# Hurricanes and Homeowner Decision-Making

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**Abstract**

*We survey coastal homeowners towards discovering whether perceptions of hurricane damages, changes in insurance, and strike probabilities change the typical homeowner's willingness to buy mitigation devices, such as storm shutters and "hurricane-proof" doors; such devices reduce damages from a strong hurricane. We find that higher income and reduced insurance availability increase the likelihood that homeowners will purchase these costly home defenses. Our data also suggest that homeowners respond in a significant fashion to changing insurance deductibles, mitigating more with higher deductibles. Insurance-regulators of such hurricane-prone states as Florida now allow dramatic increases in deductibles for damage caused by "named storms;" our results suggest this will lead to a greater likelihood among homeowners to mitigate in the next few years. This greater likelihood to mitigate may contribute to reduced losses for other stakeholders, such as insurers, lenders, taxpayers and emergency responders. Many in the hurricane-loss universe benefit from this increased mitigation by at-risk homeowners.*

## INTRODUCTION

Recent history affirms the impact and costliness of catastrophic events across the globe: losses in Burma following its typhoon, the historic earthquake(s) in China and flooding in parts of the US Midwest and across the Northeast late in the winter of 2010 highlight these costs. Media reports underscore the liabilities borne by government and society with these events. Those reports remind us that varied stakeholders have an interest in the measurement and minimization of damages from catastrophes. In this context, the costliness of hurricane landfalls earlier this decade is underscored.

Kunreuther (2008) inventories hurricane losses in the United States and concludes that a “new approach” is needed to encourage homeowners to “undertake effective mitigation” to reduce those costs suffered by varied stakeholders in the hurricane paradigm; homeowners, lenders, insurers and policymakers all suffer in the wake of these events, and all benefit when catastrophe losses are reduced.

Our findings outline a set of incentives to provide this encouragement. We discover that while property owners are hesitant to incur substantial expenses today towards minimizing far greater losses in the future, they can nonetheless be motivated with selected insurance provisions to undertake costly mitigation to their homes to reduce those future damages.

Independent of regulatory dictum, if homeowners are provided clear information on the likelihood and costliness of hurricane landfalls, in conjunction with more participatory insurance deductible provisions, the likelihood of mitigation is increased. The damages of Katrina especially underscore the timeliness of an investigation into the actions that might be taken to minimize hurricane losses.

We find that where homeowners are unable to share their risk of hurricane losses with others, through insurance, or where hurricane losses cannot be minimized with small deductibles, the homeowner is motivated to reduce losses on his own. Our data show that the typical homeowner, in an area at elevated risks of hurricane landfalls, is significantly more likely to purchase such mitigation as roof reinforcements (tie-downs) in the attic, window coverings, door coverings and garage door reinforcements when that homeowner expects to share to a greater extent in the losses.

Our research is among the first to illustrate that with existing deductibles of often less than $1,000, and with available insurance, encouragements for homeowners to mitigate on their own are reduced; one of the primary manners with which policymakers hope to reduce material losses is foregone, when that hope resides alongside generous insurance provisions.

Our central finding is that where insurance is unavailable or where deductibles are high, as with recent regulatory initiatives in Florida, the homeowner is impelled to undertake the sorts of mitigation that might otherwise be foregone. There, with damages due to “named storms” now coupled with an insurance deductible of up to 10% of the home’s value (even greater deductible provisions exist with some policies in the most at-risk areas), potential homeowner losses easily escalate from $500 or $1,000 to several tens of thousands of dollars with the more severe hurricane strikes. Against this backdrop, our model suggests that homeowner initiatives may finally be taken to reduce losses to the homeowner, and, tangentially, to the entire neighborhood of hurricane-loss stakeholders.

Insurers, lenders, policymakers, builders and homeowners each have an interest in better understanding homeowner responses to hurricane risks. These stakeholders could structure insurance policies, frame lending standards, pass legislation, better build and better manage the existing housing stock, respectively, such that overall costs borne by the community due to hurricanes is reduced. The lowest-risk homeowner may be more motivated to mitigate and less likely to buy insurance; this cross-current is another issue that motivates our research. That is the issue that underlies this entire discourse: hurricane losses and subsequent expenses are not met by the affected homeowners or directly impacted neighborhoods alone. Substantial costs are suffered by the nation as a whole, for example, through direct federal disaster expenditures and as a result of higher insurance premiums.

