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Health care cost of floods: Evidence from Typhoon Morakot in Taiwan☆

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ABSTRACT

Using the difference-in-difference (DID) method, this study uses Typhoon Morakot, which occurred in August 2009, as an example to estimate the effect of flooding on health care cost burden. The main data source is the medical claims records of a cohort of three million patients in Taiwan's National Health Insurance system. By examining flood-related physiological diseases and disaster-related mental illnesses, our results indicate that the increase in outpatient health care costs resulting from the flood caused by the typhoon is approximately NTD 8.95 billion (USD 280 million), equivalent to approximately 69% of the annual special budget for flooding prevention during the period 2006–2019 in Taiwan. Moreover, the increase in outpatient expenditure for mental illnesses is nearly 10 times that of physiological diseases. An important implication of our findings is that the cost of preventing natural disasters, such as floods, can be offset by saving health care costs, particularly for mental illnesses. Our results also suggest that in addition to providing safe drinking water and indoor residual spraying, offering continuous post-disaster mental health services can further save health care expenditures caused by natural disasters.

1. Introduction

Climate change has increased the frequency and intensity of extreme weather events, such as floods. The extreme rainfall in a short period caused by typhoons often leads to the occurrence of floods and, thereafter, severe damage and substantial economic loss. Taiwan is located on the tropical cyclone tracks of the Northwest Pacific Ocean and is affected by three to four typhoons a year. Because of the heavy rainfall for a short period of time caused by typhoons, floods are often accompanied by landslides. Typhoon Morakot struck Taiwan on August 8, 2009. The 24- and 48-hour rainfall nearly reached the world record for the maximum rainfall, which brought widespread floods to the central and southern parts of Taiwan. This typhoon caused the death or disappearance of 724 people and fully or partially damaged 838 houses. A total of 140,424 houses were flooded by more than 50 cm of water. The immediate economic loss caused by the typhoon (such as agricultural and electrical damage, as well as damage to roads, bridges, and buildings) was approximately NTD 199.83 billion (approximately USD 6.25 billion) (National Science and Technology Center for Disaster Reduction, 2010).[1] Considering the economic loss and fatalities caused by Typhoon Morakot, it is the most severe typhoon in Taiwan's

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[1] The exchange rate in 2010 was around USD 1 = NTD 31.97.

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history. However, so far, little is known about the effects of this flood on health care cost burden.

Alderman et al. (2012) conducted a systematic review of the relationship between floods and health using published articles (2004–2011) and found an increased risk of the outbreak of diseases such as hepatitis E, gastrointestinal disease, and leptospirosis after floods. Evidence of various types of diseases, such as dysentery in China (Ni et al., 2014), flood-related leptospirosis in Brazil (Londe et al., 2016), flood-related diseases of the eyes, skin, and gastrointestinal tract in Taiwan (Huang et al., 2016), and flood-related infectious diseases in China (Gao et al., 2016), highlighted the same results regarding the adverse effects of floods. A non-communicable diseases - allergic symptoms, particularly upper respiratory tract – was also found related to flood caused by hurricane in Houston (Oluyomi et al., 2021). Mallett and Etzel (2018) provided a literature review regarding the effect of flooding on pregnant women and children and found negative psychological and physiological child health and pregnancy outcomes.

Another branch of studies has focused on mental illnesses (psychosocial health) associated with exposure to floods (Reacher et al., 2004; Heo et al., 2008; Mason et al., 2010; Paranjothy et al., 2011). Recently, Lamond et al. (2015) used a postal survey of households flooded during the 2007 flood across England, and found a long-term effect of flooding on mental illness. Similarly, using a survey from households affected by flooding between 1 December 2013 and 31 March 2014 in the south of England, Waite et al. (2017) found an increasing prevalence of mental hardship six months after flooding, suggesting a significant and prolonged impact of flooding on mental health. These findings are consistent with those of Seyedin et al. (2017), which indicate an increasing one-year prevalence of post-traumatic stress disorder in the southeastern Caspian region that experienced flooding in 2012. Wei et al. (2020) also found schizophrenia is related to flood in China. Furthermore, Pesko (2018) found that due to the changes in perceived background risks from natural disasters such as Hurricane Katrina, there are spillover effects, including poor mental health and increased cigarette smoking. This increase in substance use due to psychiatric distress after one year of hurricane hit was echoed by the anniversary response among survivors of natural disasters found by Assanangkornchai et al. (2007), suggesting that significant changes that occurred in their lives due to natural disasters may have resulted in a prolonged effect on mental health and health behaviors.[2] The extent of this long-lasting impact on mental health is also associated with the type of losses caused by experiencing a devastating disaster (Isaranuwatchai et al., 2017).

Previous studies that used survey to estimate the impact on health do not have the victims' health status record before the flood. They, therefore, cannot compare the impact before and after the flood. Other previous studies which used clinical records to estimate the health impact on infectious diseases can usually only compare areas with and without floods or before and after the flood in flooded areas. The most comprehensive epidemiological study on flood-related diseases in Taiwan is conducted by Huang et al. (2016). Their results, however, do not control the trend in non-flooded areas. Because of the well-established National Health Insurance (NHI) system in Taiwan, there is relatively complete and reliable data regarding health care utilization and expenditures, which can help estimate the cost burden resulting from natural disasters. In this study, we analyzed flood-related physiological diseases and disaster-related mental illnesses based on disease categories suggested by Ahern et al. (2005).[3] Using the difference-in-difference (DID) strategy, our results indicate that the increase in outpatient health care costs resulting from the flood caused by the typhoon is equivalent to approximately 69% of the annual special budget for flooding prevention during the period 2006–2019. Furthermore, the increase in outpatient expenditure (utilization) for mental illnesses is significantly higher than that for physiological diseases, suggesting that the cost of preventing natural disasters, such as floods, can be offset by saving health care costs, particularly for mental illnesses.

