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Understanding the effects of past flood events and perceived and estimated flood risks on individuals' voluntary flood insurance purchase behavior

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ABSTRACT

Over the past several decades, the economic damage from flooding in the coastal areas has greatly increased due to rapid coastal development coupled with possible climate change impacts. One effective way to mitigate excessive economic losses from flooding is to purchase flood insurance. Only a minority of coastal residents however have taken this preventive measure. Using original survey data for all coastal counties of the United States Gulf Coast merged with contextual data, this study examines the effects of external influences and perceptions of flood-related risks on individuals' voluntary behaviors to purchase flood insurance. It is found that the estimated flood hazard conveyed through the U.S. Federal Emergency Management Agency's (FEMA's) flood maps, the intensities and consequences of past storms and flooding events, and perceived flood-related risks significantly affect individual's voluntary purchase of flood insurance. This behavior is also influenced by home ownership, trust in local government, education, and income. These findings have several important policy implications. First, FEMA's flood maps have been effective in conveying local flood risks to coastal residents, and correspondingly influencing their decisions to voluntarily seek flood insurance in the U.S. Gulf Coast. Flood maps therefore should be updated frequently to reflect timely and accurate information about flood hazards. Second, policy makers should design strategies to increase homeowners' trust in the local government, to better communicate flood risks with residents, to address the affordability issue for the low-income, and better inform less educated homeowners through various educational programs. Future studies should examine the voluntary flood insurance behavior across countries that are vulnerable to flooding.

1. Introduction

Climate change is one of the most pressing issues facing society (IPCC, 2013). The coastal region is especially vulnerable to various adverse impacts of climate change such as rising sea level, increasing hurricane activity, more severe flooding, coastal erosion, and ocean acidification (Wong et al., 2014; Aerts et al., 2014). To further complicate matters, there is a general trend of population movement to the coastal area. In the United States alone, more than 1.2 million people move to the coast annually, as a result of which more than half of the U.S. population (164 million) currently reside in densely populated coastal areas with concentrating development and enormous infrastructures (Moser et al., 2014). Coastal counties in the U.S. have witnessed a higher population increase (84.3 percent) than non-coastal counties (64.3 percent) during the period of 1960–2008 (Wilson and Fischetti, 2010). There is some evidence that the coastal population growth is likely to continue in decades to come (NOAA, 2013).

The concentrations of coastal population and properties coupled with a changing climate have become one of the major contributors

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to a dramatic rise in economic losses incurred by natural hazards (Pielke et al., 2008; Estrada et al., 2015; Hallegatte, 2015). Among all natural hazards, flood is the most costly and has affected most people (Michel-Kerjan, 2015; Michel-Kerjan et al., 2015; Michel-Kerjan and Kousky, 2010; Perry, 2000). The number of Presidential Declarations associated with floods in the United States has risen substantially over the past 50 years (Kunreuther, 2015). Flood inundation poses enormous risks to human lives and structures, and causes substantial property damages (Hatzikyriakou et al., 2015; Perry, 2000). The hurricane-induced coastal flooding is predicted to be more frequent and intensive in many coastal megacities in the future (Lin and Emanuel, 2015; Lin et al., 2016).

Faced with the enormous threat posed by flooding, it would be sensible for people in flood-prone areas to undertake some preventative actions such as purchasing flood insurance. In reality, however, only a minority of coastal residents have flood insurance. Despite the insurance discount provided, participation rates in the National Flood Insurance Program (NFIP) are quite low (Petrolia et al., 2013). For instance, as many as 80 percent of the residents affected by flooding caused by Superstorm Sandy in 2012 had no flood insurance (Michel-Kerjan et al., 2015). Homeowners who live in a Special Flood Hazard Area[2] (SFHA) are required to buy flood insurance if receiving mortgages from a federally backed or regulated lender in the U.S. However, some evidence suggests that this requirement is not strictly enforced (Dixon et al., 2006; Kriesel and Landry, 2004; Landry and Jahan-Parvar, 2011). The rate of compliance to the requirement is 75–80% in the U.S. (Dixon et al., 2006). Moreover, market penetration for flood insurance is not evenly distributed geographically. For instance, the average flood insurance take-up rate among all counties along the U.S. Gulf Coast is 24.9 percent, with Aransas, Texas having the highest rate (81.28%) and Mobile, Alabama the lowest rate (2.53%) based on FEMA's insurance policy statistics by state (FEMA, 2016). The inadequate participation rate and uneven distribution of NFIP raise an essential question: what motivate people to purchase flood insurance?

The Biggert-Waters Flood Insurance Reform, signed into law in 2012, aimed to price insurance premiums in the NFIP to reflect the actual risk. However, the implementation of this reform has been delayed due to the passage of Homeowner Flood Insurance Affordability Act of 2014. Policy makers' main concern is that the drastic increase in premium would further reduce individuals' motivation to purchase insurance and raise the issue of affordability among many low-income homeowners. It is therefore important for policy makers to understand individual's self-motivation to purchase flood insurance especially in cases where having flood insurance is not mandatory. Such an understanding would provide policy makers with insightful information that can be utilized to design specific policies that can motivate more homeowners to buy flood insurance and accordingly increase participation rates especially when risk-based premium is charged. This information may also be utilized to design effective subsidizing programs (Kousky and Kunreuther, 2014) to address the affordability issue.

Several studies have examined the factors that drove people to buy flood insurance. Some analyses were based on aggregated data to understand the flood insurance demand and purchase at the county or state level (Atreya et al., 2015; Browne and Hoyt, 2000; Kousky, 2011; Dixon et al., 2006). For example, Atreya et al. (2015) examined the effects of social factors and recent events on flood insurance take-up rates for counties in Georgia, U.S. Browne and Hoyt (2000) found a significant correlation between the state-level flood insurance purchases and flood loss of the state in the prior year. These studies revealed some important information at the aggregate level. However, the relationships at the aggregate level may not necessarily remain at the individual level (Gelman, 2009). Therefore, more studies based on individual-level data are needed.

