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Full Length Research Paper

An empirical evaluation of the determinants of household hurricane evacuation choice

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In this study, we implement a set of probit models to analyze the determinants of household hurricane evacuation choice for a sample of 1,355 households in Florida. This article contributes to the literature by accounting for two issues normally neglected in previous studies; namely, regional variability and within season variability. The empirical results suggest that households living in risky environments (mobile home and flooding areas) are more likely to evacuate. In addition, households with children and those who have experienced the threat of a hurricane also display higher probabilities to evacuate. Opposite results are found for homeowners and households with pets. Regional differences are also clearly demonstrated with households in southeast Florida less likely to evacuate than those in Northwest Florida.

Key words: Hurricane, evacuation, household behavior.

INTRODUCTION

Hurricanes are the most costly natural disasters in the U.S. and they are especially harmful to coastal areas (NSB, 2007; Ewing et al., 2007). For instance, the 2005 Atlantic hurricane season -the most active and harmful in recorded history- had an estimated direct social cost of approximately 2,300 deaths and record damages of over $130 billion (NHC, 2006). The economic losses associated with this hurricane season on the fishing, agricultural and industrial sectors are also considerable, and the full recovery of these sectors is expected to take decades (Myles and Allen, 2007). In addition, the disruption of the transportation system in the affected areas is predicted to disturb the prices of basic commodities for many years (Lara-Chavez and Alexander, 2006).

In an effort to mitigate the social and private costs associated with extreme weather events, federal agencies have financed weather research programs designed to improve the accuracy of weather forecasting and to enhance the dissemination of timely and accessible weather information (NOAA, 2005). Although these programs will not stop the natural devastation of high-intensity hurricanes, precise and timely forecasts could give individuals and decision-makers the much needed information to better prepare and reduce the economic and social impacts of these types of natural events (Letson et al., 2007). In this respect, the economic value of hurricane forecasting can be linked directly to its ability to influence human behavior; namely, evacuation choice (Williamson et al., 2002).

During the last decade there have been great advances in the sciences of climate and weather forecasting. However, hurricane prediction is still not an exact science. Inaccuracies in predicting the storm's path, intensity and time of landfall may affect people's trust and reliance on hurricane warnings and tracking information (Dow and Cutter, 1998). This lack of credibility could hinder evacuations with potentially devastating consequences if a hurricane does strike the area (Smith, 1999). The literature also shows that peoples' decision-making process under hurricane risk is a very complex issue

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influenced by many other factors (Gladwin et al., 2001). Therefore, a thorough understanding of the determinants of household evacuation behavior is important for emergency managers to improve the effectiveness of evacuation orders and decrease the chances for human losses.

Previous studies demonstrate that household evacuation behavior depends not only on the intrinsic characteristics of a hurricane (that is, path, intensity, timing, etc.) but also upon household socioeconomic and demographic characteristics. Although the available literature offers useful insights to the evacuation decision process, generally, they have been conducted using data for a single event within very specific geographical areas. Kelly et al. (2009) argue that single event studies ignore the possibility that households may learn from their own experience.

Thus, the present study constitutes a natural extension of previous research by comparing two distinct regions in Florida (FL) and four separate hurricane events during the 2005 season. By doing so, we add two new dimension on the study of the determinants of evacuation choices; namely, regional variability and within season variability. To reach our goal, we study a sample of 1,355 households living in the Northwest Panhandle (NW) and the Southeast Peninsula (SE) of FL, who have experienced the threat of major hurricane events in 2005. Information on household composition and socioeconomic characteristics, home ownership, past hurricane experience, storm preparation expenses, sources of forecast information and several other variables are used to develop a better understanding of household evacuation behavior. Specifically, a set of probit models are developed to analyze the impact of these variable and their marginal effect on influencing household evacuation choices.

The rest of this article is organized as follows. The next section presents the conceptual framework and literature review, followed by a presentation of the empirical model, a description of survey design and data, and a brief description of the hurricane events. Then, we present and discuss the empirical results. The last section contains some concluding remarks along with some suggestions for further research.

