3-28-2013

Application of a Bivariate Probit Model to Investigate the Intended Evacuation from Hurricane

Fan Jiang
Florida International University, fjian003@fiu.edu

DOI: 10.25148/etd.FI13042512

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

APPLICATION OF A BIVARIATE PROBIT MODEL TO INVESTIGATE THE INTENDED EVACUATION FROM HURRICANE

A thesis submitted in partial fulfillment of

the requirements for the degree of

MASTER OF SCIENCE

in

STATISTICS

by

Fan Jiang

2013

To: Dean Kenneth G. Furton
College of Arts and Sciences

This thesis, written by Fan Jiang, and entitled Application of a Bivariate Probit Model to Investigate the Intended Evacuation from Hurricane, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this thesis and recommend that it be approved.

Florence George

Hugh Gladwin

B. M. Golam Kibria, Co-Major Professor

Pallab Mozumder, Co-Major Professor

Date of Defense: March 28, 2013

The thesis of Fan Jiang is approved.

Dean Kenneth G. Furton
College of Arts and Sciences

Dean Lakshmi N. Reddi
University Graduate School

Florida International University, 2013

DEDICATION

I dedicate this thesis to my parents. Without their patience, understanding, support, and most of all love, the completion of this work would not have been possible.

ACKNOWLEDGMENTS

I wish to thank the members of my committee for their support, patience, and good humor. Their gentle but firm direction has been most appreciated. Dr. Pallab Mozumder was particularly helpful in guiding me toward a qualitative methodology. Dr. Florence George's interest in sense of competence was the impetus for my proposal. I was inspired by Dr. Hugh Gladwin's paper. Finally, I would like to thank my major professor, Dr. B.M. Golam Kibria. From the beginning, he had confidence in my abilities to not only complete a degree, but to complete it with excellence.

I have found my coursework throughout the Curriculum and Instruction program to be stimulating and thoughtful, providing me with the tools with which to explore both past and present ideas and issues.

ABSTRACT OF THE THESIS

APPLICATION OF A BIVARIATE PROBIT MODEL TO

INVESTIGATE THE INTENDED EVACUATION FROM HURRICANE

by

Fan Jiang

Florida International University, 2013

Miami, Florida

Professor B. M. Golam Kibria, Co-Major Professor

Professor Pallab Mozumder, Co-Major Professor

With evidence of increasing hurricane risks in Georgia Coastal Area (GCA) and Virginia in the U.S. Southeast and elsewhere, understanding intended evacuation behavior is becoming more and more important for community planners. My research investigates intended evacuation behavior due to hurricane risks, a behavioral survey of the six counties in GCA under the direction of two social scientists with extensive experience in survey research related to citizen and household response to emergencies and disasters. Respondents gave answers whether they would evacuate under both voluntary and mandatory evacuation orders. Bivariate probit models are used to investigate the subjective belief structure of whether or not the respondents are concerned about the hurricane, and the intended probability of evacuating as a function of risk perception, and a lot of demographic and socioeconomic variables (e.g., gender, military, age, length of residence, owning vehicles).

TABLE OF CONTENTS

CHAPTER PAGE

1. Introduction 1

2. Literature Review 3

3. Methodology 9

4. Results 18
   4.1 Results for Georgia Data 18
   4.2 Results for Virginia Data 43

5. Discussion 63

References 67

1. Introduction

The hurricane is one of the most costly natural disasters in the U.S. and they are especially harmful to coastal areas (NSC, 2007). For example, the 2005 Atlantic hurricane season -the most strong and harmful in recorded history- had an estimated direct cost of approximately 2,300 deaths and recorded 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 many years (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 decades (Lara-Chavez and Alexander, 2006). Increasingly, social scientists are investigating the wide range of community and household behaviors that can occur before, during and after a hurricane. Within the broad research agenda of risk management, we are interested in understanding the household evacuation behavior. Understanding this behavior would help to develop effective community evacuation plans for us (Fischer et al. 1995), which can help to reduce emergency response costs, as well as the loss of life and property. Such information would be especially useful in GCA, and where hurricanes have been increasingly impacting human habitation. Despite growing hurricane risk in the GCA in the U.S. Southeast and elsewhere, there is limited systematic information about both actual (what happens in any given event) or expected evacuation behavior (intentions prior to an event).

Stated behavior approaches use survey responses about intended behavior with respect to some hypothesized event or change in a program, policy, or product. Stated behavior and associated stated preference approaches have been used by economists and other social scientists in a variety of transportation, marketing and environmental settings (Champ et al. 2003), including intended evacuation behavior (Whitehead 2005) and valuing hurricane risk mitigation, and can be especially useful in investigating rare events or scenarios outside of observed experience. The objective of my research is to investigate the intended household evacuation behavior in the Georgia Coastal Area (GCA). Using survey stated behavior data, we apply a bivariate probit (BP) approach that jointly models whether or not the respondent is concerned about hurricane risk in their community, and the expected decision to evacuate as a function of risk perception, and socioeconomic and demographic variables. Using this approach, stated hurricane evacuation behavior is analyzed for both mandatory and voluntary hurricane evacuation orders.

The Georgia Emergency Management Agency (GEMA) with support from the Federal Emergency Management Agency (FEMA) and the U. S. Army Corps of Engineers (USACE) (Savannah District) contracted with Dewberry for a Vulnerability and Behavioral Analysis for the Georgia Hurricane Evacuation Study. SocResearch Miami was chosen by Dewberry to conduct a behavioral survey of the six counties in coastal Georgia under the direction of two social scientists with extensive experience in survey research related to citizen and household response to emergencies and disasters (Morrow and Gladwin 2009).

They conducted the behavioral survey utilizing the services of the Institute for Public Opinion Research (IPOR) at Florida International University. Gladwin is the IPOR director. The goal was to gather the relevant information about the past and potential evacuation behavior of the coastal Georgia population in response to a hurricane. The target population was located in Bryan, Camden, Chatham, Glynn, Liberty and McIntosh counties in GCA. The telephone sample included both landline and cell phones. An important feature of the research design is that responses are geo-coded, enabling analysis according to the location of the respondents' households.

Another dataset was obtained from a 2010 study by FEMA and USACE on potential evacuation behavior of the coastal Virginia population in response to a catastrophic event, such as a major hurricane, in order to inform transportation planning and emergency management. Target regions included the Eastern Shore, Northern Neck, Peninsula and South Side. Data was collected both in and outside of surge or evacuation zones in each region. The telephone survey sample included both landline phones and cell phones.

2. Literature Review

Burton et al. (1993) and Viscusi (1995) gave the theoretical basis to analyze human behavior under environmental risk (the threat of a hurricane in my 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 parts of their wealth (e.g., income, capital, savings etc.) to reduce those threats. What's more, Burton et al. (1993) state that under the threat of environmental risk an individual's response is affected by four major elements: (1) prior experience with the specific environmental risk; (2) intrinsic characteristics; (3) an individual's wealth; and (4) interaction with society.

From an empirical point of view, individuals 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 many factors including social characteristics, economic constraints, storm characteristics and planned evacuation destination and costs (e.g., Fu and Wilmot, 2004; Whitehead, 2003; Whitehead et al., 2000; Dow and Cutter,1998).

For example, Dash and Gladwin (2007) argue that risk perception and previous experience with hurricanes are important factors in explaining evacuation decisions. Whitehead (2005) explains that the main goal of an evacuation is to reduce the risk of injury or death. In these respects, people facing more risk, 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) reports that people living in areas previously affected by a major hurricane are also more willing to evacuate.

Against this planning perspective above, some attempts to standardize the disaster definitions or scales literally require inter alia the presence of significant evacuations (Nicholson 1994). As hurricane seasons in the U.S. Southeast have been worsening for some time (Fritz 2006), observed evacuations events are now commonly running into the thousands of households, and in selected cases into the tens of thousands (Spagat 2003; Broder 2003; Bosworth 2000; Lavin 1995; Rossomando 2000). Systematic information about the numbers of evacuations is hard to collected, and mainly available through newspapers, online media, and on a case-by-case basis. For instance, in the U.S., the National Hurricane Center's website (http://www.nhc.noaa.gov) provides statistics on hurricane damage, but not on evacuations.

Evacuation requires rapidly moving potentially large numbers of households out of their homes and into safe areas, with subsequent needs for temporary food and shelter. When people do not move, or do not move quickly, critical resources are often targeted toward them. Understanding the intended evacuation behavior is a part of the planning puzzle (Pfister 2002), whether it is presumed that mass evacuation is always the preferred option, or there is consideration that for some residents the right to stay home is a preferred option. Such individual choice is a protected right, as long as there is no interference with public agency actions. There is considerable debate and some evidence that staying may be a valid response for the prepared people, and that evacuating later rather than earlier or not at all may increase risks in some circumstances.

Georgia is an extremely vulnerable state to hurricane-related hazards. The geographic location of Georgia makes it susceptible to impacts from tropical storms and hurricanes from both the Gulf of Mexico and the Atlantic Ocean. Tropical storms and hurricanes have impacted Georgia from both coasts causing widespread damages and coastal evacuations. GCA has not had any hurricane impact since a Cat 1(Hurricane David) in 1979 and no major hurricane since 1893. The major hurricane of 1893 made landfall on the northern Georgia Coast on August 27. This devastating hurricane is responsible for causing over 2,500 fatalities. This hurricane is one of the worst weather-related natural disasters in Georgia's history. Last year, hurricane Sandy was coming, the deadliest and most destructive tropical cyclone of the 2012 Atlantic hurricane season, as well as the second-costliest hurricane in United States history. Research on GCA hurricane evacuation seems emergency and necessary. (http://www.gema.ga.gov/gemaohsv10.nsf/c6049b8deb5d38a185257726003aa1dd/68ec9214ddb5b64a8525773500716735)

Despite increasing hurricane risks in the GCA in the U.S. Southeast, there is limited social science research that addressing the evacuation. There is a growing number of related research with respect to natural hazards. Risk perception is one of the most important determinants of evacuation behavior (Riad and Norris 2000; Smith 1999; Whitehead et al. 2000). Overstating the intensity of hazards to instigate greater cooperation may reduce agency credibility (Smith 1999; Fischer et al. 1995). Riad and Norris (2000) found that four categories of variables affect the decision to evacuate: risk perception, preparedness, social influence and economic resources. Smith (1999) and Whitehead et al. (2000) found that gender tended to have significant effects in the choice to evacuate. Riad et al. (1998) found that women are more likely to believe that the disaster will be bad, while men are more likely to feel "in control" and safe. Whitehead et al. (2000) found that having pets made evacuation less likely than not owning pets in the home. Alexander (2000) found that pet owners often had to leave their animals behind, as motels or shelters would not accept them.

A recent survey empirical investigation (Whitehead 2005) of the probability of expected hurricane evacuation behavior provided the initial template for our own survey design. Whitehead (2005) was able to match expected or intended evacuation (stated behavior) in a validity test against subsequent actual evacuation behavior and found that the stated-preference data were 83 percent accurate in predicting evacuation; however, there was some asymmetry in these results. Roughly 50 percent of those who said they would evacuate did, while 92.6 percent of those who said they would not evacuate did not.

In previous studies, most of the hurricane evacuation studies are derived from a single equation choice models. Adamonwicz et al. (2008) discuss an extension of choice models to make them more behaviorally realistic by using structural modeling. Several other papers used structural modeling for analyzing wildfire risk (Mozumder et al., 2008), but nothing has done for hurricane risk.

My study investigates intended evacuation behavior associated with hurricane risks by using structural modeling. Bivariate probit (BP) models are used to investigate the subjective belief structure of whether or not the respondent is concerned about hurricane, and the intended probability of evacuating as a function of risk perception, and a lot of socioeconomic and demographic variables jointly. From an empirical point of view, more than one dependent variable may be of interest for a variety of reasons (e.g., for behavioral path analysis).

The Bivariate probit model allow the flexibility of including a variable as both a dependent and independent variables, which has particular relevance in exploring how preferences evolve. When some of the explanatory variables are the same across different equations and some are unique, corresponding errors are subject to contemporaneous correlation, which cannot be captured through single equation techniques.

3. Methodology

The survey questions were developed by Morrow and Gladwin (2009) on the basis of insights gained from past research and input from the agencies involved. A set of questions was submitted by the USACE to the Office of Management and Budget (OMB) for approval and it was approved with minor changes. A total of 39 questions solicited information about hurricane concern, past hurricane response and future intentions. Another 17 questions gathered demographic information for use in the analysis.

The company SocResearch Miami was contracted to complete interviews with a minimum of 1,500 households distributed through the coastal Georgia counties. The distribution across the counties was specified by GEMA on the basis of population and other concerns.

Phone numbers were purchased from Scientific Telephone Samples according to location. Landline phone numbers were geo-coded. The cell phone interviews were also geo-coded if the respondent provided location information. The location of each household for which interviews were completed is provided later in this report.

It is important to note that interviews were completed with a person qualified to speak for the household. We also note that our sample is more educated, older, and has a higher income than typical for the Georgia Coastal Area (GCA). Also there are more women and fewer African Americans in our sample. However, the 22% rate for African Americans is higher than usually attained. In this sample 82% reported that they own homes. Relevant to the warning communication process, 80% have internet access in their homes. Surprisingly, 94% of the total sample reported having cell phones in their household. Using the Computer-Assisted Telephone Interviewing (CATI) system at IPOR experienced interviewers called each working number a minimum of 10 times or until someone answered during the period from June 15 and July 15, 2010. The calls occurred mostly in the evenings and on weekends until quotas for each region and surge zone were reached. For the landline sample 8,124 numbers were attempted. Most calls did not result in valid interviews for various reasons. Some were networking or business numbers; others were located outside the target region; others were never answered, were answered by an answering machine, were answered by someone under 18, or were answered by a person who could not speak for the household. A total 2,518 calls reached a person who potentially could do the interview, and 1,398 people who answered agreed to participate, resulting in a completion rate of 55% for landline phones. The positive response is likely explained by the advance publicity the project received in the region as well as the salience of the topic for residents of coastal Georgia. The average interview length was 14 minutes for completed landline interviews while 13 minutes for cell phone interviews. 300 interviews were also made to cell phones to check for bias in response resulting from a listed landline sample. Cell phone calls had a completion rate of 33% and were added to the overall sample and verified that survey results are valid for cell phone calls as well as landline. A total of 1,425 landline interviews were completed and 273 cell phone interviews for a total of 1,698 interviews. In every county more than the targeted number of interviews was obtained. It is well known that an important predictor of future behavior is past behavior. Research has shown that people who have evacuated for a hurricane are likely to evacuate in the future. Thus, respondents were asked several questions about their past evacuation experiences. Of the total sample, 46% had evacuated previously.

