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Estimating willingness to pay and costs associated with hurricane evacuation

Fan Jiang [a], Sisi Meng [b,*], Mohammad Khan [c], Nafisa Halim [d], Pallab Mozumder [e]

[a] Department of Economics, Shanghai University of International Business and Economics, Shanghai, China
[b] Keough School of Global Affairs, University of Notre Dame, Notre Dame, IN, United States
[c] Department of Business and Economics, Wayne State College, Wayne, NE, United States
[d] Department of Global Health, Boston University, Boston, MA, United States
[e] Department of Earth & Environment, Department of Economics, Institute of Environment, Florida International University, Miami, FL, United States

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ABSTRACT

While a growing number of studies have explored evacuation expenditure for more effective evacuation planning and emergency management, few have investigated the public preferences regarding hurricane evacuation behavior and the cost of evacuation. This paper presents an empirical analysis of hurricane evacuation decisions, using both revealed preference (RP) and stated preference (SP) evacuation expenditure data from Texas residents affected by Hurricane Ike. Furthermore, we have developed a methodology framework based on utility maximization theory and the lifecycle consumption model. This approach allows us to estimate the lower bound of individuals' willingness to pay (WTP) to mitigate hurricane risks and calculate the associated cost-of-evacuation under both voluntary and mandatory evacuation orders. The study was carried out from a transportation cost perspective and included the expenditure of transportation, food, and lodging during hurricane evacuation. The findings provide policy implications for emergency management agencies in coastal communities in terms of hurricane evacuation planning and strengthening disaster management practices in the future.

1. Introduction

Hurricanes are among the most destructive natural disasters that strike coastal communities. They cause fatalities and severe property damage due to massive rains, storm surges, and damaging winds. Despite considerable increases in forecast accuracy, many casualties due to hurricanes continue to occur in the U.S. and worldwide. On September 13, 2008, Hurricane Ike made landfall on Galveston Island with devastating winds of 110 miles per hour, 22-foot storm surges, and coastal flooding. Hurricane Ike predominantly hit Texas, Louisiana, and Arkansas, killing at least 84 people and causing insured damage of around USD$19.3 billion in these three states. The total property damage was estimated to be around $24.9 billion. Hurricane Ike was the Atlantic's sixth most expensive hurricane and Texas' second most expensive hurricane (NHC, 2018).

Furthermore, over 140,000 residents who lived in Hurricane Ike-affected areas failed to evacuate. Many residents who experienced heavy traffic jams during Hurricane Rita (an earlier hurricane affecting the same area in 2005) chose not to leave home when Ike was

* Corresponding author at: 4033 Jenkins and Nanovic Halls, Notre Dame, IN 46556, United States.
E-mail addresses: fanjiang@suibe.edu.cn (F. Jiang), smeng@nd.edu (S. Meng), mokhan1@wsc.edu (M. Khan), nhalim@bu.edu (N. Halim), mozumder@fiu.edu (P. Mozumder).

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approaching. Some people could not evacuate due to flooding. Approximately 100,000 houses were flooded in Texas during Hurricane Ike. Approximately 3,000 people were rescued during that flooding. During that time, Galveston was announced to be unsuitable for living, and Houston experienced a one-week curfew due to the shortage of electricity. More than 50,000 residents of Galveston were in a mandatory evacuation zone, and unfortunately, only 60% of these residents evacuated. More than 140,000 people lived in the evacuation zone, but only 70% could leave for a safer location (National Geographic, 2008).

Researchers at Florida International University conducted a household survey in the aftermath of Hurricane Ike to investigate public preferences for responding to hurricane risks through evacuation. The survey questionnaire asked Texas residents to report their hurricane experiences and behaviors adopted to reduce risk during Hurricane Ike. Evacuees were asked how much money they spent during evacuation for transportation, food, and lodging (i.e., revealed preferences). Conversely, those residents who did not evacuate were asked to estimate their evacuation expenses had they decided to leave and go to a safer location (i.e., stated preferences). Their survey responses, therefore, allow us to jointly apply both the revealed (RP) and stated preference (SP) methods to estimate the respondents' WTP under different evacuation orders and associated cost-of-evacuation. Based on utility maximization theory and lifecycle consumption model, our objective is to contribute to the literature on WTP studies regarding hurricane evacuation to provide insights into the improved design of emergency management policies.

2. Literature review

In reducing the risk of natural disasters, the top priority of policymakers is to prevent human death. Evacuation is identified an effective option for reducing hurricane-related fatalities. In the past decades, extensive empirical and theoretical research has been carried out on evacuation behavior before a hurricane in the United States and around the world (Ng et al., 2014; Xu et al., 2016; Lindell et al., 2020; Feng and Lin, 2021; Roy and Hasan, 2021; Adjei et al., 2022; Anyidoho et al., 2022). Social scientists and community planners have found that evacuation orders are a useful policy tool in hurricane-prone areas (Urbina and Wolshon, 2003; Yi et al., 2017). During a hurricane event, emergency management policies, such as mandatory and voluntary evacuation orders, are often used to promptly evacuate many people (Lazo et al., 2015). Overall, there is a widely shared consensus in the literature that factors such as risk area and warnings by public officials are among the most significant ones influencing evacuation behavior. Other factors examined include past hurricane experiences, risk perceptions, and individual and household characteristics (Baker, 1991; Huang et al., 2016; Lindell et al., 2019).

Although evacuation orders help to ensure public safety, they often entail unanticipated expenses on evacuees in the storm's path (such as spending money on transportation, food, and housing). Individuals who find these expenses to be too high may be hesitant to evacuate, particularly those with limited financial resources, but they may subsequently suffer significant hardship due to disruptions to utilities such as electricity, water, and transportation, as well as communication channels (Halim et al., 2021; Meng and Mozumder, 2021). On the other hand, evacuees face difficult trade-offs regarding when and where to evacuate and how long to stay away. The cost of a 7-day evacuation during Hurricane Irene for a family of four without nearby relatives would be more than $2,000 in accommodation, fuel, and food (Florido, 2018). Additionally, Lindell et al. (2011) reported that the average cost of Hurricane Lili evacuation in 2002 was $88 per day (with 29% of evacuees staying in commercial facilities), Wu et al. (2012) reported an average cost of $83 per day for evacuees during Hurricane Katrina and Rita in 2005 (with 18% of evacuees staying in commercial facilities), and Wu et al. (2013) reported an average cost of $350 per day for evacuees during Hurricane Ike in 2008 (with 30% of evacuees staying in commercial facilities). As a result, it is critical for the public to better understand the cost of evacuation so that effective evacuation plans may be made for future hurricanes.

Whitehead (2005) argued that policymakers should consider both the costs and benefits when issuing evacuation orders before a hurricane makes landfall. However, limited research is available on individual or household evacuation expenditures for a hurricane event. In one of the few studies focused on estimating expenditures, Czajkowski (2011) found that the overtime total evacuation costs initially increase and then decrease after a peak. Czajkowski (2011) also argued that the "expected costs of evacuating" are lower than the "expected costs of not evacuating." Mozumder and Vásquez (2015) used survey data to estimate the average household evacuation expenditures under different hurricane evacuation orders. A few studies focus on the understanding of household hurricane evacuation logistics, examining the correlation between transportation, food, and lodging costs during a hurricane event and evacuation departure timing, destinations, and travel distances (see Wu et al., 2012; Wu et al., 2013). These previous studies imply that estimating evacuation expenditures precisely is crucial to enabling emergency managers to adopt effective evacuation policies (Mozumder and Vásquez, 2018; Thompson et al., 2017).