Conceptual framework and literature review

Burton et al. (1993) and Viscusi (1995) present one important theoretical basis to analyze human behavior under environmental risk (the threat of a hurricane in our case). In general, these authors contend that individuals make choices under the uncertainty of future environmental threat by maximizing their expected utilities, and that they might be willing to sacrifice their wealth (e.g., earning income, capital, etc.) in order to reduce those threats. Furthermore, Burton et al. (1993) state that under the threat of environmental hazard an individual's response is affected by four major elements: (1) prior experience with the specific environmental hazard; (2) an individual's wealth; (3) their intrinsic characteristics; and (4) their interaction with society.

With respect to hurricane risk, Letson et al. (2007) present a review of the economic theory concerning individuals' utility-maximizing behavior accounting for hurricane forecasts and evacuation choices. Letson et al. (2007) indicate that in studying behavior under hurricane threat it is important to consider hurricane forecasts, since this information may act as a decision aid to reduce uncertainty. However, a note of caution is presented by Dow and Cutter (1998). These authors argue that inaccurate forecasts may reduce household reliance on forecast information and reduce their perception of a hurricane threat and, consequently, reduce evacuation rates.

From an empirical point of view, individuals (or households in our case) subject to the risk of a hurricane event face a dichotomous decision: stay at home or evacuate to a safer area. Previous studies has shown that this decision is influenced by several factors including social characteristics, economic constraints, storm characteristics and planned evacuation destination and costs (Fu and Wilmot, 2004; Whitehead, 2003; Whitehead et al., 2000; Dow and Cutter, 1998; among others).

For instance, Dash and Gladwin (2007) argue that risk perception, vulnerability and previous experience with hurricanes are vital factors in explaining evacuation decisions. Whitehead (2003) explains that the main goal of an evacuation is to reduce the risk of injury or death. In this respect, people facing higher risks, such as those living in weak structures like mobile home or in areas affected by flooding, have proved to have a higher probability to evacuate (Whitehead, 2003; Smith, 1999). In addition, Baker (1991) and Riad et al. (1999) report that people living in areas previously affected by a major storm and those previously involved in evacuations are also more willing to evacuate. However, it is important to indicate that Lindell et al. (2005) found nonsignificant correlations between previous experience and evacuation.

Risk perception is also influenced by the intrinsic characteristics of a hurricane. In general, previous studies have used stated preferences data on hypothetical scenarios to evaluate the significance of key storm forecast factors (e.g., hurricane predicted path, wind speed, landfall time, etc.) on evacuation decisions. For example, Bhattacharjee et al. (2009) show that after correcting for heterogeneity, wind speed and landfall time are the most important characteristics affecting evacuation choices. Whitehead et al. (2000) contend that storm intensity is the most important predictor for evacuation.

Wealth is another factor that effects evacuation decisions. Although, it might be reasonable to think that high income households will be more willing to evacuate since they have all the necessary means to evacuate in a smooth and rapid way, previous studies have found that households with higher income tend to display lower probabilities to evacuate (Whitehead, 2003; Smith, 1999). This contradictory result could be explain by the fact that the wealthy, on average, own more capital goods (e.g., electronics, collectables, art, etc.) and they may prefer to stay with their house to protect their belongings from post-storm looting. Another explanation could be that high income families live in bigger houses, giving then a sense of security.

The influence of demographic characteristics on the evacuation choice has been mixed. For instance, Dow and Cutter (1998) and Baker (1991) argue that demographic characteristics such as age, race/ethnicity and gender are not associated with the household evacuation choice. Conversely, opposite arguments are presented by Dash and Gladwin (2007), Bateman and Edwards (2002), Whitehead et al. (2000) and Smith (1999), among others. Specifically, Bateman and Edwards (2002) and Riad et al. (1999) found that gender is a significant explanatory variable for evacuation choice; with women more likely to evacuate than men. With respect to household composition, Dash and Gladwin (2007) report that households with children display a higher probability of evacuation, while Gladwin et al. (2001) found the inverse relationship for large households and households with elderly.

Lower probabilities of evacuation are also found for households with pets (Whitehead, 2003; Whitehead et al., 2000; Smith, 1999). Lastly, education has displayed non-significant effects in the literature (Whitehead, 2003; Smith, 1999).