From the survey evidence, the mean household income for the GCA is in the $30,000-$50,000 category, with approximately 2.7 persons per household. Residents tend to be well educated, with a mean education level of some college. From the survey data we found that the average length of residence in the area is 26 years, although there are families who trace their roots in the region back several hundred years. So in many ways, this population reflects what is sometimes thought of as the classic group of newcomers to the Southeast: relatively wealthy, well-educated, and usually from somewhere else.

As part of this survey, respondents were asked two sequential questions about whether or not they would evacuate under two scenarios: a voluntary and a mandatory evacuation order. The voluntary evacuation order question read:

If a hurricane did occur in your living area and your household was given a voluntary evacuation order from government, would you evacuate your home and relocate your household to a safer location? YES NO

This was followed by exactly the same question for a mandatory evacuation order, i.e.,

If a hurricane did occur in your living area and your household was given a mandatory evacuation order from government, would you evacuate your home and relocate your household to a safer location? YES NO

We refer to this binary response to an intended evacuation question as E (YES: $E=1$, or NO: $E=0$) and VOL and MAND refer to the voluntary and mandatory questions, respectively (i.e., E_{VOL} and E_{MAND}).

To provide some point of view, compared to voluntary evacuation orders, mandatory evacuation orders are put in place in more severe conditions. Note that during a mandatory evacuation order although emergency management agencies put maximum resources and effort into encouraging evacuation, current laws do not allow agency officials to strictly require enforcement of the order (Wolshon et al. 2005). However, the difference in voluntary and mandatory evacuation orders can be seen from an operational point of view. For instance, special transportation or traffic control measures are operated during mandatory evacuation orders, which are not the same as voluntary evacuation orders (Wolshon et al. 2005).

In the survey, respondents were also asked a variety of attitudinal, behavioral and belief questions, such as, whether they are concerned that the hurricane would endanger their home, how they perceived risk of hurricane in their area, household experiences with previous hurricane happen, as well as a variety of socioeconomic and demographic questions. The survey also asked respondents other questions that are related to evacuation behavior, such as whether the respondent owned houses, and where they would relocate (e.g., a shelter). Although not a focus here, as a part of the larger research, a split-sample treatment provided half of our sample with a hurricane risk map using GIS data.

Our modeling follows the premise that the intended behavioral patterns of the community members are endogenously related to the individual's level of concern that their home may be endangered by hurricane. In the context of hurricane risk, risk perception is adaptive, dynamic and context sensitive. An evacuation order under hurricane risk can be viewed as intervention mechanism set in place by relevant agencies to reduce the loss of lives. How people respond to this intervention mechanism and what factors influence their behavior with respect to this intervention has strong implications for hurricane risk reduction in the GCA zone. A household's decision to evacuate is a self-protective behavior implemented in a multidimensional social context (MacGregor et al. 2007). Self-protective behaviors like evacuation in the face of hurricane contingencies have uncertain cost and benefits. In this context where cognitive burden is enormous to compute relevant outcomes and probabilities, decisions are more likely to be detemined on heuristics and judgment based on prior beliefs (Kahneman and Tversky 1985). Not only just past events, but current socio-economic and political factors may also influence the belief formation. Once the agent has formed the belief structure, the decision to evacuate may be affected by a variety of factors (e.g., resources needed following evacuation, factors at risk other than home, such as vehicles and shelter etc.).

We try to capture this subjective context and belief structure in our analytical approach. Specifically, if the respondent's latent level of concern that their home will be endangered by hurricane crosses some threshold, the household is viewed as considering evacuation. The specific Yes or No question to elicit the level of concern was: "Are you concerned that a hurricane may endanger your home or property?" To begin modeling household intended evacuation behavior, we first postulate that the probability of being concerned (Concern: Yes =1, 0 otherwise) is affected by a number of factors, including: house located in the area where people have to evacuate, number of hurricane respondent have ever evacuated, whether and to what extent the household was flooded by hurricane in the past, if the household has ever experienced property damage due to hurricane, and the number of years the respondent lived in the area. We also consider control variables that may affect the level of concern (e.g. gender, age, education income, and ethnic). This binary endogenous variable Concern enters into the evacuation decision equation as an explanatory variable. Additional explanatory variables used to explain the evacuation decision include, gender, age, income, education, ethnic, number of household members, own houses or not, married or not, and expected destination (e.g. public shelter).

To implement this analytical approach, we use the bivariate probit model, which jointly estimate the probability of being concerned and the probability of evacuation (under either a voluntary or mandatory situation). The bivariate probit model estimates two equations for the two binary dependent variables where the iid (independent and identically distributed) errors in each equation are correlated (Greene 2003). The bivariate system can be described as follows:

$$y_{1i}^{*} = \alpha x_i + \varepsilon_{1i} \tag{1}$$
$$y_{2i}^{*} = \beta z_i + \gamma\ y_{1i} + \varepsilon_{1i} \tag{2}$$

where y_{1i}^{*} and y_{2i}^{*} are latent variables and y_{1i} (Concern) and y_{2i} (either E_{VOL} or E_{MAND}) are dichotomous variables that observed according to the following rule.

$$\begin{cases} y_{li} = 1 & if\ \ y_{li}^{*} > 0 \\ y_{li} = 0 & if\ \ y_{li}^{*} \leq 0; \end{cases} \qquad \text{where } l = 1, 2 \tag{3}$$

Here x_i and z_i are vectors of exogenous variables and α , β and γ represent the conformable vectors of relevant coefficients or parameters of the model. The error terms are assumed to be independently and identically distributed as bivariate normal with zero mean vector and a non-zero variance-covariance matrix. Following Greene (1998, 2003), we estimate this model using a bivariate probit method, The underlying algorithm for bivariate probit estimation is full information maximum likelihood and we used the biprobit option in STATA 12 to estimate the model parameters. For details on bivariate probit model we refer our readers to Green (1998, 2003) among others.

Using the bivariate probit model, first equation estimate that the probability of being concerned (Concern: Yes =1, 0 otherwise) is affected by a number of factors. The second equation this binary endogenous variable Concern enters into the evacuation decision equation as an explanatory variable. We can estimate the probability of being concerned and the probability of evacuation (under either a voluntary or mandatory situation) better. Since it will be difficult to estimate the probability of evacuation (under either a voluntary or mandatory situation) if a people who doesn't concern about the hurricane. Additional explanatory variables used to explain the evacuation decision include, gender, age, income, education, ethnic, number of household members, own houses or not, married or not, and expected destination. Bivariate model gives room for influencing intended evacuation through risk communication, improved forecasting etc. That's why we used the bivariate probit model.

The Akaike Information Criterion (AIC) is one of the best possible ways to select a model from a set of models. This approach is based on information theory and select a model that minimizes the Kullback-Leibler distance between the estimated and the true models. Let L be the likelihood function, then the AIC is defined as

$$AIC = -2 \ln(L) + 2p, \tag{4}$$

p is the number of free parameters in the model. Generally, AIC tradeoff between accuracy and complexity of the model. In statistics, the Bayesian information criterion (BIC) or Schwarz criterion ($BIC_{Schwarz}$) is another criteria which mainly considers likelihood function, and it is closely related to Akaike information criterion (AIC). The BIC ($BIC_{Schwarz}$) is defined as

$$BIC_{Schwarz} = -2 \ln(L) + p \ln(n). \tag{4}$$

When fitting a model, it is possible to increase the likelihood by adding parameters, but doing so the result may overfit the model. However, the BIC resolves this issue by introducing a penalty term for the number of parameters in the model. The penalty term is larger in BIC than in AIC and depends on the number of observations. In both cases, a smaller the value the better the model. For more on AIC and BIC, we refer Akaike (1974) and Schwartz (1978) among others.

4. Results

4.1 Results for Georgia Data

Definitions and descriptive statistics of the variables are provided in Table 4.1.1. Preliminary analysis based on difference in proportions tests (without controlling for any other factors) shows that the evacuation responses differ by various sample characteristics. For example, consistent with prior risk-related research we find an education effect (significant at the 5 percent level). The sample mean of a positive response (Yes) to the mandatory evacuation order was 93 % versus 76 % for the voluntary evacuation order (see Table 4.1.1). Thus, we estimate the evacuation probabilities separately for mandatory and voluntary evacuation orders using the same bivariate probit modeling approach for that part of the sample where we have responses to all the variables considered.

We report the estimated evacuation probabilities from a set of models under a voluntary order in Table 4.1.2. In the first component, Panel A shows the estimated probabilities of being concerned (*Concern*) that hurricane may endanger the respondent's home. In Models 1 to 4, households are more concerned if they had past property damages due to hurricane. Other factors, such as their home located in an area where they would have to evacuate for storm surge in a hurricane (*Area*), has their household or family talked about what they might do if they had to evacuate their home for a hurricane (*Plan*), and whether they will assist others outside of their household, significantly affect the respondent's concern (*Helping*). Among the control variables, Cat3 or more (*Major hurricane*), Cat 1 or Cat 2 (*Minor hurricane*) and how long they have lived (*Lived*) tend to positively contribute to a household's concern that hurricane may endanger their home (Model 1 to 4 in Panel A, Table 4.1.2).

In the second component (Panel B in Table 4.1.2), the binary endogenous variable, *Concern* enters into the voluntary evacuation decision equation as an explanatory variable, and is found statistically significant (in Models 1 to 4). The implication is that a higher likelihood of being concerned that one's home may be endangered by hurricane leads to an increased probability of intended voluntary evacuation. Among other explanatory variables, education has a higher probability of intended evacuation (estimated coefficient is highly significant in all models in Panel B, Table 4.1.2). Respondents serving in the U.S. military and stationed in coastal Georgia (*Military*) have a higher probability of intended evacuation (Models 1 to 4). Respondents who own vehicles (*Vehicles*) have a significantly lower probability of intended evacuation in several models (Models 2 to 4) under a voluntary order.

Table 4.1.3 reports the bivariate probit estimates for the intended evacuation probability under a mandatory evacuation order. In the first component (Panel A, Table 4.1.3), variables that affect the respondent's concern (*Concern*) that their home may be endangered by hurricane are largely similar to a voluntary evacuation order. In the second component, (Panel B, Table 4.1.3) similar to voluntary evacuation, a higher likelihood of being concerned that one's home may be endangered by hurricane leads to an increased probability of a Yes response under a mandatory evacuation order (Models 5 to 8). Income (*Income)*, and serving in the U.S. military and stationed in coastal Georgia (*Military*) significantly increase the probability of intended evacuation under a mandatory order (Models 5 to 8 in Panel B). Also under a mandatory order, whoever evacuated for a hurricane (*Ever evacuated*) has significant effects (Model 8).

Respondents who own vehicles (*Vehicles*) or consult with anyone outside of their household before making their decision about evacuation (*Consulting*) have a higher probability of intended evacuation (Models 5 to 8). Finally, respondents own their house (*Own*) in the area have a lower probability under a mandatory order (Models 5 to 8). Aware that, as a consequence of the extent of low-lying areas, there will be no public shelters provided (*Knowledge*) is shown to significantly decrease the probability of intended evacuation.

Altogether, Tables 4.1.2 and 4.1.3 present multiple models to explain intended evacuation behavior. Four different models for both voluntary and mandatory evacuation orders are presented, with the primary purpose of demonstrating the robustness of key findings to alternative specifications that include additional control variables. In terms of overall fit, all models reported in both Tables 4.1.2 and 4.1.3 are highly significant (at 1% level for Wald Test Statistics in Tables 4.1.2 and 4.1.3), implying strong relevance of the variables used in the analysis. In Table 4.1.4, we provide the calculated marginal effects of corresponding coefficients on the probability of intended evacuation results reported in Tables 4.1.2 and 4.1.3. The predicted probability of intended evacuation ranges from 41% to 43% (Figure 4.1.8) under a voluntary evacuation order and from 65% to 68% (Figure 4.1.16) under a mandatory evacuation order (see Table 4.1.4). The results are valid for the bivariate probit model (Whitehead 2005). Respondents who are concerned that hurricane may endanger their home are about 58% more likely to evacuate under a voluntary evacuation order (Models1 to 4) and 38 to 45% are more likely to evacuate under mandatory evacuation order (Models 5 to 8). Respondents who experienced past property damages are more likely to be concerned by 7-9% under a voluntary order and 12-13% under a mandatory order. Respondents whose home ever be flooded as a result of a hurricane or storm are more likely to be concerned by 7% (voluntary order) to 9% (mandatory order). That is, past exposure to property damage by hurricane significantly and home ever be flooded as a result of a hurricane or storm increase the probability of intended evacuation behavior indirectly through an increased level of concern about hurricane. This suggests that risk communication efforts such as educating homeowners through dissemination of risk information may be effective in changing households hurricane-related risk behavior (e.g., Donovan et al. 2007).

Male respondents are 2-4% less likely to evacuate under a voluntary order and 1-5% more likely to evacuate under a mandatory order. Respondents who own their house are 4% less likely to evacuate under both voluntary and mandatory orders. Respondents who ever evacuated are more likely to evacuate by 5% under both voluntary and mandatory orders. Under a voluntary order, respondents who own vehicles (by 8%) and who need public or government- provided transportation (by 2-4%) are less likely to evacuate. Respondents serving in the U.S. military and stationed in coastal Georgia are also more likely to evacuate (7% voluntary order; 5% mandatory order).

From the AIC and BIC graphs (Figure 4.1.5 and 4.1.13) we observed that the BICs are bigger than the AICs. The Wald chiquare has a down slop (Figure 4.1.7 and 4.1.15) and the Pseudo likelihood has an increase tend (Figure 4.1.6 and 4.1.14). We can conclude that all models are fitted well. These figures also evident that models 3 and 4 are performing better than model 1 and 2. Figure 4.1.1-4.1.4 and 4.1.9-4.1.12 give the predicted probability of age, education, income, lived of the people who concerned about the hurricane. From Figure 4.1.1 we observed that the predicted probabilities for voluntary evacuation are higher for middle age people than young and old people.