The remainder of this article is organized as follows: Section 2 briefly presents the background of the NHI program in Taiwan and the data used in the analysis. Section 3 describes the methodology. Section 4 presents the results, and Section 5 summarizes our findings.

2. Background and data

The NHI program was initiated in 1995 and covers more than 99% of the 23 million population of Taiwan. There is no gatekeeping system, and patients do not require a referral from primary care doctors to select the health care provider they prefer. The NHI benefit scheme contains a comprehensive benefit package, which includes outpatient and inpatient care, dental services, prescription drugs, and traditional Chinese medicine services. The average number of outpatient visits per capita is around 15 times a year for adults and nearly 20 per year for children under 4 (National Health Insurance Administration, 2018). The extremely convenient access to health care services has led to a relatively high frequency of outpatient visits in Taiwan.

Health care utilization data are sourced from the National Health Insurance Research Database (NHIRD), which is compiled by the National Health Research Institute (NHRI). The NHRI issued the Longitudinal Health Insurance Database (LHID) in 2000, 2005, and 2010, and each LHID comprises medical claims records of one million people randomly sampled from those who are insured. The medical claims of those three million samples can be traced throughout the years. Combining data from the aforementioned LHIDs, the study data include background and health care utilization information, such as sex, date of birth, date of clinical visits, types of medical services, and diagnoses for outpatient and inpatient treatments, from three million insured people. We employed this data to create individual visit and expenditure datasets from August 2008 to August 2011. The International Classification of Diseases, 9th Revision,

[2] The term "anniversary response" refers to feelings of sadness that survivors experienced during the first anniversary of the disaster because they were reminded of the natural disaster.

[3] Ahern et al. (2005) used a search algorithm to divide the adverse health effects of floods into six major categories: mortality, injuries, fecal-oral diseases, rodent-borne diseases, vector-borne diseases, and mental illnesses.

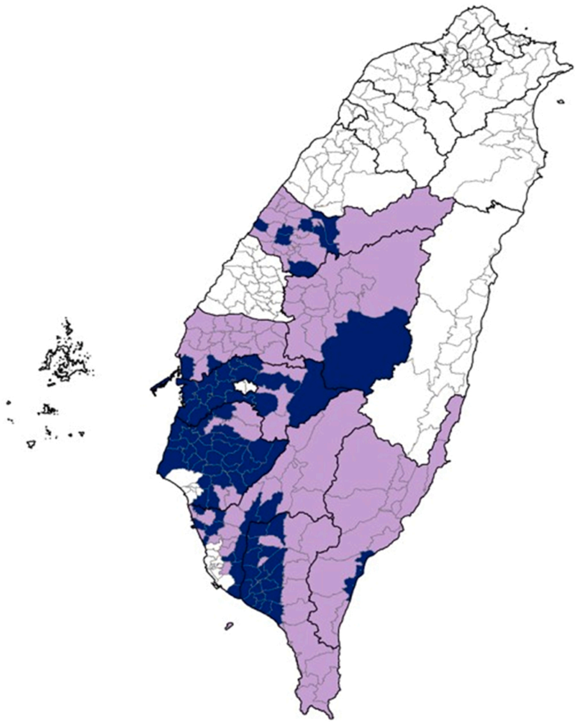

Fig. 1. Geographic distribution of the treatment and control districts/townships. Note: The cities/counties in the white zone are the ones that did not experience flooding due to Typhoon Morakot. Within each city/county, the dark blue zone indicates the geographical locations of districts or townships that suffered from floods during Typhoon Morakot, which represents the treatment regions in our study. The purple zone represents the control regions composed of districts/townships that did not experience flooding due to Typhoon Morakot. Cities/counties in the white zone were not included in our sample.

Clinical Modification (ICD-9-CM) codes of the primary diagnoses were used to identify patients who utilize health care due to flood-related diseases and aggregate outpatient (inpatient) records with individual outpatient (inpatient) expenditure and visit (stay) data.

In this study, flood-related physiological diseases include vector-borne diseases, water-borne diseases, rodent-borne diseases, flood-related eye and skin diseases, and flood-related gastrointestinal tract diseases (Huang et al., 2016). Disaster-related mental illnesses analyzed in this study include anxiety, depression, and post-traumatic stress disorder. The detailed list of ICD-9-CM codes used in this study is presented in Appendix A.[4]

With respect to flooding areas, the National Science and Technology Center for Disaster Reduction (2010) in Taiwan recorded the location and magnitude of the flood caused by Typhoon Morakot (Li et al., 2013). According to the administrative division in Taiwan, districts/townships are subcategories of cities/counties. The cities/counties that include districts/townships affected by the flood and landslides caused by the typhoon are as follows: Nantou County, Yunlin County, Chiayi County, Tainan County, Kaohsiung County, Pingtung County, Taitung County, Taichung County, and Taichung City. Medical claims from these nine cities/counties were included in our study. *Within each city/county*, we identified patients who live in the districts/townships hit by flooding during Typhoon Morakot as the patients in the treatment group, and those who live in other districts/townships that did not experience flooding due to Typhoon Morakot.as the patients in the control group (see Fig. 1). Cities/counties in the white zone were not included in our sample, because there are no districts or townships in these cities/counties experiencing floods during Typhoon Morakot.