The power of the society on influencing evacuation behavior has been mainly studied by analyzing the impact of hurricane warning and other sources of information (Sorensen, 2000). In general, these studies have focused on evaluating different characteristics of hurricane warning (e.g., type of message, language used, timely, etc.). For instance, Baker (1995) found that the actions of and the strategies used by public authorities significantly influenced people's evacuation choice. Conversely, Dow and Cutter (1998) show a limited role of official advisories on people's decision to evacuate. Dash and Gladwin (2007) argue that a warning by itself has no value since it is affected by its credibility, interpretation and the individual's aversion to risk. Smith (1999) and Lindell et al. (2005) add that mass media spend significant amounts of time disseminating this kind of information during hurricane season, making warnings and hurricane information available without restriction to the population. Consequently, social interactions can help individuals better digest the available information; making social interactions more important than the warning *per se*.

Whitehead et al. (2000) and Smith (1999) suggest that the evacuation destination and expected expenses are also important factors in evaluating the decision to evacuate or not. Specifically, evacuation destination pattern (that is, preference to evacuate to a hotel, shelter or friend/relative house) and expected evacuation expenses may account for unobserved information affecting household evacuation choice.

Regional heterogeneities on the propensity to evacuate have been previously evaluated at local levels. For instance, Lindell et al. (2005) show that households located closer to the coast are more likely to evacuate than those located in the inland. Aguirre (1991) also indicate that the elevation of the house with respect to the sea level may also affect the probability for evacuation. On the contrary, Whitehead (2005) found non statistical differences between North Carolina residents living in an island and those living in the mainland. Nonetheless, Letson et al. (2007) argue that studying regional differences is of extreme importance since the local characteristics of the population have been proven to affect the rates of evacuation as well as the time required for this procedure.

Lastly, the study of changes in evacuation patterns within a hurricane season has not received much attention in the literature. In general, previous studies have focused on analyzing evacuation responses for specific events, ignoring the fact that individuals face a multi-storm season every year. However, as indicated previously, researchers have somehow controlled for this issue by using proxies, such as previous hurricane experiences (e.g., Lindell et al. 2005; Riad et al., 1999; Baker, 1991; among others). Mixed results have been found using this approach and different explanations have been proposed to explain the conflicting findings, including data quality, variable definition and sampling problems. In this study we offer an alternative approach to analyzing this issue by comparing people's evacuation behavior for different events during a hurricane season.

Empirical model

Based on the theory proposed by Burton et al. (1993) and Viscusi (1995) and previous empirical studies the evacuation decision under the risk of a pending hurricane event can be modeled as follows:

$$E_i = f(V_i, W_i, I_i, S_i, O_i) \quad [1]$$

where E represents the dichotomous choice variable equal to 0 if individual i decides to stay home or equal to 1 if they decide to evacuate and is a function of the following exogenous variables: (1) V a vector of factors that represent an individual's vulnerability and their previous hurricane experience; (2) W a vector of factors tied to wealth and/or income; (3) I a vector of household demographics; (4) S a vector of measures of social interaction and sources of information; and (5) O a vector of other variables such as evacuation expenditures and the intensity of the hurricane.

It is important to indicate that previous studies have also used individual characteristics, such as age, gender and level of education to explain the evacuation decision. In general, these studies have used a stated preference approach to understand the individual evacuation choice under alternative hypothetical scenarios (e.g., Bhattacharjee et al., 2009; Whitehead, 2005; Smith, 1999; among others). Our study follows a different approach by using the revealed behavior of the studied households during the 2005 hurricane season. Using individual characteristics may imply that the evacuation decision is made by only one person in the household. However, previous research has shown that evacuation is a participatory process; thus, our model includes key household characteristics rather than individual demographics.

Since the dependent variable is dichotomous in nature we estimated our models using a probit procedure. A probit model is a nonlinear procedure developed to relate the choice probability P_i (evacuation choice in our case) to a set of explanatory variables. By using this approach we force the probability to remain within the [0 (or stay at home), 1 (or evacuate)] interval. The probability of evacuation is estimated as follows:

$$P_i = F(X_i \beta) \quad [2]$$

Where F is the cumulative distribution function, X is the vector of exogenous variables, β are the estimated parameters (Greene, 2003).

The variables included in the empirical model were selected based on the literature and the data availability. Tables 1 and 2 display, respectively, the definition and descriptive statistics for all the variables included in the evacuation model. The data on Table 2 has been presented for the entire sample as well as for the four studied hurricanes.