In this context, we extend the existing literature on the impact of hurricanes on housing, the housing market, and homeowners. We review the published background in the next section. That review is followed by a description of the data we collected to answer our main question: What are some of the main factors that influence a homeowner's willingness to pay for the additional cost of guarding a home against hurricane wind damage? We develop a model to use our data to begin to answer our question. We then present our findings, and close with a summary and some concluding remarks.

## BACKGROUND

Current academic work on the economic and financial impact of hurricanes takes one of several tracks, each examining the impact of these storms on the sundry vested interests: Insurers, lenders, policymakers, builders and homeowners. We briefly review three elements of that research; the first considers public policy and risk-abatement by the government and insurance industry, the second examines real estate market behavior, and the third considers responses by individual homeowners at hurricane risk.

The first group is comprised of a number of published and continuing studies. These include Burby (2006), who questions the effectiveness of government action in advance of catastrophic events; "overtopped" levies as in New Orleans with Katrina and the over-dependence by homeowners on existing building codes, absent their own up-fitting, beyond code, augment losses suffered following the more damaging hurricanes. Jaffe, Kunreuther and Michel-Kerjen (2008) encourage the design of "long-term insurance" to separate homeowners from their frequent focus on near-term returns only. Their findings suggest that long-term contracts, capturing the greater likelihood of a damaging hurricane landfall within 20 years, as opposed to one or two years, would assure more cost-effective sharing of risk by homeowners, and more effective risk abatement.

In the second group, studies by Morgan (2007) and Graham, Hall and Schuhmann (2007) illustrate responses by the residential real estate market to perceptions of hurricane risk. Markets at first decline or become erratic with significant or recurring hurricane landfalls; housing markets return to "normal" with the passage of time. These studies affirm that the actions of home buyers and home sellers are characterized by statistically significant changes during the periods following historic hurricane activity.

Among studies in the third group, Petak (1998) notes that homeowners at hurricane risk typically do not enhance their homes beyond building codes to reduce later hurricane damages; the "mitigater" is the exception. In later work, Simmons, Kruse and Smith (2002) find that participants in housing markets at hurricane risk favor the kinds of "up-fits" we consider in this study, paying more for homes along the Gulf Coast that have installed storm blinds; the blinds actually seem cost-effective, as home values are increased by an amount greater than the cost of the installed shutters. Whether due to an over-dependence by homeowners on insurance, as suggested in a theoretical model by Burrus, Dumas and Graham (2002), or their under-estimation of the likelihood of hurricanes and hurricane damages, noted by Kunreuther (1996), it is noteworthy that homeowners seem often not to buy potentially economically-justified home enhancements.

Many homeowners are willing, however, to consider an investment in these improvements. In areas exposed to elevated hurricane risk, they choose from a menu of varied housing up-fits. Though few reasonable options exist for a homeowner, once the home is built, to guard against flooding, a number of options exist to secure the home against wind damages by making improvements to the home beyond existing building codes.

We believe homeowner willingness to buy such improvements likely varies as a function of the costliness of the improvements (via the law of demand), the homeowner's perceptions of the likelihood of hurricane damages (Simmons, Kruse and Smith, 2002), the availability of insurance and the size of insurance deductibles (Burrus, Dumas, Graham 2002). We gather data in an area at elevated hurricane risk towards testing our beliefs.

## DATA

Our data were gathered in an area along the North Carolina coast that has been subject over the years to regular hurricane and tropical storm landfalls. Three hundred thirty-six homeowners in the area were surveyed.[1] Eligible respondents included people who own their residence and make decisions regarding hurricane preparations. These owners resided in Brunswick, New Hanover, and Pender counties; these counties were chosen due to their heightened hurricane strike probabilities. The survey area is on the Atlantic coast, near the border with South Carolina.

The survey collected subjective information about home value, the percent of home value damage that homeowners anticipated in the event of a hurricane, the likelihood of hurricane strikes, the number of installed hurricane mitigation devices currently protecting the home, and the number of strikes that their home had experienced since they purchased it. Of the 336 homeowners, 264 provided enough information to be included in the data set.

Areas in Florida and along the Gulf Coast have been very much in the press in the early 2000's with such storms as Charley, Jeanne, Francis, Katrina, Rita and Ike; however, the National Weather Service affirms that on a mile-for-mile basis along the Gulf or Atlantic Coasts, the Cape Fear Region is among the most at-risk fifty mile sections in the United States (the only areas with greater risk of recurring landfalls were farther up the NC coast). Within 25 miles of the mouth of the Cape Fear River, there have been eight strikes by hurricanes or tropical storms since 1996. No other coastal regions can claim such a "title." Other locations have suffered the most damaging storms, but not the sheer number of separate landfalls.