Table 4.1.1 Definitions and Descriptive Statistics

Variable	**Description**	**N**	**Mean**	**St. Dev.**
Concern	1 if respondent is very concerned or somewhat concerned about the threat of a hurricane, 0 if respondent is not concerned	1698	0.72	0.45
Damage	Home would ever be seriously damaged or destroyed by the winds of a hurricane, 1 if very likely, somewhat likely , 0 if not likely	1698	0.65	0.48
Flood	Home would ever be flooded as a result of a hurricane or storm, 1 if very likely, somewhat likely , 0 if not likely	1698	0.55	0.50
Area	Is your home located in an area where you would have to evacuate for storm surge in a hurricane, or are you not sure if it is? 1 if yes, 0 if no or not sure	1698	0.46	0.50
Low-lying	Would that term "low-lying area" apply to where you live?1 if yes, 0 if no or not sure	1698	0.39	0.49
Plan	Has your household or family talked about what you might do if you had to evacuate your home for a hurricane? 1 if yes, 0 if no	1698	0.76	0.42
Major hurricane	How likely is it that you would leave your home if the hurricane is Cat3 or more? 1 if very likely, somewhat likely , 0 if not likely	1698	0.90	0.30
Minor hurricane	How likely is it that you would leave your home if the hurricane is Cat 1 or cat 2? 1 if very likely, somewhat likely , 0 if not likely	1698	0.48	0.50
Mandatory	If government officials ordered an evacuation of your area, how likely is it that you would leave? 1 if very likely, somewhat likely , 0 if not likely	1698	0.93	0.25
Voluntary	If an evacuation was recommended but not ordered, for your specific area, how likely is it that you would evacuate? 1 if very likely, somewhat likely , 0 if not likely	1698	0.76	0.43
Consulting	Would you consult with anyone outside of your household before making your decision about evacuation? 1 if yes, 0 if no	1682	0.55	0.50

Helping	Will you have to assist others outside of your household, such as elderly parents, friends or Neighbors if there is an evacuation? 1 if yes, 0 if no or do not know	1698	0.41	0.49
Military	Are you or your household serving in the U.S. military and stationed in coastal Georgia , 1 if yes, 0 if no	1688	0.08	0.28
Age	How old are you? (in years)	1593	54.79	16.57
Member	How many people live in your household?	1658	2.72	1.61
Marital	1 if married , 0 if single or others	1698	0.64	0.48
Education	What is the highest grade of school you've completed 1 if grade school , 2 if some high school, 3 if high school graduate , 4 if some college , 5 if college graduate , 6 if graduate degree	1564	4.15	1.16
Ethnic	1 if black or African American, 0 if others	1698	0.20	0.40
Income	1 if $10, 000 or less ; 2 if $10, 001 - $20, 000 ; 3 if $20, 001 - $30, 000 ; 4 if $30, 001 - $50, 000 ; 5 if $50, 001 - $80, 000; 6 if over $80, 000	923	4.29	1.52
Gender	1 if male , 0 if female	1698	0.11	0.31
Vehicles	Are there any other kinds of vehicles you would likely take , 1 if yes, 0 if no	1684	0.11	0.31
Knowledge	Are you aware that, due to the extent of low-lying areas, there will be no public shelters provided, 1 if aware , 0 if not aware	1670	0.55	0.50
Own	Do you -- or your family -- own your home or apartment or do you rent? 1 if own , 0 if rent or other specify	1668	0.81	0.40
Lived	How long have you lived in the part of Georgia where you live now? (in years)	1666	25.77	21.68
Transportation	If you had to evacuate for a hurricane, would you need public or government- provided transportation? 1 if yes, 0 if no	1698	0.06	0.23

Ever evacuated	Have you ever evacuated your current home for a hurricane , 1 if yes, 0 if no	1698	0.46	0.50
Shelter	Are there any people living in your household who would probably stay and shelter in place even? If other people are leaving , 1 if yes, 0 if no	1698	0.07	0.26

Table 4.1.2: Estimated Probability of *Voluntary* Evacuation, Bivariate Probit Specification

Panel A: Estimated Probability of Being Concerned about Hurricane Endangering Home				
	Model 1	**Model 2**	**Model 3**	**Model 4**
Damage	0.227(0.058) ***	0.259(0.072) ***	0.219(0.08) ***	0.208(0.066) ***
Flood	0.206(0.065) ***	0.198(0.074) ***	0.193(0.08) **	0.19(0.076) **
Area	0.006(0.074)	0.003(0.078)	-0.002(0.073)	-0.013(0.062)
Low-lying	-0.043(0.078)	-0.018(0.058)	-0.011(0.077)	-0.019(0.079)
Plan	0.101(0.078)	0.098(0.078)	0.114(0.082)	0.131(0.083)
Major hurricane	0.904(0.136) ***	0.864(0.137) ***	0.861(0.143) ***	0.864(0.141) ***
Minor hurricane	0.513(0.065) ***	0.525(0.072) ***	0.533(0.072) ***	0.528(0.066) ***
Lived	0.009(0.002) ***	0.009(0.002) ***	0.009(0.002) ***	0.008(0.002) ***
Gender		-0.133(0.148)	-0.13(0.15)	-0.145(0.144)
Education	0.008(0.037)	0.014(0.038)	0.007(0.038)	0.009(0.038)
Helping			0.001(0.07)	-0.01(0.058)
Shelter				-0.059(0.144)
Constant	-1.07(0.202) ***	-1.065(0.203)***	-1.017(0.209) ***	-1.005(0.209) ***
Panel B: Estimated Probability of *Voluntary y* Evacuation (E_{VOL})				
	Model 1	**Model 2**	**Model 3**	**Model 4**

Concern	1.94(0.066) ***	1.936(0.067) ***	1.936(0.07) ***	1.928(0.067) ***
Income	-0.025(0.022)	-0.025(0.021)	-0.006(0.028)	0.004(0.023)
Age			0.001(0.003)	0.002(0.002)
Education	0.086(0.037) **	0.082(0.036) **	0.074(0.038) **	0.083(0.037) **
Gender	-0.091(0.082)	0.065(0.143)	0.055(0.144)	0.024(0.141)
Member	0.017(0.022)	0.022(0.025)	0.042(0.027)	0.041(0.028)
Marital			-0.169(0.073) **	-0.175(0.081) **
Ethnic		0.035(0.089)	0.011(0.094)	0.003(0.078)
Military	0.237(0.081) ***	0.192(0.082) **	0.204(0.1) **	0.208(0.097) **
Knowledge	-0.157(0.062)***	-0.15(0.063) **	-0.143(0.061) **	-0.174(0.063) ***
Consulting	0.076(0.06)	0.081(0.061)	0.093(0.06)	0.085(0.057)
Transportation	-0.056(0.185)	-0.087(0.189)	-0.112(0.191)	-0.112(0.132)
Vehicles		-0.226(0.102) **	-0.205(0.108) *	-0.2(0.107) *
Ever evacuated				0.153(0.073) **
Own				-0.116(0.087)
Constant	-1.136(0.169) ***	-1.12(0.185) ***	-1.204(0.245) ***	-1.226(0.213) ***
N	895	891	874	874
Pseudo LL	-900.786	-893.363	-875.987	-873.19
Wald (χ^2)	957.27 (0.00)***	951.65 (0.00)***	930.39 (0.00)***	929.38 (0.00)***
AIC	1843.571	1834.727	1805.973	1806.391
BIC	1944.304	1949.743	1934.846	1949.583
df	21	24	27	30

Table 4.1.3: Estimated Probability of *Mandatory* Evacuation, Bivariate Probit Specification

Panel A: Estimated Probability of Being Concerned about Hurricane Endangering Home				
	Model 1	**Model 2**	**Model 3**	**Model 4**
Damage	0.359(0.099) ***	0.36(0.1) ***	0.343(0.101) ***	0.367(0.1) ***
Flood	0.283(0.101) ***	0.288(0.102) ***	0.286(0.102) ***	0.276(0.103) ***
Area	0.041(0.101)	0.056(0.102)	0.07(0.103)	0.068(0.104)
Low-lying	0.02(0.107)	0.018(0.108)	-0.013(0.109)	-0.024(0.111)
Plan	0.132(0.104)	0.128(0.105)	0.136(0.107)	0.139(0.107)
Major hurricane	0.703(0.142) ***	0.698(0.144) ***	0.708(0.146) ***	0.706(0.147) ***
Minor hurricane	0.402(0.096) ***	0.399(0.097) ***	0.399(0.098) ***	0.395(0.099) ***
Lived	0.009(0.002) ***	0.01(0.002) ***	0.01(0.002) ***	0.009(0.002) ***
Gender		-0.103(0.158)	-0.095(0.16)	-0.107(0.159)
Education	-0.004(0.04)	-0.002(0.041)	-0.006(0.041)	-0.008(0.041)
Helping			0.15(0.09) *	0.154(0.091) *
Shelter				0.081(0.167)
Constant	-0.958(0.232) ***	-0.96(0.234) ***	-1.012(0.239) ***	-1.007(0.24) ***
Panel B: Estimated Probability of *Mandatory* Evacuation (E_{MAND})				
	Model 1	**Model 2**	**Model 3**	**Model 4**

Concern	1.955(0.175) ***	1.928(0.184) ***	1.94(0.185) ***	1.896(0.194) ***
Income	0.082(0.045) *	0.083(0.047) *	0.102(0.05) **	0.129(0.053) **
Age			0(0.005)	0(0.005)
Education	-0.054(0.059)	-0.046(0.061)	-0.036(0.061)	-0.032(0.063)
Gender	-0.064(0.192)	-0.043(0.21)	-0.055(0.211)	-0.117(0.218)
Member	0.048(0.043)	0.048(0.048)	0.065(0.055)	0.054(0.057)
Marital			-0.231(0.151)	-0.246(0.157)
Ethnic		0.291(0.177)	0.284(0.18)	0.203(0.183)
Military	0.493(0.235) **	0.504(0.241) **	0.467(0.252) *	0.479(0.253) *
Knowledge	-0.222(0.122) *	-0.248(0.127) *	-0.255(0.127) **	-0.311(0.133) **
Consulting	0.241(0.119) **	0.255(0.123) **	0.257(0.124) **	0.248(0.128) *
Transportation	0.235(0.347)	0.134(0.347)	0.113(0.35)	0.048(0.354)
Vehicles		0.517(0.283) *	0.549(0.286) *	0.585(0.295) **
Ever evacuated				0.463(0.151) ***
Own				-0.477(0.228) **
Constant	-0.283(0.309)	-0.353(0.32)	-0.358(0.441)	-0.151(0.474)
N	895	891	874	874
Pseudo LL	-635.724	-625.839	-614.043	-606.762
Wald (χ^2)	369.53 (0.00)***	351.44 (0.00)***	357.08 (0.00)***	344.42 (0.00)***
AIC	1313.449	1299.678	1282.086	1273.525
BIC	1414.182	1414.694	1410.959	1416.717
df	21	24	27	30

Notes: ***, **, * imply significance at 1%, 5%, 10% levels respectively; numbers in the parenthesis are robust standard errors.

Table 4.1.4: Marginal Effects of Estimated Coefficients Reported in Table 4.1.2 and 4.1.3

	Model 1	**Model 2**	**Model 3**	**Model 4**
	Voluntary **Evacuation (** E_{VOL} **) Equation**			
Concern#	0.578***	0.58***	0.58***	0.58***
Damage#	0.078***	0.089***	0.075***	0.072***
Flood#	0.07***	0.067***	0.065***	0.065***
Area#	0.002	0.001	-0.001	-0.004
Low-lying#	-0.014	-0.006	-0.004	-0.006
Plan*	0.034	0.033	0.039	0.045
Major hurricane#	0.341***	0.325***	0.324***	0.325***
Minor hurricane#	0.172***	0.176***	0.178***	0.177***
Lived	0.003***	0.003***	0.003***	0.003***
Gender#		-0.024	-0.026	-0.042

Education	0.033***	0.033***	0.028***	0.032***
Helping#			0.0004	-0.003
Shelter#				-0.02
Income	-0.009	-0.009	-0.002	0.001
Age			0.001	0.001
Member	0.006	0.008	0.015	0.014
Marital#			-0.058 ***	-0.06 ***
Ethnic#		0.012	0.004	0.001
Military#	0.078***	0.064**	0.068**	0.069*
Knowledge#	-0.054**	-0.051***	-0.049***	-0.06**
Consulting#	0.027	0.028	0.032	0.03
Transportation #	-0.02	-0.031	-0.04	-0.04
Vehicles#		-0.081*	-0.074	-0.072
Everevacuated #				0.053 **
Own				-0.039
Predicted Prob. of Yes	0.418	0.422	0.422	0.423

Model 5	Model 6	Model 7	Model 8
***Mandatory* Evacuation (E_{MAND}) Equation**			
0.443***	0.415***	0.421***	0.384***
0.123***	0.123***	0.117***	0.125***
0.095***	0.096***	0.095***	0.092***
0.013	0.018	0.023	0.022
0.007	0.006	-0.004	-0.008
0.045	0.043	0.046	0.047
0.26***	0.258***	0.262***	0.261***
0.132***	0.131***	0.131***	0.13***
0.003***	0.003***	0.003***	0.003***
-0.009	-0.04	-0.039	-0.05
-0.009	-0.006	-0.007	-0.006
		0.049*	0.05*
			0.026
0.011**	0.01**	0.013**	0.014**
		0.00005	0.00005
0.007	0.006	0.008	0.006
		-0.028	-0.026
	0.032	0.032	0.021
0.051**	0.047**	0.045**	0.04**
-0.03**	-0.031**	-0.032**	-0.034**
0.034*	0.033*	0.034*	0.029*

0.028	0.015	0.013	0.005
	0.048***	0.051***	0.046***
			0.05***
			-0.042***
0.659	0.667	0.667	0.677

Notes: Marginal effects represent the % changes in probability of evacuation decision given a unitary increase in a variable (or change from 0 to 1 in the case of binary variables marked with #). ***, **, * imply significance at 1%, 5%, 10% levels respectively;

