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Understanding Hurricane Evacuation Decisions Under Contingent Scenarios: A Stated Preference Approach

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Abstract We conduct a stated preference analysis to understand the factors that individual households take into consideration to evacuate during hurricanes. In designing the contingent scenarios for evacuation, we randomly assign varying levels of hurricane characteristics (wind speed, lead time for landfall and the height of storm surge) combined with different types of emergency management options (voluntary versus mandatory evacuation order and a voucher with varying amounts to cover evacuation expenses). Findings indicate that individual households respond, in a non-linear fashion, to the intensity of hurricanes when making evacuation decisions. Respondents are also more likely to evacuate when the storm surge reaches a certain threshold. In terms of policy interventions, mandatory evacuation orders are more effective to increase the likelihood of evacuation. The potential intervention in the form of providing evacuation vouchers to assist households to cover their expenses (e.g. for food, water, transportation and lodging) also seems effective. We discuss policy implications of our findings.

Keywords Hurricane · Evacuation · Stated preference · Contingent behavior · Evacuation order · Voucher

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1 Introduction

Hurricanes are among the most destructive natural events that coastal areas in the United States (US) face every year. For instance, hurricane Sandy, which made landfall along the southern New Jersey shore in October 29, 2012, impacted 24 states with storm surge, damaging winds, and flooding. The devastation that Sandy left behind is estimated to exceed $50 billion. Sandy was the deadliest hurricane to hit the US since hurricane Katrina in 2005 with 147 deaths directly or indirectly attributed to it (NOAA 2013). In the event of a hurricane, evacuation may be one of the most effective alternatives to reduce hurricane-related fatalities. It would be helpful to observe household evacuation behavior under different conditions to improve our understanding of evacuation decisions and thus implement effective policies to cope with hurricane disasters. However, analyzing and predicting evacuation behavior under different hurricane conditions may be difficult because households are not often exposed to hurricanes and therefore there is limited variability of hurricane characteristics (i.e. wind intensity, storm surge) in existing hurricane evacuation data. In addition, collecting data from households that have been exposed to multiple hurricanes with different characteristics can be costly and difficult.

When observed data do not allow to investigate in-depth behavioral responses, stated preferences methods are extensively used to understand individual and social preferences for varying levels of environmental attributes. The stated preference approach enables us to overcome the limited variability of hurricane characteristics in observed evacuation behaviors given that this approach can introduce exogenous variation of hurricane characteristics into contingent scenarios. Whitehead (2003) provides an example of a stated preferences study conducted to investigate hurricane evacuation behaviors in North Carolina. He developed a contingent scenario where hurricane intensity was randomly varied across respondents. Respondents were also provided with different evacuation orders (hurricane watch, voluntary order, and mandatory order) in a sequential fashion. His findings indicate that respondents take hurricane intensity into consideration to decide whether to evacuate or not. In terms of evacuation orders, his results suggest that mandatory orders increase the likelihood of evacuation, but voluntary orders do not.

Petrolia and Bhattacharjee (2010) and Petrolia et al. (2011) developed 15 scenarios with different levels of wind speed (85, 121, or 156 miles per hour), directional change in storm intensity (wind speed decreasing, remaining the same, or increasing), landfall time (3 or 5 days) and evacuation notice (advisable or mandatory) to investigate evacuation behaviors in the Gulf of Mexico states (Alabama, Florida, Louisiana and Mississippi). Petrolia et al. (2011) found that evacuation decisions are related to wind speed and landfall time. Petrolia and Bhattacharjee (2010) also found that wind speeds are relevant for households to decide whether to evacuate or stay at home, and that mandatory evacuation orders also influence evacuation decisions. Those studies have proved that eliciting stated preferences for evacuation may provide insightful information for designing effective policies to mitigate the potential impacts of hurricanes in the US.

This study follows a stated preferences approach to investigate evacuation decisions in the coastal states of northeastern and Mid-Atlantic United States, an area that has received little attention by the literature on hurricane evacuations despite having been recently hit by major hurricanes. Contingent scenarios developed in this study randomly vary key hurricane characteristics such as wind intensity based on Saffir–Simpson category, landfall time, and the height of storm surge to learn how respondents would react when facing hurricanes with these varying attributes. Our contingent scenarios also include two policy tools that can motivate households to evacuate in the event of a hurricane: evacuation orders and financial assistance in the form of vouchers for food, lodging, and transportation.

Evacuation orders set by the emergency management agency streamline the complex set of risk information and enable residents to make more informed evacuation decisions and thus it can be an important policy tool in areas vulnerable to hurricanes (Petrolia and Bhattacharjee 2010; Whitehead 2003). Financial assistance could also help reduce hurricane-related fatalities by making evacuation affordable for vulnerable households that lack resources to cope with coastal hazards. Incorporating the voucher into our experimental design allows us to estimate the minimum amount of compensation needed for a respondent to agree to evacuate in the event of a hurricane and thus helps trace evacuation costs that are hardly observed in existing hurricane studies. To the extent of our knowledge, this is the first stated preferences study that explicitly deals with the notion of financial assistance as a potential tool to encourage hurricane evacuation.

Our empirical analysis is based on responses from 1212 representative households collected through an online survey. Each respondent was provided with two sequential scenarios in order to increase the number of stated evacuation choices. Factors underlying those evacuation choices are estimated through random-effects logit models. Estimation results indicate that individuals respond, in a non-linear fashion, to the intensity of the hurricane when making evacuation decisions. Respondents are also more likely to evacuate when the height of storm surge reaches certain threshold. In terms of policy interventions, mandatory evacuation orders are found effective in increasing the likelihood of evacuation. Voluntary evacuation orders are effective as well, but to a lesser extent than mandatory orders.[1] Vouchers provided to assist households to cover their evacuation expenses also seem to be an effective policy tool.

The rest of the paper is organized as follows. Section 2 provides an overview of the online survey implemented to gather information on household risk perceptions and risk averting behaviors, and describes the contingent scenarios developed to investigate evacuation decisions under different hurricane conditions. Section 3 presents the analytical framework and econometric modeling approach followed to conduct empirical analyses of the data at hand and Sect. 4 presents the estimation results. The last Sect. 5 concludes the paper with a discussion on some policy implications of our results.

2 Survey Design

We designed an internet-based survey to gather information on individual preferences and intended behaviors as related to mitigation strategies adopted when facing hurricane related disasters. The survey design included one-on-one semi-structured conversations with faculty and staff members and a focus group with students who resided in areas affected by hurricane Sandy (in 2012). Their feedback was incorporated through different iterations in order to refine the survey questionnaire. The questionnaire was pretested and implemented online by a reputed organization, GfK (formerly known as Knowledge Networks) that routinely implements a variety of public opinion surveys using its unique panel of respondents (KnowledgePanel®). A total of 60 individuals living in the affected areas pretested the survey questionnaire in June 27–July 7, 2013.

GfK implemented the further refined online survey in counties affected by hurricane Sandy in the northeastern and Mid-Atlantic US (New Jersey, New York, Connecticut, Maryland,

[1] Though statutory variations exist across states in enforcing the mandatory evacuation order during an emergency, it is not automatically enforced and not necessarily interpreted as a legally binding order. In practice, the mandatory evacuation order is used to communicate the sheer urgency of the situation and to make additional resources available for those who are unable to evacuate voluntarily (Bohannon 2011; Wolshon et al. 2005). Also, see further discussion on this issue in Sect. 2.