Indeed, a few studies utilized individual-level data. These existing studies based on individual-level data, however, have typically focused on relatively small areas in different regions. Specifically, Michel-Kerjan and Kousky (2010) examined the variation among flood insurance buyers of different occupation types and the amount of insurance coverage based on policy-in-force data in Florida, U.S. Hung (2009) studied the attitudes of homeowners towards flood insurance purchase in Keelung River Basin of Taiwan. Brody et al. (2016) investigated the motivation to buy flood insurance outside the 100-year floodplain by focusing on four localities in Texas and Florida, US. Lo (2013a,b) explored the relationship between having flood insurance and perceptions of social expectations in Brisbane, Australia. Oulahen (2015) conducted a case study in Metro Vancouver, Canada, to examine how attitudes toward flood insurance determined residential vulnerability to flood hazards. The local foci of these studies have led to some inconsistent conclusions as to what drives flood insurance purchase behavior. Studies based on larger data samples covering larger study areas and including more diverse populations are needed to further explore factors that influence flood insurance purchase behavior. Some scholars have attempted to encompass larger study areas. For instance, Petrolia et al. (2013) examined the relationships between risk perceptions and preferences on the one hand, and holding flood insurance policy on the other in the U.S. Gulf Coast and Florida's Atlantic Coast. This study found the significant effect of risk preferences on flood insurance purchase.

Kunreuther and Slovic (1978) pointed out the importance of studying the voluntary public involvement in protecting society from natural hazards. In terms of flood insurance, it is particularly crucial to understand the voluntary motivation of individuals' involvement. The recent efforts to reform the U.S. NFIP and resistance to raising premiums to reflect actual risks make studies exploring determinants of voluntary flood insurance purchase behavior even more timely and promising. Only a few studies, however, have examined factors shaping the voluntary purchase of flood insurance. Among these studies, Lo (2013a,b) found that social norms played an essential role in determining voluntary adoption of flood insurance. Brody et al. (2016) found that voluntary purchase decisions were positively associated with long-time residence, higher value of homes, better education, perceptions of infrequent flood hazards and flood insurance affordability. These studies, however, focused on one or two angles, e.g. social-demographic factors or flood risk perception, without considering how the flood hazard estimated by policy makers would influence individual voluntary behavior to purchase flood insurance.

More studies are nevertheless needed to understand this voluntary purchase behavior. The influences of social-demographic factors and perception of flood-related risk need to be further studied with a larger data sample. Moreover, the surrounding environment consisting of both social and physical contexts has a significant impact on individuals' behaviors (Stern, 2000). To illustrate, the vulnerability to flooding in one's residence may heighten risk perceptions and correspondingly leads to proactive actions. Meanwhile, one's flood insurance purchase behavior may influence others who reside in the same community.

Our study is the first to examine the relationship between socio-demographic characteristics, individuals' perceived flood-related

[2] SFHA refers to 100-year floodplain area where the mandatory purchase of flood insurance may apply; The SFHA includes various flood zones such as coastal flood hazard zones AE zone (subject to storm surge flooding) and VE zone (subject to storm surge and significant wave).

risks, objective measures of past flood events, and government's estimated flood hazards, on the one hand, and the voluntary purchase of flood insurance, on the other. In particular, our study is the first to examine whether flood hazards reflected in FEMA's flood maps can influence individuals to purchase flood insurance voluntarily. The results will provide policy makers with insights into factors of coastal residents' voluntary behaviors to purchase flood insurance, which will correspondingly help them design more effective strategies and mechanisms to communicate actual flood risks with the public, and motivate them to mitigate economic losses from catastrophic floods in the future.

2. Data and methods

The individual-level variables are constructed based on the 2012 Gulf Coast Climate Change Survey, which was designed to understand coastal residents' perceptions of local effects of climate change, and the residents' willingness to take personal actions and to support local climate policies to adapt to climate change in the U.S. Gulf Coast (Goidel et al., 2012). The survey utilized a stratified random sampling strategy drawing independent samples across and within states including Texas, Louisiana, Mississippi, Alabama, and Florida. Data was collected by landline telephone from January 3 through April 4, 2012. The number of respondents was 3856; the response rate in this survey was 17.6 percent. The objective data include surge data from SURGEDATA (Needham and Keim, 2012), property damage data from Storm Events Database of the National Climate Data Center (NCDC), and flood maps from FEMA. More details are provided in the next section.

2.1. Dependent variables

The two dependent variables are based on responses to two survey questions. The two questions are “do you have flood insurance?” and “do you have flood insurance to feel safer or because it is required?” FEMA requires homeowners who reside in the SFHA and receive mortgages from a lender that is federally backed or regulated to purchase flood insurance. The lender requires borrowers (homeowners) to pay flood insurance along with monthly mortgage payment.

To the first question, 48.7% responded “Yes.” and 48.8% responded “No.” and the rest replied “Don't know.” The percentage of respondents in the survey who have flood insurance per county is shown in Fig. 1. The second question targeted those respondents who answered “Yes” to the first question and explored the reasons for their purchase of flood insurance. Three responses were provided for the second question, “required.” “safer.” and “both.” for the second question. The response “both” indicates that residents buy flood insurance both because it is required and they want to feel safer. The percentage of respondents in each category is shown in Fig. 2. Among the respondents who hold flood insurance, half purchase flood insurance only to feel safer. The rest of the respondents with flood insurance are required to buy (those who answered “required” or “both”). Among the people who are required to buy flood insurance, half do so out of voluntary motivation to feel safer (those who answered “both”). Based on the information provided by the two survey items, two dependent variables are created.