Jiang et al. (2022) conducted a study examining household evacuation decision and departure timing and found that evacuation expenditure is a significant predictor for both. This implies that *actual* evacuation expenditure may serve as a good proxy for *expected* evacuation costs. Kang et al. (2007) tried to investigate this issue by comparing respondents' hurricane evacuation expectations with their actual behavior during Hurricane Lili. While they did not specifically examine evacuation costs, they found that hurricane evacuation expectations aligned well with actual evacuation behavior in terms of information sources, transportation modes, vehicles, shelter types, and preparation time. Some studies have focused on using concern for evacuation costs instead of actual evacuation costs. For example, Huang et al. (2016) reviewed three studies regarding concern about evacuation expenses, with one significant positive correlation and two nonsignificant correlations reported on evacuation decision.

Moreover, given that evacuation expenditure estimations capture only out-of-pocket costs that individuals pay during evacuation, WTP measures have been reported that capture more comprehensive potential benefits (including the economic surplus and nonmarket values) to the individual from hurricane evacuation behavior (Knetsch, 2015). WTP approaches can also capture values from individuals' risk perception or risk aversion (Letson et al., 2007). Also, WTP methods could measure the monetary value that different people put on the changes in death risk (such as mortality and morbidity) caused by changes in hurricane evacuation orders (Viscusi, 2015).

Different types of life-saving policies are practiced to reduce mortality risks by changing the level of risk for affected people (Robinson, 2007). Economists have developed a method for aggregating these changes in risk exposures by using the concept of the value of statistical life (VSL) in a wide range of contexts. The VSL is a concept developed to estimate the economic value placed on changes in people's death risk. Specifically, VSL reflects the aggregation of people's willingness to pay (WTP) to avoid premature death risks (Lindhjem et al., 2011). For instance, if the members of a population of one million were willing to pay on average USD$100 per person for a mortality risk of 1/1,000,000, the corresponding VSL would be USD$100 million (Hammitt, 2020). The WTP estimates can induce more comprehensive cost-of-evacuation approaches and include economic values for reducing mortality risks.

In the literature related to this study, Mozumder and Vásquez (2015) estimated the median evacuation expenditure at USD$194 if a voluntary evacuation order is received and USD$300 if a mandatory evacuation order is received. They considered the evacuation expenditure estimations as a lower bound of household WTP for avoiding hurricane risks. Whitehead (2003) applied a joint probit model to survey data from North Carolina and calculated the difference in total expenditures for different types of evacuation orders under different storm categories. The study estimated the median household evacuation expenditure to be USD$211 if a voluntary evacuation order is received and USD$292 if a mandatory evacuation order is received. Using the VSL estimates as cost-of-evacuation approaches from Mrozek and Taylor (2002), the government could save about 14 lives by changing a Category 1 storm's voluntary evacuation order to a mandatory one.

Previous research on hurricane evacuation behavior has shown that demographic and socioeconomic variables can influence individuals' evacuation decisions. Specifically, prior evacuation experience has been found to play a significant role in shaping future evacuation decision-making, as those who have evacuated before tend to be more confident in evacuating during a hurricane event compared to those facing such a situation for the first time (Jiang et al., 2022). Age has been identified as a significant factor in evacuation behavior, with older individuals being less likely to evacuate due to potential lack of financial or other resources, as well as mobility issues as reported in studies by Lindell et al. (2005), Thompson et al. (2017), and Alawadi et al. (2020). Using a statistical *meta*-analysis (SMA), however, Huang et al. (2016) found that age did not have a significant effect on evacuation in both actual and hypothetical evacuation scenarios. Many studies indicate that gender is significantly related to hurricane evacuation (Smith and McCarty, 2009; Bateman and Edwards, 2002). Huang et al. (2012) found a significant positive correlation between female gender and evacuation decisions during Hurricane Ike. The SMA conducted by Huang et al. (2016) revealed that gender had a significant effect on evacuation in actual evacuation studies, but not in hypothetical evacuation studies.

Furthermore, existing studies have yielded inconsistent findings regarding the significant relationships between evacuation behavior, income, and education. Some studies have identified transportation and evacuation costs as barriers to evacuation for low-income populations, but have not consistently found significant relationships between income, education, and evacuation decisions (Huang et al., 2016). Conversely, other studies have reported that individuals with lower income levels are less likely to evacuate during hurricanes (Sorensen and Sorensen, 2007). Similarly, Reininger et al. (2013) found that those with some college education or higher were less likely to comply with evacuation orders, while Huang et al. (2016) found limited evidence of education affecting evacuation behavior across multiple studies. Finally, previous research has shown that homeownership has been negatively correlated with evacuation behavior, with homeowners being less likely to evacuate compared to renters (Huang et al., 2016; Morss et al., 2016). Homeowners may have concerns about the safety of their homes during a hurricane event, leading to reluctance in evacuating. There may also be concerns about the risk of looting during such events, which can contribute to homeowners choosing to stay at home during hurricanes.

Overall, although most previous research examined hurricane evacuation behavior (Alawadi et al., 2020; Wong et al., 2020; Zhu et al., 2020; Staes et al., 2021; Verma et al., 2022), few of them study from the perspective of evacuation expenditure. The focus of this paper is to contribute to the existing research on evacuation decision-making by examining expenditure data, which consists of revealed preference (RP) and stated preference (SP) evacuation expenditure. We assume that *actual* evacuation expenditure from RP data serves as a good proxy for *expected* evacuation expenses, while the SP data directly provide information on households' expected expenses. We are interested in analyzing how these expected expenditures can affect evacuation decision-making. The estimated mean evacuation expenditure is then used to calculate the lower bound of WTP and the associated cost-of-evacuation under different evacuation orders. In contrast to Whitehead (2003), we use our cost-of-evacuation estimates to calculate the lives saved under different emergency policies.[1] The results indicate that depending on the type of evacuation order, the WTP estimates range from USD$386 to USD$6,042. When using the cost-of-evacuation lower bound of USD$0.6 million, 27 lives can be saved if the government changes a voluntary evacuation order to a mandatory order. We also compare stated preference estimates to revealed preference estimates obtained in this and previous studies.

3. Methodology

This section describes the theoretical framework associated with an individual's WTP for evacuation to avoid the risk of premature mortality due to hurricane. The theoretical framework is based on the lifecycle consumption model of Yaari (1965). Cropper and Sussman (1990) utilized the model to derive an individual's WTP for fatality risk reduction. Shepard and Zeckhauser (1982) analyzed

[1] Unlike Whitehead (2003) who used the VSL estimates of labor market as cost-of-evacuation approaches (based on Mrozek and Taylor, 2002), this study estimated the individual's WTP to calculate the cost-of-evacuation.

