a capacity constraint, making it more difficult to develop a BCP when they are inundated.[13]

Overall, our DID estimation results establish a positive and statistically significant effect of inundation and direct loss experience on BCP development.[14] This suggests that first-hand experience of disasters does induce businesses to adopt risk management strategies to better prepare for future disaster events. Moreover, the greater effect of inundation on BCP development among larger plants suggests that a fixed cost of BCP development may be a hurdle for small businesses. Of course, developing a BCP is not the only risk management strategy for businesses. In the next subsection, we investigate how inundation experience

[12]The results do not change substantially even when we include an interaction term between the plant size measure and post-flood dummy to control for the possibility that the direct effect of a given plant size measure on BCP development changes before and after the 2011 floods. Therefore, to increase efficiency, we report results without such interaction terms.

[13]In contrast, we find no evidence of a heterogeneous effect on flood risk awareness, as shown in Appendix A.3. This is not surprising because updating risk awareness likely does not involve significant fixed costs. Moreover, this suggests that smaller inundated plants increased their flood risk awareness but did not develop a BCP, further underscoring the role of fixed costs in the development of BCPs.

[14]In Appendix C, we investigate the effect heterogeneity with respect to pre-flood business conditions. Furthermore, we also investigate the nonlinear effects of flood inundation and the relationship between BCPs and government assistance.

also affects flood insurance subscription.

4.3 Impacts on Flood Insurance Subscription

To estimate the effects of inundation experience on flood insurance subscription, we estimate equation (1), using dummy variables indicating the status of flood insurance subscription. We estimate the impacts on insurance for property damage (PD) and for business interruption (BI) separately.

The estimation results are presented in Table 7. Columns (1) and (4) include the inundation dummy instead of plant fixed effects to demonstrate the pre-flood differences in the insurance subscription rate between inundated and non-inundated plans. The positive and statistically significant coefficients on both PD and BI insurance indicate that the pre-flood insurance subscription rate was higher among inundated plants. This suggests that adverse selection was present before the 2011 floods. Namely, inundated plants were more likely to subscribe to flood insurance than non-inundated plants before the 2011 floods, presumably because they were more likely to be aware of the flood risk, as shown in Table 3.

More importantly, the coefficients of the interaction terms are consistently *negative* and statistically significant for both PD and BI (Columns 1 and 3). We observe similar patterns after controlling for plant fixed effects (Columns 2 and 4) and even after controlling for the baseline plant characteristics (Columns 3 and 6). The estimates in Columns 3 and 6 indicate that the inundation experience *lowered* the insurance subscription rates by 26.2 percentage points (PD) and 18.3 percentage points (BI). These magnitudes of the effects are sizable given that the pre-flood insurance subscription rates were 62.2% (PD) and 26.6% (BI) as shown in Table 1.

Considering that inundation experience has increased awareness of future flood risk, as shown in Table 3, these results on insurance subscriptions may seem puzzling. They are also in contrast with the past literature documenting that households' disaster insurance take-up increases after disasters (Gallagher, 2014). What can explain the negative impact on disaster insurance subscription? Our field interviews suggest that this may be because of the supplier's responses. That is, (re)insurance companies revised their risk assessments after the floods and, consequently, severely reduced the supply of flood insurance to plants that are now deemed to face higher inundation risks. Previous studies on the Thai insurance market have also noted that insurance companies reduced the supply of flood insurance after the 2011 floods by imposing flood coverage limits, increasing premiums, and even quitting the Thai market (Courbage et al., 2012; Ghaderi et al., 2015).[15]

4.4 Relationship between BCPs and Insurance

Our findings so far suggest that inundation experience induces plants to better prepare for future disaster risks by developing a BCP, while it also lowers the flood subscription rate. How can we reconcile these two seemingly contradictory results? Although our research design does not allow us to identify the causal relationship between BCP development and insurance subscription, here we test whether inundation experience still affects BCP development even after accounting for the changes in insurance subscription. To do so, we estimate equation (1) by controlling for flood insurance subscription for PD and BI, admitting that flood insurance subscription is an endogenous outcome of the inundation experience. If inundated plants developed a BCP as a substitute for flood insurance because they could no longer subscribe to it after the floods, then we would expect that accounting for the changes in insurance subscription should attenuate the effect of inundation experience on BCP development.

Table 8 presents the results. Column (1) replicates the previous result on the effect on BCP development for comparison. Column (2) shows that the estimated effect of inundation experience on BCP development becomes substantially smaller and not statistically different from zero once we account for the changes in insurance subscription. This suggests that the effect of inundation experience on BCP development is almost entirely explained by the changes in insurance subscriptions. Moreover, the estimates show a negative and statistically significant association between flood insurance subscription (PD) and BCP development. Taken together, the results suggest that inundated plants developed a BCP as a substitute for flood insurance as it became unavailable for them after the floods.

[15]Figure B.1b and B.1c present the trends in flood insurance subscription. It shows that the subscription rate declined among inundated plants, while it slightly increased or remained stable among non-inundated plants. This pattern is consistent with the view that insurance providers restricted the supply of flood insurance specifically to plants affected by inundation.

As subscription of PD and BI flood insurance are highly correlated, one might be concerned that multicollinearity between two insurance dummies may bias the result in Column (2). To deal with this concern, we create a dummy variable indicating the subscription of *any* type of insurance, which is equal to one if a plant subscribes to at least one of PD or BI insurance, and control for it in Column (3). Reassuringly, the results are similar to that in Column (2), suggesting that the multicollinearity is not driving the results in Column (2).

Finally, to examine to what extent the effect on BCP development is explained by the change in flood risk awareness per se, we control for the changes in flood risk awareness instead of flood insurance subscription in Column (4). Interestingly, the estimated effect of inundation on BCP development changes only slightly after accounting for the change in flood risk awareness. This suggests that the increase in flood risk awareness by inundation experience alone does not necessarily induce plants to develop a BCP. Instead, our results suggest that whether inundation experience leads to BCP development crucially depends on the market availability of flood insurance.

5 Conclusion

This paper has examined how disaster experiences influence corporate disaster risk management practices by using a unique plant-level data set from the 2011 Thailand floods. We find that plants that were inundated during the floods became more aware of the flood risk and are more likely to develop a BCP after the floods. At the same time, however, subscription to property-damage and business-interruption flood insurance dropped substantially among plants that were inundated during the floods, suggesting that the supply of flood insurance has largely dried up for plants located in inundated areas, i.e., flood insurance markets went missing there. A positive impact of inundation experience on BCP development and a negative impact on flood insurance subscription suggest that plants would subscribe to flood insurance when it is available, and would develop a BCP only when insurance is not available to them. That is, BCPs can serve as a substitute for flood.