The first dependent variable includes two categories: people without flood insurance indicated by “0.” and those who have flood insurance only because it makes them feel safer, represented by “1.”The behavior of those who buy flood insurance to feel safer is purely voluntary because their purchase behavior was not influenced by the requirement. Therefore, the first dependent variable differentiates homeowners without flood insurance from those who buy flood insurance entirely out of voluntary motivation. In terms of the second dependent variable, respondents who responded “safer” are combined with those who responded “both” to the second question. “Both” indicates that the reasons for their flood insurance purchase are both the requirement and their wish to feel safer. Different from the group of people who responded “safer”, people who responded “both” are required to buy flood insurance. However, this behavior is also driven by some degree of voluntary motivation to protect themselves from flood loss. The second variable differentiates those with no flood insurance from those who purchase flood insurance out of totally and partially voluntary motivations altogether. The inclusion of the second dependent variable enables this study to investigate whether the significance of explanatory factors in the series of models on the first dependent variable remains when people who are partially driven by voluntary motivations are added.

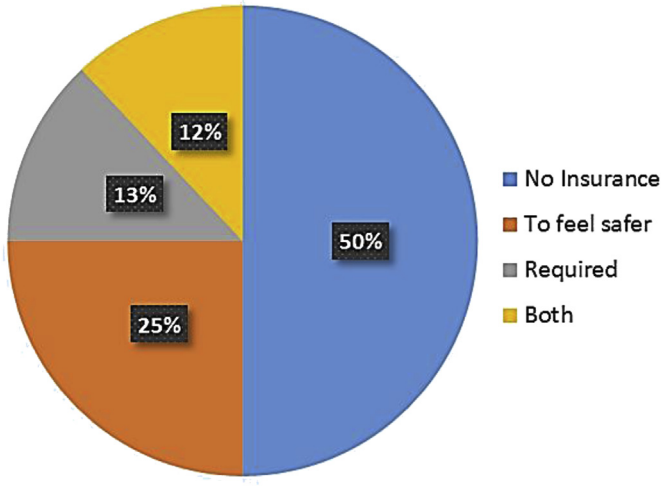

Fig. 1. Proportion of respondents in each flood insurance category (i.e. 1. Without insurance; 2. They buy insurance only to feel safer; 3. They buy insurance as they know that they are required; 4. They buy insurance both because to feel safer and they know they are required).

2.2. Independent variables

The individual-level independent variables, including socio-demographic features, home ownership, distance from the coast (self-reported), trust in the local government and flood-related risk perceptions, are all constructed based on survey items. Table 1 demonstrates how these variables are coded and the frequencies and percentages of each category within each variable. It should be noted that regression diagnostics for multicollinearity are conducted among all the individual-level independent variables. None of the variance inflation factors (VIFs) are sufficiently large to indicate that multicollinearity is a matter of concern in our study.

The contextual variables include spatial information about flood hazards estimated by FEMA, peak height of storm surge from the most recent hurricane landfall, and economic damages from the most recent and most impacted flooding events, respectively. They are all at county-level. Flood hazards are indicated by the percentages of SFHA (100-year flood zones: A zones plus V zones) and high coastal flood risk VE zone per county, which are calculated based on FEMA's flood maps. The 100-year flood A and V zones refer to areas that would be inundated by a flood event with the chance of one percent every year. VE zones represent areas that are located in the proximity of the coast and are vulnerable to both storm surge induced flooding and waves. Thus, the percentages of

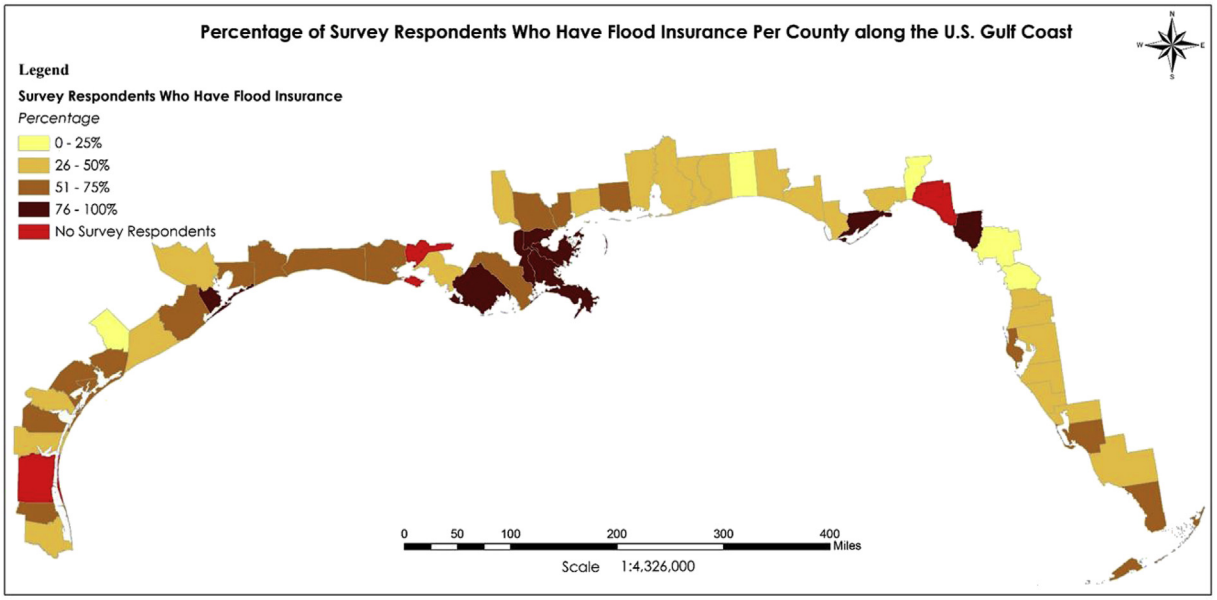

Fig. 2. The spatial distribution of percentage of survey respondents who have flood insurance per county along the U.S. Gulf Coast.

the SFHA and VE zone per county can indicate varying levels of flood hazard across these coastal counties. The inclusion of contextual variables associated with the most recent hurricane landfall and flooding events is grounded on the theory of availability bias (Tversky and Kahneman, 1974). When judging risks and making decisions under uncertainty, humans are subject to availability bias, referring to "situations in which people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind." (Tversky and Kahneman, 1974: 1127) The recent intensive events with high storm surge height and substantial economic damages are supposedly easy for individuals to recollect. The objective variables as shown in Tables 2 and 3 are described in detail as follows.