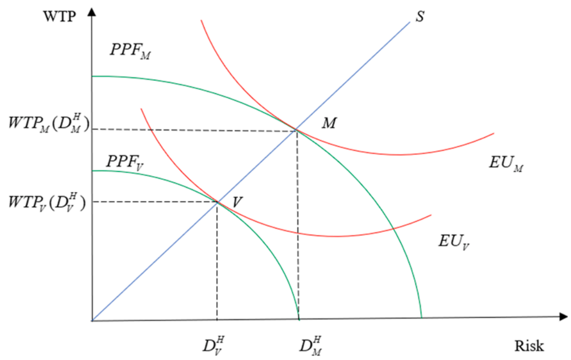

Fig. 1. Visual Representation of Trade-off between Hurricane Risk and Willingness to Pay (WTP) for Evacuation. Note: The production possibility frontier (PPF) curves are shown as green lines. The D_j^H is the probability that an individual will experience hurricane risks, and $WTP_j(D_j^H)$ is the WTP. Subscript M represents the individual who received mandatory evacuation orders and subscript V represents the individual who received voluntary evacuation orders. The optimal WTP is the point where the individual's constant expected utility locus EU(the red lines) is tangent to the PPF (Point M for mandatory evacuation orders received and Point V for voluntary evacuation orders received). The observed points $(D_j^H, WTP_j(D_j^H))$ reflect the influence of both supply and demand on the equilibrium for the entire set of individuals; all points $(D_j^H, WTP_j(D_j^H))$ compose the blue line S.

the lifecycle consumption model and derived the WTP for an increment in survival rate. The lifecycle consumption model can also be applied to investigate the effects of health status and age on the WTP for fatality risk reduction (Alberini et al., 2002). The theoretical framework used here is based on the utility maximization theory (Aleskerov et al., 2007) and lifecycle consumption model, where an individual at the beginning of period i (i.e., at age i), receives the expected utility (EU_i) over the remainder of his lifetime:

$$EU_i = \sum_{t=i}^{T} p_{i,t}(1+r)^{i-t}U_t(C_t) \tag{1}$$

where C_t is the consumption in time t, $U_t(C_t)$is the present value of utility derived from consumption in each period t, is$p_{i,t}$ the probability of an individual surviving from age i to t, and r is the discount rate of time preference. T is the maximum length of life. Based on Eq. (1), Yaari (1965) calculated the budget constraint that people could borrow and lend at the riskless rate r:

$$W_i = \sum_{t=i}^{T} p_{i,t}(1+r)^{i-t}C_t - \sum_{t=i}^{T} p_{i,t}(1+r)^{i-t}Y_t \tag{2}$$

where Y_t is the income in time t, W_i is the initial wealth in each period i. The present value of expected lifetime earnings $(\sum_{t=i}^{T} p_{i,t}(1+r)^{i-t}Y_t)$ plus initial wealth (W_i) equals the present value of expected consumption $(\sum_{t=i}^{T} p_{i,t}(1+r)^{i-t}C_t)$. The individuals aim to maximize their EU_i subject to the budget constraint in Eq. (2). If the probability that an individual will die during the current period is $D_i$and $p_{i,t}$is the product of the individual's survival probabilities in all periods, then

$$p_{i,t} = (1-D_i)(1-D_{i+1})\ldots(1-D_{t-1}) \tag{3}$$

The life-cycle consumption model can be used to determine the amount of initial wealth (W_i) that an individual would be willing to give up in order to reduce $D_i$since a reduction in $D_i$would increase the probability of survival to all future periods ($p_{i,t}$).

According to Eq. (1) to (3), the rate of substitution between $D_i$and W_i corresponds to the WTP for an individual of age i, and can be expressed as:

$$WTP_i = -\frac{dEU_i/dD_i}{dEU_i/dW_i} = -\frac{dW_i}{dD_i} \tag{4}$$

For the empirical approach cost-of-evacuation, we adopt a methodology similar to that used for the labor market. Controlling for other factors influencing evacuation, we estimate the individual's WTP to avoid hurricane risks. The production possibility frontier (PPF) curves of voluntary and mandatory evacuation orders are shown in Fig. 1 as green lines. D_j^H is probability of premature mortality due to a hurricane, and $WTP_j(D_j^H)$ is the WTP for avoiding the risk of premature mortality. Both D_j^H and $WTP_j(D_j^H)$ are calculated for each type of evacuation order (j). In Fig. 1, for an individual who reported receiving evacuation orders, the optimal WTP is the point where the individual's constant expected utility locus EU(the red lines) is tangent to the PPF. The subscript, M, represents the individual who reported receiving a mandatory evacuation order and the subscript, V, represents the individual who reported receiving a voluntary evacuation order.

The observed points $(D_j^H, WTP_j(D_j^H))$ reflect the influence of both supply and demand on the equilibrium for the entire set of individuals; all points $(D_j^H, WTP_j(D_j^H))$ compose the blue line S. The estimated tradeoff $\frac{dWTP_j}{dD_j^H}$ equals the slope of S, thus providing a local

Table 1
Description of Variables and Summary Statistics.

Variable	Description	Mean	SD	Min	Max
EVAC	If the respondent evacuated for Hurricane Ike (1 = Yes, 0 = Otherwise)	0.55	0.50	0	1
INDEXP	Evacuation expenditures of all respondents	306.61	650.56	0	7,500
RPINDEXP	Actual evacuation expenditures of respondents who evacuated for Hurricane Ike	226.70	432.96	0	4,750
SPINDEXP	Expected evacuation expenditures of respondents who did not evacuate for Hurricane Ike	404.93	835.14	0	7,500
VOLUNTARY	If the respondent received a voluntary order to evacuate (1 = Yes, 0 = Otherwise)	0.27	0.44	0	1
MANDATORY	If the respondent received a mandatory order to evacuate (1 = Yes, 0 = Otherwise)	0.34	0.47	0	1
EXPERIENCE	If the respondent evacuated for Hurricane Rita before (1 = Yes, 0 = Otherwise)	0.69	0.46	0	1
AGE	The respondent's age (in years)	59.83	14.96	18	92
GENDER	Gender of respondents (1 = Male, 0 = Female)	0.34	0.48	0	1
INCOME	Households' annual income in intervals of USD$10,000 (1 = USD$10,000 or less …. 11 = over USD $100,000)	6.24	2.82	1	11
EDUC	If the respondent had a college degree (1 = Yes, 0 = Otherwise)	0.54	0.50	0	1
OWNER	If the respondent owned the house (1 = Yes, 0 = Otherwise)	0.88	0.33	0	1

measure of the WTP-risk tradeoff for marginal changes in risk. For any given individual located along the line S, the estimated slope simultaneously reflects the marginal willingness to accept (MWTA) the risk and the marginal willingness to pay (MWTP) for greater safety. Suppose that $EVAC(WTP_j)$ represents individuals' survival from hurricane risks if they evacuate and $STAY(WTP_j)$ represents the individuals' premature mortality due to hurricane if they do not evacuate. The WTP-risk combinations that maintain an individual's constant expected utility level consist of the points that satisfy the following equation:

$$S = (1 - D_j^H)EVAC(WTP_j) + D_j^H STAY(WTP_j) \tag{5}$$

Based on Eq. (4) and (5), the WTP-risk tradeoff can be expressed as:

$$\frac{dWTP_j}{dD_j^H} = -\frac{S_{D^H}}{S_{WTP}} = \frac{EVAC(WTP_j) - STAY(WTP_j)}{(1 - D_j^H)EVAC'(WTP_j) + D_j^H STAY'(WTP_j)} \tag{6}$$

From Eq. (6), we expect that the WTP would increase as the hurricane risk increases (i.e., $\frac{dWTP_j}{dD_j^H} > 0$).

In empirical analyses, we can utilize the revealed or stated behavior data even though they both have their own limitations (Adamowicz et al., 1994). For hurricane evacuation, RP data provide actual hurricane evacuation behavior but are often limited to specific hurricane events (Whitehead et al., 2008). On the other hand, the hypothetical nature of SP data may be subject to some biases as the respondents do not face budget constraints when stating evacuation behavior and related expenses. One approach to control these limitations, albeit to some extent, is to combine the RP and SP data (Whitehead et al., 2000). By doing so, researchers can minimize some of these limitations and leverage their respective strengths (Mozumder and Vásquez, 2015).[2]

Given our research goal of estimating the WTP to avoid hurricane risks using evacuation expenditure, and the limitation of not being able to actual evacuation expenses for non-evacuees, we employed the approach that combines observed evacuation behavior (RP) data with evacuation intention (SP) data to proceed. Whitehead (2005) predicted the validity by combining the RP and SP behavior data from a survey of North Carolina's coastal area. Smith (2000) estimated the hurricane evacuation expenditures by using combined RP and SP data. Price (1999) conducted an RP and SP analysis and estimated individuals' WTP in environmental decision-making. Using the combined RP and SP data, we estimate the individual's marginal WTP based on the above framework and compare the individual's marginal WTP (SP = mean) and the revealed WTP (SP = 0) under different hurricane risk levels. The concepts of various economic terms used in the methodology section are summarized in Appendix Table B1 for reference.