Table 1 Experimental design

Attributes	Levels
Hurricane category (in Saffir–Simpson scale)	1, 2, 3, 4, 5
Time for the hurricane to make landfall	6, 12, 18, 24 h
Storm surge	2, 4, 6, 8 ft
Evacuation voucher	\$100, \$200, \$300, \$400, \$500
Evacuation order	None, voluntary, mandatory

Massachusetts, Virginia, Delaware, Pennsylvania, Rhode Island and West Virginia). GfK ensures the representativeness of KnowledgePanel survey samples as measured by their proximity to population benchmarks. The survey was posted online on July 11, 2013 and was closed 2 weeks later on July 22. A total of 1,212 individuals completed the survey with a response rate of 61.93%. Altogether the survey had 48 questions on issues related to hurricane risk, coastal vulnerability, individual preferences and intended behaviors related to hurricane events. On average, it took about 15 min to complete the survey.

The survey included contingent behavior questions on intended evacuation in the face of an approaching hurricane. Three hurricane attributes were randomly changed across contingent scenarios to describe particular conditions under which the respondent could choose to evacuate or not (see Table 1). First, respondents were provided with a hurricane approaching to the area where they live. The category of that hurricane was randomly varied between 1 and 5 in the Saffir–Simpson scale. Second, the time when the hurricane was expected to make landfall on the respondent's neighborhood was randomly varied among four possibilities: 6, 12, 18, and 24 h. These hours are consistent with preplanned evacuation times implemented by some states in the northern Atlantic coast (Wolshon et al. 2005). Third, the scenario provided information on the height of the storm surge expected in the area, varying from 2 feet to 8 feet in increments of 2 feet. These attributes and levels were chosen based on our own experiences from previous work on evacuation behavior, discussions with colleagues who work in this area, and conversations with national and local emergency management personnel (at the National Hurricane Center and local emergency management in Miami). In addition to hurricane characteristics, the scenarios also included two policy tools: an evacuation order and financial assistance in the form of a voucher for those households who decide to evacuate their homes. Respondents were randomly given no official order to evacuate, a voluntary evacuation order, or a mandatory order. Financial assistance in the form of a voucher for evacuees randomly varied from \$100 to \$500 with increments of \$100.

We have considered a number of factors in setting up the bid distribution for evacuation vouchers. First, we have considered findings from earlier research on evacuation related expenses (Mozumder and Vásquez 2015 estimated that, on average, households spent \$194 for voluntary evacuation order and \$300 for mandatory order during hurricane Ike in the Gulf Coast region). Second, we have incorporated feedback from focus groups and individual interviews before launching the survey. We have extended the lower and upper bounds of the bid distribution based on that feedback. We did not restrict vouchers to be offered only for voluntary evacuation. Although during a mandatory evacuation order emergency management agencies put maximum resources and effort to encourage evacuation, current laws do not allow agencies to strictly enforce the order (Wolshon et al. 2005).[2] The contingent behavior questions read as follows:

[2] A mandatory evacuation order is not considered as a legally binding order as it is neither effective nor beneficial (Bohannon 2011; Wolshon et al. 2005), and during a hurricane emergency, a mass arrest of residents

> Suppose that a hurricane category [1, 2, 3, 4, 5], in the Saffir–Simpson scale, will hit the area where you live in [6, 12, 18, 24] h. The surge is expected to be at least [2, 4, 6, 8] feet. There is [no official, a voluntary, a mandatory] order of evacuation. A federal program will provide evacuees with a voucher for [$100, $200, $300, $400, $500] to buy food, water and gas, as well as to pay for lodging while away from home. Would you evacuate under these conditions?

Each respondent observed two sequential contingent scenarios with levels of hurricane characteristics and policy instruments that were randomly varied across respondents and contingent scenarios. Given the number of attributes and levels, our experimental design generated 1200 choice scenarios ($5 \times 4 \times 4 \times 3 \times 5 = 1200$) and each of our 1212 respondents (who recorded two sequential responses) had an equal probability to see one of those choice scenarios. After each scenario, respondents were asked whether or not they would evacuate under the given conditions. Factors driving evacuation decisions can be identified by analyzing responses to our survey questionnaire and, more specifically, to the contingent scenarios presented here.

3 Analytical Framework and Econometric Modeling

Hurricane evacuation choices can be analyzed using a state-dependent utility theoretic framework. Let us assume that the utility function (V) for an individual depends on her disposable income (I) and is also affected by the level of safety (s), which can vary across different states of the world ($w \in 1, 2, \ldots$, n). There is uncertainty in the state of the world that the individual will face and $\pi(w)$ is the perceived probability that state w will occur. In the face of an approaching extreme weather event (a hurricane), the individual confronts the dilemma of evacuation decision-making ($E \in 0, 1$). The state-dependent utility function (Smith 1983; Cameron 2005) of evacuation can be described as $U^E = \sum_{w=1}^{n} V(I,\ s_w^E)\ \pi(w)$. Now to elaborate, if the individual chooses to evacuate in the presence of an approaching hurricane, she will have to incur the associated cost of evacuation (C) in order to maintain her safety at an acceptable level s_w^1. The indirect utility function can be expressed as $U^1 = \sum_{w=1}^{n} V(I - C,\ s_w^1)\ \pi(w)$. If the individual does not evacuate (and incurs no evacuation cost), her safety can be compromised for some states of the world (e.g. when facing a hurricane is imminent) and her safety could be the same for other states (e.g. the hurricane does not hit the area where the individual lives), i.e. $s_w^1 \geq s_w^0$. The decision of no evacuation yields a utility level of $U^0 = \sum_{w=1}^{n} V(I,\ s_w^0)\ \pi\ (w)$.

Footnote 2 continued
who refuse to comply with a mandatory evacuation order is unforeseen. It is widely documented that a significant proportion of residents does not comply with mandatory evacuation orders due to their personal circumstances and preferences (Dow and Cutter 2000; Dash and Morrow 2001; Dostal 2015). However, the emergency management agencies vividly communicate the dangerous scenarios for those who decide to stay put. For instance, for an approaching hurricane, they are informed that intense storm with strong wind and high water could isolate those residents for extended periods and emergency rescue officials will not risk their lives to respond in mandatory evacuation areas during the storm. Those who decide not (or are unable) to comply with the official order are expected to remain fully self-sufficient during and immediately after the storm as basic utilities (e.g. electricity, water, phone and internet) and emergency services (e.g. police rescue, fire, ambulance) may not be available. So the difference in voluntary and mandatory evacuation orders can be seen as a mechanism to communicate the urgency and the severity of danger, and more from an operational point of view. For example, special transportation and traffic control measures are operated during mandatory evacuation orders, which are not common during voluntary evacuation orders (Wolshon et al. 2005; Mozumder et al. 2008).