Table 1 reveals the frequency of these landfalls over the last 12 years, and suggests that homeowners in the area likely have a greater appreciation for potential consequences of a hurricane than is the case with most households. As in that table, Hurricane Bertha began a three-year run of four storms; in 2004, 2005 and 2006, Hurricanes Charley and Ophelia, and Tropical Storm Ernesto struck. Tropical Storm Hanna made landfall near Wilmington in 2008. These last four storms, and the near-miss of Hurricane Isabel in 2003, are emblematic of the area's exposure.

The homeowners were asked whether their homes had features to protect against hurricane winds. Almost half of the respondents reported the existence of roof reinforcements in the attic, 29 percent reported having storm resistant window coverings, 16 percent reported having door coverings, and 10 percent reported having reinforced garage doors.[2] Next, homeowners were asked whether their homes had features designed to protect against flood waters. Thirty-two percent, 73 percent, and 13 percent of respondents reported their homes being built on fill dirt, on a crawl space, or on pilings, respectively. Twenty-eight percent of respondents reported that their outdoor appliances were raised. The typical home was equipped with 2.5 of the eight possible mitigation features.

Respondents also reported their annual household income and their subjective estimates of the annual likelihood of a category 3 hurricane strike. Average annual income was approximately $49,000 and the mean perception of the probability of a category 3 hurricane strike was approximately 0.38. This number is, admittedly, rather high and might be inflated by news media reports of hurricane intensity that differ from the reality of the intensity of land-falling winds.

The survey also posited three willingness-to-pay questions. Homeowners were asked whether they would buy, at a given price, a set of home improvements that would prevent all damage from a Category 3 hurricane but would provide no protection against stronger hurricanes.[3] Respondents were advised that a category 3 hurricane would completely destroy their home if the improvements were not installed and that the improvements would provide no protection against higher category storms.

One of three possible prices, $1,500, $3,000, or $6,000, was selected at random for each respondent; of the usable data, 88 respondents were assigned the price of $1,500, 89 were assigned the $3,000 price, and 87 were assigned the $6,000 price. Fourteen out of 88 respondents (15.9%), 20 out of 89 respondents (22.5%), and 16 out of 87 respondents (18.4%) indicated that they would buy the improvements for $1,500, $3,000, and $6,000, respectively. The differences are not statistically significant ($\chi^2 = 1.27$ with 3 df), a finding seemingly contrary to the law of demand.

If respondents answered that they would not pay for the improvements, they were then asked whether they would buy the improvements if their insurance deductibles were increased by a factor of five. The factor of 5 is not arbitrary, as insurance deductibles varied between $500 and $2,500 (both in our study and in anecdotal discussions with homeowners across the study region), a factor of five. The lower limit was the norm. Employing a similar measure with our examination of the power of changing deductibles seemed appropriate. From the survey, deductibles averaged around $500; thus, the average homeowner would experience a $2,500 deductible under the guidelines of this question. After considering the increase, twenty-four (27.3%), 33 (37.1%), and 30 (34.5%) respondents indicated that they would buy the improvements for $1,500, $3,000, and $6,000, respectively. Again, the differences in proportions were not statistically significant ($\chi^2 = 2.06$ with 3 df).

If respondents answered that they would not pay for the improvements with the increased deductibles, they were asked if they would buy the improvements if insurance were unavailable. Twenty-six (29.5%), 40 (44.9%), and 34 (39.1%) respondents indicated that they would buy the improvements for $1,500, $3,000, and $6,000, respectively, if insurance were unavailable assuming that homeowners answering that they would purchase the improvements before the increase in deductibles, or after the increase in deductibles, would also purchase the improvements if insurance were unavailable ($\chi^2 = 4.54$ with 3 df).

## THEORETICAL MODEL

Homeowner "willingness to pay" (WTP) for structural mitigation is estimated by applying the survey data to the following theoretical model. Indirect utility is a function of income and other household characteristics: $v = v(Y, \mathbf{z}_j)$ where Y is income and $\mathbf{z}_j$ is a vector of household characteristics. If the home is destroyed in a hurricane, utility is equal to only $v = v(Y - LOSS, \mathbf{z}_j)$ where LOSS is the financial loss associated with the destruction of the home.