4. Survey data and sample characteristics

The household survey was conducted by the Florida International University Metropolitan Center using a random probability sample targeting the Hurricane Ike-affected areas. The geocoded zip code area stratified sampling frame was employed to oversample areas of higher risk of storm surge (delineated by the Federal Emergency Management Agency [FEMA][3]). A post-stratification adjustment was also employed based on demographic distributions from the Current Population Survey (CPS) to reduce the effects of any non-response and non-coverage bias.

A total of 14,164 calls were placed to 12,710 unique numbers, and the disposition of the call outcomes is shown in Appendix Table 1. As a result, we have 1,093 complete interviews with a response rate of 36%.[4] A total of 1,099 households were

[2] There may be a hypothetical bias since we predicted median willingness to pay at the average of independent variables (SP=mean), we corrected these estimates by setting the SP indicator to be zero (SP=0).

[3] See FEMA Mitigation Assessment Team Report. Hurricane Ike in Texas and Louisiana. Available at: https://www.fema.gov/sites/default/files/2020–08/fema757.pdf.

[4] Response rate is calculated as complete interviews/(Ready to Continue + Initial Refusal + Mid-terminate + Not Resident/Visitor, Not Living in Area in 2008 For Ike + Respondent Under 18) = 1093/3068=0.3563.

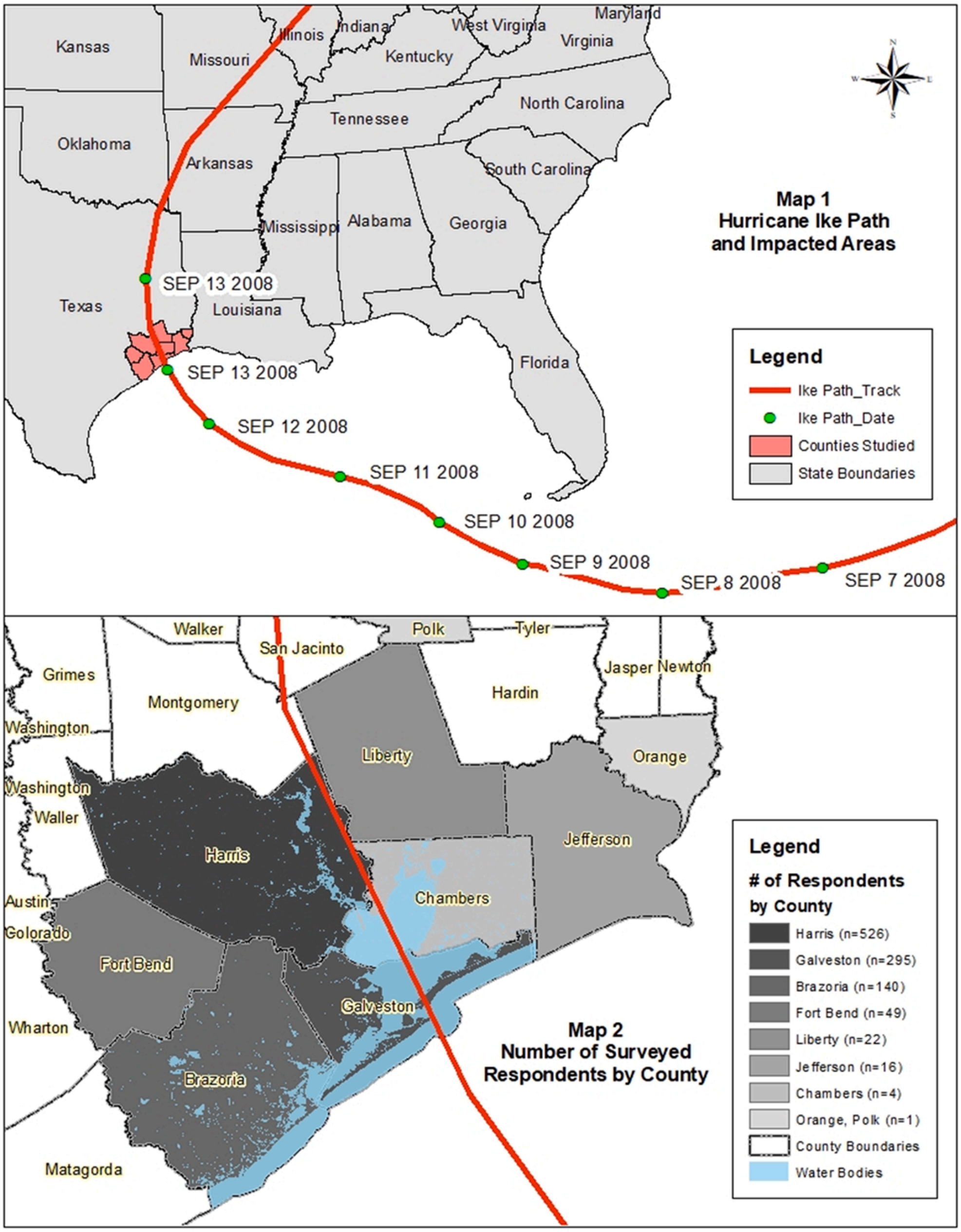

Fig. 2. Hurricane Ike Impact and Surveyed Respondents by County. Note: On September 13, 2008, Hurricane Ike made its landfall in the United States in Galveston, Texas. Map 1 shows the path of Hurricane Ike and the impacted counties included in the study. Map 2 provides a closer view of the landfall location and the number of respondents by county from the survey, conducted by researchers at Florida International University in 2010.

included in our sample (1,093 complete interviews + 6 Mid-terminate). Fig. 2. Map 1 shows the path of Hurricane Ike and the counties selected for the survey, and Map 2 depicts the surveyed household locations from nine affected counties near the Hurricane Ike's landfall.

The respondents were asked to answer a series of questions related to their evacuation experience, including the evacuation decision, destination, means of transportation, timing, and expenditure. Evacuees were asked to indicate their actual cost of evacuation, including transportation, lodging, and meals, while non-evacuees were asked to provide an estimate if they were to evacuate for a similar hurricane in the future. To calculate the WTP under different evacuation orders, the survey asked whether respondents received an evacuation order during Hurricane Ike and the type of order (voluntary or mandatory). Respondents also reported whether or not they (or their community) undertook any hurricane preparedness or mitigation measures (such as elevating their housing unit and

Table 2
Revealed and Stated Preference: Evacuations by Scenario.

Scenario	Revealed		Stated		All	
Types	Cases	Percent	Cases	Percent	Cases	Percent
Voluntary	98	28.2	69	24.5	167	26.6
Mandatory	187	53.9	24	8.5	211	33.5
No order	62	17.9	189	67.0	251	39.9
Total	347	100	282	100	629	100

Note: Revealed scenario represents evacuees for Hurricane Ike and by different types of orders. The stated scenario represents respondents who did not evacuate for Hurricane Ike and by different types of orders.