Brief history of 2005 hurricane events in Florida

To examine regional differences and within season variability on hurricane evacuations three hurricanes, with four landfall events, will be examined. In chronological order they are DENNIS (NW FL), KATRINA (NW and SE FL) and WILMA (SE FL). Table 3 presents basic information on the studied storms. For more details on these storms, see the National Hurricane Center's Tropical Cyclone Reports at http://www.nhc.noaa.gov/2005atlan.shtml.

The first hurricane event begin July 4, 2005 as tropical depression number 4 just west of the Windward Islands, hurricane DENNIS quickly grew to a category 4 storm (on the Saffir-Simpson scale) as it passed through the southern Caribbean, making landfall on July 10th near Pensacola, FL as a category 2 storm with winds in excess of 100 mph. The NW region of FL was under a variety of both mandatory and volunteer evacuation orders. Generally counties closer to the eventual area of landfall (Pensacola) were under mandatory evacuations for coastal areas and mobile homes. Counties further east were more likely to have volunteer orders for mobile homes and low-lying areas.

The second and third hurricane events involved hurricane KATRINA. Starting August 23, 2005 just off the east coast of FL as tropical depression 12, KATRINA barely managed to reach hurricane force (winds > 74 mph) as it came ashore along the Broward-Miami-Dade county line (SE FL) on August 25th.

Table 1. Variable definition.

Variable	Definition
	Dependent variable
Evacuation	Dummy variable equals 1 if the household evacuated their house during the studied storm, 0 otherwise.
	Prior experience and vulnerability
Experience	Dummy variable equals 1 if the household has had previous experience with hurricanes, 0 otherwise.
Mobile	Dummy variable equals 1 if the household lives in a mobile home, 0 otherwise.
Flood	Dummy variable equals 1 if the household lives in an area with flood risk, 0 otherwise.
	Wealth
Income	Combined household income (US $1,000).
Own	Dummy variable equals 1 if the household owns their house, 0 otherwise.
	Household characteristics
Famsize	Number of people living in the household.
Children	Number of children in the household (less than 18 yeas of age).
Pets	Dummy variable equals 1 if the household owns a pet, 0 otherwise.
	Interaction with society
Friends	Dummy variable equals 1 if the decision to evacuate was influenced by friends
NOAA	Dummy variable equals 1 if the household uses the NOAA Weather Radio, 0 otherwise.
	Others
Expenses	Total cost (US $) for the household storm preparation plan.
SFL	Dummy variable equals 1 if the household is located in South East Florida, 0 otherwise.
Major	Dummy variable equals 1 if the hurricane landed as a Category 3 or higher in the study area, 0 otherwise.

Table 2. Descriptive statistics.

Variable (unit)	ALL		SE Florida				NW Florida			
			Katrina SE		Wilma		Dennis		Katrina NW	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Evacuation (Dummy)	0.43	0.49	0.34	0.48	0.32	0.47	0.60	0.49	0.60	0.49
Experience (Dummy)	0.73	0.44	0.65	0.48	0.64	0.48	0.88	0.33	0.89	0.32
Mobile (Dummy)	0.11	0.31	0.08	0.26	0.08	0.26	0.18	0.38	0.16	0.37
Flood (Dummy)	0.28	0.45	0.37	0.48	0.33	0.47	0.14	0.35	0.18	0.39
Income (US $1,000)	55.71	16.43	59.37	19.56	62.21	18.87	53.43	15.11	55.53	15.29
Own (Dummy)	0.72	0.45	0.71	0.46	0.75	0.44	0.70	0.46	0.70	0.46
Famsize (Number)	2.64	1.28	2.55	1.30	2.50	1.25	2.86	1.29	2.85	1.26
Children (Number)	0.57	0.95	0.50	0.90	0.48	0.89	0.74	1.03	0.68	0.99
Pets (Dummy)	0.65	0.48	0.62	0.49	0.63	0.48	0.71	0.45	0.70	0.46
Friends (Dummy)	0.30	0.46	0.31	0.46	0.29	0.45	0.30	0.46	0.32	0.47
NOAA (Dummy)	0.26	0.44	0.24	0.43	0.23	0.42	0.29	0.45	0.33	0.47
Expenses (US $)	317.43	1,053.95	333.89	1,271.61	363.35	1,292.87	260.83	420.89	252.77	351.99
Major (Dummy)	0.14	0.34	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Cases	1,355		360		506		305		184	

Mandatory evacuation orders were issued for residents of mobile homes and voluntary evacuation orders were issued for people in low-lying areas. KATRINA then moved across the FL peninsula entering the Gulf of Mexico where it quickly intensified into a

Table 3. Summary statistics for the studied tropical storms.