Given that the individual makes the evacuation decision ex-ante, we consider the compensated option price for evacuation (*COP*) instead of compensated variation (*CV*). The compensated option price is similar to the concept of option price with supply uncertainty. That is, uncertainty is arising from the state of the world as opposed to individual decisions and preferences (see, Smith 1985; Graham-Tomasi and Myers 1990; Cameron 2005). The compensated option price (*COP*) that makes the expected utility identical across all states can be expressed as $\sum_{w=1}^{n} V(I - COP,\ s_w^1)\ \pi\ (w) = \sum_{w=1}^{n} V(I,\ s_w^0)\ \pi(w)$. It is worth mentioning that the individual will not evacuate if evacuation costs are higher than the compensated price option (i.e. $U^1 < U^0$ if $C > COP$).

As described in the state-dependent utility framework, when a hurricane is approaching to make a landfall in a given area, uncertainty remains over both evacuation and non-evacuation decision made by the individual to stay in a less hazardous environment. The individual may have some good information on some characteristics of the state of the world such as hurricane intensity, time remaining for landfall, storm surge and advisory in the form of evacuation order. Evacuation orders are instrumental in reducing uncertainty about the state of world and the expected level of safety associated with it. Yet, some other characteristics of the state of the world remain unknown at the moment of decision-making to evacuate or to stay at home.

Depending on the state of the world, the ex-ante evacuation (or non-evacuation) decision can lead to different ex-post outcomes and utility levels. For instance, in ex-post considerations, an evacuation may be seen unnecessary due to a last minute changing track of a hurricane or a non-evacuation may be seen appealing due to heavy traffic congestion in the evacuation path. Our contingent scenarios simulate these conditions from a realistic perspective, where we have exogenously varied the level of some key attributes of the forecasted state of the world (i.e. hurricane intensity, time remaining for landfall, storm surge) and advisory information to reduce the exposure to hazard risk (evacuation order), while not including some other factors in the contingent scenarios as they are more likely to be revealed ex-post (e.g. hurricane track uncertainty, traffic condition for evacuation, etc.).

A key attribute that is explicit in the survey is the voucher which can influence the evacuation decision particularly when evacuation costs surpass the individual's compensated option price for evacuation (i.e. $C > COP$). We consider that people living in the hazard prone areas are subject to a wide range of behavioral biases in perceiving the risks posed by low probability high consequence extreme weather events (Kunreuther et al. 2013). A majority of people are also constrained by resources needed to act on in mitigating these risks (Mozumder and Vásquez 2015; Vásquez et al. 2016). On the other hand, the public agency has an obligation to protect its citizens from these impending risks and would like to help them by offering information and incentives to persuade to take risk mitigation measures.

In addition to providing risk information in the form of hurricane intensity, time remaining for landfall, height of storm surge and evacuation order (what we usually see), suppose that the public agency [e.g. Federal Emergency Management Agency (FEMA) in the US context], is considering to offer evacuation vouchers to subsidize the cost of evacuation. With this contingent set-up, we attempt to estimate the minimum amount of compensation needed to induce people to evacuate. The estimated minimum amount of compensation or voucher (m) can be considered as a lower bound of the *COP*. With the voucher (m), the utility gap between evacuating and not evacuating can be represented by a latent variable Y^*, where $Y^* = \sum_{w=1}^{n} V(I - C + m,\ s_w^1)\ \pi(w) - \sum_{w=1}^{n} V(I,\ s_w^0)\ \pi(w)$. Consequently, Y^* is a function of income, evacuation costs, the voucher, and safety levels that vary with different attributes of the state of the world (e.g. hurricane intensity and storm surge), as well as the perceived occurrence probability of different states of the world.

The individual will evacuate if and only if Y^* is greater than zero. However, Y^* cannot be observed, but it can be uncovered using the individual responses on intended evacuation elicited through two sequential contingent scenarios included in our survey questionnaire. Although respondents were asked to evaluate those scenarios independently from each other, the errors across the respondent's choices are likely to be correlated (Petrolia et al. 2011). For this reason, the data was structured as a panel where respondent i will evacuate at time t (with $t = 1, 2$) if and only if $Y_{it}^* > 0$. Under the assumption that Y_{it}^* follows a linear specification, the individual i's choice of evacuating at time t (E_{it}) can be modeled using a logit specification as follows:

$$\begin{array}{ll} E_{it} = 1 & \quad \textit{if} \;\; Y_{it}^* = \beta X_{it} + \delta Z_i + \nu_{it} + u_i > 0 \\ E_{it} = 0 & \quad \textit{otherwise} \end{array} \tag{1}$$

where, X represents safety-related attributes of the state of the world known to the individual that were randomly varied across the contingent scenarios (i.e. hurricane intensity, time remaining for landfall, storm surge, evacuation orders, and the voucher).The vector Z represents individual characteristics such as income and other sociodemographic factors that can affect the perceived probability of potential states of the world and the decision to evacuate. Vectors β and δ are the conformable vectors of coefficients to be estimated. These coefficients reflect both individual preferences towards money and safety levels and also the perceived probabilities of states of the world [π (w)] since the evacuation choice is made based on expected utility maximization (de Palma et al. 2008). The idiosyncratic error term is represented by ν, and u represents individual effects included to model unobserved heterogeneity across respondents.

In linear panel data, the unobserved heterogeneity of respondents depicted by the u_i term can be modeled through fixed or random effects. However, in nonlinear panel data such as the binary indicator E_{it}, fixed effects models yield biased and inconsistent estimators due to the incidental parameters problem (see Greene 2012). This leaves us with random effects logit specifications to model the unobserved heterogeneity of respondents (see Petrolia et al. 2011 for a recent application of random effects logit models used to analyze stated hurricane evacuation decisions).

Table 2 introduces the hurricane related attributes included in vector X that were derived from the experimental design. Contingent scenarios could vary in hurricane intensity, expected time left for the hurricane landfall, and the extent of storm surge. A set of binary variables is used to represent the Saffir–Simpson scale of hurricane intensity that respondents confront in the contingent scenario: CATEG2, CATEG3, CATEG4, and CATEG5. The hurricane of category 1 is excluded from the random effects logit models to serve as base of comparison. Given that the expected level of safety decreases with the hurricane category, those indicators are expected to have positive coefficients (i.e. increase the likelihood of evacuation). Similarly, a set of binary indicators are used to represent the lead time in terms of number of hours for expected hurricane landfall: HOURS6, HOURS12 and HOURS18. These indicators are compared to an expected landfall time of 24 h. The likelihood of evacuation is expected to increase as the landfall time approaches. Three binary indicators, SURGE4, SURGE6 and SURGE8 are included in the logit models to estimate the impact of expected height of storm surge on the likelihood of evacuation. Given that the lowest surge (2 feet) in the experimental design is used as base of comparison, the surge indicators are expected to have positive coefficients because safety level would decrease in a state of the world with relatively higher level of storm surge.