Storm surge from the latest hurricane landfall refers to the peak storm surge height from the latest hurricane landfall. The data are extracted from the updated version of SURGEDAT, which compiles data from 62 sources and identifies 195 storm surge events with the minimum height of 1.22 m (Needham and Keim, 2012). Peak storm surge height indicates the relative severity of coastal flooding events. *Percentage of SFHA* per *county* is defined as the ratio of the area of SFHA in a county to the total area of the county. The variable is calculated based on the digital Flood Insurance Rate Map (FIRM) of FEMA in Geographical Information System (GIS). *Percentage of high risk VE zone* per *county* is defined as the ratio of the area of VE zone of a county to the total area of the county. This variable is also calculated by using the FEMA flood maps. These two contextual variables related to flood zones represent varying coastal flood hazards estimated by FEMA across counties. In addition to these two contextual variables, the individual-level variable -distance from the coast can represent vulnerability to flood hazard at the building level. The correlations between distance from the coast, and the two contextual variables related to flood hazard are quite low, with 0.0095 (percentage of SFHA per county) and −0.0507 (percentage of high risk VE zone per county). Together with the distance from the coast, these contextual variables reflect varying levels of coastal flood risks. *Maximum annual property damage from flooding in the last 10 years* and *annual property damage from the latest year when flooding occurred* are two variables related to the consequences of flooding events at the county level. These two variables are calculated using the Storm Events Database, an official database of the National Climate Data Center (NCDC). The annual property damage from flooding is a cumulative measure over a year. The rationale of adopting a cumulative measure instead of a single-even measure is as follows. Flood occurs more often than some other extreme weather events such as hurricanes. Many small storms can generate flooding with small amounts of damages. People may not be able to recall a particular flooding event with a small impact, but they may be left with deeper impression about the cumulative impacts of frequent flooding events that happened in a particular year. The selection of 10 years as the time frame for constructing the maximum annual property damage from flooding is based on two considerations. First, people tend to have short memories. Any events that occurred in the far distant past (e.g., over 20 years ago may be difficult for one to recall). Second, drawing statistically meaningful trends out of a too short time period (e.g., 3 years) is difficult. Nevertheless, in addition to the timeframe of 10 years, 5- and 20-year timeframes are also tested in our study, but the results are not sufficiently different from the 10-year timeframe, indicating that this measurement is not sensitive to various timeframes. This study also includes the contextual variable of the *County average insurance premium* to test the price elasticity of demand at the county level. It measures the responsiveness of the demand for flood insurance to a change in its price. A previous study used the county-level insurance premium and take-up rate to test price elasticity (Atreya et al., 2015).

2.3. Methods

The 2012 Gulf Coast Climate Change survey data provide state and county fips codes, allowing us to merge the individual-level data with contextual data to develop mixed-effects logit regression models. Merging individual-level and contextual data raises certain statistical complications, i.e. the error terms of individual observations nested within the same county are no longer independent of one another. In addition, to account for the unmeasured factors at the state level (e.g. state policies to address natural hazards, state economic conditions, state building code, etc.) that may affect the adoption of flood insurance and are correlated with the

Table 1
Individual-level independent variables.

Individual-level Independent Variables	Code	Frequency	Percent (%)
Socio-demographic			
Age			
18–24	1	79	2.0
25–34	2	205	5.3
35–44	3	393	10.2
45–54	4	733	19.0
55–64	5	981	25.4
65 and over	6	1431	37.1
Gender			
Female	1	2305	59.8
Male	0	1551	40.2
Race			
White	1	2797	72.5
Others	0	1055	27.4
Education			
Less than HS	1	220	5.7
HS degrees	2	770	20.0
Some college	3	1214	31.5
College degree	4	1609	41.7
Income			
Under $10,000	1	186	4.8
$10,000–$19,999	2	255	6.6
$20,000–$29,999	3	292	7.6
$30,000–$39,999	4	273	7.1
$40,000–$49,999	5	255	6.6
$50,000–$74,999	6	506	13.1
$75,000–$99,999	7	434	11.3
$100,000 or more	8	653	16.9
Partisanship			
Democrat	−1	1100	28.5
Independent	0	1232	32.0
Republican	1	1246	32.3
Home Ownership (Dummy Variables)			
Own		3191	82.8
Rent		447	11.6
Distance from the coast			
Adjacent/On the water	1	379	9.8
Near the water/within 1–2 miles	2	591	15.3
Within 2–5 miles	3	447	11.6
5–10 miles	4	592	15.4
11–30 miles	5	992	25.7
31–60 miles	6	545	14.1
More than 60 miles	7	224	5.8
Trust in Local Government's Preparedness to Address Climate Change Issues			
Not prepared at all	0	736	19.1
Not very prepared	1	779	20.2
Somewhat prepared	2	1487	38.6
Very prepared	3	591	15.3
Perceptions of Flooding Amount, Hurricane Number/Strength, and Climate Change			
Flood Amount			
Decreased	−1	658	17.1
About the same	0	2195	56.9
Increased	1	902	23.4
Hurricane number			
Decreased	−1	901	23.4
About the same	0	2034	52.7
Increased	1	819	21.2
Hurricane Strength			
Not as strong	−1	521	13.5
About as strong	0	1634	42.4
Stronger	1	1466	38.0
Belief in Climate Change			
Climate change is happening	1	2870	74.4
Climate change is not happening	0	820	21.3

variables of interest, the state indicators need to be included in the models. Therefore, to account for the multilevel data structure and avoid violating the fundamental assumption in regression analysis, multi-level mixed-effects logit regression models (Hamilton, 2012) are employed in the study.

3. Results and discussions

This study attempts to understand what factors drive residents to voluntarily purchase flood insurance. Results of this study are especially important for policy makers to design effective communication strategies and mechanisms to motivate the purchase of flood insurance among individuals who are not currently required to buy flood insurance but are nevertheless exposed to varying levels of flood risks. Moreover, understanding voluntary purchase of flood insurance is useful for policy makers to design effective policy tools to increase the insurance market penetration in the reformed NFIP.