Without purchasing the mitigation features, there are three (really two) possible states of the world: (i) no hurricanes strike the home or a category 1 or 2 hurricane strikes but does no damage, (ii) a category 3 hurricane strikes the home and destroys the home, and (iii) a category 4 or 5 storm strikes the home and destroys the home. State (i) – associated with mild intensity or no hurricanes - occurs with a probability of $P_L$, state (ii) occurs with a probability of $P_3$, and state (iii) – associated with strong hurricanes – occurs with a probability of $P_s$. If no mitigation is purchased, expected utility equals:

$$EU = P_m v(Y, \mathbf{z}_j) + (P_3 + P_s) v(Y - LOSS, \mathbf{z}_j).$$

In the survey, the mitigation (home improvements) prescribed to respondents protects against category 3 storms but not against higher category hurricanes; few devices exist to realistically counter the damage of category 4 or 5 hurricanes. In reference to the three states mentioned above, mitigation completely saves the home in state (ii) but adds no additional protection in states (i) and (iii); mitigation does not matter with no storm or low-intensity storms, nor does it matter with the strongest storms that destroy the home regardless. If mitigation is purchased, expected utility is:

$$EU = (P_m + P_3)v(Y - PRICE, \mathbf{z}_j) + P_s v(Y - LOSS - PRICE, \mathbf{z}_j)$$

where PRICE is the price of mitigation.

An owner is willing to purchase mitigation if the difference in expected utility with mitigation and expected utility without mitigation exceeds zero:

$$\Delta EU = (P_m + P_3)v(Y - PRICE, \mathbf{z}_j) + P_s v(Y - LOSS - PRICE, \mathbf{z}_j) - P_m v(Y, \mathbf{z}_j) - (P_3 + P_s)v(Y - LOSS, \mathbf{z}_j) > 0. \quad (1)$$

In other words, the owner will purchase mitigation as long as the gain in expected utility from home and wealth protection exceeds the decrease in utility from the purchase of mitigation. Willingness to pay is the price that just equates expected utility with mitigation and without mitigation:

$$(P_m + P_3)v(Y - WTP, \mathbf{z}_j) + P_s v(Y - LOSS - WTP, \mathbf{z}_j) - P_m v(Y, \mathbf{z}_j) - (P_3 + P_s)v(Y - LOSS, \mathbf{z}_j) = 0. \quad (2)$$

**EMPIRICAL MODEL AND RESULTS**

Selected variable names and descriptions and mean values are given in Table 2. To analyze the responses to the willingness to pay questions, we construct a dependent variable, MIT, which takes the value 1 if the owner desires to purchase mitigation (answers 'yes') at the given price and 0 otherwise. The probability that the ith respondent answers 'yes' to the willingness to pay question equals the probability that the change in expected utility from equation (1) is larger than 0: $Pr(MIT_i = 1) = Pr(\Delta EU > 0)$. A s the probit methodology is specifically tailored for an estimating environment with a dichotomous independent variable, it was selected to measure the probability of a homeowner's purchase of mitigation, in differing circumstances. (See Greene, 1993, p.636 – 655) Probit seems the best methodology to provide an idea of the likelihood of differing types of homeowners taking costly action to reduce the varied costs borne by public and private stakeholders with a hurricane strike.

For estimation purposes, we assume that utility in equation (1) is linear ($v = \alpha + \beta Y + \boldsymbol{\delta} \mathbf{z}_j$) and then use a linear approximation for the change in indirect utility:

$$\Delta EU_i = \alpha PRICE_i + \gamma P_3 + \theta LOSS_i + \boldsymbol{\delta}_j \mathbf{z}_{ji} + \upsilon_i \quad (3)$$

where $\boldsymbol{\delta}_j$ is a vector of parameters for the household characteristics such that $\boldsymbol{\delta}_j \mathbf{z}_{ji} = \Sigma \delta_j z_{ji}$ and $\upsilon_i$ is a component of preferences known to the individual respondent but not observed by the researcher (Haab and McConnell, 2002). In other words, the probability of purchasing mitigation is given by:

$$Pr(MIT_i = 1) = Pr(\alpha PRICE_i + \gamma P_3 + \theta LOSS_i + \boldsymbol{\delta}_j \mathbf{z}_{ji} + \upsilon_i > 0). \quad (4)$$

We assume that $\upsilon_i$ is distributed normally with mean 0 and standard deviation $\sigma$. If $\varepsilon = \upsilon/\sigma$, $\varepsilon$ is distributed as a standard normal variable. Thus,

$$\Pr(MIT_i = 1) = \Pr(\varepsilon < (\alpha PRICE_i + \gamma P_3 + \theta LOSS_i + \boldsymbol{\delta_j z_{ji}})/\sigma)), \quad (5)$$

and a probit regression model is used to estimate the probability of a 'yes' response to the WTP questions. Since each respondent was asked 3 mitigation decision questions, we estimate the probability of a 'yes' response using a random effects probit model for panel data with a total number of observations equal to 792 (264 times 3).