The experimental design also included two evacuation policy tools: financial support and evacuation orders. The variable LNVOUCHER represents the natural logarithm of the amount

Table 2 Definition and descriptive statistics of experimental variables

Variables	Definition	Mean	SD
EVACUATE	If respondent chooses to evacuate (1 = yes, 0 = otherwise)	0.555	0.497
CATEG2	If the hurricane is category 2 (1 = yes, 0 = otherwise)	0.193	0.395
CATEG3	If the hurricane is category 3 (1 = yes, 0 = otherwise)	0.197	0.397
CATEG4	If the hurricane is category 4 (1 = yes, 0 = otherwise)	0.202	0.401
CATEG5	If the hurricane is category 5 (1 = yes, 0 = otherwise)	0.209	0.407
HOURS6	If the hurricane is predicted to make landfall in six hours (1 = yes, 0 = otherwise)	0.244	0.429
HOURS12	If the hurricane is predicted to make landfall in 12 hours (1 = yes, 0 = otherwise)	0.258	0.438
HOURS18	If the hurricane is predicted to make landfall in 18 hours (1 = yes, 0 = otherwise)	0.262	0.440
SURGE4	If four feet surge is expected (1 = yes, 0 = otherwise)	0.246	0.431
SURGE6	If six feet surge is expected (1 = yes, 0 = otherwise)	0.247	0.431
SURGE8	If eight feet surge is expected (1 = yes, 0 = otherwise)	0.255	0.436
LNVOUCHER	The natural logarithm of the voucher amounts offered to evacuees	5.565	0.568
VOLUNTARY	If a voluntary evacuation order has been issued (1 = yes, 0 = otherwise)	0.332	0.471
MANDATORY	If a mandatory evacuation order has been issued (1 = yes, 0 = otherwise)	0.349	0.476

Category 1 hurricane, hurricane landing in 24 h, two feet surge, and no evacuation order as used as corresponding bases of comparison

of financial support to be offered to households who decide to evacuate in the contingent scenario. As stated above, this variable is expected to have a positive effect on the likelihood of hurricane evacuation because such a transfer may help relax budget constraints (i.e. it can reduce the cost of evacuation). By including the voucher amount in logarithmic form, it is guaranteed that subsequent prediction of the median compensation needed to induce people to evacuate is non-negative. The binary indicators VOLUNTARY and MANDATORY represent evacuation orders. The indicator VOLUNTARY takes the value of one if a voluntary order is issued in the contingent scenario, and zero otherwise. The indicator MANDATORY is defined in a similar way for mandatory orders. Both indicators are expected to increase the likelihood of evacuation because they provide information about a state of the world that could compromise the level of safety. Mandatory evacuation orders are expected to have a larger impact on the decision to evacuate relative to voluntary evacuation advice.

Table 3 Definition and descriptive statistics of control variables

Variables	Definition	Mean	SD
INCOME	Household's income (measured in intervals of $ 25,000)	3.917	1.987
AGE	Age of the respondent (in years)	53.405	15.273
FEMALE	If the respondent is female (1 = yes, 0 = otherwise)	0.584	0.493
PETS	Number of pets living at the respondent's home	1.084	1.734
CONCERN[a]	If the respondent's concern on hurricane impacts is above the average (1 = yes, 0 = otherwise)	0.452	0.497
SANDYEVAC	If the respondent evacuated due to hurricane Sandy in 2012 (1 = yes, 0 = otherwise)	0.072	0.258
PRIOREVAC	If the respondent has evacuated due to at least one hurricane prior to Sandy (1 = yes, 0 = otherwise)	0.086	0.280
EVACPLAN	If the household has a hurricane evacuation plan (1 = yes, 0 = otherwise)	0.347	0.476
GENERATOR	If the household owns an electric generator (1 = yes, 0 = otherwise)	0.231	0.422
HOUSEAGE	Age of the respondent's housing unit (in years)	54.575	51.253
WINDOWS	If windows of the respondent's house have protection against hurricanes (1 = yes, 0 = otherwise)	0.048	0.214
MODIFIED	If the respondent's house has been modified to reduce hurricane damages (1 = yes, 0 = otherwise)	0.103	0.305
SMOKE	If the respondent smokes (1 = yes, 0 = otherwise)	0.098	0.297
DISABLE	Number of household members who are disabled	0.193	0.517
SENIOR	Number of household members who are 65 years old or older	0.509	0.761

[a] The subjective risk elicitation question (CONCERN) was as follows: what is your personal level of concern about the projected impacts of hurricanes, storm surge, flooding and other hurricane-related events on your household's well-being (health, finances, property), on a scale from 0 to 10, where 0 is 'Not concerned at all' and 10 is 'Highly concerned'?

Table 3 shows sociodemographic factors included to control for potential heterogeneity of respondents (see Dash and Gladwin 2007 for a detailed review of diverse factors driving hurricane evacuation decisions). In addition to responding to hurricane characteristics, individuals may decide to evacuate based on their preparedness to cope with hurricane threats, experience with hurricanes, and risk attitudes (Solís et al. 2010), as all these factors may affect the perceived probability to experience a state of the world where safety may be compromised. The variables HOUSEAGE, WINDOWS, MODIFIED, GENERATOR, and EVACPLAN are included to represent preparedness to cope with hurricane events. Compared to old houses, newer dwelling units may be more resistant to hurricane force winds due to updated building codes. Thus, the perceived probability of facing a less safe state of the world would be lower for individuals living in newer houses and, consequently, the likelihood of evacuation may increase with the age of housing units. Likewise, households with a hurricane evacuation plan are expected to be more likely to evacuate because presumably they have already given some thoughts on how to proceed during the evacuation (Petrolia and Bhattacharjee 2010). The binary indicators WINDOWS, MODIFIED and GENERATOR are expected to have negative coefficients because all of them represent housing improvements that can help mitigate hurricane related hazards and increase safety levels.

The binary indicators SANDYEVAC and PRIOREVAC are included to control for the respondent's evacuation experience, as individuals tend to incorporate those experiences in their expected state of the world which can drive their evacuation decision process (Dow and Cutter 2000). Respondents' attitudes are depicted by the variables CONCERN and SMOKE. Individuals whose concerns about projected impacts of hurricane-related events on their households' well-being are above the average are expected to be more likely to evacuate as they may overestimate the probability of an unsafe state of the world. In contrast, respondents who are more likely to adopt risky behaviors (e.g. smoking) are expected to stay at home in the event of a hurricane (Shaw et al. 2012).

The variables PETS, DISABLE, SENIOR and INCOME are included to further control for respondents' heterogeneity. For instance, individuals with a larger number of pets may find it more expensive to evacuate and, in turn, may prefer to stay at home with their pets (Solís et al. 2010). Similarly, the cost of evacuation may increase with the number of disabled and senior members in the household (Gladwin and Peacock 1997; Van Willigen et al. 2002). The expected effect of INCOME is ambiguous. On one hand, households with higher income may afford to pay for evacuation expenses and thus would be more likely to evacuate. On the other hand, richer households may live in homes that are less vulnerable to hurricanes and they can afford to being prepared to cope with hurricanes. In those cases, households may prefer to stay at home in the event of a hurricane because the perceived probability to experience a relatively unsafe state of the world is minimal. Evacuation decision models also include individual characteristics such as age and gender. The effects of those characteristics on the likelihood of evacuation remain to be empirically estimated.

4 Results

Table 4 presents estimates of marginal effects derived from two random effects logit models. Model 1 includes the experimental indicators only. Model 2 includes a number of individual and household characteristics included to control for potential heterogeneity of respondents and their perceived probability of different states of the world. Results show a considerable degree of robustness, although the Akaike and Bayesian Information Criteria (AIC and BIC, respectively) favor Model 2 over Model 1. Hence, hereafter, results are discussed based on Model 2. The estimated intra-class correlation (ρ) is significant at 1% levels in both models in Table 4 indicating the presence of correlated errors across individuals, which validates the estimation of random-effects models. Moreover, in Model 2, the ρ estimate indicates that more than 68% of the total variance in intended evacuation can be explained by unobserved heterogeneity at the individual respondent level depicted by random effects.