Table 3
Revealed and Stated Preference: Individual Evacuation Expenditure.

Scenario	Revealed		Stated		All	
Types	Cases	Mean Expenditure (USD$)	Cases	Mean Expenditure (USD$)	Cases	Mean Expenditure (USD$)
Voluntary	98	146	69	558	167	316
Mandatory	187	296	24	289	211	296
No order	62	144	189	364	251	309
Total	347	227	282	405	629	307

Note: Revealed scenario represents the evacuation expenditure of evacuees on transportation, food, and lodging. The stated scenario represents the evacuation expenditure estimated by non-evacuees if they would have decided to leave.

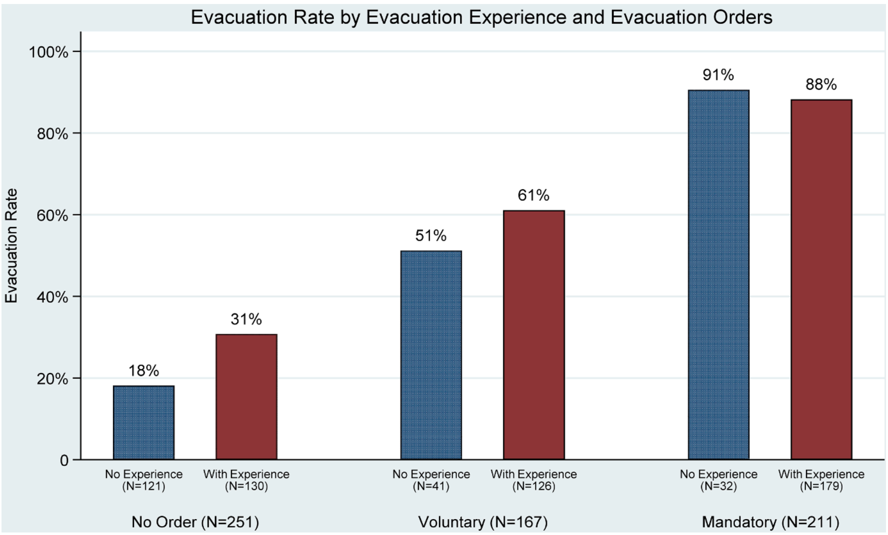

Fig. 3. Evacuation Rate by Evacuation Experience and Orders. Note: Fig. 3 presents the evacuation rates of respondents, categorized by their prior Hurricane Rita evacuation experiences and the types of evacuation orders they received.

installing shutters or window protection) before the hurricane event. To gain an idea of the budget constraints of residents during a hurricane evacuation, the respondents were asked to report their annual income. The survey also gathered other socioeconomic characteristics of respondents (i.e., sex, marital status, age, and education).

Table 1 provides the description of each variable used in the empirical analysis and their summary statistics. According to the information regarding the dependent variable *EVAC* (the evacuation decision), approximately half of the respondents evacuated for Hurricane Ike. The variable *INDEXP* represents the combined evacuation expenditure, including *RPINDEXP* for actual evacuation expenditure and *SPINDEXP* for expected evacuation expenditure. The individual expenditure for hurricane evacuation includes food, lodging, and transportation cost. The average *RPINDEXP* is USD$227, the average *SPINDEXP* is USD$405, and the average *INDEXP* is USD$307. Mozumder and Vásquez (2015) found that stated evacuation expenditures tend to be higher than revealed expenditures, presumably because stated expenditures are subject to hypothetical bias. This suggests that there may be a potentially significant psychological difference between people's reports of what they actually paid for their evacuation and reports of what they would expect to pay for an evacuation.

The dummy variables *VOLUNTARY* and *MANDATORY* represent whether respondents reported receiving voluntary or mandatory evacuation orders, respectively. Approximately 27% of respondents received voluntary evacuation orders and 34% of respondents received mandatory orders. Table 2 classifies hurricane evacuation by scenarios, evacuation orders (voluntary or mandatory), and data type (RP or SP). Table 3 categorizes individuals' evacuation expenditures in the same way as Table 2.

The variable, *EXPERIENCE* represents whether the respondent evacuated for a previous hurricane that affected the same area (Hurricane Rita in 2005). The estimates indicate that 69% of respondents evacuated for Hurricane Rita and 55% of respondents evacuated for Hurricane Ike. These results are consistent with previous findings that the evacuation rates for Hurricane Ike were consistently lower than those for Hurricane Rita in Galveston, Harris, and Jefferson County (Wei et al., 2014). Fig. 3 presents the evacuation rates of respondents, categorized by their prior Hurricane Rita evacuation experiences and the types of evacuation orders they received. When voluntary evacuation orders were in effect, respondents with prior evacuation experience for Hurricane Rita had a slightly higher evacuation rate compared to those without experience, but the difference was not statistically significant ($p = 0.267$). Similarly, under mandatory evacuation orders, there was no statistically significant difference in the evacuation rates based on evacuation experience ($p = 0.701$). However, among respondents who did not receive any evacuation orders during Hurricane Ike, those with prior evacuation experience had a significantly higher evacuation rate compared to those without such experience ($p = 0.021$).

Finally, the descriptive statistics of the socio-demographic variables used in the empirical analysis are presented in Table 1. Approximately 34% of respondents were male, and the average age of respondents was 60 years. Approximately 88% of respondents owned their houses, and the average household income was between USD$60,000 and USD$70,000. Approximately 54% of respondents had a college degree.

5. Empirical results

5.1. Regression specification and hypotheses

Based on the methodology presented in Section 3, we utilize the combined RP and SP data to compare the WTP estimations of median evacuation expenditures under different hurricane risk levels. Specifically, we employ the following Logistic model to analyze the evacuation decisions:

$$Logit(EVAC) = \alpha + \beta_{INDEXP} INDEXP + \beta_j RISK_j + \beta_{EXPERIENCE} EXPERIENCE + \beta_k K \tag{7}$$

The dependent variable is denoted as *EVAC*, which takes the value of 1 if the individual chooses to evacuate and 0 otherwise. *INDEXP* represents individual evacuation expenditures.$RISK_j$ is a binary variable taking the value of 1 if the respondent reported receiving an evacuation order (including mandatory and voluntary) and 0 otherwise, and *EXPERIENCE* takes a value of 1 if the respondents had prior evacuation experience. *K* represents a vector of independent variables consisting of individual characteristics, and β_{INDEXP}, β_j, $\beta_{EXPERIENCE}$, and β_k are the coefficients to be estimated. Finally, $\alpha$is the intercept of the regression model.

Based on Equation (7), we test the following hypotheses:

$$H_1 : \beta_{INDEXP} < 0$$

$$H_2 : \beta_{MANDATORY} > \beta_{VOLUNTARY} > 0$$

$$H_3 : \beta_{EXPERIENCE} > 0$$

The first hypothesis (H_1) is based on the fundamental intuition that the evacuation probability of an individual decreases with the expenditures expected to be incurred during the evacuation. According to the second hypothesis (H_2), individuals who reported receiving a voluntary evacuation order have a higher likelihood of evacuating than those who reported receiving no evacuation order. Moreover, individuals who reported receiving a mandatory evacuation order have a higher probability of evacuating than those who reported receiving a voluntary evacuation order. The influences on evacuation behaviors for these two types of evacuation advisories have been examined in the literature (Baker, 1991; Lindell et al., 2019). The last hypothesis (H_3) indicates that individuals who have prior hurricane evacuation experiences are more likely to evacuate than those who have not.