Regarding the identification of the health care expenditures related to floods, first, we needed to know whether the patients live in the district/township hit by flooding due to Typhoon Morakot. In the NHIRD, the residential area of enrollees is not necessarily identical to their household registries. This study uses the location of health care providers an enrollee visits the most when he/she has a respiratory tract infection to identify the residential area of the patient because patients seldom go to a provider far away from their residences for respiratory diseases (Lin et al., 2011). Second, this study traced the individual health care utilization of patients who live in the districts/townships hit by flooding due to Typhoon Morakot from 7 August 2008–7 August 2010 as the treatment group. The patients in the control group are those who live in the districts/townships that did not experience flooding caused by Typhoon

[4] Since 462 of the 724 fatalities of Typhoon Morakot were located in Siaolin village, the site affected by one major landslide, the triggering of a large-scale landslide would be the most important factor. Due to the incompleteness of the data on first aid in Taiwan, the quantitative causal analysis of mortality and injuries from typhoons cannot be carried out directly. Although allergic symptoms was found related to flood, many victims would not use outpatient services. That was not considered in this study.

Table 1
Sample statistics of main variables for patients with flood-related physiological diseases from outpatient care.

	Treatment group		Control group	
	Pre-period	Post-period	Pre-period	Post-period
	N = 69,996	*N = 69,996*	*N = 89,394*	*N = 89,394*
Exp. ratio	0.0809	0.0759	0.0802	0.0731
	(0.1631)	(0.1573)	(0.1595)	(0.1540)
Visit ratio	0.0953	0.0896	0.0940	0.0865
	(0.1608)	(0.1555)	(0.1563)	(0.1520)
Age	42.84	43.82	41.40	42.38
	(21.98)	(21.98)	(21.60)	(21.60)
Male	0.50	0.50	0.49	0.49
	(0.50)	(0.50)	(0.50)	(0.50)
Employed	0.70	0.70	0.68	0.68
	(0.46)	(0.46)	(0.47)	(0.46)
Low income	0.02	0.02	0.02	0.02
	(0.12)	(0.12)	(0.14)	(0.14)
Major illness	0.04	0.04	0.04	0.04
	(0.19)	(0.19)	(0.19)	(0.19)
Chronic disease	0.48	0.51	0.44	0.46
	(0.50)	(0.50)	(0.50)	(0.50)
Experiences of flooding	4.23	4.23	2.49	2.49
	(2.34)	(2.36)	(2.22)	(2.22)
Population density	1961.93	1967.89	4830.38	4847.79
	(1673.97)	(1688.64)	(6620.50)	(6621.04)
# of medical personnel per 100,000	953.21	1140.31	777.25	969.15
	(1141.68)	(1186.98)	(707.75)	(816.95)

Note: Standard deviations are in parentheses.

Morakot. We also traced the health care utilization of patients in the control group from 7 August 2008–7 August 2010. If a patient moves to another district/township, he/she is still in the treatment/control group. The reason is that if these patients keep utilizing health care services, we can still trace their health care utilization by individual ID in the LHID data set. Thus, the problem of migration is relatively limited in this study. Third, after selecting the patients who live in the districts/townships hit by flooding due to Typhoon Morakot, we used the ICD-9-CM codes to identify the patients who have outpatient (inpatient) records due to flood-related diseases in the treatment group and aggregated outpatient (inpatient) records to individual monthly outpatient (inpatient) expenditures and visits (stays) data.

3. Methodology

Using the information regarding the background of the individuals before the flood and the trends in non-flooding areas, we employed the following the DID equation to estimate the causal impact of flooding on the variables of interest while controlling the effects of demographic variables and characteristics of districts/townships[5]:

$$Y_{ijt} = \beta_0 + \beta_1 DID_{it} + \beta_2 Treatment_{it} + \beta_3 Post_{it} + \beta_4^{'} X_{it} + \beta_5^{'} Z_{jt} + \delta_j + \varepsilon_{ijt} \quad (1)$$

where Y_{ijt} represents the ratios of flood-related outpatient (inpatient) expenditures from the total outpatient (inpatient) expenditures at patient i, district/township j, and period t.[6] Flood-related health care expenditure is defined as the outpatient (inpatient) care expenditures due to flood-related physiological diseases and disaster-related mental illnesses. Flood-related outpatient visits (inpatient stays) are defined as outpatient visits (inpatient stays) due to flood-related physiological diseases and disaster-related mental illnesses.[7] *DID* represents the interaction variable between *Treatment* and *Post* (*Treatment* × *Post*). *Treatment* denotes whether an individual lived in the districts or townships that were flooded during the typhoon, whereas *Post* denotes the dummy variable representing the period after the typhoon. This study defines the pre-period as one year before the flood caused by the typhoon (i.e., a one-year period before August 8, 2009) and the post-period as a year after the flood (i.e., a one-year period after August 8, 2009). To examine the relatively long-term effect of a major disaster, we also traced the health care utilization of patients with mental illnesses over two years after the flood. In the second-year estimation, the post-period refers to the second year after the flood (i.e., from August 2010 to August 2011).