Findings indicate that the likelihood of evacuation increases with the hurricane intensity as measured by the Saffir–Simpson scale. This result is not unusual as the level of safety drops with hurricane intensity. Moreover, the intensity effect on evacuation decisions is nonlinear, S-shaped with the highest increase in the likelihood of evacuation occurring from category 2 to category 3 (about 20% points), followed by the increase in intensity effect occurring from category 3 to category 4 (about 13% points). The probability of evacuation for a hurricane of category 5 is 42% points greater than for the evacuation probability in the event of a hurricane

Table 4 Random effects logit models of contingent evacuation behavior

	Model 1	Model 2
LNVOUCHER	0.092 (0.022)***	0.086 (0.021)***
CATEG2	0.046 (0.039)	0.064 (0.036)*
CATEG3	0.268 (0.039)***	0.262 (0.037)***
CATEG4	0.400 (0.036)***	0.397 (0.035)***
CATEG5	0.440 (0.036)***	0.423 (0.034)***
HOURS6	−0.002 (0.037)	0.009 (0.035)
HOURS12	−0.037 (0.036)	−0.024 (0.033)
HOURS18	−0.006 (0.035)	0.011 (0.033)
SURGE4	0.097 (0.034)***	0.086 (0.032)***
SURGE6	0.175 (0.034)***	0.163 (0.032)***
SURGE8	0.207 (0.034)***	0.180 (0.032)***
VOLUNTARY	0.063 (0.029)**	0.054 (0.028)*
MANDATORY	0.418 (0.028)***	0.394 (0.027)***
INCOME	–	−0.020 (0.008)***
AGE	–	−0.005 (0.001)***
FEMALE	–	0.102 (0.031)***
PETS	–	−0.023 (0.009)***
CONCERN	–	0.121 (0.030)***
SANDYEVAC	–	0.135 (0.074)*
PRIOREVAC	–	0.085 (0.059)
EVACPLAN	–	0.065 (0.032)**
GENERATOR	–	−0.056 (0.036)
HOUSEAGE	–	−0.0002 (0.0002)
WINDOWS	–	−0.106 (0.074)
MODIFIED	–	−0.024 (0.047)
SMOKE	–	0.030 (0.050)
DISABLE	–	−0.027 (0.030)
SENIOR	–	0.025 (0.024)
Observations	2375	2186
ρ	0.704***	0.676***
AIC	2661.46	2370.71
BIC	2748.06	2541.41

***; **; * Imply significance at 1, 5, and 10% levels respectively. Corresponding robust standard errors are reported in parentheses

of category 1. Petrolia and Bhattacharjee (2010), Petrolia et al. (2011), Smith and McCarty (2009), and Whitehead (2003) present similar evidence indicating that evacuation decisions are closely associated with hurricane intensity.

Storm surge is also an important factor affecting evacuation decisions. The choice probability of evacuation increases by almost 9% points when expected storm surge increases from two to four feet. Individuals who were provided with storm surge of six or eight feet are more likely to evacuate than those who were presented with an expected storm surge of two feet by more than 16% points. As in the case of hurricane intensity, storm surge is inversely associated to the individual's safety, which would explain the individual decision to evacuate when surge levels are relatively higher. Interestingly, no evidence was found to support the hypothesis that remaining time for landfall affects evacuation decisions, at least in the range of 24 h before the hurricane landfall. Petrolia et al. (2011) found that landfall time is a significant determinant of evacuation decisions in contingent scenarios that varied between 3 and 5 days for a hurricane to make landfall (rather than in a matter of hours as in our scenarios).

The evacuation policy tools show a significant impact on the likelihood to evacuate. Estimated coefficients on LNVOUCHER are positive and statistically significant in both models. This suggests that financial assistance in the form of a voucher increases the likelihood of evacuation. Based on Model 2 (see Table 4), a 1% increase in the voucher amount would increase the likelihood of evacuation by 0.086% points. This is an important result because budget constraints may prevent poorer households from evacuating in the event of a hurricane, putting their lives at risk due to their low income levels and the lack of formal assistance. As expected, mandatory orders of evacuation are effective in increasing the probability of evacuation by more than 39% points. Voluntary evacuation orders are somewhat effective as shown by statistically significant effects of VOLUNTARY (at 10% level). The probability of evacuation increases by 5% points with voluntary orders (see Table 4). Petrolia and Bhattacharjee (2010) present similar evidence on the effectiveness of mandatory evacuation orders in their stated preferences study of evacuation behaviors in Gulf of Mexico states. Whitehead (2003) also found that households who received a mandatory order of evacuation due to Hurricane Bonnie in 1998 were more likely to evacuate than households who did not receive such order.

Table 4 also shows some interesting results regarding sociodemographic factors that can influence evacuation decisions such as household income, age, sex, and the number of pets at home. Household income has a negative impact on evacuation decisions implying that, compared to poor households, households with higher income are less likely to evacuate in the event of a hurricane. It could be presumed that well-off households live in safer structures and areas that may be less vulnerable to hurricanes. It could also be expected that richer households can afford to be prepared with food, water and other goods to stay at home during a hurricane event. Smith and McCarty (2009) also present evidence that income may have a negative impact on the decision to evacuate for hurricanes. In contrast, Petrolia et al. (2011), Solís et al. (2010) and Whitehead (2003) found that household income is not a significant determinant of evacuation choices in both real and hypothetical settings.

The decision to evacuate is related to the individual's age and gender. The likelihood of evacuation decreases with the respondent's age by about 0.5% points per year of age. Female respondents are more likely to evacuate than males by almost 10% points. This result is consistent with prior studies (e.g. Smith and McCarty 2009). Bateman and Edwards (2002) argue that females have a more heightened perception of risk than males, which may explain why they are more likely to evacuate. Consistent with previous findings (e.g. Solís et al. 2010; Whitehead et al. 2000), estimated coefficients on PETS suggest that the likelihood of evacuation decreases with the number of pets at home, presumably because pets increase evacuation costs.

The attitudinal variable CONCERN has a significant impact on the likelihood of evacuation (see Table 4). Respondents who are concerned beyond the average level regarding the impacts of future hurricanes on their well-being are approximately 12% points more likely to evacuate than respondents with a concern level below the average. Those respondents (relative to their counterpart) may perceive a higher probability that their safety will be compromised under given hurricane conditions. Estimated effects of SANDYEVAC are positive and statistically significant. This result implies that recent evacuation experience may increase the probability of evacuation to cope with future hurricanes. However, much older evacuation experiences (PRIOREVAC) have no impact on evacuation decisions. Although it seems to

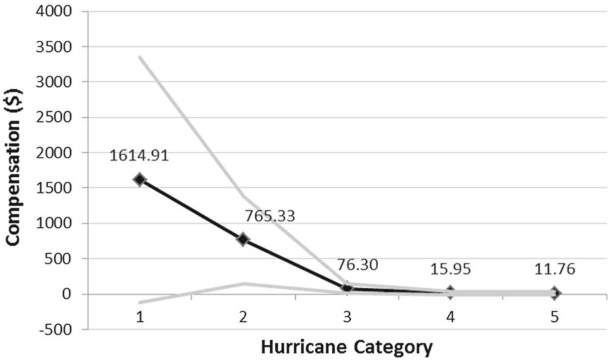

Fig. 1 Median compensation for evacuation by hurricane intensity (with 95% confidence interval)

be a learning process in making evacuation decisions, individuals' memory may experience some attenuation over time when it comes to hurricane evacuation. In terms of preparedness variables, EVACPLAN has a significant impact on the choice to evacuate. Those households with an evacuation plan are more likely to evacuate than households who do not. This result also suggests that effective measures to assist households in preparing and planning for evacuation can motivate households to evacuate in the event of a hurricane. Other variables were found to be statistically insignificant.