Using the coefficients estimated in the regression model in Eq. (7), we calculate the individuals' marginal WTP for different evacuation orders by using the following formula (Cameron, 1988):

$$MWTP_j = \left| -\frac{\beta_j}{\beta_{INDEXP}} \right| \tag{8}$$

Using this formula, we can obtain estimates of WTP for each evacuation order from the empirical models. To improve the estimates, we apply additional information about the WTP distributions. Rheinberger (2011) used the mixed logit model to simulate the WTP distributions and estimated the confidence intervals, median, quartile, and mean of WTP. We use the same approach and find the upper limit, lower limit, and mean of WTP for our estimates. Mozumder et al. (2009) integrated an empirical approach and jointly estimated the WTP values by using a system of equations with measures of the respondent's risk perception and risk mitigation behavior. Based on the empirical model, we use the nonlinear transformations of the estimated parameter vectors from the fitted models and apply the delta method to calculate the variance and standard error of the estimated parameters. We assume that the estimated parameters follow the normal distribution, by using $z = (x - \mu)/\sigma$, we build the WTP space by calculating the corresponding confidence intervals of

Table 4
Means, SD, and Intercorrelations among Variables.

Variable	*Mean*	*SD*	*EVAC*	*INDEXP*	*SPINDEXP*	*RPINDEXP*	*VOLUNTARY*	*MANDATORY*	*EXPERIENCE*	*AGE*	*GENDER*	*INCOME*	*EDUC*
EVAC	0.55	0.50											
INDEXP	306.61	650.56	−0.13***										
SPINDEXP	226.70	432.96	−0.33***	0.85***									
RPINDEXP	404.93	835.14	0.33***	0.42***	−0.11								
VOLUNTARY	0.27	0.44	0.04	0.01	0.05	−0.07							
MANDATORY	0.34	0.47	0.48***	−0.01	−0.18***	0.29***	−0.43***						
EXPERIENCE	0.69	0.46	0.24***	−0.03	−0.08	0.10	0.08	0.24***					
AGE	59.83	14.96	0.06	0.01	0.01	0.00	0.07	−0.05	−0.04				
GENDER	0.34	0.48	−0.07	−0.03	−0.01	−0.04	0.01	−0.01	−0.06	−0.03			
INCOME	6.24	2.82	−0.00	−0.04	−0.04	0.00	−0.01	−0.01	0.04	−0.12***	0.14***		
EDUC	0.54	0.50	−0.05	−0.04	−0.00	−0.08	−0.03	−0.04	−0.02	−0.08	0.11	0.30***	
OWNER	0.88	0.33	0.03	0.04	0.03	0.03	0.05	−0.04	0.05	0.14***	−0.01	0.29***	0.09

Note: *** imply significance at 1% level.

Table 5
Logistic Regression of Evacuation Decision (*Dependent variable: EVAC*).

	Model 1	*Model 2*	*Model 3*	*Model 4*
INDEXP	−0.00085***(0.00023)	−0.00085***(0.00028)	−0.00091***(0.00024)	−0.00090**(0.00024)
VOLUNTARY	1.506*** (0.218)	1.414*** (0.219)	1.413*** (0.226)	1.413*** (0.225)
MANDATORY	3.285*** (0.272)	3.161*** (0.282)	3.231*** (0.282)	3.217*** (0.281)
EXPERIENCE		0.459** (0.209)	0.448** (0.218)	0.464** (0.217)
AGE			0.012*(0.007)	0.013**(0.007)
GENDER			−0.426**(0.214)	−0.426*(0.210)
INCOME			0.007(0.040)	
EDUC			−0.055(0.209)	
OWNER			0.288(0.330)	
Constant	−0.912***(0.154)	−1.165***(0.194)	−1.985***(0.542)	−1.781***(0.452)
N	629	629	629	629
Pseudo R^2	0.263	0.268	0.279	0.278
AIC	645.659	643.110	643.773	638.794
BIC	663.436	665.331	688.215	669.903
df	4	5	10	7

Note: ***, **, * imply significance at 1%, 5%, and 10% levels respectively; numbers in parentheses are corresponding standard errors.

WTP. From the WTP space and Eq. (7), we utilize these estimates to calculate the corresponding cost-of-evacuation (VSL_j) by using the following formula:

$$VSL_j = \frac{WTP_j}{dD_j^H} \tag{9}$$

where dD_j^H is the change in the risk of premature mortality due to Hurricane Ike. The amount an individual is willing to pay for hurricane evacuation (WTP_j) is, in turn, the product of VSL_j and the size of the risk of premature mortality reduction (dD_j^H). Finally, we obtain the aggregate estimated evacuation expenditure as follows:

$$\text{Total expenditure} = \text{mean evacuation expenditure} \times \text{population} \times \text{percentage of evacuation} \tag{10}$$

5.2. Empirical analysis and results

Table 4 presents the correlation matrix among all the variables used in this study. As shown, there is a statistically significant negative correlation between individuals' expected evacuation expenditures (*SPINDEXP*) and their evacuation decisions (*EVAC*), indicating that higher expected evacuation costs are associated with a lower likelihood of evacuation. In addition, we found a statistically significant positive correlation between actual evacuation expenditures (*RPINDEXP*) and evacuation decisions (*EVAC*), suggesting that those who evacuated for Hurricane Ike incurred higher costs for transportation, lodging, and food. Overall, the combined RP and SP data for individuals' evacuation expenditures (*INDEXP*) were significantly correlated with their evacuation decisions (*EVAC*).

Moreover, respondents who reported receiving a mandatory evacuation order (*MANDATORY*) were significantly and positively associated with actual evacuation expenditures (*RPINDEXP*) and were more likely to evacuate (*EVAC*). Respondents who had prior hurricane evacuation experience for Hurricane Rita (*EXPERIENCE*) were more likely to evacuate (*EVAC*) for Hurricane Ike, suggesting that individuals with previous evacuation experience were more likely to evacuate again. These findings emphasized the role of mandatory evacuation orders and past evacuation experience in shaping evacuation behavior.

Table 5 presents four regression models aimed at investigating individuals' evacuation behaviors. Following prior literature that utilizes the Logistic model to analyze individuals' choices (Fu and Wilmot, 2004; Feng and Lin, 2022), we employ Logistic models to regress binary evacuation decisions on individual evacuation expenditures while controlling for other factors. Specifically, Model 1 serves as the baseline model and includes only the expenditure and risk variables required to estimate willingness to pay (WTP). However, as the decision to evacuate is influenced by additional factors, we need to control for them to mitigate omitted variable bias and obtain more accurate WTP estimates. Hence, Model 2 includes past evacuation experience, while Model 3 incorporates various demographic and socio-economic variables that reflect individuals' preferences and affordability to evacuate. Finally, Model 4 presents the regression results with all insignificant variables excluded. We also report the Akaike information criterion (AIC) and Bayesian information criterion (BIC) in Table 5, and observe that Model 4 provides the best fit.

Notably, the coefficients of the main independent variables of interest (i.e., expenditure and hurricane risk measured by evacuation orders) are statistically significant in all four models. Furthermore, previous evacuation experience is also found to be a statistically significant factor influencing individuals' evacuation decisions. These findings support the hypothesis H_1, which states that an increase in the expenditures expected to be incurred during the evacuation will decrease the probability of evacuation. The results also provide support for the hypothesis H_2 that official evacuation orders increase the likelihood of evacuation, with higher coefficients observed for mandatory orders compared to voluntary orders. These results indicate that individuals who believe they were given evacuation orders are more likely to evacuate, and that those who believe they were given mandatory evacuation orders have a higher rate of evacuation than those who believe they were given voluntary orders. While mandatory evacuation orders may not legally force people

Table 6
Estimated Willingness to Pay (WTP) for Hurricane Evacuation.