***Voluntary* Evacuation**

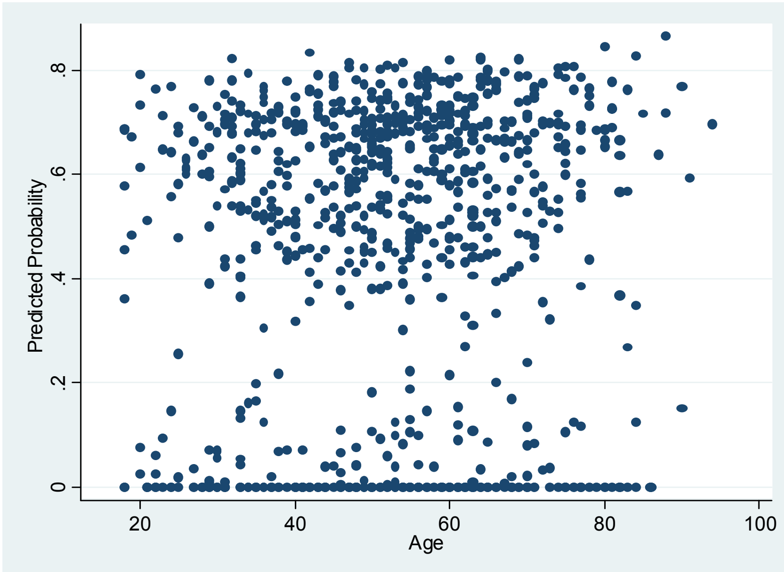

Figure 4.1.1 Predicted probability for Age

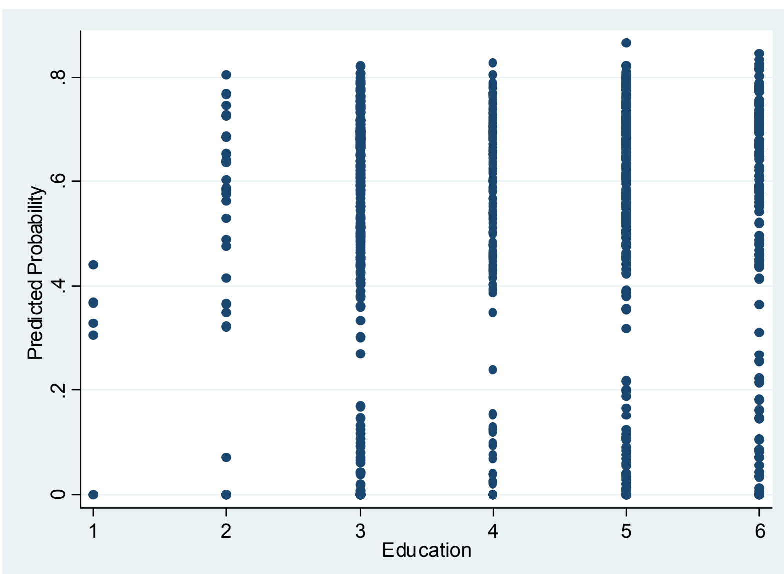

Figure 4.1.2 Predicted probability for Education

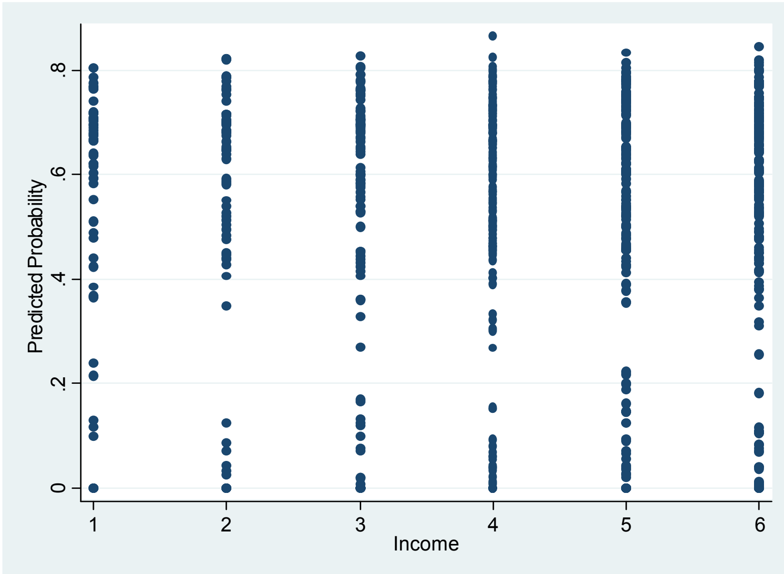

Figure 4.1.3 Predicted probability for Income

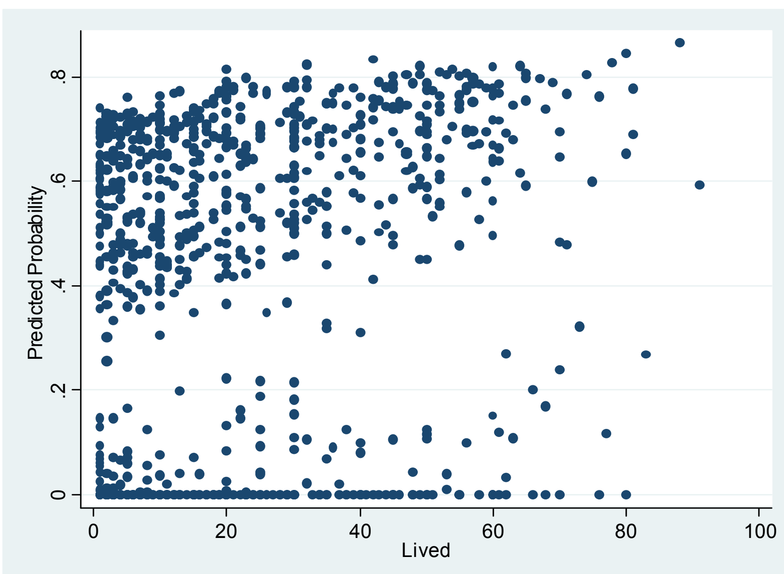

Figure 4.1.4 predicted probability for Lived

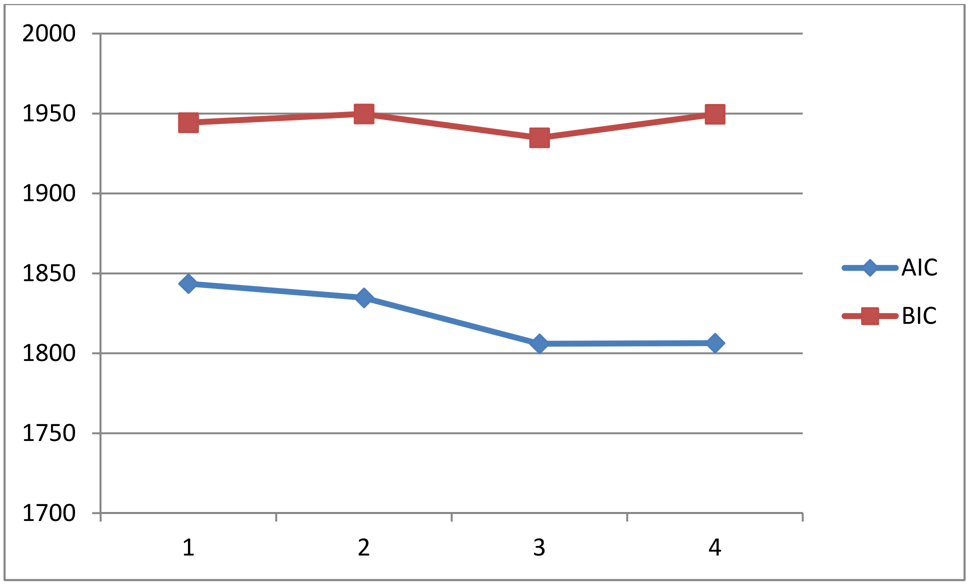

Figure 4.1.5 AIC BIC for voluntary evacuation

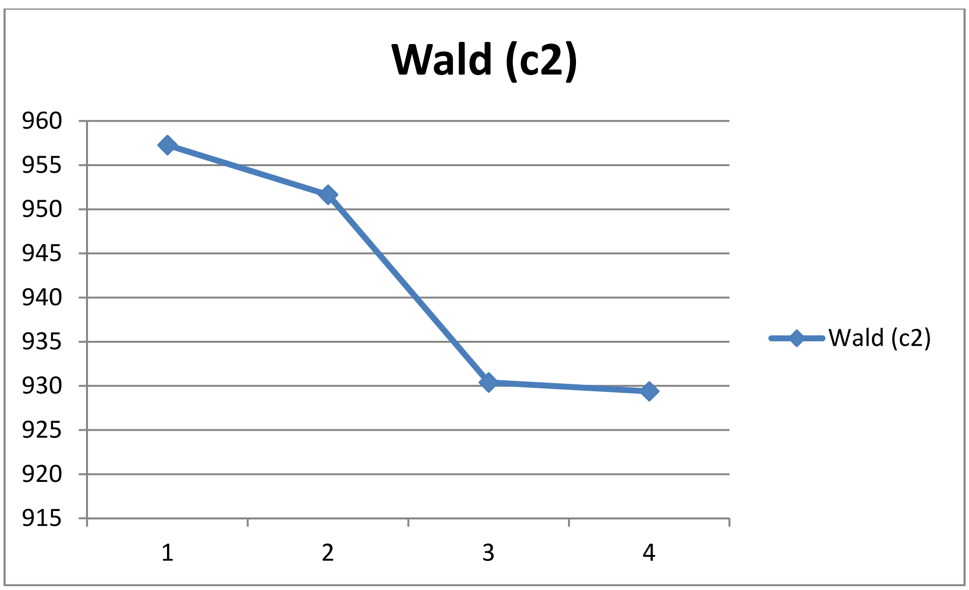

Figure 4.1.6 Wald (c2) for voluntary evacuation

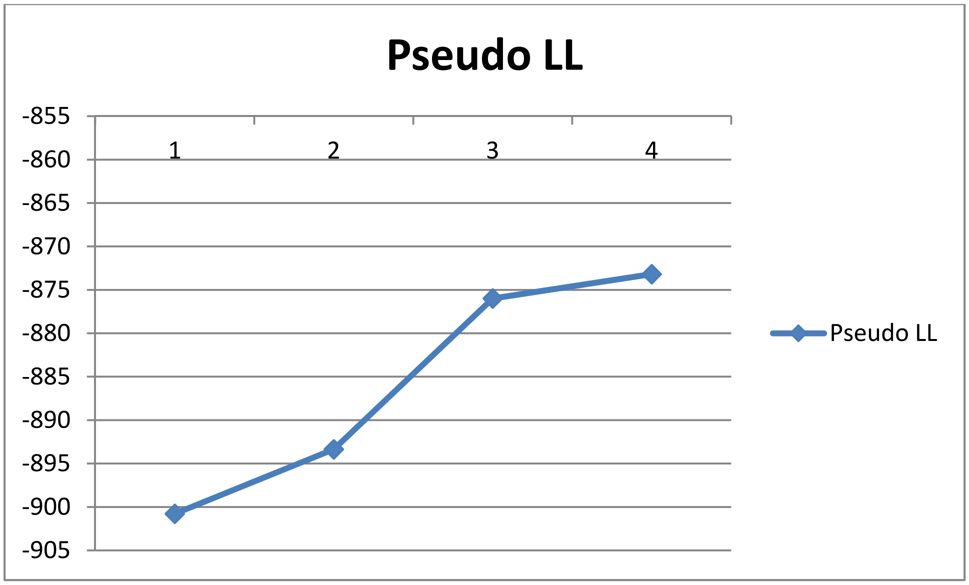

Figure 4.1.7 Pseudo LL for voluntary evacuation

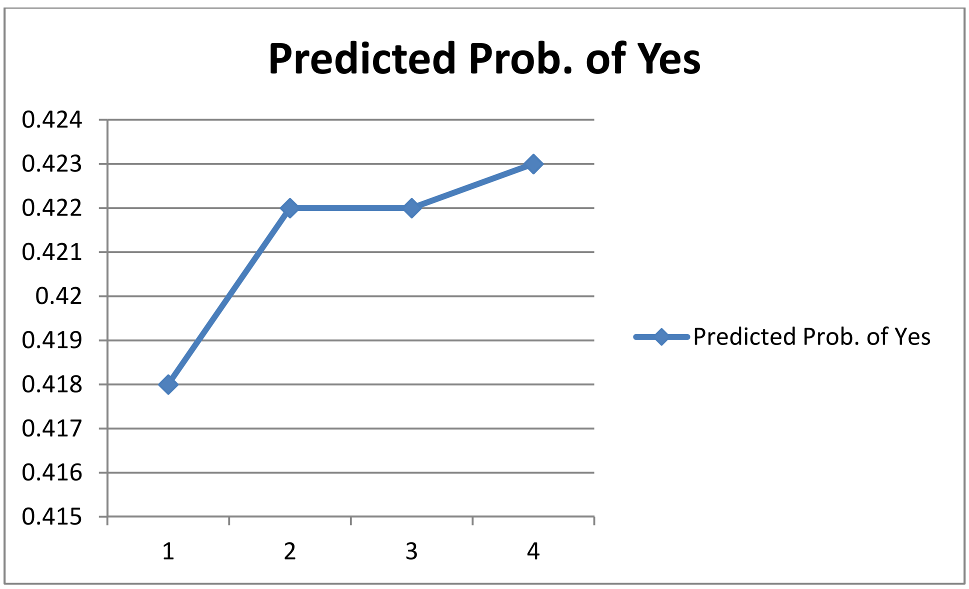

Figure 4.1.8 Predicted Probability of Yes for voluntary evacuation

Mandatory **Evacuation**

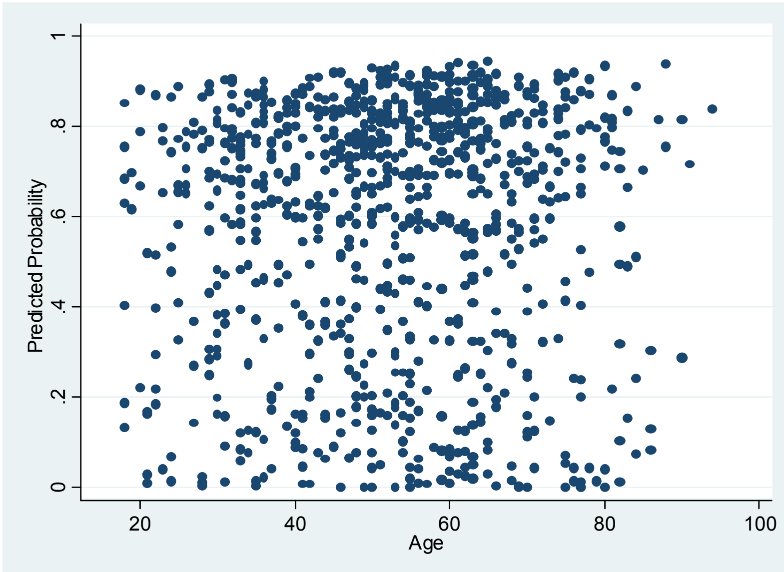

Figure 4.1.9 Predicted probability for Age

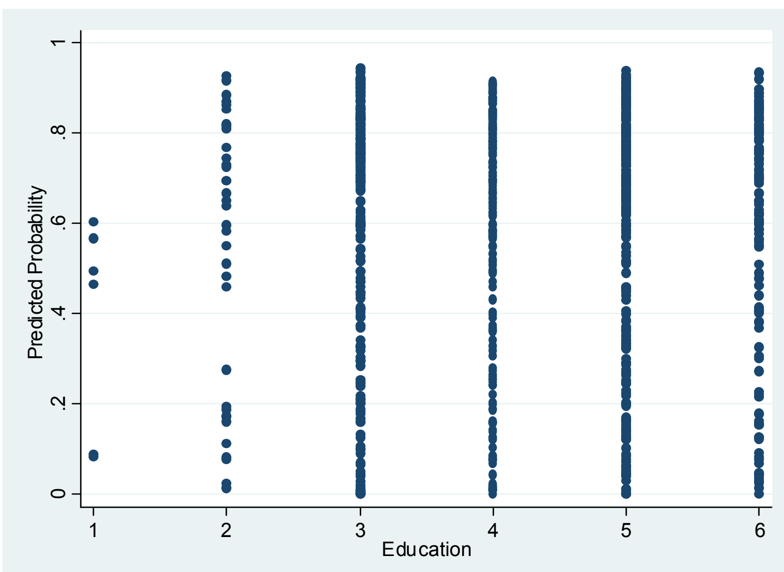

Figure 4.1.10 Predicted probability for Education

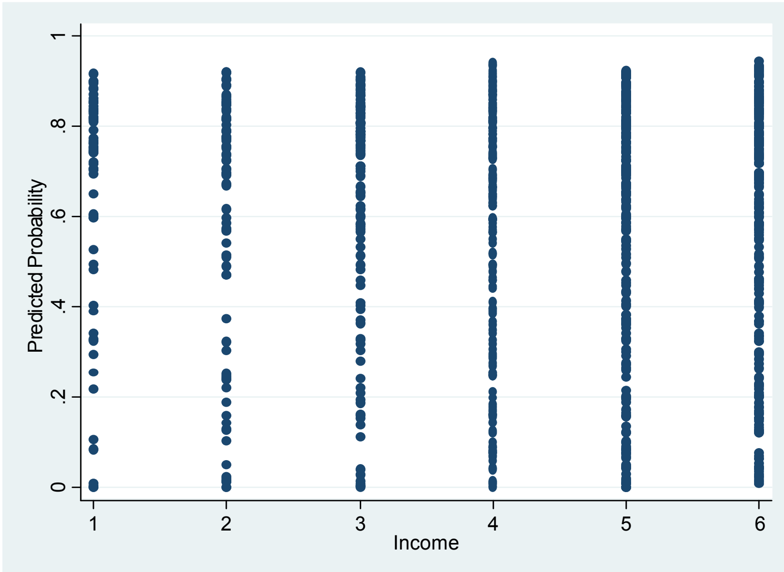

Figure 4.1.11 Predicted probability for Income

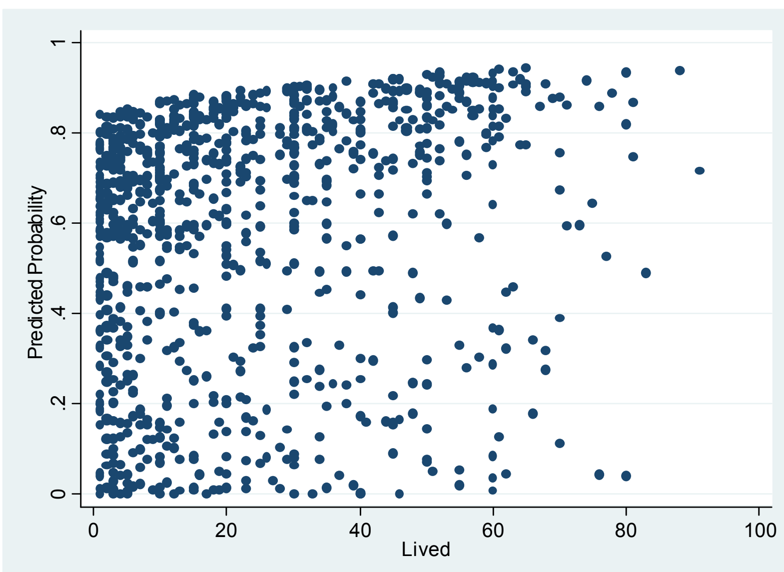

Figure 4.1.12 Predicted probability for Lived

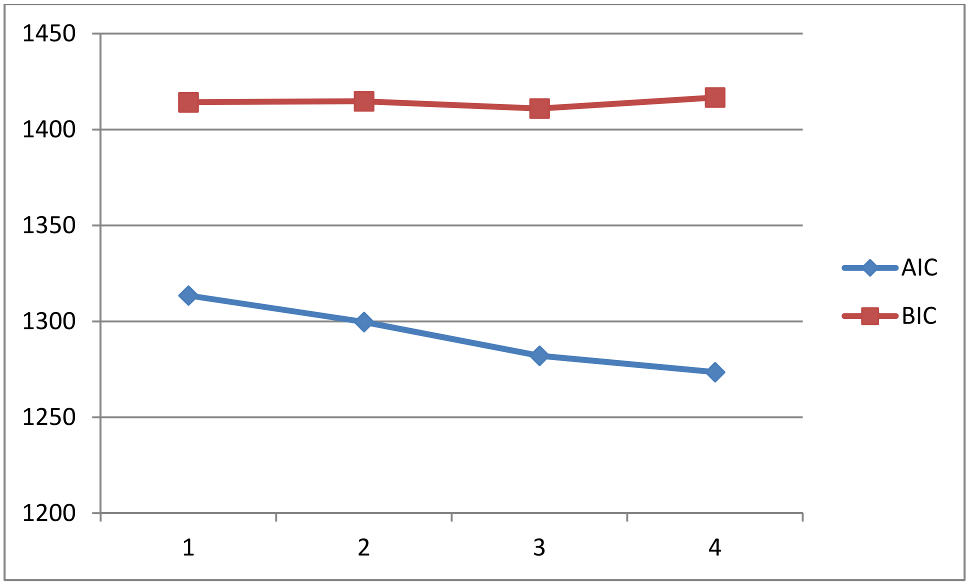

Figure 4.1.13 AIC BIC for mandatory evacuation

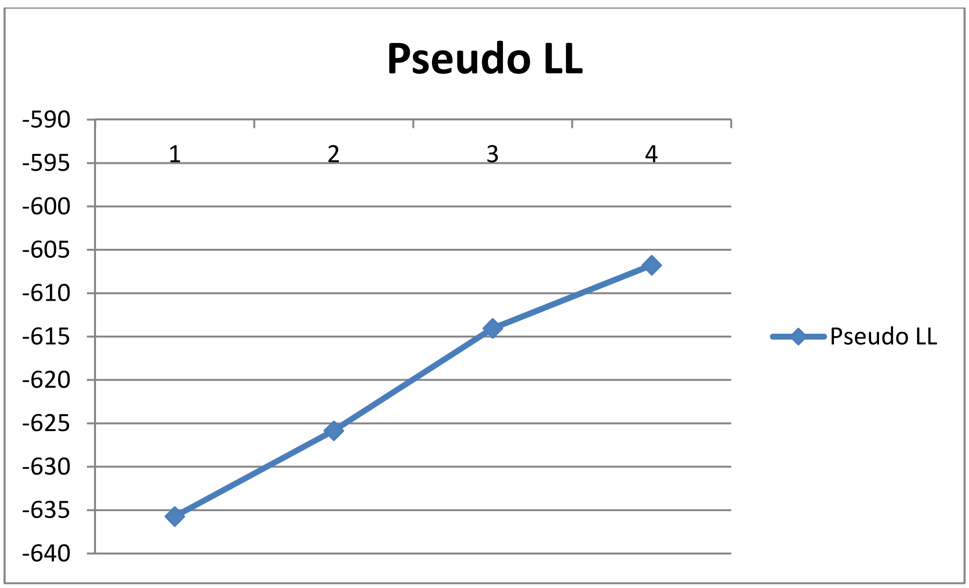

Figure 4.1.14 Pseudo LL for mandatory evacuation

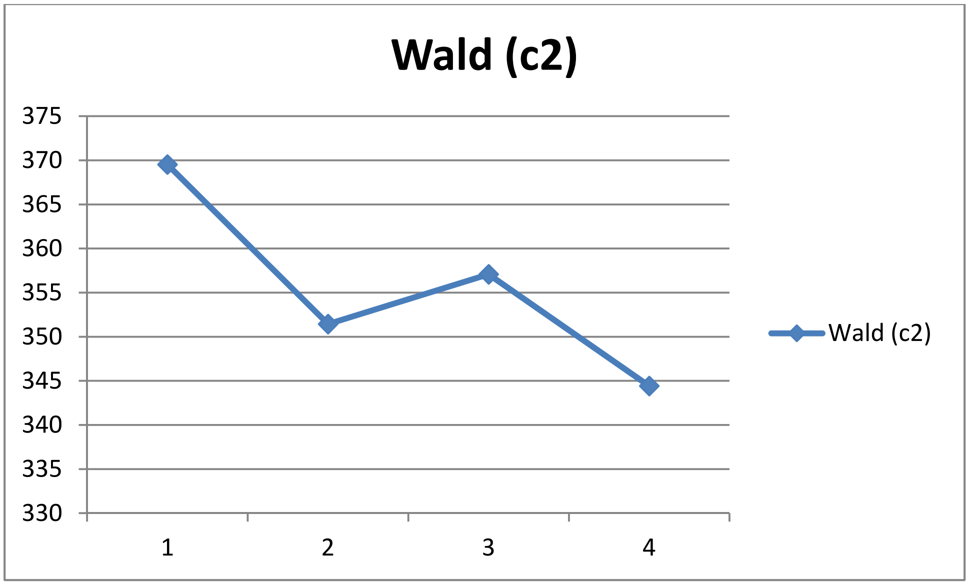

Figure 4.1.15 Wald(c2) for mandatory evacuation

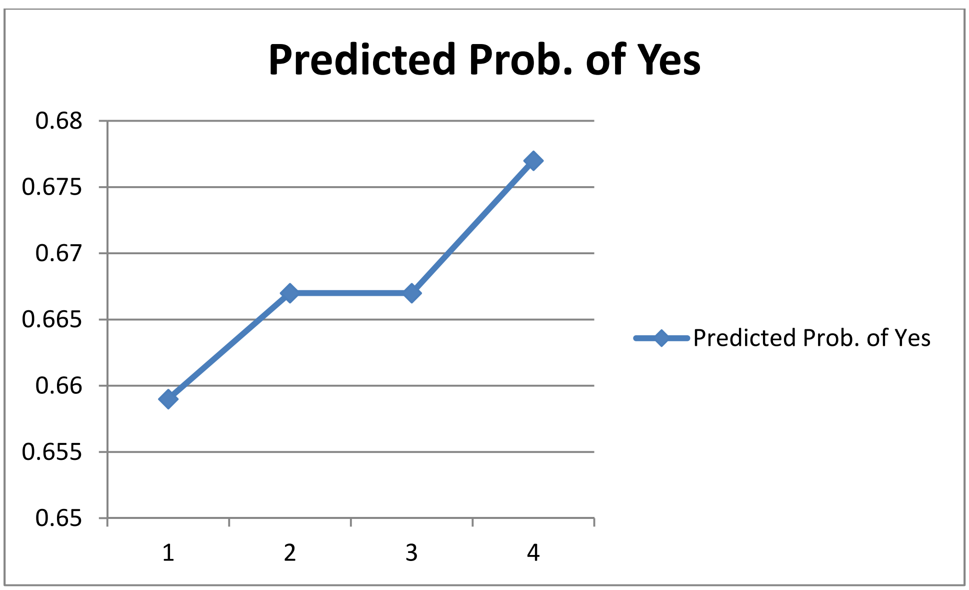

Figure 4.1.16 Predicted Probability of Yes for mandatory evacuation

4.2 Results for Virginia Data

Definitions and descriptive statistics of the variables are provided in Table 4.2.1. Preliminary analysis based on difference in proportions tests (without controlling for any other factors) shows that the evacuation responses differ by various sample characteristics. The sample mean of a positive response (Yes) to the mandatory evacuation order was 93 % versus 73% for the voluntary evacuation order (see Table 4.2.1). Thus, we estimate the evacuation probabilities separately for mandatory and voluntary evacuation orders using the same bivariate probit modeling approach for that part of the sample where we have responses to all the variables considered.