[5] Most studies that have estimated the health effects of floods by conducting surveys do not have data regarding victims' health status before floods. Therefore, these studies could not compare data obtained before and after floods to identify the health effect of floods on victims.

[6] Because the monetary value of flood-related and non-flood-related outpatient (inpatient) expenditures may decrease or increase simultaneously, we used the expenditure ratios of flood-related expenditures from total outpatient (inpatient) records as outcome variables.

[7] The ratios of flood-related outpatient expenditures (visits) is equal to the flood-related outpatient expenditures (visits) divided by total outpatient expenditures (visits) for each patient. The ratios of flood-related inpatient expenditures (stays) is equal to the flood-related inpatient expenditures (stays) divided by total inpatents expenditures (stays) for each patient.

Table 2
Sample statistics of main variables for patients with disaster-related mental illnesses from outpatient care.

	Treatment group		Control group	
	Pre-period	Post-period	Pre-period	Post-period
First Year				
	N = 29,680	*N = 29,680*	*N = 39,363*	*N = 39,393*
Exp. ratio	0.2034	0.2009	0.2055	0.2028
	(0.2632)	(0.2598)	(0.2634)	(0.2602)
Visit ratio	0.1747	0.1762	0.1787	0.1777
	(0.219)	(0.2192)	(0.2203)	(0.2182)
Age	52.75	53.72	51.41	52.35
	(17.26)	(17.24)	(17.02)	(17.02)
Male	0.63	0.63	0.64	0.64
	(0.48)	(0.48)	(0.48)	(0.48)
Employed	0.80	0.80	0.78	0.78
	(0.40)	(0.40)	(0.41)	(0.41)
Low income	0.01	0.01	0.01	0.01
	(0.11)	(0.11)	(0.12)	(0.12)
Major illness	0.03	0.02	0.03	0.03
	(0.15)	(0.16)	(0.16)	(0.16)
Chronic disease	0.01	0.01	0.01	0.01
	(0.12)	(0.12)	(0.12)	(0.12)
Second Year				
	N = 26,477	*N = 26,477*	*N = 35,192*	*N = 35,192*
Exp. ratio	0.1923	0.1348	0.1961	0.1384
	(0.2547)	(0.2265)	(0.2544)	(0.2295)
Visit ratio	0.1633	0.1257	0.1681	0.1296
	(0.2087)	(0.2058)	(0.2103)	(0.208)
Age	53.14	54.92	51.76	53.52
	(17.04)	(17.12)	(16.77)	(16.82)
Male	0.64	0.64	0.64	0.64
	(0.48)	(0.48)	(0.48)	(0.48)
Employed	0.82	0.82	0.80	0.80
	(0.39)	(0.39)	(0.40)	(0.40)
Low-income	0.01	0.02	0.01	0.02
	(0.12)	(0.14)	(0.12)	(0.16)
Major illness	0.02	0.10	0.02	0.10
	(0.15)	(0.30)	(0.15)	(0.31)
Chronic disease	0.01	0.01	0.01	0.01
	(0.11)	(0.11)	(0.12)	(0.12)

Note: Standard deviations are in parentheses.

Table 3
Estimates of OLS regression for patients with flood-related physiological diseases from outpatient expenditures and visits.

	Exp. Ratio		Visit Ratio	
Specification	(1)	(2)	(1)	(2)
Outpatient Care				
DID	0.0030 * *	0.0031 * *	0.0029 *	0.0024
	(0.0014)	(0.0014)	(0.0015)	(0.0015)
Post	-0.0064 * **	-0.0046 * *	-0.0049 * *	0.04910 * **
	(0.0010)	(0.0021)	(0.0024)	(0.0029)
Treatment	0.0025 *	0.1850 *	0.0934	0.0025
	(0.0014)	(0.102)	(0.0911)	(0.0045)
District/Township Dummies	N	Y	N	Y
N	318,780	318,780	318,780	318,780

Note: Suppressed controls include a set of individual control variables (such as age, sex, and whether the individual is employed, is a civil servant, is from a low-income family, has a major illness or a chronic disease) and district/township control variables (such as population density, the number of flooding experiences, the population ratio with college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average household income, population ratios in industrial and commercial services, whether the district/township has experienced landslide disasters, and the interaction between flooding and landslides). Standard errors clustered at the district/township level are in parentheses. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

X_{it} is a set of individual control variables, including age, sex, and information regarding whether an individual is employed, is a civil servant, is from a low-income family, or has a major illness or chronic disease. Z_{jt} is a vector of district/township control variables, including population density, the number of flooding experiences (the frequency of flooding from 2000 to 2009), the ratio of the population with a college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average

Table 4
Estimates of OLS regression for patients with disaster-related mental illnesses from outpatient expenditures and visits.