Storm	Saffir-Simpson category in the study area	Landfall area in the U.S.	Landfall day in the U.S.
Dennis	2	Santa Rosa Island, FL	June 10
Katrina SE	1	Aventura, FL	August 25
Katrina NW	3	Buras-Triumph, LA	August 29
Wilma	2	Cape Romano, FL	October 23

category 5 storms. It moved toward the Louisiana – NW FL coastline as very large and dangerous storm, coming ashore on the Mississippi coast on August 25^{th} as a category 3 event. Several NW FL counties called for mandatory evacuations of barrier islands (Escambia, Santa Rosa, Okaloosa and Gulf) and mobile homes (Gulf). Others called for voluntary evacuations of low-lying areas (Gulf and Franklin).

The fourth hurricane event began October 15, 2005 as tropical depression 24 just west of Jamaica and grew into hurricane WILMA, a category 4 storm has it passed around Cuba, striking southwest FL October 24^{th} as a category 3 storm and passing northeastward over the Broward and Palm Beach counties (SE FL) reentering the Atlantic just north of Palm Beach. Hurricane force winds in excess of 100 mph (category 2 force winds) were experienced throughout much of SE FL. Mandatory evacuation orders were issued for residents of mobile homes in the Broward, Miami-Dade and Palm Beach area and a voluntary evacuation order was issued for residents of low-lying areas.

Data collection

In March, 2007 and January, 2008, an internet-based survey was administered to a panel of FL households (the questionnaire is available from the author upon request). This panel was part of a larger nation-wide household database maintained by Survey Sampling International Inc. The panel focused on SE FL (Miami/Dade, Broward and Palm Beach counties) and NW FL (all FL counties west of the Apalachicola River). Participants were asked if they had experienced a hurricane during the 2005 season. Hurricane experience was defined as:

> "People can experience hurricanes or tropical storms in a variety of ways. Some endure physical impacts, such as flooding or downed tree limbs, while others may miss time at work evacuating from or preparing for a storm that may not necessarily come their way. Did you experience any hurricanes or tropical storms during 2005?

If they answered yes, those living in SE FL were queried about hurricanes KATRINA and WILMA and households in NW FL were questioned about hurricanes DENNIS and KATRINA. They were asked a series of questions regarding: (1) their previous experience with hurricanes; (2) sources of hurricane forecast information; (3) home ownership; (4) type and condition of their home (including if their home was a mobile home and/or located in flood zone); (5) any preparation they took for the hurricane(s); (6) their household demographics (including level of education, gender and age of household members and if they owned a pet); (7) household income; and (8) their post-hurricane outcome (including losses) and if they were satisfied with their pre-hurricane choices concerning hurricane preparation and evacuation.

A total of 23,828 invitations were submitted to the target population, and 3,134 household accepted the invitation and completed the survey with no missing data on the relevant variables for this study. That is, the response rate of 'useable surveys' for this study was 13.1%. It is important to indicate that this response is within the range reported by Cook et al. (2000) in their meta-analysis of web- or internet-based surveys. Of this 3,134 households, 2,571 (82%) experienced one or more storms in 2005. The sample was further reduced to only those households living in our study areas (NW and SE FL) during the 2005 hurricane season and who experienced KATRINA, WILMA or DENNIS and answered variables key to our analysis. Thus, the final dataset encompasses a total of 1,355 households.

In the present article we focus our attention on studying the prevalence of behaviors rather than conducting qualitative analysis of how specific communities behave. In this respect the use of internet sampling has been granted as a good alternative for information gathering (see Cameron et al. (2005) for details). Of course the two modes of research inform one another and are complementary.

RESULTS AND DISCUSSION

Four evacuation probit models are estimated to evaluate the determinants of households' evacuation behavior for each storm included in the analysis (that is, KATRINA SE, WILMA, DENNIS and KATRINA NW). In addition, an aggregated model (that is, ALL) including the whole sample is also estimated.