Guided by this goal, the respondents are first classified into two groups and six models are estimated to explain the difference between these two groups, i.e., one without flood insurance and the other who buy flood insurance only because they want to feel safer (the flood insurance is not required for them). Model 1 of Table 2, presents results of a two-level multilevel model with fixed effects of individual-level variables and random effects of states. Three out of the five socio-demographic variables stand out as significant factors that explain individuals' voluntary decisions on flood insurance purchase. Compared to racial minorities, white people are less likely to buy flood insurance voluntarily when controlling for the effects of all other variables in this model. Numerous previous studies have demonstrated that racial minorities are more likely to perceive environmental risks and therefore express higher levels of concern due to their propensity to environmental distress (Finucane et al., 2000; Marshall, 2004; McCright and Dunlap, 2011; Mohai and Bryant, 1998). The same interpretation can be applied here: white people are less likely than racial minorities to perceive flooding risks and therefore lack motivation to buy flood insurance voluntarily.

Another significant socio-demographic attribute is education. Individuals with higher levels of education tend to buy flood insurance for more safety. This fact indicates that higher level of education may lead to better awareness of flood risks, which in turn positively affects one's voluntary decisions on flood insurance purchase. Local policy makers may consider raising awareness of flood risks among residents through various educational programs. Meanwhile, as expected, people with higher levels of income tend to buy flood insurance to feel safer. Higher income is undoubtedly related to more resources that can be allocated to prevent one from excessive loss to natural hazards. This result conveys an important message to policy makers that affordability can cause substantial concern among low-income residents. According to the theory of hierarchy of human needs (Maslow, 1943), humans tend to satisfy physiological needs such as food, shelter, and economic stability before turning attention to other needs such as environmental quality and self-actualization. Restricted by financial resources, low-income residents spend money on items necessary for survival, and they have no additional money to invest in flood protection even if they perceive high risks. Policy makers need to take this fact into consideration and design policies to assist low-income residents to be shielded from flood hazards. The voucher programs, designed to help those for whom insurance can be a substantial economic burden, may be a feasible and effective solution for low-income homeowners (Kousky and Kunreuther, 2014; Zhao et al., 2015). Vouchers can only be used to cover the portion of insurance premium and costs of loans for hazard mitigation measures that exceed the economic limitations of low-income homeowners. The voucher program would operate in parallel with risk-based insurance premium pricing in the reformed NFIP (Kousky and Kunreuther, 2014).

Furthermore, being an owner of a house increases one's probability of buying flood insurance voluntarily. Previous studies have

Table 2
Models of totally voluntary flood insurance behavior.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	b	Z	b	Z	b	Z	b	Z	b	Z	b	Z	b	Z
Socio-demographic														
Age	0.027	0.55	0.000	−0.01	0.001	0.03	0.001	0.03	0.054	1.01	0.030	0.62	0.000	0.00
Gender: female	−0.119	−1.02	0.019	0.15	−0.043	−0.34	−0.053	−0.42	−0.036	−0.29	−0.067	−0.59	−0.045	−0.37
Race: white [−]	−0.382	−2.56**	−0.394	−2.45**	−0.550	−3.26***	−0.506	−3.00**	−0.454	−2.77**	−0.453	−3.06***	−0.499	−3.09***
Education [+]	0.253	3.30***	0.264	3.19***	0.251	2.94**	0.272	3.16***	0.212	2.65**	0.219	6.89**	0.258	3.16***
Income [+]	0.193	5.91***	0.215	6.20***	0.200	5.61***	0.196	5.51***	0.229	6.63***	0.253	3.38***	0.211	6.12***
Political orientation														
Partisanship	0.014	0.17	−0.049	−0.59	0.000	0.00	0.009	0.10	−0.092	−1.12	−0.069	−0.91	−0.009	−0.11
Home ownership														
Owner [+]	1.011	2.60**	1.078	2.35**	0.946	1.84*	0.924	1.79*	0.5251.32	0.734	2.02*	1.046	2.15*	
Renter [−] (Control group: Something else)	−0.134	−0.31	−0.115	−0.23	−0.190	−0.34	−0.225	−0.40	−0.769	−1.67*	−0.461	−1.14	−0.222	−0.42
Distance from the coast [−]	−0.258	−7.05***	−0.273	−7.02***	−0.292	−6.71***	−0.290	−6.82***	−0.295	−6.99***	−0.269	−6.99***	−0.277	−6.93***
Trust in local government [+]	0.103	1.79*	0.092	1.50	1.43	0.065	0.072	1.14	0.096	1.57	0.087	1.55	0.082	1.35
Perceptions														
Flooding amount [+]	0.174	1.83*												
Hurricane number [+]	0.087	0.92												
Hurricane strength [+]	0.180	1.95*												
Belief in climate change [+]	0.127	0.86												
Objective conditions														
Storm surge [+]			0.019	2.14*										
Percentage of 100-year flood zone per county [+]					1.136	2.87**								
Percentage of 100-year flood zone (high risk) per county [+]							1.145	2.01*						
Maximum property damage from flooding in the last 10 years [+]									0.000	1.58				
Property damage from the latest flooding [+]											−0.000	−0.66		
County average premium [−]													−0.000	−0.12
Random intercept	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
State	0.273	0.185	0.186	0.134	0.121	0.097	0.139	0.108	0.275	0.202	0.326	0.232	0.234	0.167
County			0.000	0.000	0.027	0.048	0.026	0.046	0.188	0.095	0.172	0.088	0.043	0.057
p(LR)	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
N	1645		1448		1428		1428		1538		1805		1531	

*p < 0.05; **p < 0.01; ***p < 0.001.

found that homeowners may value their properties and thus are more compelled to prepare for tornadoes and floods than those who rent (Mulilis et al., 2000; Takao et al., 2004). Our study reveals that homeownership affects voluntary flood insurance purchase behavior. The result suggests that policies related to flood insurance in the reformed NFIP should be tailored to target both homeowners and renters. To no one's surprise, the distance from the coast has a negative effect on individuals' voluntary decision to buy flood insurance. People who live relatively far away from the coast feel less vulnerable to flood impacts and choose not to buy flood insurance. This result is consistent with some previous studies (Kriesel and Landry, 2004; Petrolia et al., 2013). In fact, a greater distance from the coast nevertheless does not always reflect lower flood risks and therefore may mislead residents. In other words, greater distance from the coast may bring a false sense of security. Local governments should inform coastal residents of their actual flood risks.