Disasters are often said to be hard to predict, and the severest ones may even be unforeseeable ex ante. Considering the apparently common unpreparedness against disasters, we believe our study would make novel contributions to both the academic literature and policymaking by providing real-world evidence on the driving factors of business management practices against disasters – in particular, ex ante and ex post resilience building to disasters. Finally, while this paper shows that past disaster experience is an important determinant of BCP development, it does not examine whether BCPs are indeed effective for plants to mitigate the losses from disasters. It would be a promising direction for future research.[16]

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[16] Along this line, Grover and Karplus (2021) show that structured management practices can mitigate the adverse impacts of COVID-19 shocks.

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Tables

Table 1: Summary Statistics

	N	Mean	SD	Min.	Max.
Panel A. Flood experience					
Flooded	304	0.372	0.484	0.000	1.000
Direct loss	297	0.421	0.495	0.000	1.000
Indirect loss	297	0.582	0.494	0.000	1.000
Panel B. Basic firm characteristics					
Distance from Chao Phraya river (km)	311	0.266	0.391	0.000	3.131
Plant age	272	11.522	8.682	0.000	52.000
Employment	224	346.509	1074.665	2.000	12000.000
Lot size (km^2)	220	0.030	0.052	0.000	0.340
Multistoried building	282	0.340	0.475	0.000	1.000
Subsidiary firm	314	0.599	0.491	0.000	1.000
Panel C. Pre-flood business sentiment					
Performance: increasing	210	0.367	0.483	0.000	1.000
Performance: deccreasing	210	0.100	0.301	0.000	1.000
Sales: increasing	197	0.609	0.489	0.000	1.000
Sales: deccreasing	197	0.096	0.296	0.000	1.000
Profits: increasing	171	0.409	0.493	0.000	1.000
Profits: deccreasing	171	0.140	0.348	0.000	1.000
Panel D. Pre-flood outcomes					
BCP development	264	0.038	0.191	0.000	1.000
Flood insurance (property damage)	185	0.622	0.486	0.000	1.000
Flood insurance (business interruption)	192	0.266	0.443	0.000	1.000
Flood risk awareness	270	0.259	0.439	0.000	1.000
Panel E. Post-flood outcomes					
BCP development	264	0.148	0.356	0.000	1.000
Flood insurance (property damage)	165	0.533	0.500	0.000	1.000
Flood insurance (business interruption)	140	0.179	0.384	0.000	1.000
Flood risk awareness	277	0.440	0.497	0.000	1.000
Belief formation about future floods	263	0.380	0.486	0.000	1.000
Subjective probability of future floods	100	55.150	33.071	0.000	100.000

Notes: See texts for the definition of each variable.

Table 2: Balance Test

	Flooded			Non-flooded			
	N	Mean	SD	N	Mean	SD	Diff.
Panel A. Basic firm characteristics							
Distance from Chao Phraya river (km)	112	0.020	0.031	189	0.413	0.437	-0.393***
Plant age	88	14.364	9.333	175	10.383	8.056	3.981***
Employment	78	414.167	1031.510	139	325.619	1124.149	88.548
Lot size (km^2)	84	0.023	0.038	130	0.034	0.059	-0.011
Multistoried building	106	0.358	0.482	170	0.335	0.473	0.023
Subsidiary firm	113	0.549	0.500	191	0.639	0.482	-0.090
Panel B. Pre-flood business sentiment							
Performance: increasing	94	0.415	0.495	114	0.333	0.473	0.082
Performance: deccreasing	94	0.074	0.264	114	0.114	0.319	-0.040
Sales: increasing	83	0.699	0.462	113	0.540	0.501	0.159**
Sales: deccreasing	83	0.084	0.280	113	0.106	0.309	-0.022
Profits: increasing	75	0.400	0.493	95	0.421	0.496	-0.021
Profits: deccreasing	75	0.160	0.369	95	0.126	0.334	0.034
Panel C. Pre-flood outcomes							
BCP development	97	0.041	0.200	164	0.037	0.188	0.005
Flood insurance (property damage)	96	0.885	0.320	87	0.333	0.474	0.552***
Flood insurance (business interruption)	94	0.415	0.495	96	0.125	0.332	0.290***
Flood risk awareness	110	0.382	0.488	157	0.178	0.384	0.203***
Panel D. Post-flood outcomes							
BCP development	97	0.289	0.455	164	0.067	0.251	0.222***
Flood insurance (property damage)	79	0.557	0.500	83	0.506	0.503	0.051
Flood insurance (business interruption)	70	0.157	0.367	68	0.191	0.396	-0.034
Flood risk awareness	109	0.752	0.434	164	0.238	0.427	0.514***
Belief formation about future floods	99	0.485	0.502	160	0.325	0.470	0.160**
Subjective probability of future floods	48	54.917	32.962	52	55.365	33.491	-0.449

Notes: * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 3: The Effect of the Floods on Flood Risk Awareness

Dependent variable	Flood risk awareness		
	(1)	(2)	(3)
Flood	0.203***		
	(0.056)		
Flood × Post	0.311***	0.314***	0.201**
	(0.065)	(0.065)	(0.084)
Plant FE		Yes	Yes
Time FE	Yes	Yes	Yes
Plant characteristics			Yes
Observations	540	522	522
Plants	279	261	261
R-squared	0.168	0.091	0.024
Mean of dep. var.	0.354	0.358	0.358

Notes: The dependent variable for all columns is a dummy variable indicating awareness of flood risk. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 4: The Effect of the Floods on BCP Development

Dependent variable	BCP development			
				BCP with FAP
	(1)	(2)	(3)	(4)
Flood	0.005			
	(0.025)			
Flood × Post	0.217***	0.217***	0.188***	0.166***
	(0.046)	(0.046)	(0.052)	(0.051)
Plant FE		Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Plant characteristics			Yes	Yes
Observations	522	522	522	522
Plants	261	261	261	261
R-squared	0.070	0.111	0.064	0.053
Mean of dep. var.	0.094	0.094	0.094	0.071

Notes: The dependent variable for columns 1 to 3 is a dummy variable indicating the BCP development. Column 4 uses a dummy variable indicating the development of BCP with a flood action plan (FAP) as the dependent variable. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 5: The Effect of the Floods on BCP Development by Loss Status