Estimated random effects logit models can be used to predict the minimum amount of compensation needed for the median respondent to agree to evacuate in the event of a hurricane (m^*). Given that the voucher was included in logarithmic form, the median compensation for evacuation can be computed as follows:

$$m^* = \exp\left(-(\hat{\beta}\bar{X} + \hat{\delta}\bar{Z})/\hat{\beta}_{LNVOUCHER}\right). \tag{2}$$

where $\bar{X}$ represents the average vector of experimental variables excluding LNVOUCHER, $\bar{Z}$ is the average vector of control variables, $\hat{\beta}$ and $\hat{\delta}$ are vectors of coefficients estimated in Model 2, and $\hat{\beta}_{LNVOUCHER}$ is the estimated coefficient of LNVOUCHER. Note that the predicted median compensation is non-negative. We estimated Eq. 2 using the delta method to provide estimates of the median compensation for evacuation and corresponding 95% confidence intervals. The median compensation for evacuation is estimated at \$107.73, statistically significant at 1% level. The median respondent from the subsample of households who evacuated their homes due to the last hurricane in sampled areas (Sandy) spent a total of \$111.50 on food, lodging, transportation, and other needs. The median compensation estimated here is 96.6% of that evacuation cost implying that our stated preference estimate of compensation is close to the revealed preference estimate of actual spending of evacuation during the recent hurricane.

Figure 1 shows estimates of the median compensation for evacuation and corresponding 95% confidence intervals for each hurricane category in the Saffir–Simpson scale. This is done by modifying hurricane intensity indicators in vector $\bar{X}$ (see Eq. 2). That is, we predicted the median compensation for each hurricane category while keeping other explanatory variables at their average levels (e.g. for category 5 hurricane we set CATEG5 equal to one and all other hurricane category variables are set equal to zero). It can be seen that the minimum amount of compensation needed to induce evacuation decreases with hurricane intensity, varying from \$1615 to \$12 depending on the hurricane category. Moreover, those estimates are statistically

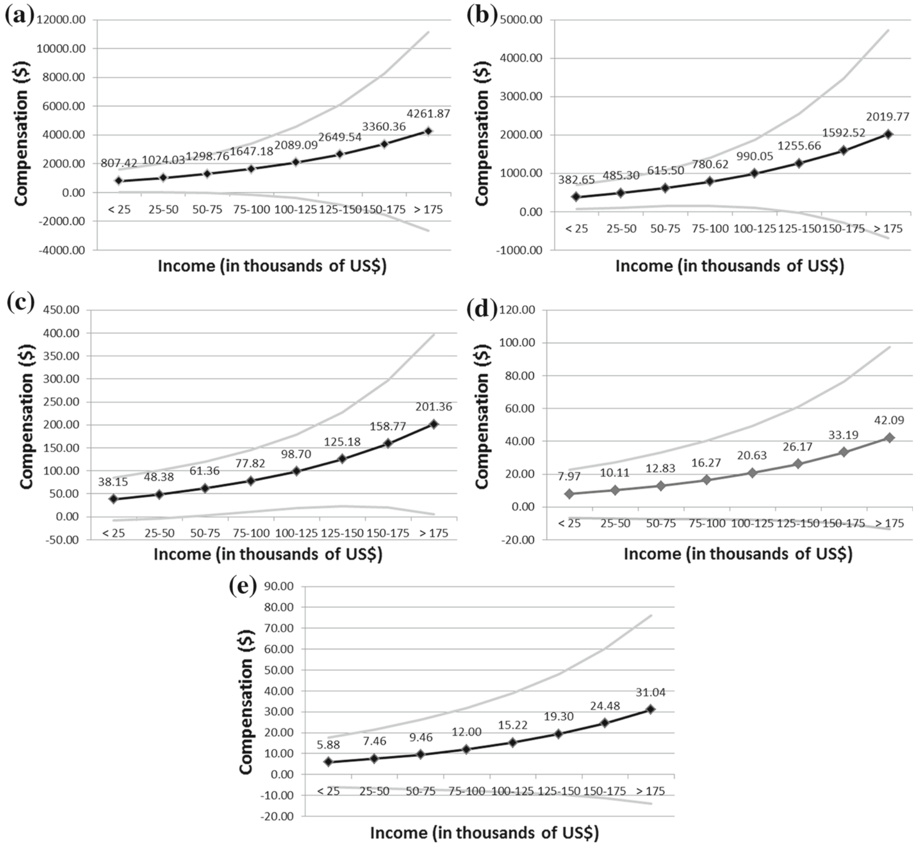

Fig. 2 Median compensation for evacuation by hurricane intensity and income (with 95% confidence interval). **a** hurricane category 1 (H1), **b** hurricane category 2 (H2), **c** hurricane category 3 (H3), **d** hurricane category 4 (H4), **e** hurricane category 5 (H5)

insignificant for hurricanes of category 4 and 5. Under those circumstances, safety becomes the priority for evacuation decisions, and budgetary constraints play a secondary role. In contrast, when the hurricane intensity is moderate (e.g. category 3), the money-risk tradeoff is more balanced and evacuation vouchers can be decisive for some households to evacuate. According to estimates presented in Fig. 1, the median household would take approximately $76 as an incentive to evacuate due to a hurricane of category 3. For hurricanes of category 1 or 2, the median household would require a considerable amount to evacuate presumably because the household do not consider their safety to be compromised by those low intensity hurricanes.

It is policy relevant to have estimates of the minimum compensation needed to induce evacuation for different income levels as evacuation vouchers would be intended to assist the poor. Figure 2 provides compensation estimates by hurricane category and income levels. Note that those estimates are based on main effects only because the interaction of hurricane category and income levels was found statistically insignificant. More specifically, we predicted the median compensation varying income levels for each hurricane category while keeping other explanatory variables at their average levels (e.g. in Fig. 2e, INCOME varies