Trust in local government is another positive factor driving individuals to buy flood insurance voluntarily. The US NFIP is administered by the partnership between FEMA and local governments. Homeowners, especially those who are not required to buy flood insurance, need to have adequate trust in the local government to deal with climate-related risks in order to feel comfortable of purchasing flood insurance. This finding is in line with that of Atreya et al. (2015): those who lack trust in the local government's competence have less voluntary willingness to buy flood insurance. This finding highlights the importance of building trust between the government and the governed. Local policy makers need to think of ways to earn more trust from residents to motivate them to actively seek flood protection measures.

Among all variables relating to environmental perceptions, beliefs in increasing flooding amount and hurricane strength exert positive impacts on voluntary decisions to buy flood insurance. Specifically, people who perceive that the amount of flooding has increased and that hurricanes have become stronger are more likely than others to buy flood insurance voluntarily. The connection between perceptions of increasing flooding amount and voluntary purchase of flood insurance is straightforward. Because hurricane strength is associated with storm surge flooding, the perception of increasing hurricane strength leads to a higher probability of voluntarily purchasing flood insurance. The results provide empirical evidence to support the relationship between risk perception and voluntary behavior, and urges policy makers to design effective risk communication tools to convey accurate flood risks to coastal residents.

The standardized coefficients of individual-level variables are also estimated to compare their contributing effects on the voluntary flood insurance purchase behavior. Standardized coefficients reveal that income is the most influential factor followed by homeownership and distance from the coast. This provides local policy makers with useful information on which they can prioritize

specific policy strategies to motivate more residents to purchase flood insurance.

Models 2–7 of Table 2 demonstrate results of six multilevel models with six county-level contextual variables of flood risks, respectively. These variables include: peak storm surge height from the latest hurricane landfall, percentage of the area of SFHA per county, percentage of the area of high risk VE zone per county, annual maximum property damage from flooding in the last 10 years, annual property damage from the latest flooding event, and county average flood insurance premium. When estimating the effects of these six contextual variables, variables of flood-related risk perceptions are intentionally left out. The advantage of including contextual factors for studies of behaviors is that they are exogenous variables: the geographic context can cause flood insurance purchase behavior, but this behavior cannot change the context. Thus to determine if geographic context affects flood insurance purchase behavior, a very simple and valid test is therefore a regression in which the behavior is predicted solely by contextual indicators. Control variables are added to models if covariates are of concern, in cases where (1) these covariates may confound the context-behavior relationship (2) but are not themselves caused by the context. Controls are ruled out if they do not satisfy the second condition because in this estimation context they are "post-treatment" variables that mediate the context-behavior relationship (Gelman and Hill, 2007, p. 188–190). Including post-treatment variables as controls thus underestimate the magnitude of the effects of the context, because the estimates represent only the contextual effects after removing any contextual effect that occurs through the mediators. Perceptions of flood-related risks, and belief in climate change can be caused by the contextual factors (Shao, 2015; Shao et al., 2016; Shao and Goidel, 2016), and thus they must be considered as mediators. Hence, we estimate the effects of subjective risk perceptions of flooding and objective contextual flooding risks separately.

Three contextual variables stand out as significantly positive factors in determining whether or not one chooses to buy flood insurance to feel safer. Specifically, residents in counties with higher peak storm surge heights in the latest hurricane landfall, higher percentages of SFHA and high risk VE zone are more likely than residents elsewhere to buy flood insurance to feel safer. For those who buy flood insurance totally voluntarily, the memory of the destructive power associated with the last peak storm surge may be vivid. This result suggests that peak storm surges with higher intensity are more likely to evoke stronger emotions and leave longer impressions. These high-impact events are therefore more retrievable in one's mind as a previous study found (Shao et al., 2016). In addition to all the contextual variables presented in the paper, the effect of 10-year trends of the annual number of floods is also tested but turns out to be insignificant. The significant effect of storm surge from the latest hurricane landfall combined with the insignificant impact of trend of floods further reinforces the availability bias.

The statistically significant results about percentage of SFHA and high risk VE zone per county illustrate that FEMA's flood maps may have been effective in conveying the relative coastal flooding hazards to residents in different possible ways. First, people may view the flood map themselves through the Floodsmart.gov website or FEMA website to determine the flood risk of their property and their surrounding environment when deciding to purchase flood insurance. Second, FEMA and the local government are in partnership about informing local residents of their flood risks through education programs, community meetings, and personal communications with local officials. For example, one of the authors in this study had an opportunity to interview a city hydrologist in the city of Huntsville, Alabama in September 2016. The hydrologist stressed his frequent role of persuading homeowners who live in the proximity of SFHA to purchase flood insurance even they are not required to do so by showing them FEMA's flood maps. Third, the flood hazards in flood maps can be indirectly conveyed through the behavior of the people living close by, e.g., neighbors. In our study, we found that the contextual flood hazard conveyed through the flood map is correlated with the flood insurance take-up rate at the county-level (a correlation of 0.52), and the take-up rate is also statistically significant to voluntary purchase of flood insurance. This finding suggests that it is possible that the perception of flood hazards through flood maps may indirectly influences people's behavior. Overall, FEMA's flood maps have the capacity of influencing voluntary flood insurance purchase behaviors. Individuals living in counties with higher percentages of flood hazard zones estimated by FEMA are more likely to buy flood insurance to feel safer than those living in counties with lower percentages of flood hazard regions. FEMA's flood maps serve as an important risk communication tool for coastal residents, and further affect their decisions on voluntary purchase of flood insurance.