Dependent variable	BCP development			
			BCP with FAP	
	(1)	(2)	(3)	(4)
Direct loss × Post	0.169***	0.182***	0.153***	0.145***
	(0.046)	(0.059)	(0.045)	(0.055)
Indirect loss × Post	-0.002	0.008	0.015	0.009
	(0.038)	(0.022)	(0.037)	(0.022)
Direct loss × Indirect loss × Post		-0.022		0.014
		(0.084)		(0.082)
Plant FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes
Observations	514	514	514	514
Plants	257	257	257	257
R-squared	0.056	0.056	0.048	0.048
Mean of dep. var.	0.095	0.095	0.072	0.072

Notes: The dependent variable for columns 1 to 2 is a dummy variable indicating the BCP development. Columns 3 and 4 use a dummy variable indicating the development of BCP with a flood action plan (FAP) as the dependent variable. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 6: The Heterogeneous Effects of the Floods on BCP Development by Plant Size

Dependent variable	BCP development				
	(1)	(2)	(3)	(4)	(5)
Flood × Post	0.188***	0.205***	0.230***	0.076	0.042
	(0.052)	(0.068)	(0.067)	(0.056)	(0.053)
Flood × Post × Employment/1,000 (demeaned)		0.076**			
		(0.035)			
Flood × Post × Lot size (demeaned)			3.579***		
			(0.801)		
Flood × Post × (#Floors - 1)				0.231***	
				(0.050)	
Flood × Post × Subsidiary					0.254***
					(0.082)
Plant FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes	Yes
Observations	522	398	378	478	522
Plants	261	199	189	239	261
R-squared	0.064	0.085	0.132	0.176	0.125
Mean of dep. var.	0.094	0.118	0.122	0.100	0.094

Notes: The dependent variable for all columns is a dummy variable indicating the BCP development. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 7: The Effect of the Floods on Flood Insurance Subscription

Dependent variable	Flood insurance subscription					
	Property damge			Business interruption		
	(1)	(2)	(3)	(4)	(5)	(6)
Flood	0.552***			0.290***		
	(0.061)			(0.061)		
Flood × Post	-0.501***	-0.362***	-0.262*	-0.324***	-0.212***	-0.183**
	(0.094)	(0.105)	(0.155)	(0.065)	(0.063)	(0.082)
Plant FE		Yes	Yes		Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Plant characteristics			Yes			Yes
Observations	345	280	280	328	260	260
Plants	205	140	140	198	130	130
R-squared	0.168	0.084	0.025	0.071	0.077	0.031
Mean of dep. var.	0.580	0.593	0.593	0.229	0.219	0.219
P-value: Flood + Flood × Post = 0	0.519			0.601		

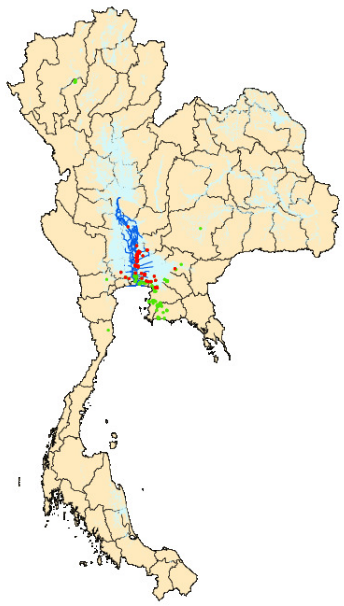
Notes: The dependent variable for columns 1-3 and 4-6 use a dummy variable indicating the subscription to flood insurance for property damage and for business interruption as the dependent variable, respectively. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table 8: BCP Development, Insurance Subscription, and Risk Awareness

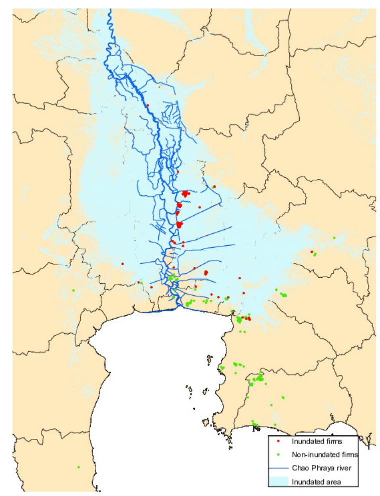
Dependent variable	BCP development			
	(1)	(2)	(3)	(4)
Flood × Post	0.188***	0.074	0.074	0.174***
	(0.052)	(0.095)	(0.087)	(0.060)
Flood insurance subscription (property damage)		-0.126**		
		(0.061)		
Flood insurance subscription (business interruption)		0.058		
		(0.109)		
Flood insurance subscription (any)			-0.090*	
			(0.049)	
Flood risk awareness				-0.029
				(0.047)
Plant FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes
Observations	522	216	288	468
Plants	261	108	144	234
R-squared	0.064	0.048	0.029	0.045
Mean of dep. var.	0.094	0.144	0.132	0.098

Notes: The dependent variable for all columns is a dummy variable indicating the BCP development. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Figures



(a) Thailand



(b) Chao Phraya River basin

Figure 1: Study Areas

Notes: Panel (a) shows the map of the entire Thailand, and panel (b) focuses on the Chao Phraya River basin. The GIS data for the Chao Phraya River and the inundated area were downloaded from the FAO map catalog (http://www.fao.org/geonetwork/srv/en/main.home) and the Thai Flood Monitoring System (http://flood.gistda.or.th/), respectively.