We report the estimated evacuation probabilities from a set of models under a voluntary order in Table 4.2.2. In the first component, Panel A shows the estimated probabilities of being concerned (*Concern*) that hurricane may endanger the respondent's home. In Models 1 to 4, households are more concerned if they had past property damages due to hurricane. Other factors, such as their home located in an area where they would have to evacuate for storm surge in a hurricane (*Located*), whether you will evacuate because of Winds (*Winds*), and whether you will evacuate because of Flooded (Flooded). Among the control variables, Cat3 or more (*Major hurricane*), Cat 1 or Cat 2 (*Less serious hurricane*) and how long they have lived (*Lived*) tend to positively contribute to a household's concern that hurricane may endanger their home (Model 1 to 4 in Panel A, Table 4.2.2).

In the second component (Panel B in Table 4.2.2), the binary endogenous variable, *Concern* enters into the voluntary evacuation decision equation as an explanatory variable, and is found statistically significant (in Models 1 to 4). The implication is that a higher likelihood of being concerned that one's home may be endangered by hurricane leads to an increased probability of intended voluntary evacuation. Among other explanatory variables, education has a higher probability of intended evacuation (estimated coefficient is highly significant in all models in Panel B, Table 4.2.2). Respondents who married (*Marital*) have a higher probability of intended evacuation (Models 1 to 4). Respondents who own vehicles (*Vehicles*) have a significantly lower probability of intended evacuation in several models (Models 2 to 4) under a voluntary order.

Table 4.2.3 reports the bivariate probit estimates for the intended evacuation probability under a mandatory evacuation order. In the first component (Panel A, Table 4.2.3), variables that affect the respondent's concern (*Concern*) that their home may be endangered by hurricane are largely similar to a voluntary evacuation order. In the second component, (Panel B, Table 4.2.3) similar to voluntary evacuation, a higher likelihood of being concerned that one's home may be endangered by hurricane leads to an increased probability of a Yes response under a mandatory evacuation order (Models 5 to 8). Education (*Education)*, and who own pets (*Pets*) significantly increase the probability of intended evacuation under a mandatory order (Models 5 to 8 in Panel B). Also under a mandatory order, whoever evacuated for a hurricane (*Ever evacuated*) has significant effects (Model 8). Respondents who own vehicles (*Vehicles*) or who married (*Marital*) have a higher probability of intended evacuation (Models 5 to 8). Finally, respondents own their house (*Own*) in the area have a lower probability under a mandatory order (Models 5 to 8). Aware that, the responders who are male (*Gender*) is shown to significantly decrease the probability of intended evacuation.