Table 4 presents the empirical results of our analysis. This table presents the estimated coefficients and the marginal effects (MEs) for each of the exogenous variables. In our case, MEs measure the percent change in the probability of evacuation due to a one unit change in an exogenous variable. MEs for the continuous variables are computed as $\mathrm{ME} = \phi(\beta X)\beta$, where ϕ is the probability density function, X is the vector of exogenous variables, β are the estimated parameters, and all regressors are set at their mean values (Greene, 2008). The MEs for the dummy variables are measured by taking the difference between the value of the prediction when the dummy equals 1 and when it equals 0, holding all other variables at their respective means (STATA, 2003).

Overall, the estimated evacuation models perform well and consistently across the storms considered. Specifically, the null hypothesis that all coefficients are simultaneously zero is rejected consistently at the 1% significance level. Individually, approximately 55% of all parameters are statistically different from zero and their signs are generally consistent with expectations. In addition, the percentages of correctly predicted

Table 4. Probit estimates of evacuation decision.

Variable	ALL		Katrina SE		Wilma		Dennis		Katrina NW	
	Coef.	ME	Coef.	ME	Coef.	ME	Coef.	ME	Coef.	ME
Constant	0.168	--	-0.259	--	-0.411*	--	-0.189	--	-0.231	--
	0.133		*0.262*		*0.230*		*0.356*		*0.474*	
Experience	0.141*	0.059	0.409*	0.161	0.205*	0.083	0.108	0.039	0.060	0.021
	0.071		*0.228*		*0.123*		*0.151*		*0.129*	
Mobile	0.881**	0.333	1.098***	0.420	1.031***	0.438	0.751***	0.322	0.701**	0.291
	0.125		*0.347*		*0.268*		*0.214*		*0.291*	
Flood	0.226***	0.099	0.557***	0.187	0.237*	0.086	0.082	0.031	0.073***	0.028
	0.085		*0.178*		*0.136*		*0.223*		*0.019*	
Income	0.019	0.005	-0.013	-0.005	0.057	0.020	0.025	0.009	0.057	0.021
	0.011		*0.057*		*0.050*		*0.076*		*0.100*	
Own	-0.231***	-0.106	-0.473**	-0.175	-0.482**	-0.177	-0.093*	-0.034	-0.279*	-0.102
	0.079		*0.177*		*0.225*		*0.053*		*0.143*	
Famsize	-0.026	-0.011	-0.099	-0.036	-0.067	-0.023	0.013	0.005	-0.014	-0.005
	0.047		*0.080*		*0.076*		*0.094*		*0.119*	
Children	0.103*	0.050	0.187*	0.069	0.165*	0.059	0.121***	0.047	0.144***	0.053
	0.057		*0.113*		*0.096*		*0.017*		*0.021*	
Pet	-0.206**	-0.078	-0.487**	-0.166	-0.354**	-0.119	-0.260*	-0.101	-0.228**	-0.091
	0.096		*0.193*		*0.161*		*0.146*		*0.108*	
Friends	0.062	0.028	0.086	0.032	0.111	0.040	0.041	0.015	0.105	0.040
	0.081		*0.157*		*0.132*		*0.171*		*0.213*	
NOAA	-0.039	-0.017	-0.130	-0.047	-0.046	-0.016	0.120	0.046	-0.046	-0.018
	0.078		*0.173*		*0.149*		*0.122*		*0.213*	
Expenses	-0.047**	-0.020	-0.091*	-0.034	-0.032	-0.012	-0.097**	-0.039	-0.073**	-0.028
	0.025		*0.052*		*0.1349*		*0.045*		*0.031*	
Major	0.574***	0.221	--		--		--		--	
	0.069									
SFL	-0.423**	-0.199	--		--		--		--	
	0.170									
Log likelihood		-906.35		-369.73		-235.10		-327.03		-218.22
McFadden Pseudo R^2		0.37		0.33		0.31		0.32		0.34
Model χ^2 [df]	171.62 [13]		124.48 [11]		153.25 [11]		126.62 [11]		119.58 [11]	
% of Correct		74.15		62.48		61.61		67.23		69.15
N		1,355		360		506		305		184

Note: The dependent variable is a dichotomous variable equals 1 is the household evacuated the house. Values in *Italic* are standard error. The marginal effect for the dummies variables is computed as Pr[y|x=1]- Pr[y|x=0]. Correction for heteroscedasticity was performed using the White's heteroscedasticity-robust covariance matrix. * = p < 0.1, ** = p < 0.05 and *** = p < 0.01.

responses are high (between 74.2% for model ALL and 61.6% for Hurricane Wilma). The average Pseudo-R^2 in this study is 0.34 which is within normal rates for social studies.