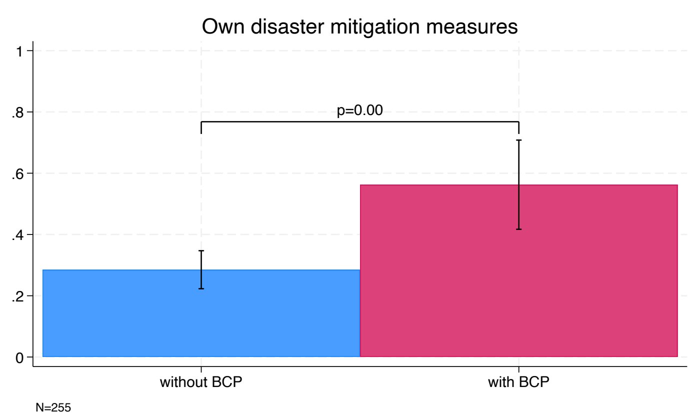
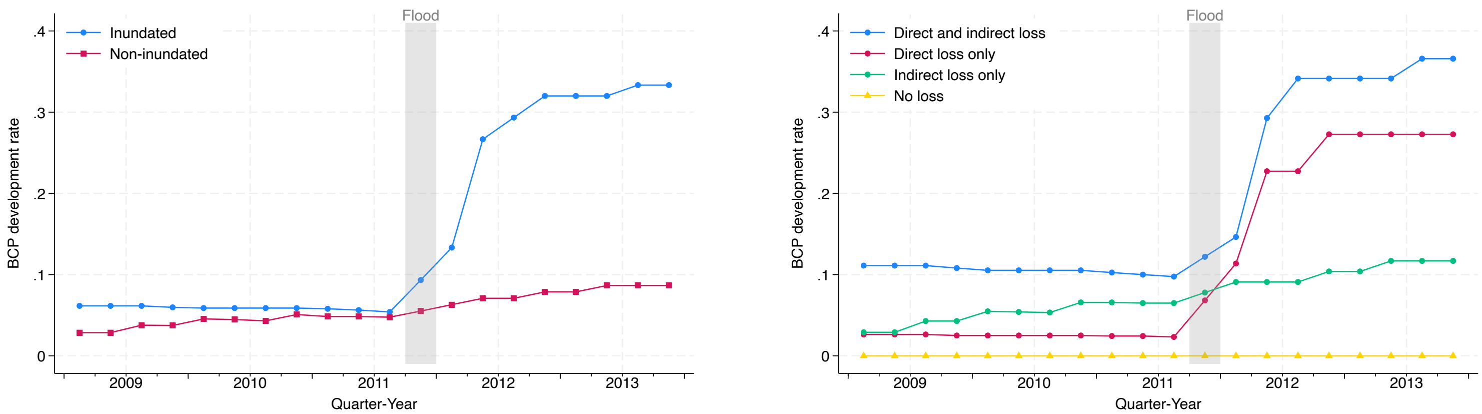


Figure 2: BCP and Disaster Mitigation

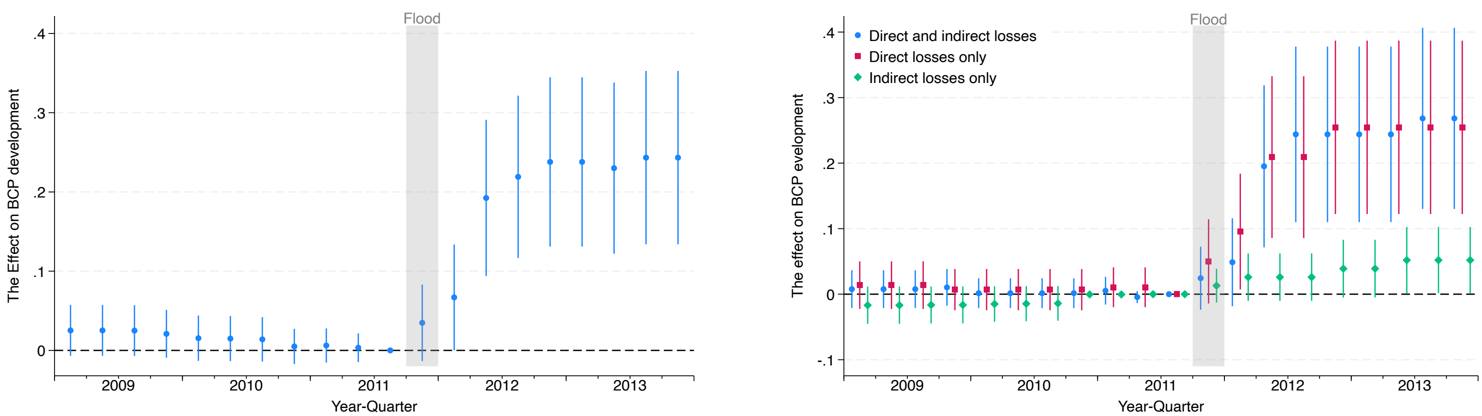
Notes: The figure shows the proportion of plants which have their own disaster mitigation measures by the BCP development status. The vertical bars represent the 95% confidence intervals.



(a) Inundated vs. Not Inundated

(b) By Loss Experience

Figure 3: Floods and BCP Development



(a) Inundated vs. Not Inundated

(b) By Loss Experience

Figure 4: The Difference-in-Differences Effects of Floods and BCP Development

Notes: The figures plot the estimates of β_τ in equation (2). The vertical bars associated with each marker represent the 95% confidence intervals. The third quarter of 2011 is defined as the reference period and the coefficient is normalized to be zero.

Appendix

A Additional Tables

Table A.1: The Effect of the Floods: Robustness to Controlling for Respondent Characteristics

Dependent variable	Flood risk awareness		BCP development		PD insurance		BI insurance	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Flood × Post	0.174**	0.186**	0.191***	0.187***	-0.384**	-0.296*	-0.195**	-0.177**
	(0.086)	(0.085)	(0.055)	(0.054)	(0.157)	(0.157)	(0.087)	(0.082)
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Executives	Yes		Yes		Yes		Yes	
Survey location		Yes		Yes		Yes		Yes
Observations	482	522	478	522	256	280	242	260
Plants	241	261	239	261	128	140	121	130
R-squared	0.024	0.028	0.067	0.064	0.065	0.042	0.044	0.037
Mean of dep. var.	0.353	0.358	0.094	0.094	0.602	0.593	0.227	0.219

Notes: The dependent variable is a dummy variable indicating awareness of flood risk (Columns 1-2), a dummy variable indicating the development of a BCP (Columns 3-4), and a dummy variable indicating subscription to property damage insurance (Columns 5-6), and a dummy variable indicating subscription to business interruption insurance (Columns 7-8). Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table A.2: The Effect of the Floods: Robustness to Probit Estimation

Dependent variable	Flood risk awareness	BCP development	PD insurance	BI insurance
	(1)	(2)	(3)	(4)
Flood	0.426*	0.073	1.374***	0.684**
	(0.242)	(0.364)	(0.276)	(0.292)
Flood × Post	0.400	0.623*	-1.199***	-0.839***
	(0.256)	(0.334)	(0.366)	(0.288)
Time FE	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes
Observations	538	483	345	328
Plants	279	259	205	198
Mean of dep. var.	0.355	0.101	0.580	0.229