Altogether, Tables 4.2.2 and 4.2.3 present multiple models to explain intended evacuation behavior. Four different models for both voluntary and mandatory evacuation orders are presented, with the primary purpose of demonstrating the robustness of key findings to alternative specifications that include additional control variables. In terms of overall fit, all models reported in both Tables 4.2.2 and 4.2.3 are highly significant (at 1% level for Wald Test Statistics in Tables 4.2.2 and 4.2.3), implying strong relevance of the variables used in the analysis. In Table 4.2.4, we provide the calculated marginal effects of corresponding coefficients on the probability of intended evacuation results reported in Tables 4.2.2 and 4.2.3. The predicted probability of intended evacuation ranges from 47% to 48% (Figure 4.2.8) under a voluntary evacuation order and from 68% to 69% (Figure 4.2.16)under a mandatory evacuation order (see Table 4.2.4). The results are valid for the bivariate probit model (Whitehead 2005). Respondents who are concerned that hurricane may endanger their home are about 56% more likely to evacuate under a voluntary evacuation order (Models1 to 4) and 45 to 47% are more likely to evacuate under mandatory evacuation order (Models 5 to 8). Respondents who you will evacuate because of Winds are more likely to be concerned by 9% under a voluntary order and 8% under a mandatory order. Respondents you will evacuate because of Flooded are more likely to be concerned by 9% (voluntary order) to 10% (mandatory order). That is, past exposure to property damage by hurricane significantly and home ever be flooded as a result of a hurricane or storm increase the probability of intended evacuation behavior indirectly through an increased level of concern about hurricane. This suggests that risk communication efforts such as educating homeowners through dissemination of risk information may be effective in changing households hurricane-related risk behavior (e.g., Donovan et al. 2007).

Male respondents are 9-11% less likely to evacuate under a voluntary order and 4-6% more likely to evacuate under a mandatory order. Respondents who own their house are 7% less likely to evacuate under both voluntary and mandatory orders. Respondents who ever evacuated are more likely to evacuate by 6% under both voluntary and mandatory orders. Under a voluntary order, respondents who own vehicles (by 0.4%) and who own pets (by 2%) are less likely to evacuate. Respondents who are younger are also more likely to evacuate (2% voluntary order; 8% mandatory order).

From the AIC and BIC graphs (Figure 4.2.5 and 4.2.13) we can see that the BIC are bigger than the AIC. The Wald chiquare has a down slop (Figure 4.2.7 and 4.2.15) and the Pseudo likelihood has a increase tend (Figure 4.2.6 and 4.2.14). We can conclude the models are fitted well. These figures also evident that model 3 and 4 are performing better than model 1 and 2. Figure 4.2.1-4.2.4 and 4.2.9-4.2.12 give the predicted probability of age, education, income, lived of the people who concerned about the hurricane. From Figure 4.2.1 we observed that the predicted probabilities for voluntary evacuation are higher for middle age people than young and old people.

Table 4.2.1 Variable definitions and descriptive statistics

Variable	**Description**	**N**	**Mean**	**St. Dev.**
Concern	1 if respondent is very concerned or somewhat concerned about the threat of a hurricane,0 if respondent is not concerned, don't know, no response	1719	0.74	0.44
Major hurricane	If you will evacuate because of Major hurricane 1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1728	0.75	0.43
Less serious hurricane	If you will evacuate because of Less serious hurricane, 1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1728	0.28	0.45
Winds	If you will evacuate because of Winds, 1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1728	0.58	0.49
Flooded	If you will evacuate because of Flooded,1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1728	0.35	0.48

Ever evacuated	1 if yes, 0 if no , do not know, no response	1726	0.20	0.40
Mandatory	1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1703	0.93	0.25
Voluntary	1 if very likely , somewhat likely ,0 if not very likely , don't know , no response	1684	0.73	0.44
Special needs	1 if yes, 0 if no , do not know, no response	1728	0.02	0.16
Vehicles	1 if yes, 0 if no , do not know, no response	1714	0.07	0.25
Pets	1 leave them at home ,0 others	1708	0.49	0.50
Own	1 own , 0 others	1684	0.86	0.35
Age	99 for no response	1645	56.70	16.63
Lived	99 for no response	1693	27.66	21.73
Located	Is your home located in an area where you would have to evacuate for storm surge in a hurricane.1 if yes, 2 if no ,3 if do not know, no response	1728	1.98	0.78
Younger	99 for no response	1403	1.81	11.72
Marital	1 single, 0 others	1728	0.62	0.49
Education	1 grade school 2 some high school 3 high school grad 4 some college 5 college graduate 6 graduate degree 7 don't know 8 no response	1631	4.20	1.19
Income	1 $10,000 or less 2 $10,001 - $20,000 3 $20,001 - $30,000 4 $30,001 - $50,000 5 $50,001 - $80,000 6 over $80,000 7 don't know/no response	970	4.35	1.48
Gender	1 male, 0 female	1728	0.40	0.50

Table 4.2.2: Estimated Probability of *Voluntary* Evacuation, Bivariate Probit Specification

Panel A: Estimated Probability of Being Concerned about Hurricane Endangering Home				
	Model 1	**Model 2**	**Model 3**	**Model 4**
Located	0.049(0.046)	0.052(0.046)	0.062(0.047)	0.066(0.048)
Major hurricane	0.688(0.083) ***	0.673(0.084) ***	0.674(0.085) ***	0.674(0.085) ***
Less serious hurricane	0.236(0.083) ***	0.24(0.083) ***	0.234(0.084) ***	0.242(0.084) ***
Winds	0.286(0.071) ***	0.289(0.071) ***	0.299(0.072) ***	0.297(0.072) ***
Flooded	0.29(0.082) ***	0.3(0.083) ***	0.299(0.083) ***	0.304(0.084) ***
Lived		-0.002(0.002)	-0.001(0.002)	-0.001(0.002)
Ever evacuated	0.217(0.091) **	0.216(0.091) **	0.209(0.092) **	0.201(0.092) **
Gender			0.129(0.081)	0.133(0.081)
Age	0.012(0.002)***	0.012(0.003)***	0.013(0.003) ***	0.013(0.003) ***
Education				0.051(0.034)
Income				-0.021(0.025)
Constant	-0.967(0.192)***	-0.945(0.193)***	-1.066(0.204) ***	-1.192(0.283) ***
Panel B: Estimated Probability of *Voluntary* Evacuation (E_{VOL})				

	Model 1	**Model 2**	**Model 3**	**Model 4**
Concern	1.769(0.084) ***	1.78(0.084) ***	1.78(0.086) ***	1.781(0.086) ***
Income	-0.007(0.02)	-0.009(0.02)	-0.006(0.02)	0.004(0.023)
Age	-0.012(0.002) ***	-0.011(0.003) ***	-0.01(0.003) ***	-0.01(0.003) ***
Education	0.079(0.027) ***	0.08(0.028) ***	0.091(0.028) ***	0.067(0.033) ***
Gender	-0.322(0.066) ***	-0.321(0.066) ***	-0.386(0.075) ***	-0.386(0.075) ***
Pets	-0.057(0.065)	-0.053(0.066)	-0.034(0.067)	-0.032(0.067)
Marital	0.096(0.077)	0.094(0.077)	0.122(0.079)	0.122(0.078)
Younger	0.062(0.045)	0.065(0.045)	0.059(0.046)	0.06(0.046)
Vehicles		-0.013(0.122)	-0.004(0.123)	-0.003(0.124)
Own			-0.221(0.107) **	-0.227(0.108) **
Special needs				-0.043(0.203)
Constant	-0.353(0.218)	0.223(0.385)	-0.29(0.227)	-0.24(0.242)
N	1243	1231	1219	1219
Pseudo LL	-1258.960	-1245.801	-1231.999	-1230.645
Wald (χ^2)	793.83 (0.00)***	796.83	775.45	780.02
AIC	2553.919	2531.602	2507.999	2511.29
BIC	2646.174	2633.913	2620.326	2638.934
df	18	20	22	25

Table 4.2.3: Estimated Probability of *Mandatory* Evacuation, Bivariate Probit Specification

Panel A: Estimated Probability of Being Concerned about Hurricane Endangering Home

	Model 1	**Model 2**	**Model 3**	**Model 4**
Located	0.026(0.051)	0.025(0.052)	0.039(0.052)	0.045(0.053)
Major hurricane	0.597(0.091) ***	0.597(0.092) ***	0.597(0.092) ***	0.597(0.092) ***
Less serious hurricane	0.164(0.093) *	0.17(0.094) *	0.164(0.094) *	0.169(0.094) *
Winds	0.239(0.078) ***	0.238(0.079) ***	0.242(0.079) ***	0.24(0.079) ***
Flooded	0.32(0.089) ***	0.339(0.091) ***	0.339(0.091) ***	0.345(0.091) ***
Lived		0(0.002)	0.001(0.002)	0.001(0.002)
Ever evacuated	0.187(0.103)*	0.181(0.104) *	0.183(0.104) *	0.178(0.104) *
Gender			0.106(0.082)	0.11(0.082)
Age	0.012(0.002) ***	0.011(0.003) ***	0.012(0.003) ***	0.012(0.003) ***
Education				0.057(0.035) *
Income				-0.008(0.025)
Constant	-1.07(0.202) ***	-1.065(0.203)***	-0.883(0.217)***	-1.104(0.294) ***

Panel B: Estimated Probability of *Mandatory* Evacuation (E_{MAND})

	Model 1	Model 2	Model 3	Model 4
Concern	1.889(0.196) ***	1.888(0.201) ***	1.933(0.2) ***	1.94(0.2) ***
Income	-0.023(0.03)	-0.029(0.031)	-0.025(0.031)	-0.022(0.033)
Age	-0.005(0.004)	-0.004(0.004)	-0.005(0.004)	-0.005(0.004)
Education	0.039(0.042)	0.049(0.043)	0.049(0.043)	0.025(0.046)
Gender	-0.42(0.105) ***	-0.427(0.107) ***	-0.478(0.112) ***	-0.475(0.112) ***
Pets	0.045(0.1)	0.048(0.102)	0.068(0.102)	0.071(0.102)
Marital	0.146(0.117)	0.131(0.119)	0.144(0.12)	0.147(0.12)
Younger	0.05(0.073)	0.051(0.074)	0.058(0.075)	0.061(0.075)
Vehicles		0.046(0.19)	0.045(0.19)	0.054(0.19)
Own			-0.052(0.157)	-0.039(0.157)
Special needs				0.298(0.413)
Constant	0.263(0.376)	0.223(0.385)	0.239(0.388)	0.303(0.387)
N	1249	1237	1225	1225
Pseudo LL	-899.929	-886.435	-871.121	-875.454
Wald (χ^2)	358.79 (0.00)***	350.15	358.42	368.24
AIC	1835.858	1812.87	1798.242	1800.908
BIC	1928.199	1915.279	1910.677	1928.675
df	18	20	22	25

Notes: ***, **, * imply significance at 1%, 5%, 10% levels respectively; numbers in the parenthesis are robust standard errors.

Table 4.2.4.: Marginal Effects of Estimated Coefficients Reported in Table 4.2.2 and 4.2.3

	Model 1	Model 2	Model 3	Model 4
	***Voluntary* Evacuation (E_{VOL}) Equation**			
Located	0.0155	0.0164	0.0194	0.0206
Major hurricane#	0.2345***	0.2293***	0.2292***	0.2292***
Less serious hurricane #	0.0714***	0.0723***	0.0707***	0.0729***
Winds #	0.0911***	0.092***	0.0953***	0.0943***
Flooded #	0.0881***	0.091***	0.0909***	0.092***
Lived		-0.0005	-0.0003	-0.0002
Ever evacuated #	0.0647**	0.0647**	0.0625**	0.0603**
Gender#	-0.1088***	-0.1085***	-0.0905***	-0.0891***
Age	-0.0002	0.0001	0.0005	0.0005
Education	0.0265***	0.0266***	0.0305***	0.0384***
Income	-0.0024	-0.003	-0.002	-0.0051
Concern#	0.5546***	0.5576***	0.5564***	0.5573***
Pets#	-0.0192	-0.0177	-0.0113	-0.0107
Marital status#	0.0327	0.0318	0.0416	0.0414
Younger	0.0207	0.0216	0.0196	0.02
Vehicles#		-0.0042	-0.0012	-0.0009

Own#			-0.0701**	-0.0717**
Special needs#				-0.0143
Predicted Prob. of Yes	0.478	0.479	0.479	0.480

Model 5	**Model 6**	**Model 7**	**Model 8**
***Mandatory* Evacuation (E_{MAND}) Equation**			
0.008	0.0078	0.0121	0.0138
0.2026***	0.2026***	0.2027***	0.2027***
0.0495*	0.0512*	0.0495*	0.051*
0.0751***	0.0746***	0.0762***	0.0754***
0.0958***	0.1012***	0.1014***	0.1028***
	0.0002	0.0002	0.0004
0.0556*	0.0539*	0.0543*	0.053*
-0.0645	-0.0638	-0.039	-0.0375
0.003***	0.0029***	0.003***	0.0029***
0.0056***	0.0069***	0.0068***	0.0213***
-0.0033	-0.0041	-0.0036	-0.0054
0.4572**	0.4505**	0.463**	0.4658**
0.0066	0.0067	0.0096	0.01
0.0223	0.0194	0.0214	0.0218
0.0073	0.0072	0.0082	0.0086
	0.0063	0.0062	0.0073
		-0.007	-0.0053