	Evacuation order	95% Lower limit	Median	95% Upper limit
Model 1	Voluntary	727	1,772	2,818
	Mandatory	1,833	3,865	5,898
Model 2	Voluntary	505	1,658	2,811
	Mandatory	1,370	3,706	6,042
Model 3	Voluntary	403	1,554	2,704
	Mandatory	1,162	3,553	5,944
Model 4	Voluntary	386	**1,571**	2,756
	Mandatory	1,114	**3,575**	6,036

Note: Unit: (USD$).

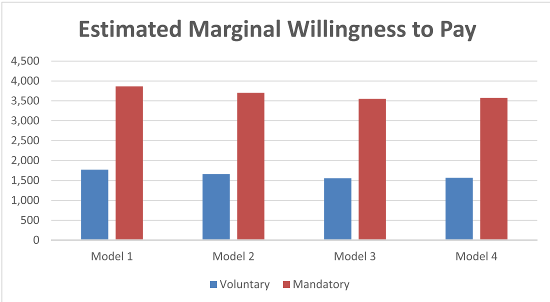

Fig. 4. Estimated Marginal Willingness to Pay (MWTP) by Evacuation Orders. Note: Fig. 4 shows the predicted MWTP across different models. Unit: (USD$).

to leave their homes, they serve as a communication of the severity of danger and the potential unavailability of emergency services (e.g., 911 and rescue service) in the evacuation zone. Regarding hurricane evacuation experience, our results show that individuals who had previously evacuated for Hurricane Rita were more likely to evacuate for Ike, as evidenced by the statistically significant coefficients of *EXPERIENCE* in Models 1–3. This finding provides evidence in support of the hypothesis H_3.

Moreover, our findings reveal that older respondents were more likely to evacuate during Hurricane Ike, as evidenced by the positive and significant coefficients on age. On the other hand, female respondents were more likely to evacuate for Hurricane Ike, as indicated by the negative and significant coefficients on gender. We did not find statistically significant evidence for the influence of income, education, and ownership on evacuation decision-making.

5.3. Estimating willingness to pay and Cost-of-Evacuation

Table 6 displays the estimated WTP, and Fig. 4 provides a visualization of the WTP by types of evacuation orders. Using Eq.(8), we apply the nonlinear transformations of the estimated parameter vector, coefficient of individual expenditure, and coefficients of type of evacuation order received (mandatory or voluntary order) to obtain the mean and standard deviation of the estimated WTP. Model 4 is the best of all the models since AIC is the smallest in Model 4. Accordingly, the MWTP is USD$1,571; the 95% confidence interval of WTP ranges from USD$386 to USD$2,756 for respondents who have received voluntary evacuation orders. The MWTP is USD$3,575; the 95% confidence interval of WTP ranges from USD$1,114 to USD$6,036 for those who have received mandatory evacuation orders. These results also verify Eq.(6); the WTP amount increases as the change in risk level increases from voluntary to mandatory evacuation order received. We argue that Table 6 reports the lower bound of the WTP based on the revealed and stated evacuation expenditure to avoid hurricane risks.

Using Eq.(9), we estimate the corresponding cost-of-evacuation. Cropper and Sahin (2009) reported that the cost-of-evacuation is equal to the sum of reductions in the death risk multiplied by the total population. According to the National Weather Service office report, approximately 500,000 residents of Galveston were in an evacuation zone when Hurricane Ike landed. From officials' statements, the population of the Harris County evacuation zone is nearly 245,000. We add these numbers and use the combined number (745,000 people) as the total population. Hurricane Ike caused 84 fatalities, and approximately 140,000 individuals were in the specific death zone. Approximately 30% of residents who lived in that zone did not evacuate; i.e., nearly 42,000 people remained home and lived with the worst risk of the storm surges. We calculate the hurricane mortality risks by using the 84 hurricane-induced fatalities divided by 140,000. Table 7 displays the estimated cost-of-evacuation, and Fig. 5 provides a visualization to compare the values by types of evacuation orders. Based on the results, cost-of-evacuation ranges from USD$0.6 million to USD$4.6 million for the voluntary evacuation order and USD$1.9 million to USD$10.1 million for the mandatory evacuation order.

Using the predicted evacuation probabilities under different evacuation orders reported in Table 2, we calculate the total number of predicted evacuees by multiplying the evacuation probabilities by the total population. Using Eq.(10) and multiplying the total

Table 7
Estimated Cost-of-evacuation (VSL) by Evacuation Orders.

	Evacuation order	95% Lower limit	Median	95% Upper limit
Model 1	Voluntary	1.2	3.0	4.7
	Mandatory	3.1	6.4	9.8
Model 2	Voluntary	0.8	2.8	4.7
	Mandatory	2.3	6.2	10.1
Model 3	Voluntary	0.7	2.6	4.5
	Mandatory	1.9	5.9	9.9
Model 4	Voluntary	0.6	**2.6**	4.6
	Mandatory	1.9	**6.0**	10.1

Note: Unit: (one million USD$).

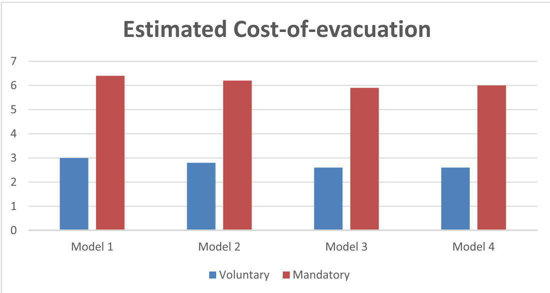

Fig. 5. Estimated Cost-of-evacuation (VSL) by Evacuation Orders. Note: Fig. 5 shows the predicted cost-of-evacuation across different models. Unit: (one million USD$).

Table 8
Predicted Number of Evacuees and Associated Total Expenditures of Evacuation.

Voluntary evacuation order		Mandatory evacuation order	
Evacuees	Total expenditures	Evacuees	Total expenditures
197,798	$60,646,419	249,913	$76,625,115

Table A1
The Disposition of Call Outcomes.

ANSWERING MACHINE	5,559
BUSINESS	173
BUSY	342
DISCONNECT	1,521
FAX/MODEM/CELL/BEEP	283
HANG UP	782
INITIAL REFUSAL	1,553
MID-TERMINATE	6
NO ANSWER	1,922
NOT RESIDENT/VISITOR, NOT LIVING IN AREA IN 2008 FOR IKE	310
RESPONDENT UNDER 18	33
READY TO CONTINUE	1,166
	13,650

Note: As there were multiple calls placed to some numbers, the dispositions in Table A1 do not add up to either of these numbers.

number of predicted evacuees by the estimated individual evacuation expenditure provides an estimate of the total hurricane evacuation expenditure. The total evacuation expenditures for different types of evacuation orders range from approximately USD$61 million to USD$77 million, as presented in Table 8.

This empirical analysis of evacuation behavior and related hurricane evacuation expenditures provides useful insights applicable to future emergency management efforts. The total expenditures of mandatory evacuations are approximately USD$16 million more than the total cost of voluntary evacuation orders; the tradeoff of changing a voluntary evacuation order to a mandatory order is how many lives can be saved. In Table 8, the cost-of-evacuation estimates based on the MWTP are between USD$0.6 million and USD$10.1 million. Applying the lower bound of cost-of-evacuation (USD$0.6 million), approximately 27 lives could be saved if the government

Table B1
Concepts of Economics Term Used.