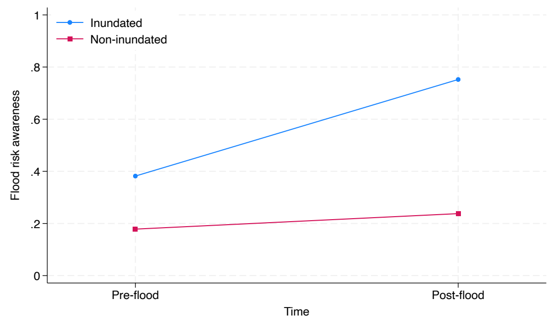
Notes: The dependent variable is a dummy variable indicating awareness of flood risk (Column 1), a dummy variable indicating the development of a BCP (Column 2), and a dummy variable indicating subscription to property damage insurance (Column 3), and a dummy variable indicating subscription to business interruption insurance (Column 4). Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

Table A.3: The Heterogeneous Effects of the Floods on Risk Awareness by Plant Size

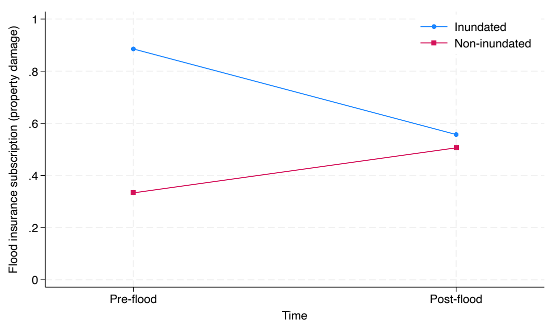
Dependent variable	Flood risk awareness				
	(1)	(2)	(3)	(4)	(5)
Flood × Post	0.201**	0.202**	0.166*	0.311***	0.263***
	(0.084)	(0.097)	(0.098)	(0.090)	(0.096)
Flood × Post × Employment/1,000 (demeaned)		-0.000			
		(0.052)			
Flood × Post × Lot size (demeaned)			1.070		
			(1.581)		
Flood × Post × (#Floors - 1)				-0.115*	
				(0.066)	
Flood × Post × Subsidiary					-0.110
					(0.109)
Plant FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes	Yes	Yes
Observations	522	382	382	484	522
Plants	261	191	191	242	261
R-squared	0.024	0.026	0.018	0.052	0.029
Mean of dep. var.	0.358	0.346	0.374	0.360	0.358

Notes: The dependent variable for all columns is a dummy variable indicating awareness of flood risk. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

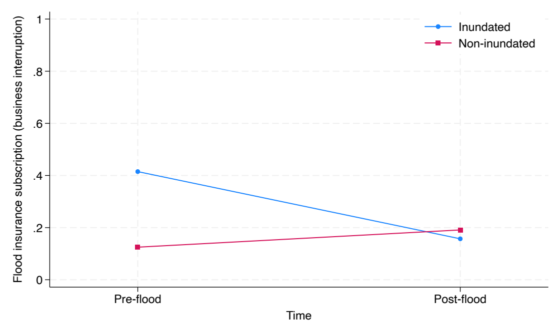
B Additional Figures



(a) Flood Risk Awareness



(b) Flood Insurance (Property Damage)



(c) Flood Insurance (Business Interruption)

Figure B.1: Changes in Risk Awareness and Flood Insurance Subscription

C Additional Analysis

C.1 Heterogeneous Effect of Flood Experience on BCP Development by Pre-flood Business Sentiment

We investigate whether the effect of inundation experience on BCP development differs depending on plants' pre-flood business sentiment. It is theoretically ambiguous how the effect of inundation depends on business sentiment. On the one hand, the effect could be larger for better-performing plants because they can afford to develop a BCP. Conversely, such plants might prioritize other resources over BCP development and/or underestimate flood risks due to a more optimistic outlook on their business, potentially diminishing the perceived need for a BCP.

To examine this heterogeneity, we utilize three measures of pre-flood business sentiment. Specifically, we construct dummy variables indicating whether a plant's (1) overall business performance, (2) sales, and (3) profits improved (increased), worsened (decreased), or remained the same (constant) in the first half of 2011 compared to 2010. Then we re-estimate equation (1) by interacting these performance indicators with $Flood_i \cdot Post_t$.

Graphically summaries of the estimation results are shown in Figure C.1, with the full results presented in Table C.1. While the small sample size makes it difficult to be conclusive, it appears that the effects of inundation experience on BCP development are larger among plants that had been performing *worse* before the 2011 floods. This could suggest that better-performing plants might have prioritized other resources over BCP development or felt overly confident in managing future flood risks.

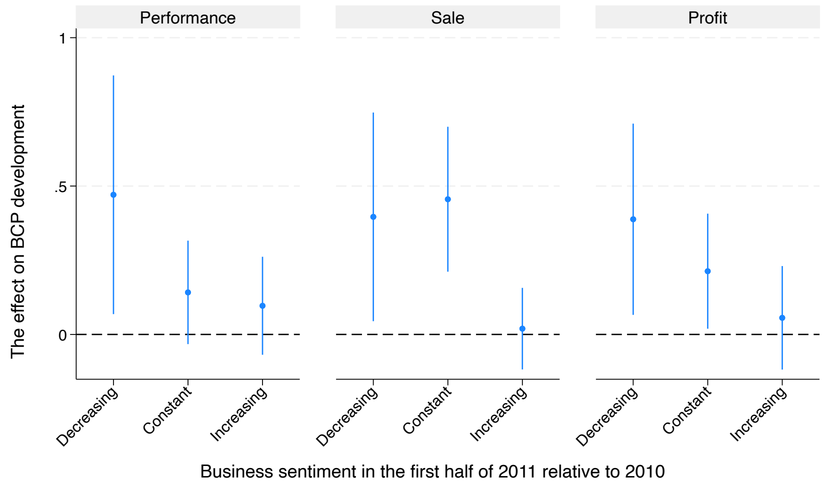


Figure C.1: Heterogeneous Effects of Floods on BCP Development: By Pre-Floods Business Sentiment

Table C.1: The Heterogeneous Effects of the Floods on BCP Development by Pre-flood Business Sentiment

Dependent variable	BCP development		
	Performance	Sales	Profits
	(1)	(2)	(3)
(a) Flood × Post	0.142	0.456***	0.213**
	(0.089)	(0.125)	(0.099)
(b) Flood × Post × Decreasing	0.329	-0.059	0.175
	(0.209)	(0.208)	(0.175)
(c) Flood × Post × Increasing	-0.045	-0.436***	-0.157
	(0.104)	(0.125)	(0.117)
Plant FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Plant characteristics	Yes	Yes	Yes
Observations	374	354	308
Plants	187	177	154
R-squared	0.070	0.172	0.093
Mean of dep. var.	0.118	0.119	0.133
p-value: (a) + (b) = 0	0.023	0.028	0.019
p-value: (a) + (c) = 0	0.253	0.781	0.530