On the other hand, serious issues arise in cases where FEMA flood maps do not reflect flood risks accurately or properly. FEMA flood maps can provide misleading information to coastal residents, resulting in less ideal decisions on flood protection. For instance, people who live on slightly higher grounds but very close to the coast may have a false sense of safety because FEMA often designates such locations as low flood risk zones. However, they are subject to heavy coastal flooding and wave hazards due to the proximity to the sea (Xian et al., 2015). Some previous studies have also raised potential issues with using relatively low-resolution FEMA flood maps for local risk assessments (Czajkowski et al., 2013). FEMA's flood maps need to consider the detailed distribution of hazards, and be updated more frequently with more accurate and timely projections of storm characteristics and improved hydraulic and wave modeling (Crowell et al., 2007; Czajkowski et al., 2013; Shan et al., 2009; Xian et al., 2015). Therefore, policy makers should exercise caution when using the FEMA flood map to communicate the actual risks to the public.

Annual maximum property damage from flooding in the last 10 years (5 and 20 years are also tested and none of them are statistically significant) and annual property damage flooding in the latest year do not appear to have any significant effects on one's decision to buy flood insurance voluntarily. One possible reason for this finding is that these two county-level measures of property damages from flooding provide only aggregate information of economic losses county wide. Aggregate damage may not necessarily reflect individual personal property damages, and thus have limited influence affecting personal voluntary flood insurance behavior.

The insignificance of average flood insurance premiums at the county-level reveals some degrees of price inelasticity of demand for flood insurance, which is consistent from previous study (Atreya et al., 2015). On the contrary, we found a positive income effect at the individual level, as discussed before.

This study attempts to identify the factors that motivate voluntary behaviors. Therefore, the group of individuals who buy flood insurance out of a combination of voluntary and mandatory reasons cannot be ignored. Accordingly, the respondents are classified into two groups based on the survey questions, i.e., individuals without flood insurance and those with flood insurance because they want to feel safer regardless of the requirement. Individuals who buy flood insurances only to feel safer are combined with those who buy insurance both because they want to feel safer and the flood insurance is required to them, and this combined group is compared with individuals who have no flood insurance. As shown in Table 3, the results are similar to those revealed in the

models of Table 2. First, racial minorities and individuals with higher education and more income are more likely than their counterparts to buy flood insurance. Homeowners and people who live near the coast and have more trust in the local government are more inclined to buy flood insurance. Perceptions of changing flooding amount and hurricane strength are found to be positively related to the choice to purchase flood insurance.

Among the contextual forces, percentages of the area of SFHA and coastal high risk VE zone per county remain to be strong factors in determining voluntary purchase of flood insurance. The major difference is that peak storm surge from the last landfall hurricane appears not to be significant in Table 3. This difference can be explained by the fact that flood insurance buyers who act out pure voluntary motivation tend to assign a heavier weight to the latest intensive flooding experience when deciding to purchase flood insurance compared to those partially voluntary flood insurance holders. In other words, the most recent intense flood event may lead some individuals to live in fear which compels them to buy flood insurance just to “feel safer”.

4. Conclusions

The economic damage from coastal flooding has been dramatically growing in recent decades due to the combination of massive population movement to the coastal zone and climate change effects. The U.S. NFIP has been in billions of debt to the Treasury Department since Hurricane Katrina. The Biggert-Waters Act of 2012 aimed to solve the problem of NFIP's insolvency but has met with strong resistances among coastal residents. The flood insurance market penetration is relatively low and far from being universal across coastal counties. A substantial number of people facing high flood risks do not hold flood insurance (Dixon et al., 2006). Against this backdrop, it is imperative to understand coastal residents' voluntary flood insurance purchase behaviors to help policy makers reform the NFIP to make it more effective and efficient. This study attempts to investigate factors that drive individuals' voluntary purchase of flood insurance by using survey data for coastal counties along the entire U.S. Gulf Coast. Results of this study reveal some relationships between some socio-demographic attributes and perceived and estimated flooding risks, on the one hand, and voluntary flood insurance purchase behavior, on the other. Specifically, four main findings arise, and the associated implications are discussed.

First, racial minorities are more likely to buy flood insurance voluntarily. This finding can be interpreted in the light of existing literature on race and environmental risk perceptions. Racial minorities, due to the excessive burden of environmental distress (Mohai and Bryant, 1998), tend to perceive environmental risks (Finucane et al., 2000; Marshall, 2004) and express more concern for these risks (McCright and Dunlap, 2011). These heightened risk perceptions may influence voluntary behaviors to mitigate risks, as shown in our study. As expected, individuals with more income are