	Exp. Ratio		Visit Ratio	
Specification	(1)	(2)	(1)	(2)
First Year				
DID	0.0214 * **	0.0235 * **	0.0125 * *	0.0169 * **
	(0.0024)	(0.0027)	(0.005)	(0.0054)
Post	0.0001	0.0487 * **	-0.0006	0.0554 * **
	(0.0033)	(0.0047)	(0.0034)	(0.0044)
Treatment	3.201 * **	0.0717	2.538 * **	0.0555
	(0.586)	(0.357)	(0.749)	(0.56)
City/Township Dummies	N	Y	N	Y
N	138,086	138,086	138,086	138,086
Second Year				
DID	0.0211 * **	0.0180 * **	0.0179 * **	0.0155 * **
	(0.0028)	(0.0041)	(0.0044)	(0.0059)
Post	-0.0811 * **	0.119 * **	-0.0596 * **	0.0978 * **
	(0.0042)	(0.0059)	(0.0039)	(0.0053)
Treatment	1.83 * **	-0.151	-0.563 * *	1.67 * *
	(0.751)	(0.169)	(0.243)	(0.755)
District/Township Dummies	N	Y	N	Y
N	123,338	123,338	123,338	123,338

Note: Suppressed controls include a set of individual control variables (such as age, sex, and whether the individual is employed, is a civil servant, is from a low-income family, has a major illness or a chronic disease) and district/township control variables (such as population density, the number of flooding experiences, the population ratio with college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average household income, population ratios in industrial and commercial services, whether the district/township has experienced landslide disasters, and the interaction between flooding and landslides). Standard errors clustered at the district/township level are in parentheses. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

household income, population ratios working in industrial and commercial services, and whether the district/township experienced landslides. δ_j denotes the district/township fixed effect. Standard errors are clustered at the district/township level.

One important assumption for adopting the DID method is that the time trends of health care utilization and expenditures in the treatment and control districts/townships are the same in the pre-period. A graphical analysis was used to verify this assumption. For robustness check, we used leukemia, coronary heart diseases, and gastric cancer as a placebo test.

4. Results

Fig. 1 presents the treatment and control regions from nine cities/counties experiencing flooding due to Typhoon Morakot. Approximately 15% of the total population of Taiwan lives in treatment districts or townships. Tables 1 and 2 summarize the statistics of the main variables in the outpatient sample. Compared with patients in the control group, those in the treatment group had more experiences of flood-inflicted damage. The population density of treatment districts/townships was lower than that of the control ones, suggesting that areas prone to floods tend to be relatively small districts/townships. The average number of medical personnel per 100,000 people in the treatment group was slightly higher than that of the control group. The distributions of age and sex were similar between the treatment and control groups.

Tables 3 and 4 report the estimated coefficients of Eq. (1). Table 3 presents coefficient estimates for physiological diseases, whereas Table 4 presents coefficient estimates for mental illnesses. To investigate whether our results are sensitive to the alternative specifications of the regression model, specification (1) presents results without district/township dummy variables, but specification (2) presents results while including district/township dummy variables. Our results indicate that Typhoon Morakot caused an increase in outpatient expenditures and visits for flood-related physiological diseases and mental illnesses. This expenditure-increasing effect for physiological diseases was lower than that for mental illnesses, which may be due to the timely environmental cleaning after the typhoon struck.

With respect to inpatient care, Table A1 and Table A2 provide the results of inpatient expenditures and stays from flood-related physiological diseases and mental illnesses, respectively. The DID estimates were not significant, suggesting that flooding does not significantly affect inpatient health care costs. A plausible explanation is that individual may visit a physician immediately before progression from non-sever to severe disease, because of the convenient accessibility of health care services under the NHI program. Thus, we focus on the results of outpatient care in the rest of this study.

As shown in Table 3, the coefficients of the DID variables were significantly positive for expenditure and visit ratios of flood-related physiological diseases after fully controlling for the effect of other factors. In specification (2) of Table 3, the coefficient estimates of the DID variables for the expenditure and visit ratios were 0.0031 and 0.0024 respectively, in our study sample, indicating that the flood led to an increase of 0.31 (0.24% points in the expenditure (visit) ratio for flood-related physiological diseases, after controlling for