Notes: The dependent variable for all columns is a dummy variable indicating the BCP development. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

C.2 Nonlinear Effect of Flood Experience on BCP Development

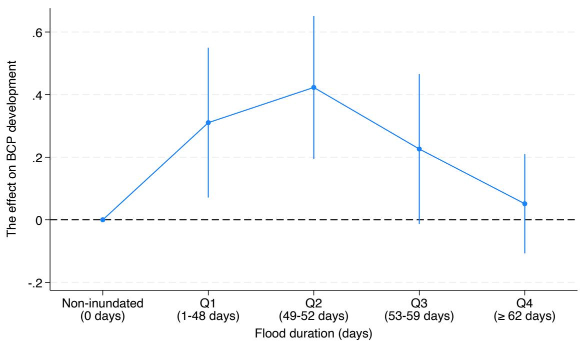
Here, we examine whether the effect of inundation experience on BCP development is nonlinear in the intensity of inundation. On the one hand, more intense inundation may increase plants' risk perception more and may give plants a larger incentive to develop a BCP. On the other hand, if inundation is too intense to the extent that the plant's capacity to develop a BCP is deprived, it may hinder BCP development.

To examine the possible nonlinearity, we measure the intensity of inundation by the duration of inundation (in days). We construct four dummy variables for each quarter of inundation or flood duration, and estimate the following equation:

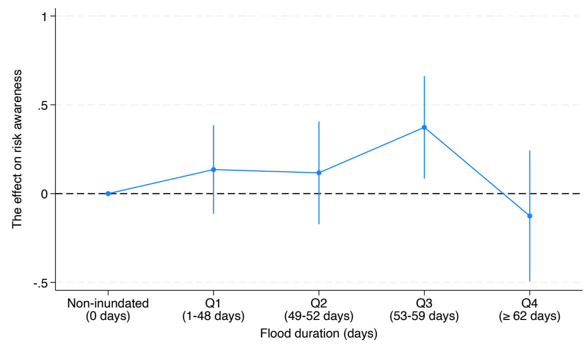
$$BCP_{it} = \sum_{k=1,2,3,4} \beta^k \cdot Flood\,Duration_i\,Q(k) \cdot Post_t + X'_{it}\theta + \gamma_i + \delta_t + \varepsilon_{it}, \tag{3}$$

where $Flood\,Duration_i\,Q(k)$ is a dummy variable which is equal to 1 if the duration of the flood that plant i is exposed to falls into its k-th quarter of its distribution

Figure C.2a displays the estimation results graphically and the full estimation results are shown in Table C.2. The results show that the effect is likely hump-shaped in the intensity of inundation. Specifically, the effect of the inundation on BCP development is largest when the duration of inundation is modest. In fact, the estimated effect is less than ten percentage points and not significantly different from 0 among plants that were inundated most intensely. We also find that the effect of inundation experience on risk awareness exhibits a similar inverse U-shaped pattern (Figure C.2b). Further empirical investigation into this non-linearity is needed to uncover the mechanism.



(a) BCP development



(b) Flood risk awareness

Figure C.2: The Nonlinear Effect of the Floods

Table C.2: Nonlinear Effects of the Floods on BCP Development

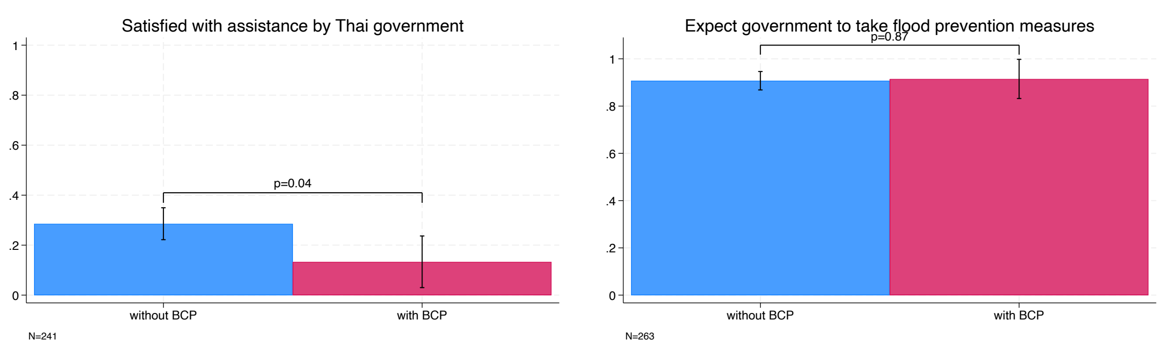
Dependent variable	BCP development
	(1)
Flood duration Q1 × Post	0.310**
	(0.121)
Flood duration Q2 × Post	0.423***
	(0.116)
Flood duration Q3 × Post	0.226*
	(0.122)
Flood duration Q4 × Post	0.051
	(0.081)
Plant FE	Yes
Time FE	Yes
Plant characteristics	Yes
Observations	466
Plants	233
R-squared	0.170
Mean of dep. var.	0.103

Notes: The dependent variable is a dummy variable indicating the BCP development. Plant characteristics include the distance to Chao Phraya river and plant age, both interacted with the post-flood dummy. To preserve the sample size, we handle missing values in the plant characteristics variables by replacing the missing values with zeros and creating a dummy variable to indicate a missing value. The dummy variables for missing values are also interacted with the post-flood dummy. Standard errors in parentheses are clustered at the plant-level. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.

C.3 Relationship between BCP development, Government Assistance, and Public Disaster Mitigation Systems

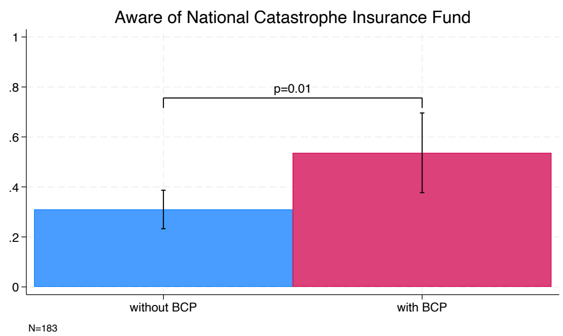
It is possible that the lack of effective government assistance after the floods led plants to help themselves in the form of BCPs. Consistent with this view, we find that plants that have developed a BCP are less satisfied with the post-flood assistance by the Thai government (Figure C.3a). Nonetheless, plants that have developed a BCP expect the Thai government to provide flood countermeasures to the same extent as plants that have not developed a BCP (Figure C.3b).