			0.0338
0.685	0.688	0.688	0.688

***Voluntary* Evacuation**

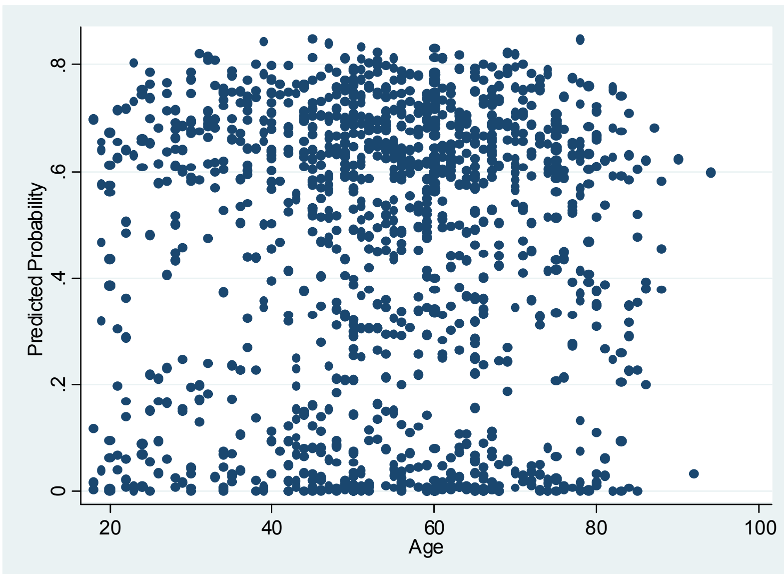

Figure 4.2.1 Predicted probability for Age

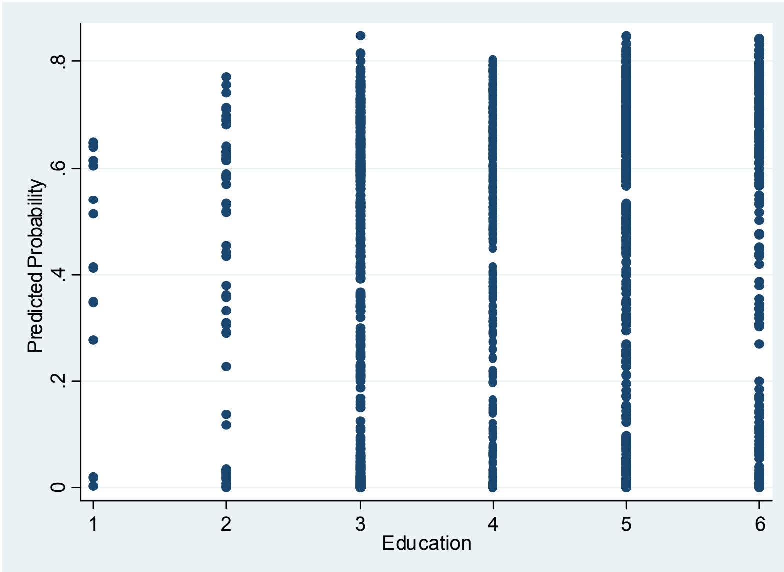

Figure 4.2.2 Predicted probability for Education

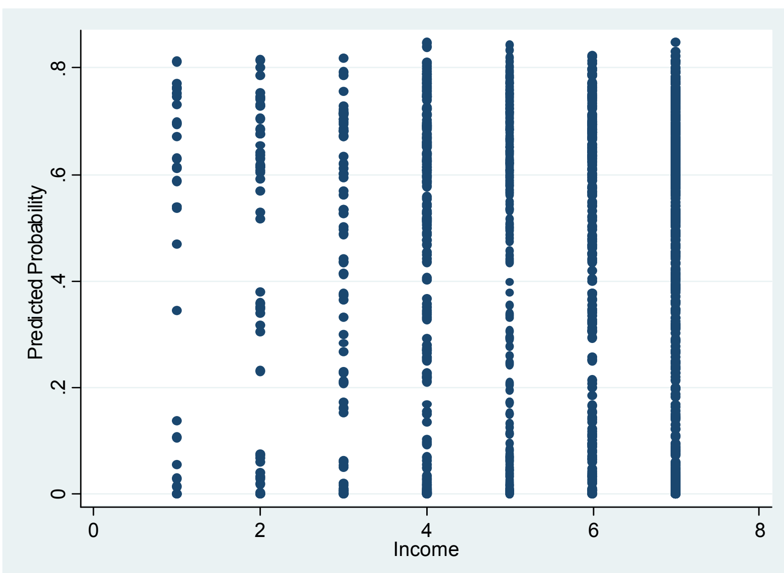

Figure 4.2.3 Predicted probability for Income

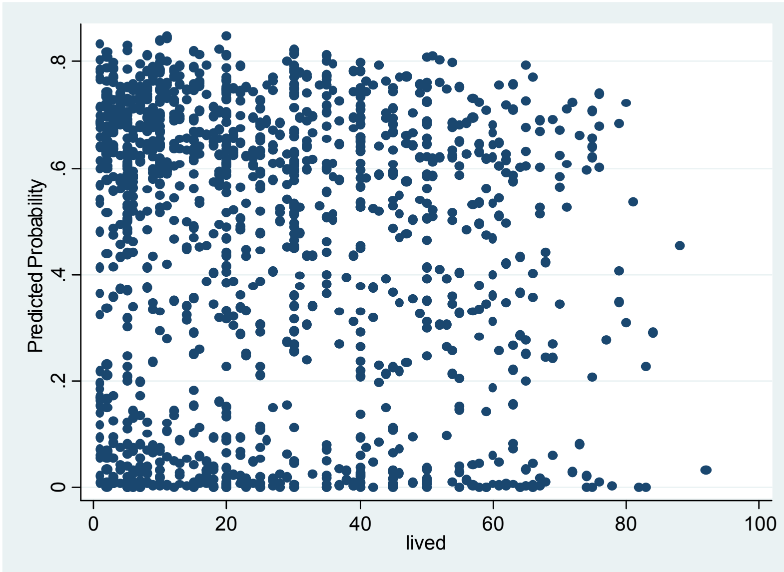

Figure 4.2.4 Predicted probability for lived

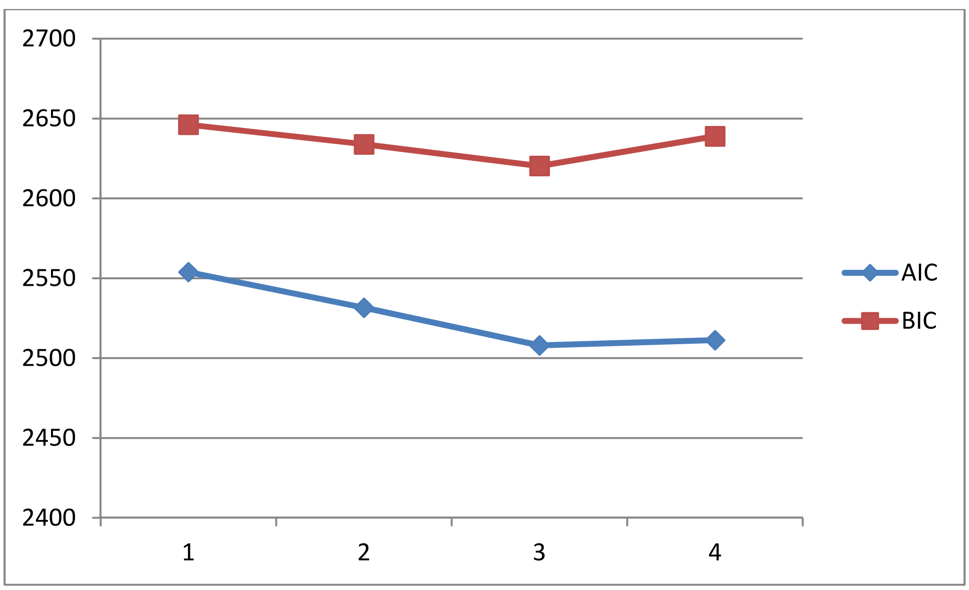

Figure 4.2.5AIC BIC for voluntary evacuation

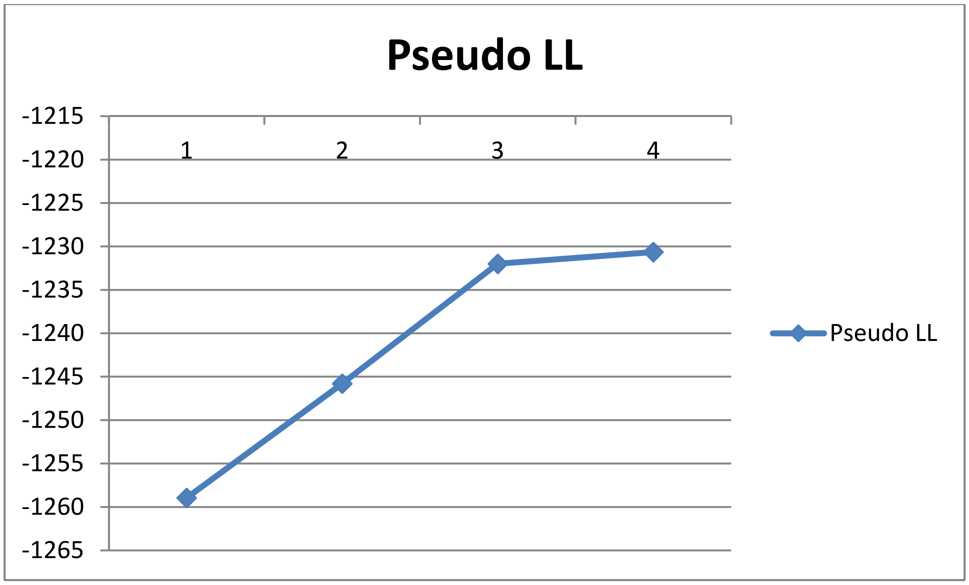

Figure 4.2.6 Pseudo LL for voluntary evacuation

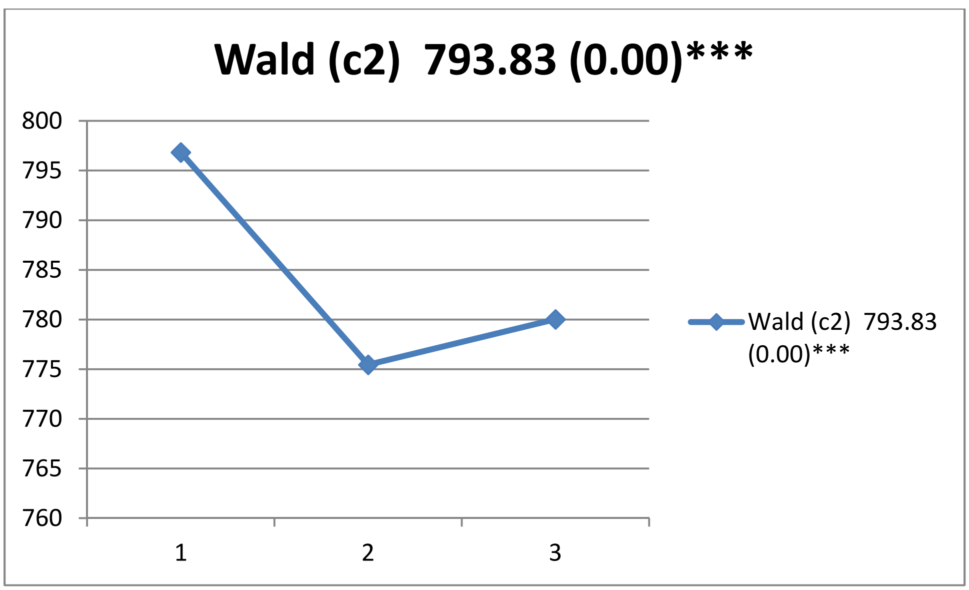

Figure 4.2.7 Wald(c2) for voluntary evacuation

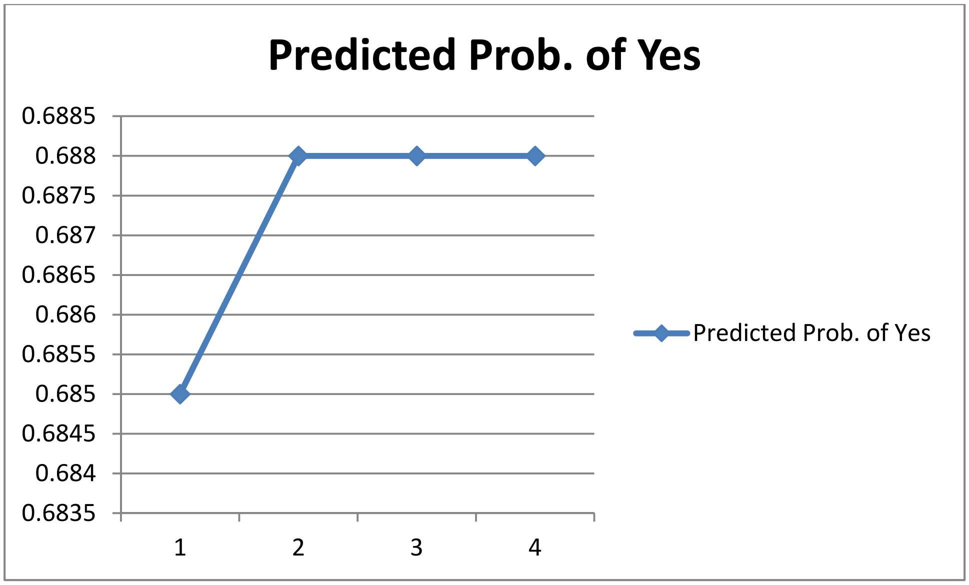

Figure 4.2.8 Predicted Probability of Yes for voluntary evacuation

Mandatory **Evacuation**

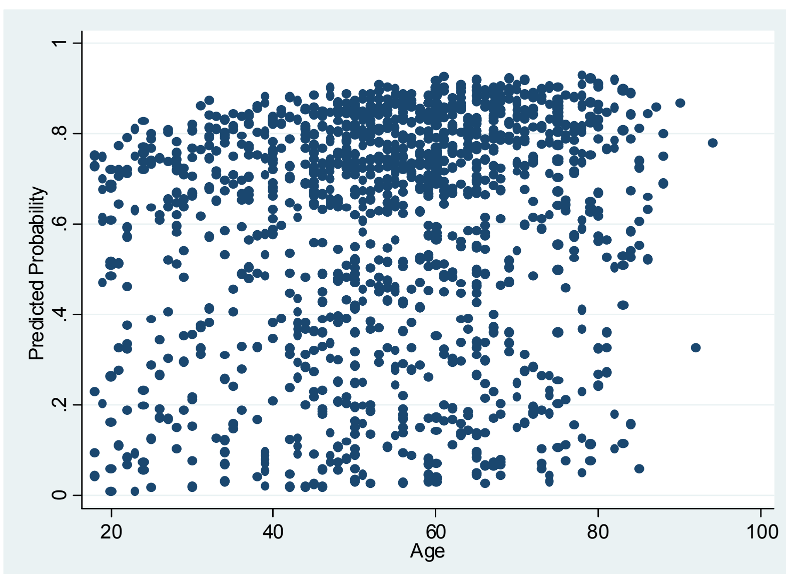

Figure 4.2.9 Predicted probability for Age

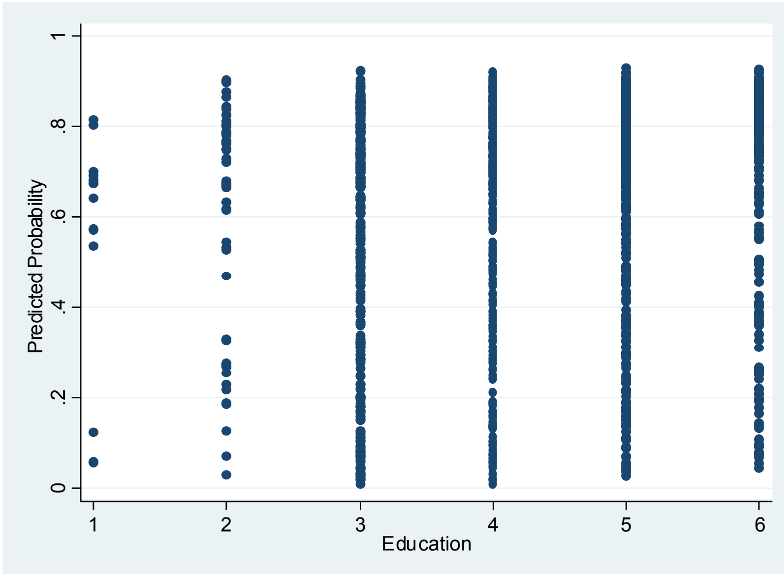

Figure 4.2.10 Predicted probability for Education

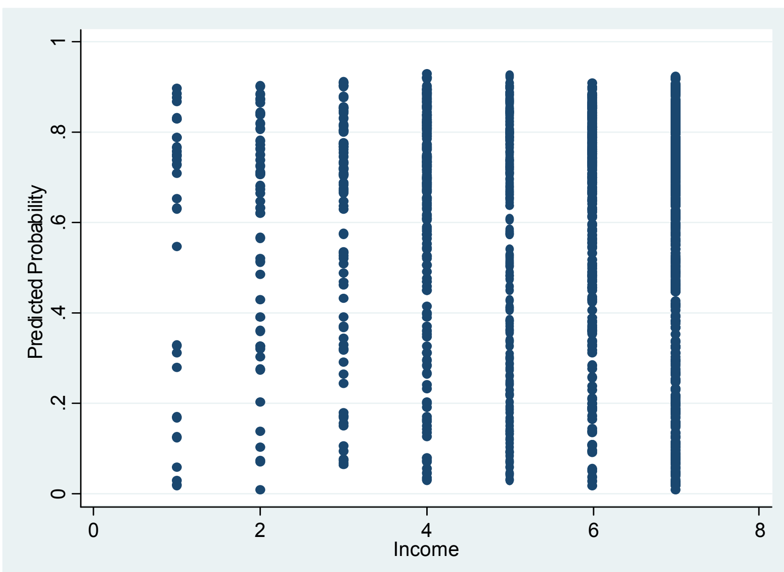

Figure 4.2.11 Predicted probability for Income

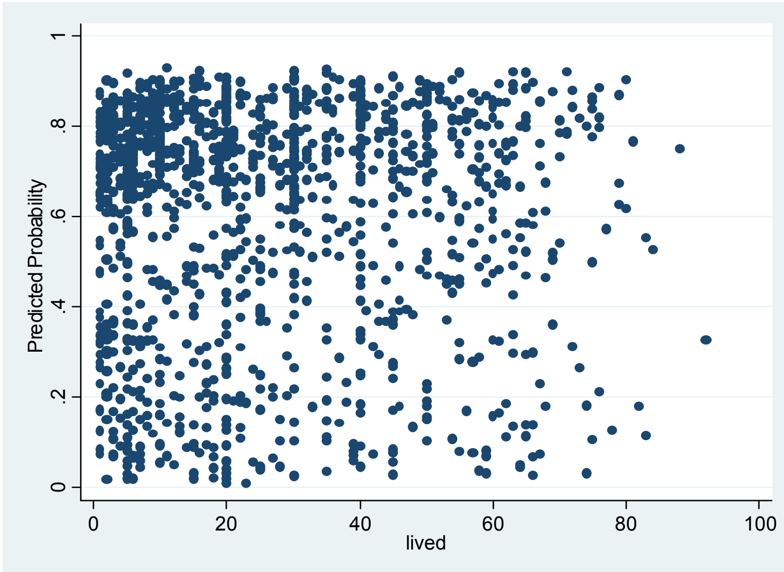

Figure 4.2.12 Predicted probability for Lived

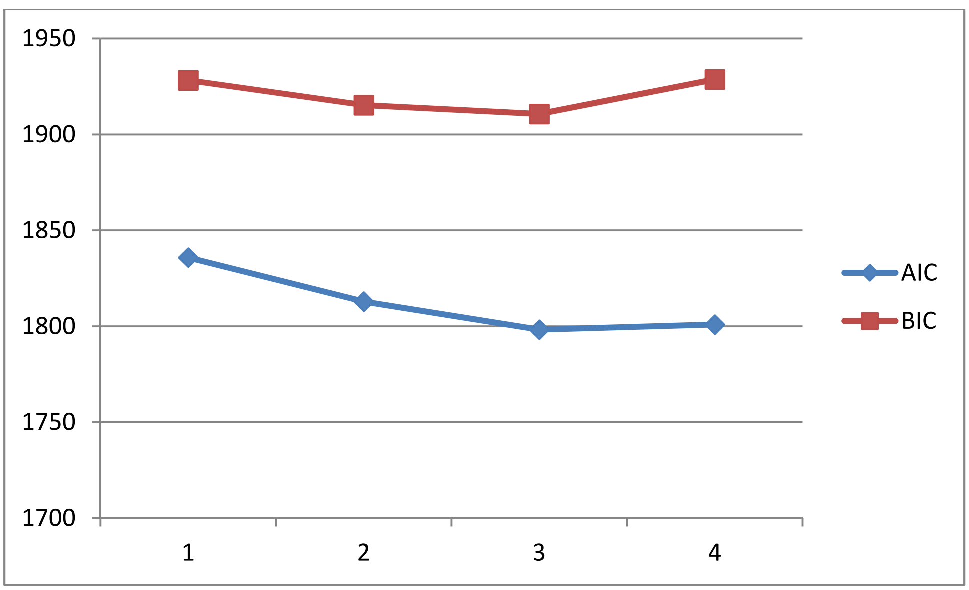

Figure 4.2.13AIC BIC for mandatory evacuation

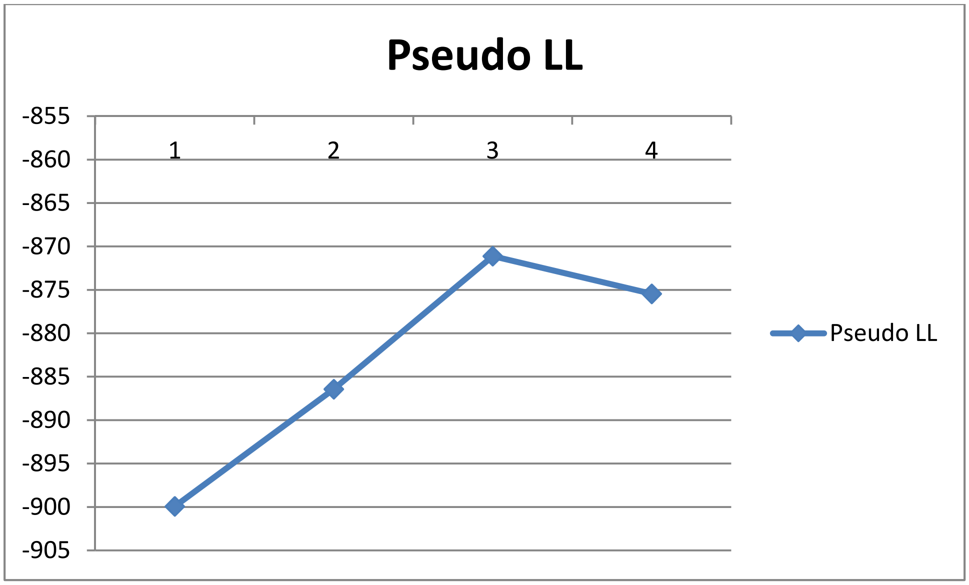

Figure 4.2.14 Pseudo LL for mandatory evacuation

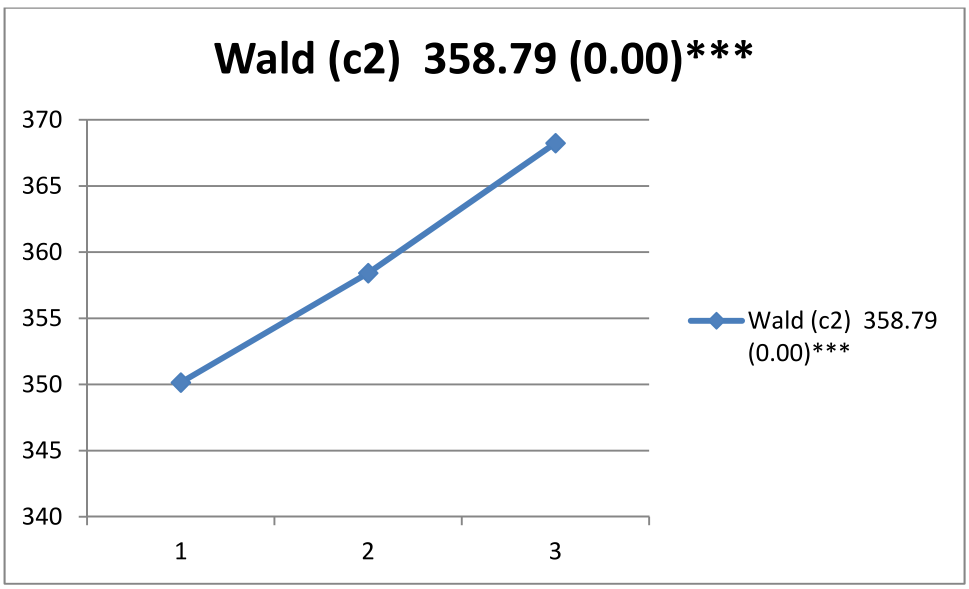

Figure 4.2.15 Wald(c2) for voluntary evacuation

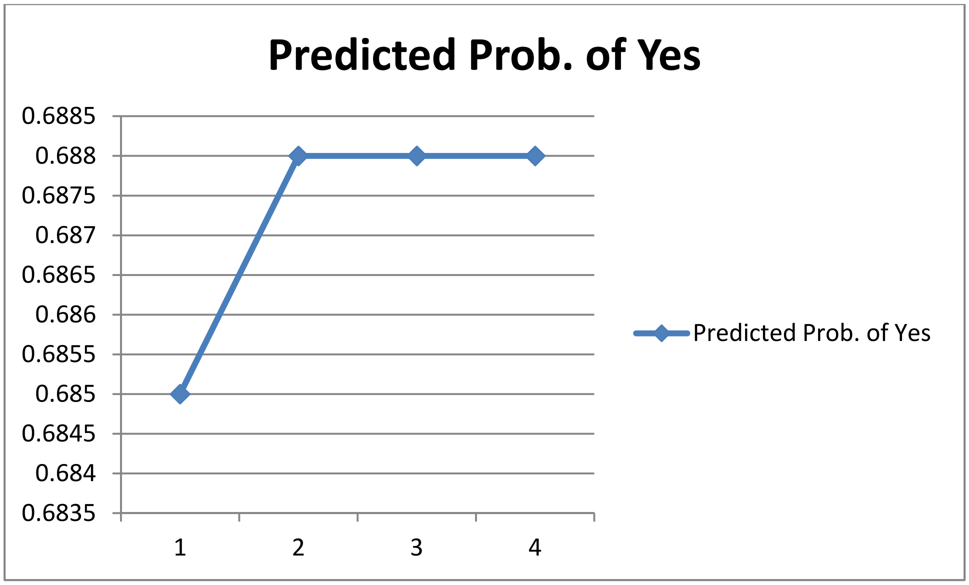

Figure 4.2.16 Predicted Probability of Yes for mandatory evacuation

5. Discussion

This study captured the knowledge, attitudes, and intentions of a random sample of coastal Georgians in response to the threat of a hurricane. The information is intended to guide evacuation planning by emergency management and transportation officials. The random sample was chosen to represent households in six counties: Bryan, Camden, Chatham, Glynn, Liberty, and McIntosh. The survey was conducted via both landline and cellular telephones. A summary of the main findings of the paper and their implications are as follows.

The results suggest some potential strategies for community and emergency preparedness planners that can be implemented within the current planning environment in Georgia and elsewhere in the U.S. Southeast. Beginning with the expectation that eliciting stated behavior through surveys can provide systematic information for predicting actual behavior (Johnson1985; Johnson and Zeigler 1983; Whitehead 2005), evacuation planning and adaptive management can begin to incorporate these expectations. For example, local planning agencies, including rural and county police departments, which tend to be the first line of defense in the case of hurricane in the GCA, may find the information useful. In the GCA, there is an active interagency body and survey results have been shared with them. As a baseline consideration, sample respondents were significantly more likely to evacuate under a mandatory versus a voluntary order (93% versus 76%).