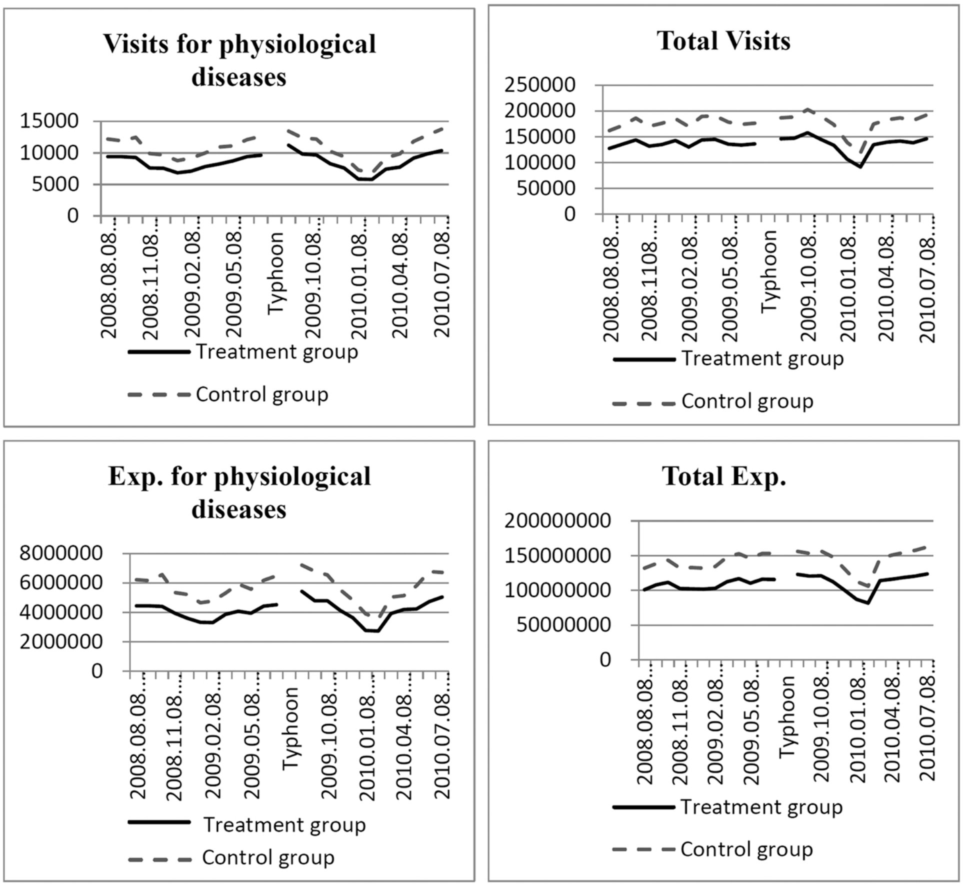

Fig. 2. Time trends of outpatient expenditures and visits for flood-related physiological diseases from August 2008 to August 2010. *Note:* The x-axis shows the study period (year-month-day).

other factors. The total NHI outpatient care expenditure (excluding traditional Chinese medicine and dental care) was nearly NTD 338 billion (approximately USD 11 billion) in 2016 (Ministry of Health and Welfare, 2016), implying that the flood increased health care expenditures related to flood-related physiological diseases by approximately NTD 1.05 billion (approximately USD 33 million).[8]

Regarding disaster-related mental illnesses, Table 4 indicates that the coefficient estimates of the DID variables were positive and statistically significant both in the first- and second-year periods. Moreover, in the first-year panel of Table 4 for specification (2), it can be seen that the flood led to an increase of 2.35 (1.69) percentage points in the expenditure (visit) ratio related to mental illnesses during this period. Through the same calculation process, we deduced that the flood increased health care expenditures related to mental illnesses by nearly NTD 7.9 billion (approximately USD 247 million).[9] Comparing the estimated coefficients of the DID variables between physiological diseases and mental illnesses, the increase in outpatient health care costs for mental illnesses caused by flooding was nearly 10 times that for physiological diseases. This finding suggests that using specialized mental health services to enhance resilience and wellness among people who have experienced disasters is also an important post-flood recovery measure.

Combining the estimation coefficients of flood-related physiological diseases and disaster-related mental illnesses, the increase in outpatient health care costs caused by flooding due to Typhoon Morakot is approximately NTD 8.95 (7.9 + 1.05) billion (nearly USD 280 million). Compared with the special budget allotted for flooding prevention from 2006 to 2019, which is more than NTD 13 billion per year,[10] the flood caused by Typhoon Morakot led to a fairly sizable outpatient health care cost burden, which is equivalent to

8 NTD 0.8 billion = 338 billion × 0.0024. The exchange rate in 2016 was around USD 1 = NTD 32.

9 NTD 7.9 billion = 338 billion × 0.0235.

10 To counter damages inflicted by floods in land subsidence, low-lying, and suburban areas, two special budgets that are not subjected to the debt ceiling were spent and ratified. The Regulation Project of Flood-Prone Areas cost NTD 116 billion from 2006 to 2013. The Comprehensive River Basin Management Plan cost NTD 66 billion from 2014 to 2019. Another special budget, the budget for the Forward-looking Infrastructure Development Program, was initiated in 2017, and a part of it was to be used for flood reduction, which cost NTD 79 billion from 2017 to 2020. In addition to the special budget, the official budget of the Water Resource Agency, which is in charge of flood reduction in major rivers, was approximately NTD 14 billion in 2017.

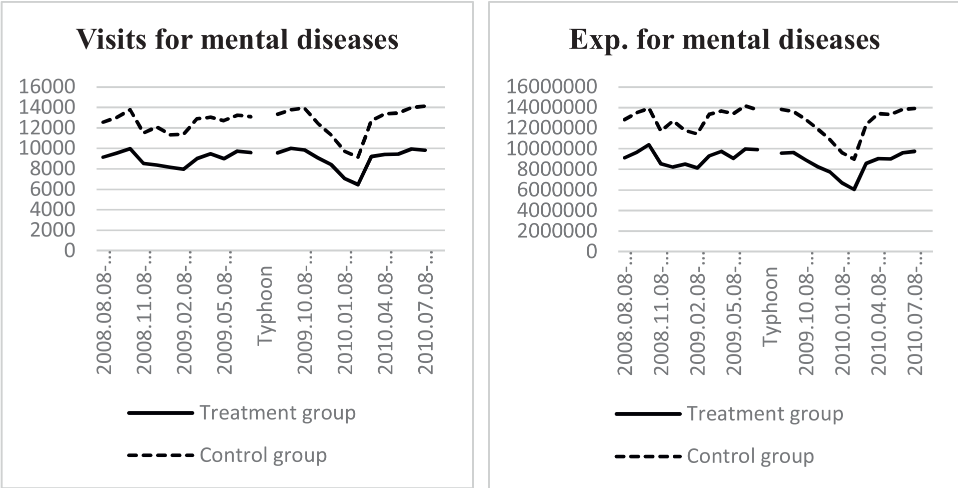

Fig. 3. Time trends of outpatient expenditures and visits for disaster-related mental illnesses from August 2008 to August 2010. *Note:* The x-axis shows the study period (year-month-day).