We also investigate the association between BCPs and public disaster mitigation systems in Figure C.4. We find that plants that developed a BCP are more likely to be aware of the National Catastrophe Insurance Fund (Figure C.4a), the flood control plan of the Thai government (Figure C.4b), and the flood prediction system of the Japan International Cooperation Agency (JICA) (Figure C.4c). We also find that, among plants that are aware of the JICA flood prediction system, those with a BCP are more likely to have used the system (Figure C.4d). Overall, these patterns suggest that public disaster mitigation systems may play a complementary role with plants' BCPs.

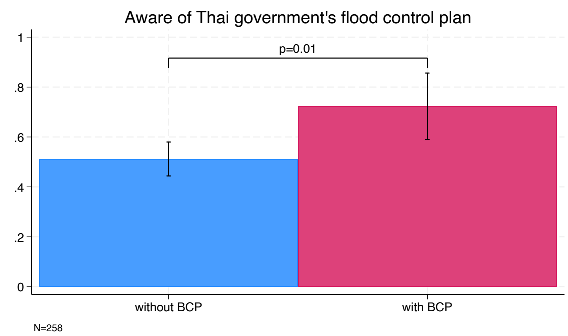


(a) (b)

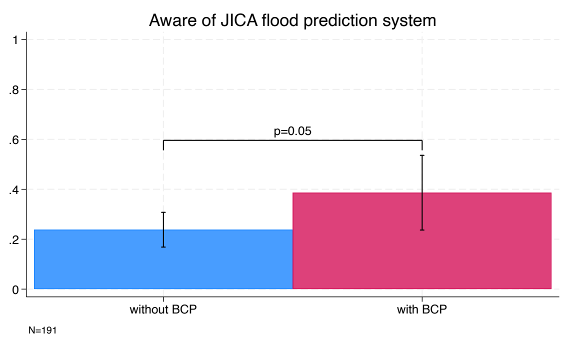
Figure C.3: BCP and Attitudes towards Thai Government



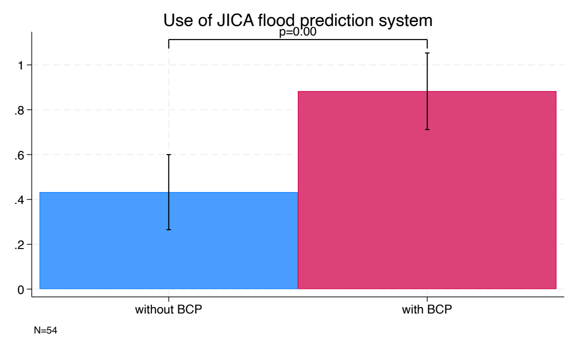
(a)



(b)



(c)



(d)

Figure C.4: BCP and Awareness of Disaster Mitigation Policies

C.4 Flood Experience and Probabilistic Beliefs

In the main body of the paper, we show that flood experience increases the awareness of flood risk, but do plants consider future flood risks based on a subjective probability? If so, does the flood experience also affect the subjective probability of future floods? According to the common classification of uncertainties in decision theory, it is important to distinguish situations in which the decision maker forms a probabilistic belief to make decisions from those in which the decision maker does not form one. The latter is often referred to as *Knightian uncertainty*

To explore this, we draw on the questions on the respondent's subjective probability of future floods in the RIETI survey. Specifically, it asks, "*what do you think is the probability of an occurrence of flooding as severe as the 2011 floods in the next 50 years?*". The respondents were supposed to provide a numeric value of their subjective probability between 0 and 100, but the survey also allowed them to choose "*I do not know*" to this question. If the respondent chooses to answer "*I do not know*", we arguably interpret this as him not being able to form a subjective probability about future floods. Accordingly, we define a dummy variable indicating whether the respondent was able to form a subjective probability and use it to examine whether the exposure to the 2011 flood affected the probabilistic belief formation.[17] In addition, we also use the numeric values of the respondents' subjective probability to investigate the impact of the 2011 flood among those who were able to form a probabilistic belief about future floods. Unfortunately, the servery does not contain information on the subjective probability before the 2011 floods. Therefore, the analysis here is cross-sectional.

Specifically, we estimate the following regression models:

$$BF_i = \alpha_1 Flood_i + \alpha_2 X_i + u_i, \tag{4}$$

$$SP_i = \phi_1 Flood_i + \phi_2 X_i + v_i, \tag{5}$$

where BF_i is a dummy variable indicating that plant i forms a probabilistic belief about future floods, SP_i is the subjective probability about future floods, $Flood_i$ is the same flood dummy defined above, X_i is a vector of control variables, and u_i and v_i are the error terms. Note that Equation (5) is estimated using the subsample for which $BF_i = 1$.

Table C.3 presents the estimation results. Columns (1)-(2) show the effect on subjective belief formation. In Panel A, we use the inundation experience as the treatment variable. Column (1) includes no control variables and we find the coefficient of the flood dummy to be positive and statistically significant. Column (2) controls for the baseline plant characteristics: distance to Chao Phraya River and plant age. Reassuringly, the coefficient of the flood dummy is still positive and statistically significant, suggesting that inundated plants are more likely to form a probabilistic belief.

Do inundated plants attach a higher probability to future floods? In Table C.3 Columns (3)-(4), we show the relationship between the subjective probability and flood experience.

[17] Some respondents did not provide the numeric answer of the subjective probability nor choose "*I do not know*". Such observations are dropped and not used in the analysis.