The variables associated to vulnerability and experience (that is, MOBILE, MAJOR, FLOOD and EXPERIENCE) have a significant and positive association with evacuation. Indeed, MOBILE display the highest ME in all five models, suggesting that households living in mobile homes are, on average, 36.3% more likely to evacuate than households living in more secure homes. This large difference is not surprising since, as reported by Baker (1991), emergency managers tend to target mobile home residents in their evacuation procedures. As expected, those households facing a major storm (category 3 and above) also display higher probability of evacuation (22.1% higher than their counterparts). Households located in flooding areas display on average, an 8.6% higher probability to evacuate than those living in non-flooding zones. It is important to notice that the variables MOBILE, MAJOR, FLOOD could also be acting as proxies of a mandatory evacuation orders, leading to a potential overestimation of their marginal effects. To solve this issue it would be necessary to control for those household forced to evacuate. Unfortunately, this information was not available for this study. This could be an area for future refinement of the model implemented here.

The variable EXPERIENCE is positive in all estimated models and statistically significant in three of them. This last result suggests that, in general, those households that have experienced the threat of a major hurricane are also more likely to evacuate.

Household wealth presents some interesting results. On the one hand, home ownership significantly reduces the probability of evacuation in all estimated models. In fact, owning a house decreases the probability of evacuation from 3.4% (DENNIS) to 17.7% (WILMA). This result could be explained using alternative approaches. As indicated early, homeowners could prefer staying at home to protect their belongings from post-storm looting. An alternative explanation is that homeowners are more responsible in protecting their houses from hurricanes by installing storm shelters and better roof. On the other hand, INCOME is not statistically different from zero in all estimated models. Mixed results on the impact of income on evacuation choice have been previously reported in the literature. For instance, Whitehead et al. (2000) found a positive association between income and evacuation for coastal residents in North Carolina. Conversely, Whitehead (2003) and Smith (1999) found, respectively, a negative or a not significant relationship between income and evacuation rates also for coastal residents in North Carolina.

Household composition also presents an interesting finding. The number of children (CHILDREN) in the household is statistically significant and positively associate with evacuation, which agrees with the findings presented by Lindell et al. (2005). Our estimates suggest that one additional child in the household increases the probability to evacuate on approximately 4%. Family size (FAMSIZE) is not significantly correlated with evacuation. Lastly, households with pets (PETS) have also lower rates of evacuation. Specifically, owning a pet decreases the average probability to evacuate in 8%. This outcome is in the line of those presented by Whitehead et al. (2000) who suggested that establishing pet-friendly shelters could significantly increase the evacuation rates among coastal residents in North Carolina.

Although approximately one-third of the sample indicated that the opinion of friends and/or the information from NOAA radio was used to make their evacuation choice, the coefficient for these two variables are not statistically different than zero in any of the models. These outcomes suggest that there are other (unobserved) sources of information that have higher weights in the household's evacuation choice. In fact, almost all the surveyed households (96%) indicated that they used information from national television in their evacuation decision-making process. However, we are unable to evaluate the impact of information from mass media in the present study since a dummy variable for television will display an almost perfect correlation with the intercept coefficient. One way to solve this issue could be to disaggregate this variable (information from television) into the specific programs or channels that the households watch (e.g., local news, the Weather Channel, etc.). However, this disaggregated information is not currently available. Thus, this is an area that deserves further research.

The total cost for the household storm preparation plan (EXPENSES) is negative and statistically significant associated with evacuation. The variable EXPENSES include household expenditures on the following actions and/or items: removed items from the deck and yard; boarded up windows and doors; purchased large ticket items (e.g., generators, chainsaws etc); purchasing building materials (e.g., plywood, nails, etc); purchased extra supplies (e.g., food, water, candles, etc.); filled up auto/truck with gas; boarded pets; secured boat, RV's, etc; and other expenses. On average, an extra dollar expended in the storm preparation plan decreases the probability of evacuation in a 2%. This result indicates that households with higher cost of storm preparation present a lower probability to evacuate. This result could be explained by the fact that the more a household expends preparing for a hurricane the higher is its sense of security.