Table 5
Estimates of OLS regression for patients with leukemia, coronary heart diseases, and gastric cancer from outpatient expenditures and visits (placebo test).

	Exp. Ratio		Visit Ratio	
Specification	(1)	(2)	(1)	(2)
Leukemia				
DID	0.4138	-0.0668	-0.5548	-0.0729
	(2.1870)	(0.1342)	(2.6122)	(0.1600)
N	828	828	828	828
Coronary heart diseases				
DID	-0.0015	-0.0014	-0.0015	-0.0015
	(0.0028)	(0.0029)	(0.0026)	(0.0028)
N	61,189	61,189	61,189	61,189
Gastric cancer				
DID	-0.0014	-0.0030	0.0014	0.0024
	(0.0258)	(0.0278)	(0.0227)	(0.0249)
N	1203	1203	1203	1203
District/Township Dummies	N	Y	N	Y

Note: Suppressed controls include a set of individual control variables (such as age, sex, and whether the individual is employed, is a civil servant, is from a low-income family, has a major illness or a chronic disease) and district/township control variables (such as population density, the number of flooding experiences, the population ratio with college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average household income, population ratios in industrial and commercial services, whether the district/township has experienced landslide disasters, and the interaction between flooding and landslides). Standard errors clustered at the district/township level are in parentheses. * denotes significance at the 10% level; ** denotes significance at the 5% level; *** denotes significance at the 1% level.

approximately 69% of the annual special budget for flood prevention.[11] A noteworthy point is that this estimate ignores the cost of other symptoms that do not result in seeking health care or health care episodes that cannot be directly attributed to floods due to the lack of available data regarding factors, such as injuries, likely underestimating the full health care costs of flooding.

In the panel of the second-year period shown in Table 4, the coefficient estimates of the DID variables were positive and statistically significant both for the expenditure and visit ratios related to disaster-related mental illnesses. As reported in specification (2), the flood led to an increase in the expenditure (visit) ratio by approximately 1.80 (1.55) percentage points. This positive effect in the second-year period may be due to the survivors' anniversary reaction to a major catastrophe, as mentioned by Assanangkornchai et al. (2007). Nevertheless, compared with the magnitude of the effect in the first-year period, the increase in the expenditure (utilization) related to mental illnesses caused by the flood is lower in the second-year period than in the first-year period.

[11] 69% = (8.95/13) × 100.

4.1. Robustness check

Figs. 2 and 3 illustrate that the treatment district/township group exhibited a pattern of expenditures and visits similar to the control group one year before the flood in August 2009, to a large extent, indicating that the causal effects were identified in our findings.[12] We also performed a placebo test by examining whether the flood affected outpatient health care expenditures or visits for a disease unrelated to floods. By selecting leukemia, coronary heart diseases, and gastric cancer as examples, as shown in Table 5, we found that the relevant estimates of placebo tests were insignificant, which suggests that our primary findings are driven by floods rather than by some unobservable variables.[13] The robustness tests indicate that our results do not suffer from the problem of selection bias.

5. Conclusion

In this paper, we used Typhoon Morakot as an example to investigate the health care cost effect induced by floods due to extreme rainfall. Based on the NHI sampling claims data that include three million patients between 2008 and 2011, we employed the DID method to estimate the causal effect of flooding by comparing differences between districts/townships affected by the flood (treatment group) and districts/townships unaffected by the flood (control group), as well as the difference between the pre-period and post-period of the disaster. Focusing on flood-related physiological and disaster-related mental diseases, our results indicate that floods have increased the outpatient expenditures and visits for these diseases. In particular, health care costs induced by the flood resulting from the typhoon are equivalent to approximately 69% of the annual special budget for flood prevention during the period 2006–2019. Moreover, the increase in expenditure (utilization) for mental illnesses caused by floods is significantly greater than that of physiological diseases.

Our results suggest that although the prevention of natural disasters results in a cost burden, these costs can be offset by savings in health care expenditures. In addition, our findings indicate that the cost effect from mental illnesses is relatively salient. This finding is consistent with previous studies that indicate flooding results in a prolonged and profound effect on mental health deterioration. Therefore, in addition to providing safe drinking water and indoor residual spraying, offering continuous post-disaster mental health services is an important avenue to save health care expenditures caused by natural disasters.

This study has two limitations. First, as the NHI program in Taiwan is well established and health care services are highly accessible, our findings may not be generalized to countries where the benefit package of the NHI program is less comprehensive. Second, our results focus on the one-year effects of flooding on health care expenditures and visits. The shock of a sudden natural disaster may affect the frailest individuals at the very beginning, resulting in a higher incidence of flood-related diseases in the short term (Karlsson and Ziebarth, 2018; Luy et al., 2020). Thus, the higher flood-related health care expenditures after Typhoon Morakot may be partially due to this "harvesting effect," likely resulting in the temporary increase on health care expenditures. However, because our study period is one year for physiological diseases and two years for mental illness after flooding, the potential impact from the harvesting effect may be limited due to the relatively long-term study period in our estimation.