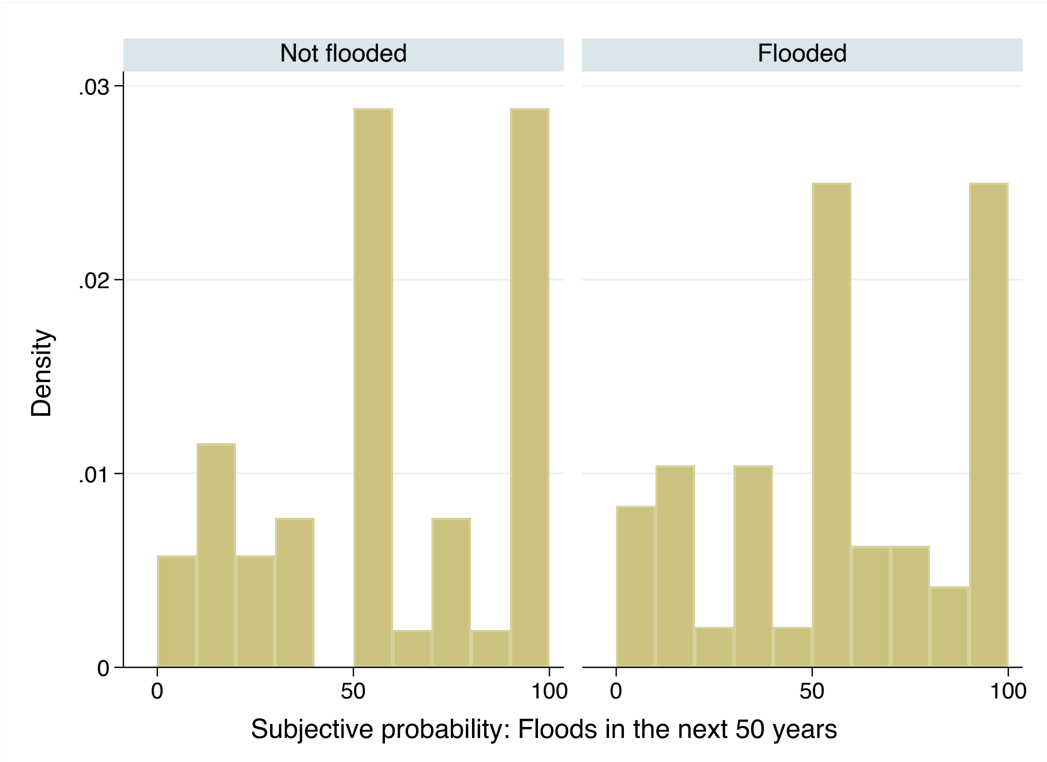
The results show no evidence that inundation experience affects the subjective probability of future floods. Figure C.5 shows the distributions of plants' subjective probabilities by inundation experience. The distributions remain diverse and do not differ between inundated and non-inundated plants.

Table C.3 Panel B presents the impacts of flood loss experience on beliefs, which exhibits a similar pattern as in Panel A. The plants that incurred direct losses are more likely to form a probabilistic belief, but their subjective probabilities are not affected by direct loss experience. We also find that indirect loss experience has little effect on belief formation and subjective probability. There is also no evidence that experiencing both direct and indirect losses amplifies the effect. The distribution of the subjective probability by loss experience is shown in Panel B of Figure C.5.

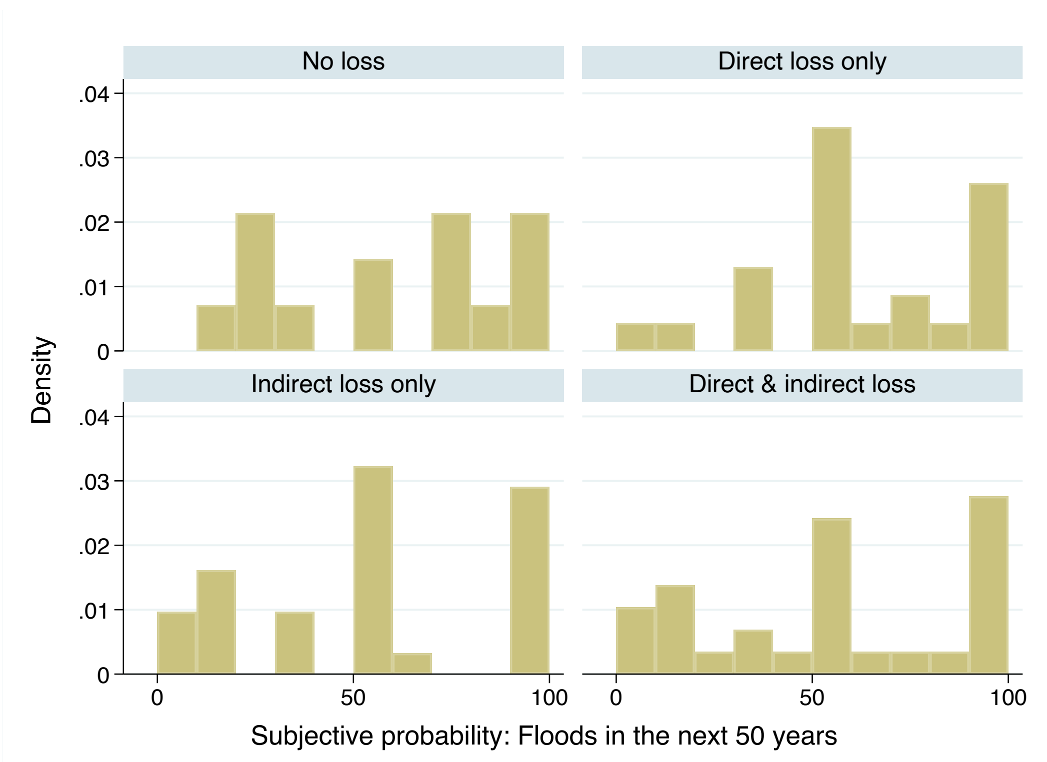
Table C.3: Effects of Floods/Loss Experience on Belief Formation and Subjective Probability

Dependent variable	Belief formation		Subjective Probability	
	(1)	(2)	(3)	(4)
Panel A. Inundated vs Not inundated				
Flood	0.160**	0.131*	-0.449	2.539
	(0.063)	(0.079)	(6.649)	(8.673)
Observations	259	226	100	91
R-squared	0.025	0.045	0.000	0.078
Mean of dep. var.	0.386	0.403	55.150	55.604
Panel B. By loss exerience				
Direct losses	0.205**	0.199*	5.000	5.873
	(0.092)	(0.105)	(10.183)	(12.340)
Indirect losses	0.090	0.086	-3.742	2.924
	(0.078)	(0.084)	(10.304)	(11.526)
Direct losses × Indirect losses	-0.074	-0.058	-2.948	3.946
	(0.124)	(0.134)	(13.721)	(14.308)
Observations	256	224	97	89
R-squared	0.031	0.055	0.010	0.088
Mean of dep. var.	0.379	0.397	54.485	55.056
Panel C. Controls (for both panel A and B)				
Plant characteristics		Yes		Yes

Notes: The dependent variable in columns 1 to 2 is a dummy variable indicating that plants form a probabilistic belief about future floods. Columns 3 to 4 restrict the sample to the plants that form a probabilistic belief and use the subjective probability about future floods as the dependent variable. Plant characteristics include the distance to Chao Phraya River and plant age. Robust standard errors are in parentheses. * denotes statistical significance at 0.10, ** at 0.05, and *** at 0.01.



(a) Inundated vs. Not Inundated



(b) By Loss Experience

Figure C.5: The Distribution of the Subjective Probabilities