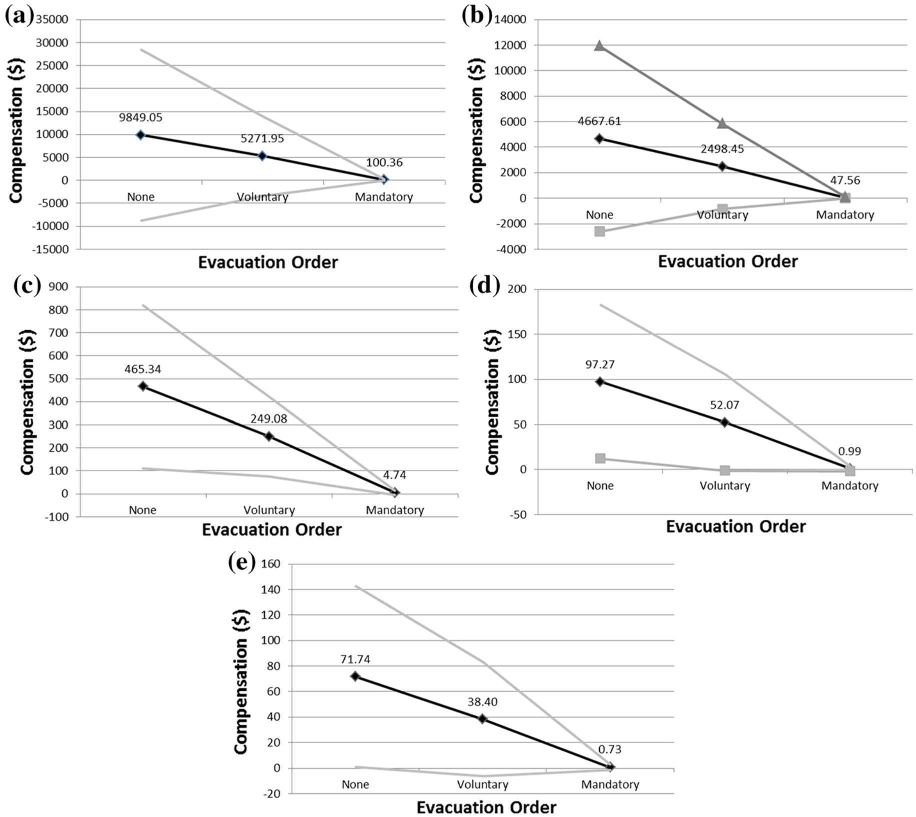

Fig. 3 Median compensation for evacuation by hurricane intensity and evacuation order (with 95% confidence interval). **a** hurricane category 1 (H1), **b** hurricane category 2 (H2), **c** hurricane category 3 (H3), **d** hurricane category 4 (H4), **e** hurricane category 5 (H5)

from one to eight, CATEG5 is set equal to one, and all other hurricane category variables are set equal to zero). Corresponding confidence intervals widen for estimates above the fourth income interval (US$ 75,000–100,000), as estimated coefficients are representative of the average respondent. Hence, compensation estimates must be interpreted and used with caution for households whose income is above the average. Overall, the amount of compensation needed to induce evacuation increases with income. This is expected because richer households are less likely to evacuate than poorer households and, consequently, would demand relatively higher compensation to evacuate their home in the event of a hurricane. The median compensation for evacuation is considerable large for hurricanes of category 1 and 2, even for poor households. Results indicate that households with an income below $25,000 would require at least $807 to evacuate due to a hurricane of category 1 (see Fig. 2a), and about $382 when the hurricane reaches category 2 (see Fig. 2b). For hurricanes of category 3, the compensation for evacuation varies from $38 to $201 depending on the household income level (see Fig. 2c). The compensation estimates for hurricanes of category 4 and 5 (presented in Fig. 2d, e respectively), are statistically insignificant at all income levels.

Figure 3 presents estimates of compensation for evacuation by hurricane category and type of evacuation orders (predicted by varying evacuation orders for each hurricane category while keeping other explanatory variables at their average levels). The compensation needed to induce evacuation decreases with the enforcement of evacuation orders. For minor hurricanes (categories 1 and 2), the median household would require substantial financial support to evacuate if no evacuation order is issued (see Fig. 3a, b, respectively). The required monetary incentives are also considerably high when voluntary evacuation is advised, presumably because households do not perceive their safety to be compromised by hurricanes category 1 and 2. However, under similar hurricane conditions, the median household would require less support (about $100 for hurricane of category 1 and $47 for hurricane of category 2) when evacuation is mandatory, presumably because mandatory orders imply a higher likelihood of experiencing a state of the world in which safety is significantly compromised. Moreover, the median household would require less financial support to evacuate if a mandatory order is issued due to a hurricane of category 3 or above (see Fig. 3c–e). With voluntary evacuation order, the median household would take about $249 to evacuate for a hurricane of category 3, $52 for a hurricane of category 4, and $38 for a hurricane of category 5. The compensation needed to induce evacuation increases further when no evacuation order is issued for hurricanes of category 3–5. Combining voluntary evacuation orders with vouchers would increase the number of evacuees. In addition, if there is any logistic and/or legal constraint in issuing mandatory orders, the voucher option can be an effective instrument for emergency management to achieve the same objective.

5 Conclusions

Understanding hurricane evacuation behavior is a part of the planning process for building sustainable coastal communities. Dissemination of hurricane forecasts, public risk perception, and evacuation decision-making are intertwined complex processes, which often puzzle people and constrain their ability to carry on risk averting behavior. When revealed preference data is inadequate to capture the various dimensions of behavioral responses to many aspects of hurricane risks and management interventions, analyzing intended evacuation behavior with granular household survey data can provide a more comprehensive understanding of evacuation behavior. Whitehead (2005) finds that hypothetical stated preferences predict actual hurricane evacuation behaviors reasonably well, which implies that stated preference data of evacuation behavior has predictive validity.

Emergency management decisions are often implemented on an ad hoc basis and there is room for improvement with efficient use of disaster management tools, particularly in coastal communities where hurricanes had not been commonly observed until recent years such as the Northeastern and Mid-Atlantic US. In this paper we used a stated preferences approach to identify factors underlying household decisions to evacuate during a simulated hurricane event. Findings indicate that likelihood of evacuation increases with hurricane intensity in a non-linear fashion, with more significant responses observed for hurricanes that are category 3 or higher in the Saffir–Simpson scale. Households also react to storm surge, particularly when it reaches 4 feet or higher. These results are expected because hurricane intensity and storm surge represent a state of the world where individuals' safety is significantly compromised, which tends to reduce the expected utility of not evacuating.

In terms of policy tools, both mandatory and voluntary evacuation orders are found effective in increasing the probability of evacuating, but voluntary orders are not as effective as mandatory orders. These findings suggest that mandatory evacuation orders can be an important policy tool in areas highly vulnerable to hurricanes. This is more so in major coastal cities where a large group of households face the need of evacuation in a short period of time (e.g. New York City, Miami, Houston or New Orleans). Evacuation orders can synthesize the complex risk information and help forming mental scenarios of hurricane vulnerability to finally choosing between evacuating or staying at home. Those orders can include very specific information about the wind intensity and storm surge information and can direct resources to enable households to decide whether to evacuate or stay at home.

Results show that, for hurricanes of category 3 or lower, financial assistance in terms of vouchers can help alleviate evacuation costs for households (e.g. food, water, transportation and lodging) and thus can increase the likelihood of evacuation in the event of a hurricane. Households may have perceived that their safety is not compromised by hurricanes of category 3 or lower, and therefore would require monetary incentives to evacuate their homes. For hurricanes of category 4 and 5, compensation estimates are statistically insignificant suggesting that budgetary constraints would play a minimal role for evacuation decisions when hurricane risks are perceived to be high. Under these circumstances, mandatory orders may be enough for households to evacuate as the utility derived from increasing safety levels may compensate or surpass the utility lost due to evacuation costs.