Expected Utility (EU)[5]	Expected utility (EU) represents the utility that an entity or aggregate economy is expected to reach under any number of circumstances. The expected utility is calculated by taking the weighted average of all possible outcomes under specific conditions.
The Production Possibility Frontier (PPF)[6]	In microeconomics, a production–possibility frontier (PPF) is a graphical representation showing all the possible options of output for two goods that can be produced using all factors of production, assuming full and efficient utilization of resources over a given time period. This tradeoff can be applied to decision-making at all levels, including individuals, households, and economic organizations.
Willingness to Pay (WTP)[7]	Willingness to pay (WTP) is the maximum price a consumer is willing to pay for a product or service, representing their reservation price in standard economic theory. WTP is also commonly used to measure consumer valuation of non-market goods, such as health improvements, risk reductions, and environmental quality enhancements.
Marginal Willingness to Pay (MWTP)[8]	Marginal willingness to pay (MWTP) is the additional amount of money consumers are willing to pay for each additional unit of goods or services, over and above what they are currently paying for the existing units.
Willingness to Accept (WTA)[9]	In economics, willingness to accept (WTA) is the minimum monetary amount that a person is willing to accept to sell a good or service, or to bear a negative externality, such as pollution. In contrast to WTP, WTA is the maximum amount of money a consumer is willing to pay to purchase a good or service, or to avoid something undesirable. Choice modeling techniques, such as choice experiments or contingent value techniques, are commonly used to estimate the value of WTA by asking respondents what they would be willing to accept for different hypothetical scenarios.
The Value of a Statistical Life (VSL)[10]	The value of a statistical life (VSL) represents the local tradeoff rate between fatality risk and monetary resources. When the tradeoff values are derived from choices made in market contexts, the VSL serves as both a measure of the population's willingness to pay for risk reduction and the marginal cost of enhancing safety.

[5]Expected Utility: Definition, Calculation, and Examples By James Chen, Updated May 07, 2021, Reviewed by Thomas Brock, https://www.investopedia.com/terms/e/expectedutility.asp.
[6]Sickles, R., & Zelenyuk, V. (2019). Measurement of Productivity and Efficiency: Theory and Practice. Cambridge: Cambridge University Press.
[7]Varian, Hal R. (1992), Microeconomic Analysis, Vol. 3. New York: W.W. Norton.
[8]https://conjointly.com/guides/how-to-interpret-marginal-willingness-to-pay/.
[9]Martín-Fernández, J., del Cura-González, M. I., Gómez-Gascón, T., Oliva-Moreno, J., Domínguez-Bidagor, J., Beamud-Lagos, M., & Pérez-Rivas, F. J. (2010). Differences between willingness to pay and willingness to accept for visits by a family physician: a contingent valuation study. BMC Public Health, 10(1), 1–11.
[10]Kniesner, T. J., & Viscusi, W. K. (2019). The value of a statistical life. Forthcoming, Oxford Research Encyclopedia of Economics and Finance, Vanderbilt Law Research Paper, (19–15).

were to change a voluntary evacuation order to a mandatory order. Using the upper bound of cost-of-evacuation (USD$10.1 million), approximately 1 life could be saved if the government were to change a voluntary evacuation order to a mandatory order.

6. Discussions and conclusion

In this study, we conducted an empirical exercise to analyze individuals' evacuation behaviors under a hurricane threat based on the theoretical framework of utility maximization and lifecycle consumption model. We used individuals' evacuation expenditures and the intensity of hurricane risks (evacuation orders) to obtain individuals' preferences for responding to risk. Specifically, we utilized the revealed preference data (respondents' actual evacuation costs) and the stated preference data (respondents' estimated evacuation costs had they chosen to evacuate) on evacuation costs and evacuation decisions during Hurricane Ike. The findings from the estimated models revealed three primary sets of determinants of evacuation decisions: 1) evacuation expenditures, 2) evacuation orders, and 3) past evacuation experience. These results suggest that as expected evacuation costs increase, the probability of evacuation decreases; respondents who receive evacuation orders are more likely to leave; and individuals with past hurricane evacuation experiences are more likely to evacuate in future disasters.

Moreover, we estimate the individuals' WTP for evacuating to for responding to hurricane risk. Individuals' evacuation expenditures presented in this study can be considered a lower bound of individual WTP for risk aversion through hurricane evacuation. The findings indicate that the average cost of an individual's hurricane evacuation is USD$227, and the total expenditures for coastal communities in Texas range from approximately USD$61 million (under voluntary evacuation orders) to USD$77 million (under mandatory evacuation orders) (Table 7). The approach presented here is useful because hurricane evacuation costs are often challenging to measure. The estimates provided in our analysis can offer valuable insights for future evacuation planning and decision-making efforts.

We acknowledge several limitations of the study. First, we estimated hurricane evacuation expenditures by combining RP (actual expenditures) and SP (expected expenditures) responses. The limitation here is that the actual expenditures were incurred as a result of the hurricane evacuation, therefore, they cannot influence the pre-disaster evacuation decision-making. Thus, we relied on the assumption that actual evacuation expenditures are a "reasonable" proxy for expected evacuation costs, and that is most likely to be true for those with previous evacuation experience (Kang et al., 2007). Second, the expected expenditures (SP data) were notably higher compared to the actual expenditures (RP data). This may indicate a significant psychological difference between individuals' reports of what they actually paid for their evacuation (which is based on memory) and reports of what they would expect to pay for an evacuation (which is likely based on their previous travel experience, such as evacuations, vacations, or other travel). While it is reasonable to assume that reports of actual evacuation expenses are relatively accurate, there appear to be no studies that have examined the accuracy of expected evacuation expenses. Future research could further investigate the comparison between expected and actual evacuation behaviors in terms of expenditures. Furthermore, the data measured people's perceived evacuation orders, which are not necessarily the same as the official orders that were issued for their locations (Baker, 1991). Future studies can explore ways to validate the perceived evacuation orders with official evacuation records to ensure the accuracy of the data. Our survey targeted households that were impacted by Hurricane Ike, and as a result, the majority of respondents were clustered in two counties (Harris and Galveston) near Ike's landfall location. If the study uses stated preference methods based on hypothetical hurricane scenarios, a more diverse sample can be collected, covering populations from different regions to measure the WTP for different hurricane and flood risks based on location.

In conclusion, this study used empirical analysis to estimate the individual's WTP for avoiding hurricane risks under voluntary and mandatory evacuation orders and calculated the associated cost-of-evacuation. Despite the limitations, the study contributes to the understanding of evacuation expenditure and evacuation decision-making. The theoretical framework and economic approach of calculating the willingness to pay (WTP) and cost-of-evacuation adds a different dimension to the literature on examining hurricane evacuation behaviors. This same methodology can be applied to different hurricane events or other types of natural hazards (e.g., wildfire, tsunami) in other regional contexts, by combining additional survey datasets to obtain the WTP estimates. The results provide practical insight that can enable emergency management agencies to issue appropriate evacuation orders before a hurricane hits. Moreover, the findings indicate that evacuation is more likely to occur in areas with mandatory evacuation orders than in areas with voluntary evacuation orders, suggesting that more lives can be saved if governments issue a mandatory evacuation order instead of a voluntary evacuation order when it is necessary. The findings of this study may be useful for emergency management agencies and community planners in Texas and other coastal communities facing similar challenges.

CRediT authorship contribution statement

Fan Jiang: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Sisi Meng:** Visualization, Formal analysis, Writing - review & editing. **Mohammad Khan:** Writing – review & editing. **Nafisa Halim:** Writing – review & editing. **Pallab Mozumder:** Conceptualization, Methodology, Supervision, Data curation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix. .

See Table A1 and Table B1.

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