Specific results from this study indicate that underlying concern and risk perception significantly affect intended evacuation behavior, thus the content of risk communication can play a crucial role in influencing residents' evacuation decisions. Whatever the goals of community planning, (e.g., increasing early evacuation or better preparing those who intend to stay), improved understanding of intended household behavior can help planners target information distribution to particular groups or settings, ensure that the information they provide is consonant with the level of hurricane risk, as well as facilitating concrete evacuation suggestions and resource allocations. For example, equipping emergency shelters with better amenities, facilitating communications within the social network (e.g., communications with friends and relatives) may encourage evacuation responses. Some factors, such as education and income indirectly affect intended evacuation (through the level of concern). Thus, it may be important to prioritize the relatively poor and less educated, those who expect to stay in public shelters, and those who are lacking social networks in any intervention mechanism. Other specific examples would include identifying expected shelter space, and suggesting that people who need government transportation evacuate from hurricane.

The results support several actions: 1) Risk communication initiatives to better acquaint citizens about the dangers of surge and inland flooding from even minor hurricanes; 2) Initiate mechanisms for informing citizens about the elevation of their homes and their location in areas that should be evacuated; 3) Increase the use of new technologies, such as the internet and cell phones, in warning communications; 4) Target women and children as leaders in educational campaigns to promote appropriate response; 5) Target elderly households in vulnerable areas for programs to promote appropriate response; 6) Gather additional information regarding who needs transportation assistance and/or special medical needs shelters; 7) Address citizen concerns about traffic problems during evacuation.

All of these efforts imply a multi-pronged approach that combines initiatives to provide relevant information to targeted groups with educational programs directed at helping the citizens of coastal Georgia make responsible evacuation decisions. While my study focused on hurricane response, it can be assumed that more effective household hurricane planning would have carryover benefits for response to other catastrophic events. Thus, it is essential to improve our understanding of evacuation behavior. In doing so, stated (intended) behavior studies can be part of an expanded social science toolkit.

The Bivariate probit model has been used to analyzed the evacuation data, which can also be used to investigate the intended evacuation from hurricane or any other natural disasters in any other states, especially in the state of Florida. Such research might be useful and necessary for the policy makers/planners. We may come up with the similar kind of models, however, without doing such research it is hard to make any definite statement. If people didn't know the database well, they can make definitions and descriptive statistics informatively and understand the socioeconomic and demographic variables well. Then they can add variables into the two equations more effectively and can be benefitted by using the bivariate probit model.

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