An important goal of this study is to evaluate potential differences in evacuation patterns among households living in different geographical areas, as well as for temporal changes in behavior for households living in the same area. Even though all estimated models display similar patterns, the magnitude of the estimated coefficients presents some variation among models. These differences reflect important structural features for the studied households.

The geographical variation is first evaluated using a version of the likelihood ratio (LR) tests developed to test for equality among alternative models using restricted data sets (Greene, 2008, p. 820). Specifically, the estimated LR test is:

$$LR = 2^*(lnL_{all} - (lnL_{NW} + lnL_{SE})) \quad [3]$$

Where lnL_{all}, lnL_{NW} and lnL_{SE} represent the log-likelihood function obtain for the evacuation model using the complete sample (unrestricted model), and the NW and SE sub samples (restricted model), respectively. The evacuation model used in this test includes all the variables used in the individual hurricane models presented in Table 4. That is, the variables SFL and MAJOR where excluded in this test.

The estimated LR test likelihood ratio test (LR = 22.35) rejects the null hypothesis for equality at the 1% level; suggesting that the parameters explaining the evacuation behavior differ across the two geographical regions. The geographical variation is confirmed by the statistically significance of the variable SFL in model ALL. More precisely, the ME for SFL suggest that households living in SE FL are, approximately, 20% less like to evacuate than people living in NW FL, presumably because of the greater difficulty in the former of avoiding coastal hazards, or because their extremely limited evacuation options (Dow and Cutter, 1998). The regional difference found here is of significant importance in developing evacuation policies. Fu and Wilmot (2004) state that accurate information at the local level could provide the authorities the necessary information to develop better evacuation plans based on the specific characteristic of the population.

A set of LR tests is also used to test for changes in behavior within the hurricane season. In this case, the unrestricted model includes the aggregate data for each geographical area, and the unrestricted model is the sum of the two individual hurricanes in its respective area. The results of the LR test suggests that households living in NW FL behaved in the same way for the two studied storms ($LR = 1.4$); that is, no within season variation. Conversely, households living is SE FL did change their behavior through time ($LR = 9.6$). These results agree with the pattern found for the variable EXPERINCE. While previous experience with a major hurricane was statistically different from zero among households in SE FL, EXPERINCE shows non-significance among NW FL residents.

Concluding remarks

This study analyzes the determinants of household hurricane evacuation choice for a sample of 1,355 households in Florida. This article contributes to the literature by accounting for two issues normally neglected in previous studies. First, we account for regional variability by selecting households from two distinctive geographical areas in Florida (that is, SE and NW Florida). In addition, we analyze within season variabilities by evaluating the household evacuation behavior for four hurricanes that impacted Florida during the 2005 season.

In general our empirical results suggest that households living in risky environments (mobile home and flooding areas) are more likely to evacuate. In addition, households with children and those who have experienced the threat of a hurricane also display higher probabilities to evacuate. In contrast, homeowners and households with pets are less likely to evacuate than their counterparts.

It is also important to indicate that the results obtained in the estimated models may be a useful tool to identify the willingness to evacuate for broad demographic groups. This information may help emergency managers to target resources more efficiently focusing not only on those individuals with higher risk but also on those groups with lower probabilities to evacuate. Nevertheless, further research is needed to test the validity of the model and its variability across different geographical areas.

Presently, it appears that the source of forecast information and the relative importance of media origin are not significant factors to the evacuation decision, yet Lindall et al. (2005) assert that social interaction is important. While this research is inconclusive, the importance of information in the process of deciding to incur a large expense (evacuate) while facing an uncertain event (hurricane) is certainly complex and should be the subject of further study.

Regional differences in propensity to evacuate are clearly demonstrated, with households in SE Florida less likely to evacuate than those in NW Florida. This knowledge could prove helpful to policy makers in allocating their evacuation efforts in the future.

Lastly, looking across storms within SE Florida, a level of sophistication emerges. Household experience with hurricanes prior to the 2005 season proved a positive influence on evacuation and may be contrary to the anecdotal evidence of evacuation fatigue. WILMA, while a more powerful storm than KATRINA (as a SE event), was less threatening to the SE region because of its eastward path, removing the danger of ocean flooding. Households responded to this storm by evacuating at lowers rates than they did KATRINA and by showing less concern about the danger of flooding. Thus, further research should try to incorporate, as an explanatory variable in explaining evacuation behavior, people's expectations on the potential impact of a storm on their surroundings.

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