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Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Data availability

The authors do not have permission to share data.

Appendix: ICD-9-CM for Diseases in This Study

The International Classification of Diseases, 9th Revision, Clinical Modification was used to screen primary diagnoses to identify whether samples were infected with flood-related diseases. The flood-related diseases are categorized as follows:

[12] Because this study estimates the total health care cost instead of per capita, we show the summation of health care expenditures in Figs. 2 and 3.

[13] The ICD-9-CM codes for leukemia include 204–208. ICD-9-CM codes for coronary heart diseases include 410–414. ICD-9-CM code of gastric is 151.

Table A1
Estimates of OLS regression for patients with physiological diseases from inpatient expenditures and stays.

	Exp. Ratio		Stay Ratio	
Specification	(1)	(2)	(1)	(2)
DID	0.0158	0.0179	0.0189	0.0189
	(0.0241)	(0.0245)	(0.0205)	(0.0211)
Post	-0.0327	-0.0030	-0.0315 *	-0.0053
	(0.0209)	(0.0393)	(0.0175)	(0.0352)
Treatment	0.0182	-8.247	0.0128	-9.035
	(0.0200)	(8.4130)	(0.0170)	(6.7910)
City/Township Dummies	N	Y	Y	Y
N	3508	3508	3508	3508

Note: Suppressed controls include a set of individual control variables (such as age, sex, and whether the individual is employed, is a civil servant, is from a low-income family, has a major illness or a chronic disease) and district/township control variables (such as population density, the number of flooding experiences, the population ratio with college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average household income, population ratios in industrial and commercial services, whether the district/township has experienced landslide disasters, and the interaction between flooding and landslides). Standard errors clustered at the district/township level are in parentheses. * denotes significance at the 10% level; * * denotes significance at the 5% level; * ** denotes significance at the 1% level.

Table A2
Estimates of OLS regression for patients with mental illness from inpatient expenditures and stays.

	Exp. Ratio		Stay Ratio	
Specification	(1)	(2)	(1)	(2)
First Year				
DID	-0.0285	-0.0345	-0.0536	-0.0622
	(0.0297)	(0.0315)	(0.0570)	(0.0684)
Post	0.0232	0.0169	0.0422 * *	0.0266
	(0.0200)	(0.0510)	(0.0191)	(0.0465)
Treatment	0.0566 * *	-1.251 * **	0.0610 * **	-0.767 *
	(0.0220)	(0.441)	(0.0211)	(0.460)
City/Township Dummies	N	Y	Y	Y
N	3508	3508	3508	3508
Second Year				
DID	-0.0256	-0.0246	-0.0468	-0.0412
	(0.0276)	(0.0285)	(0.0437)	(0.0346)
Post	0.00484	0.0467	0.0101	0.0305
	(0.0192)	(0.0424)	(0.0184)	(0.0401)
Treatment	0.0362	-1.145 * **	0.0449 * *	-1.366 * **
	(0.0223)	(0.176)	(0.0194)	(0.145)
District/Township Dummies	N	Y	N	Y
N	1045	1045	1045	1045

Note: Suppressed controls include a set of individual control variables (such as age, sex, and whether the individual is employed, is a civil servant, is from a low-income family, has a major illness or a chronic disease) and district/township control variables (such as population density, the number of flooding experiences, the population ratio with college degree, the elderly population ratio, the number of medical personnel per 100,000 people, average household income, population ratios in industrial and commercial services, whether the district/township has experienced landslide disasters, and the interaction between flooding and landslides). Standard errors clustered at the district/township level are in parentheses. * denotes significance at the 10% level; * * denotes significance at the 5% level; * ** denotes significance at the 1% level.

Flood-related physiological diseases

1. Vector-borne diseases: Dengue fever (061), malaria (084), schistosomiasis (120), mosquito-borne viral encephalitis (062), arthropod-borne hemorrhagic fever (065), and other arthropod-borne viral diseases (066).
2. Water-borne diseases: Melioidosis (025) and leptospirosis (100).
3. Rodent-borne diseases: Plague (020), louse-borne (epidemic) typhus (080), other typhus (081), and Lyme disease (08881).
4. Flood-related eye diseases: Trachoma (076), acute conjunctivitis (3720), infective dermatitis of eyelid of types resulting in deformity (3734), other infective dermatitis of eyelid (3735), and parasitic infestation of eyelid (3736).
5. Flood-related skin diseases: Dermatophytosis (110), dermatomycosis, other and unspecified (111), acariasis (133), carbuncle and furuncle (680), cellulitis and abscess of finger and toe (681), other cellulitis and abscess (682), impetigo (684), other local infections of skin and subcutaneous tissue (686), and rash and other nonspecific skin eruption (7821).
6. Flood-related gastrointestinal tract diseases: Cholera (001), typhoid and paratyphoid fevers (002), other salmonella infections (003), shigellosis (004), amebiasis (006), other protozoal intestinal diseases (007), intestinal infections due to other organisms (008), gastritis and duodenitis (535), regional enteritis (555), toxic gastroenteritis and colitis (5582), peritonitis (567), and unspecified disorder of peritoneum (5689).

Disaster-related mental illnesses

Mental illnesses: Anxiety (300), depression (296), and post-traumatic stress disorder (309.81).

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