It is worth mentioning that the minimum amount of compensation needed for a respondent to agree to evacuate increases with household income. This is expected because well-off households were found to be less likely to evacuate in the event of a hurricane than poorer households. It can be argued that affluent households live in homes with stronger structures and in areas that are less vulnerable to hurricanes (with the exception of beachfront homes). Due to perceived safety, well-off households may have strong preferences to stay at home in a hurricane event, thus requiring higher monetary incentives to reverse those preferences. It is also true that well-off households have more resources to cover their evacuation costs. Consequently, compensation estimates for affluent households should be interpreted as lower bound of their evacuation costs rather than using them as baseline for financial assistance programs that they do not need. On the other hand, this financial assistance would relax the budget constraints for poor households and for households facing disproportionately high evacuation costs (e.g. households with disabled or senior members), who otherwise would be unable to evacuate, putting their lives at risk.

The provision of vouchers to offset evacuation costs also has a positive effect on the likelihood of evacuation. Hurricane evacuation may impose significant costs on households, which varies by income and other socio-demographic characteristics (Whitehead 2003; Mozumder and Vásquez 2015). By incorporating a voucher program into contingent scenarios, this study has provided estimates of the minimum compensation needed to induce evacuation that can be used to better understand the magnitude of evacuation costs for optimal design of evacuation policies. To the extent of our knowledge, hurricane prone states do not have any formal program to financially assist households with their evacuation costs. Our estimates can help emergency management agencies to design programs to efficiently organize evacuation behaviors especially among populations in need.

Finally, we offer some suggestions for future research. Our results suggest that landfall time does not influence the decision to evacuate in a window of 24 h to landfall. In contrast, Petrolia et al. (2011) found that landfall time is a significant determinant of evacuation decisions in a window of 3–5 days. Future studies could investigate the dynamics of evacuation decisions as this is very much relevant for identifying the appropriate timing of issuing evacuation orders (Dash and Gladwin 2007). Also, more research is needed to assess the feasibility and design characteristics of voucher programs for hurricane evacuation. Special attention can be given to strategies to target populations in need and to effectively deliver financial assistance to those households to facilitate evacuation. We hope that this study will motivate further research on alternative emergency management tools such as evacuation voucher programs.

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References

Bateman JM, Edwards B (2002) Gender and evacuation: a closer look at why women are more likely to evacuate for hurricanes. Nat Hazards Rev 3(3):107–117

Bohannon D (2011) Fight or flight: on enforcing mandatory evacuations. Law practice today. A web-based magazine from American Bar Association, Special Edition. Dealing with Disasters—Emergency Preparedness, April 2011

Cameron TA (2005) Individual option prices for climate change mitigation. J Public Econ 89(2):283–301

Dash N, Morrow BH (2001) Return delays and evacuation order compliance: the case of Hurricane Georges and the Florida Keys. Glob Environ Change Part B Environ Hazards 2(3):119–128

Dash N, Gladwin H (2007) Evacuation decision making and behavioral responses: individual and household. Nat Hazards Rev 8(3):69–77

Dostal PJ (2015) Vulnerability of urban homebound older adults in disasters: a survey of evacuation preparedness. Disaster Med Public Health Prep 9(3):301–306

Dow K, Cutter SL (2000) Public orders and personal opinions: household strategies for hurricane risk assessment. Glob Environ Change Part B Environ Hazards 2(4):143–155

de Palma A, Ben-Akiva M, Brownstone D, Holt C, Magnac T, McFadden D, Moffatt P, Picard N, Train K, Wakker P, Walker J (2008) Risk, uncertainty and discrete choice models. Mark Lett 19(3):269–285

Gladwin H, Peacock WG (1997) Warning and evacuation: a night for hard houses. In: Morrow BH, Gladwin H (eds) Hurricane Andrew: gender and ethnicity and the sociology of disasters. Routledge, New York, pp 52–74

Graham-Tomasi T, Myers RJ (1990) Supply-side option value: further discussion. Land Econ 66(4):425–429

Greene WH (2012) Econometric analysis, 7th edn. Prentice Hall, Upper Saddle River

Kunreuther H, Michel-Kerjan E, Pauly M (2013) Making America more resilient toward natural disasters: a call for action. Environ Sci Policy Sustain Dev 55(4):15–23

McFadden D (1973) Conditional logit analysis of qualitative choice models. In: Zarembka P (ed) Frontiers of econometrics. Academic Press, New York

Mozumder P, Vásquez WF (2015) Hurricane and risk averting behavior: analyzing the cost of evacuation using revealed and stated preference data. Nat Hazards 79(1):81–92

Mozumder P, Raheem N, Talberth J, Berrens RP (2008) Investigating intended evacuation from wildfires in the wildland-urban interface: application of a bivariate probit model. For Policy Econ 10(6):415–423

NOAA (2013) Service assessment: hurricane/post-tropical cyclone Sandy, October 22–29, 2012. National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, Silver Spring, Maryland

Petrolia DR, Bhattacharjee S (2010) Why don't coastal residents choose to evacuate for hurricanes? Coast Manag 38(2):97–112

Petrolia DR, Bhattacharjee S, Hanson TR (2011) Heterogeneous evacuation responses to storm forecast attributes. Nat Hazards Rev 12(3):117–124

Shaw WD, Jakus PM, Riddel M (2012) Perceived arsenic-related mortality risks for smokers and non-smokers. Contemp Econ Policy 30(3):417–429

Smith VK (1983) Option value: a conceptual overview. South Econ J 49(3):654–668

Smith VK (1985) Supply uncertainty, option price and indirect benefit estimation. Land Econ 61(3):303–307

Smith SK, McCarty C (2009) Fleeing the storm(s): an examination of evacuation behavior during Florida's 2004 hurricane season. Demography 46(1):127–145

Solís D, Thomas M, Letson D (2010) An empirical evaluation of the determinants of household hurricane evacuation choice. J Dev Agric Econ 2(3):188–196

Stein RM, Dueñas-Osorio L, Subramanian D (2010) Who evacuates when hurricanes approach? The role of risk, information, and location. Soc Sci Q 91(3):816–834

Van Willigen M, Edwards T, Edwards B, Hessee S (2002) Riding out the storm: experiences of the physically disabled during hurricanes Bonnie, Dennis, and Floyd. Nat Hazards Rev 3(3):98–106

Vásquez WF, Murray TJ, Mozumder P (2016) Understanding hurricane evacuation planning in the Northeastern and Mid-Atlantic United States. Nat Hazards Rev. doi:10.1061/(ASCE)NH.1527-6996.0000198

Whitehead JC (2003) One million dollars per mile? The opportunity costs of hurricane evacuation. Ocean Coast Manag 46(11–12):1069–1083

Whitehead JC (2005) Environmental risk and averting behavior: predictive validity of jointly estimated revealed and stated behavior data. Environ Resour Econ 32(3):301–316

Whitehead JC, Edwards B, Van Willigen M, Maiolo JR, Wilson K, Smith K (2000) Heading for higher ground: factors affecting real and hypothetical hurricane evacuation behavior. Glob Environ Change Part B Environ Hazards 2(4):133–142

Wolshon B, Urbina E, Wilmot C, Levitan M (2005) Review of policies and practices for hurricane evacuation. I: transportation planning, preparedness, and response. Nat Hazards Rev 6(3):129–142