Table 3
Models of totally and partially voluntary flood insurance behavior.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	b	Z	b	Z	b	Z	b	Z	b	Z	b	Z	b	Z
Socio-demographic														
Age	0.030	0.69	−0.018	−0.36	−0.011	−0.22	−0.012	−0.24	0.046	0.94	0.016	0.37	−0.018	−0.38
Gender: female	0.006	0.05	0.089	0.78	0.034	0.29	0.035	0.30	0.082	0.72	0.056	0.54	0.044	0.39
Race: white [−]	−0.384	−2.87**	−0.430	−2.88**	−0.484	−3.10***	−0.482	−3.10**	−0.462	−3.07***	−0.448	−3.30***	−0.488	−3.29***
Education [+]	0.166	2.49	**0.170	2.31*	0.201	2.63**	0.206	2.70**	0.151	2.11*	0.158	2.39**	0.175	2.40**
Income [+]	0.182	6.32***	0.214	6.77***	0.187	5.79***	0.189	5.87***	0.221	7.06***	0.216	7.52***	0.203	6.54***
Political orientation														
Partisanship	−0.034	−0.47	−0.068	−0.89	−0.034	−0.44	−0.029	−0.38	−0.124	−1.65	−0.102	−1.48	−0.037	−0.49
Home ownership														
Owner [+]	0.913	2.84**	0.896	2.39**	0.738	1.77*	0.743	1.77*	0.673	1.86*	0.778	2.45**	0.912	2.29*
Renter [−] (Control group: Something else)	0.291	−0.82	−0.314	−0.76	−0.419	−0.92	−0.422	−0.92	−0.802	−1.92*	−0.481	−1.36	−0.387	−0.89
Distance from the coast [−]	−0.283	−8.63***	−0.309	−8.00***	−0.292	−6.71***	−0.342	−8.48***	−0.320	−8.18***	−0.306	−8.58***	−0.315	−8.33***
Trust in local government [+]	0.111	2.10*	0.080	1.40	1.43	0.065	0.060	1.03	0.104	1.85*	0.085	1.64*	0.068	1.21
Perceptions														
Flooding amount [+]	0.171	2.02*												
Hurricane number [+]	0.046	0.54												
Hurricane strength [+]	0.183	2.21*												
Belief in climate change [+]	0.170	1.26												
Objective conditions														
Storm surge [+]			0.021	1.63										
Percentage of 100-year flood zone per county [+]					1.136	2.87**								
Percentage of 100-year flood zone (high risk) per county [+]							1.594	2.86**						
Maximum property damage from flooding in the last 10 years [+]									0.000	1.31				
Property damage from the latest flooding [+]											−0.000	−0.58		
County average premium [−]													0.000	0.54
Random intercept	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
State	0.387	0.254	0.292	0.216	0.196	0.152	0.202	0.149	0.375	0.272	0.437	0.308	0.354	0.251
County			0.130	0.087	0.090	0.072	0.057	0.057	0.299	0.112	0.279	0.102	0.138	0.083
p(LR)	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
N	1645		1671		1620		1620		1779		2093		1756	

*p < 0.05; **p < 0.01; ***p < 0.001.

more likely to buy insurance regardless of the requirement. Another important finding about the socio-demographic characteristics is the significant effects of education in determining one's voluntary choice to buy flood insurance. The interpretation can be that better education leads to a higher level of awareness and better knowledge of flood risks, which correspondingly can translate into behaviors to mitigate these risks. These results highlight the importance of informing coastal residents of their flood risks especially among those less educated homeowners. This can be achieved by FEMA in partnership with local policy makers through educational programs and other forms of community engagement.

Second, perceptions of flooding amount, and hurricane strength shifts over the recent past are found to have positive effects on voluntary purchase of flood insurance. Coastal residents who perceive increasing trends of flooding amount and hurricane strength are more likely to hold flood insurance to feel safer. The results provide empirical evidence that heightened perceptions of flood-related hazards can motivate people to proactively seek protection measures. Policy makers should explore approaches to provide scientific information on these flood-related hazards.

Third, the other two individual-level variables that are significantly associated with voluntary purchase of flood insurance are: self-reported distance from the coast and belief in the local government's preparedness to address climate change. As expected, with the increase of distance from the coast, the probability of voluntarily purchasing flood insurance decreases. Greater distance from the coast nevertheless does not always mean lower flood risks, and therefore can give residents a false sense of safety. This finding suggests that local policy makers should inform and educate coastal residents about their actual flood risks. Meanwhile, individuals' trust in local governments' preparedness to address climate change can lead to voluntary purchase of flood insurance. This finding implies that coastal residents rely on the local government to mitigate flooding hazards. It also highlights the importance of the trust between the local government and residents.

Fourth, the most important finding of this study is the significant impact of contextual forces. The positive effect of peak storm surge from the last hurricane landfall confirms the theory of availability bias. These characteristics of intensive and recent storm surge flooding event present some mental ease with which individual accesses and retrieves past information compared to the trend of storm surge intensity (Shao et al., 2016). More importantly, percentages of the areas of SFHA and high-risk VE zones per county affects voluntary flood insurance behavior. These contextual forces of flood risks conveyed through FEMA's flood maps can motivate individuals to buy flood insurance to feel safer even when they are not required to. This significant finding about the flood zones designated by FEMA sends both positive and negative messages to policy makers. From a positive perspective, FEMA has been successful, at least as shown in the Gulf Coast, in conveying varying county-level flooding risks to coastal residents via their maps. On the other hand, some previous studies have demonstrated that FEMA's maps may not be accurate and hence can send misleading signals to coastal residents (Shan et al., 2009; Czajkowski et al., 2013; Xian et al., 2015). FEMA therefore needs to update its maps more frequently and apply the best available methods to reflect the real flood risks in a timely fashion.

The research agenda on individuals' flood insurance purchase behaviors is far from complete. First, many questions related to the flood insurance behavior remain to be addressed. For example, what factors would determine the amount of insurance coverage and the amount of deductible that homeowners are willing to take? Second, some scholars have proposed feasible solutions to NFIP's insolvency and individuals' affordability issues (Kunreuther, 2016; Kunreuther and Michel-Kerjan, 2009; Kousky and Kunreuther, 2014; Zhao et al., 2015). Vouchers are proposed to target low-income homeowners who cannot afford risk-based insurance premium (Kousky and Kunreuther, 2014). The voucher program would operate in parallel with risk-based insurance pricing to solve the NFIP's insolvency. More studies are needed to test whether the proposed policy solution would be feasible and acceptable among low-income coastal residents and local officials. Third, tailored studies are needed to examine how exactly coastal residents perceive FEMA's flood maps and other governmental tools that aim to reflect flood risks (e.g. flood return period, probability distribution of flood levels or probability of flooding over a certain period). Fourth, the important information that needs to be communicated with residents in flood-prone areas include: the likelihood of future floods, the potential damages these floods will incur, and insurance premiums calculated based on real risks under the contexts of climate change and sea level rise. Future studies should aim to assist policy makers in designing more effective risk communication tools to convey the state-of-the-art risk information to members of flood-prone communities. Fifth, with increasing flood risks in the future, flood insurance can be an effective way to protect homeowners from significant flood losses. Understanding voluntary motivations in flood insurance purchase is crucial in other countries that are also vulnerable to flooding but lack national flood insurance programs and enforced requirements such as Netherlands, Vietnam, China, etc. More studies exploring determinants of flood insurance purchase behavior in other countries should be invited.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.watres.2016.11.021.

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