The PRICE variable is coded as $1,500, $3,000 or $6,000. The law of demand states that an increase in the price of mitigation will decrease the quantity demanded of mitigation, ceteris paribus; we anticipate a negative sign for the PRICE coefficient. Because respondents were told that a category 3 hurricane strike completely destroys the home, we expect an increase in the probability of a category 3 hurricane strike to increase the probability of purchasing mitigation. A positive sign is anticipated for $\gamma$.

Because the WTP questions specified that an unmitigated home is completely destroyed by a category 3 hurricane, we posit that LOSS is a function of the owner's insurance deductible. Changes in the insurance deductible are captured by a set of two dummy variables (with the omitted category as the homeowner's original deductible level). DEDUC is a dummy variable taking the value 1 when deductibles are increased to 5 times the original level (i.e. the dummy is always 1 for the for the second WTP observation for each respondent.) NOINS is a binary variable taking the value 1 when no insurance is available (the third WTP question). We expect that the probability of purchasing mitigation increases as a homeowner's insurance options are less desirable.

Other household characteristics include INCOME and INDEX. INCOME is household income and the coefficient estimate is expected to be positive; mitigation is a normal good and demand for it should increase with higher income. INDEX is the number of mitigation devices with which the home is currently equipped. We anticipate that the probability of purchasing additional mitigation decreases with current mitigation "holdings."

Using equation (5) and the preceding discussion, the probit model that will be estimated is:

$$\Pr(MIT_i = 1) = \Pr(\varepsilon < \beta_0 + \beta_1 PRICE_i + \beta_2 P_{3i} + \beta_3 DEDUC_i + \beta_4 NOINS_i + \beta_5 INCOME_i + \beta_6 INDEX_i) \quad (6)$$

where the parameters in (6) are estimates of their corresponding parameters from equation (5) divided by $\sigma$ (for example, $\beta_1$ is an estimate of $\alpha/\sigma$).

A point estimate of mean WTP can be found by using the parameter estimates from (6) to find the price that would make respondents indifferent to purchasing the mitigation ($\Delta EU = 0$). Thus,

$$WTP = [\beta_0 + \beta_2 P_3 + \beta_3 DEDUC + \beta_4 NOINS + \beta_5 INCOME + \beta_6 INDEX]/-\beta_1. \quad (7)$$

**Results**

Variables employed in our empirical analysis (developed in the system of equations above) are listed and described in Table 2 while the differences in the three cohorts randomly receiving the differing prices for mitigation are presented in Table 3.

Coefficient estimates for the probit model in equation (3) are presented under Model 1 in Table 4. These estimates were obtained using LIMDEP. A likelihood ratio test indicates that the set of coefficient estimates is significantly different from zero ($\chi^2 = 420.21$). In addition, the $\rho$ parameter indicates that almost all of the variation is at the individual level and the random effects specification is appropriate.

The coefficient estimates on $P_3$, DEDUC, NOINS, and INCOME are statistically significant (at the 5% level) with signs in the expected directions. The coefficient estimate on INDEX, however, is significant with a positive sign. This indicates that respondents who had previously installed mitigation devices are more likely to buy our set of improvements. Perhaps this variable is simply capturing risk aversion.

The coefficient on PRICE is positive and significant, an unexpected result inconsistent with the law of demand. The source of the unexpected sign on PRICE may be found in the descriptive statistics. Although more respondents were willing to purchase the mitigation improvements at a price of $3,000 compared to the number willing to purchase at $6,000 (as expected), it was also the case that more respondents were willing to purchase the mitigation improvements for $3,000 than were willing to purchase for $1,500 (an unexpected result). Apparently, the influence of purchase decisions inconsistent with the law of demand outweighed the influence of purchase decisions consistent with the law of demand in the estimation of the PRICE coefficient.

A possible explanation of the inconsistent behavior may be that respondents believed that the $1,500 mitigation improvements were of inferior quality. Burrus, Dumas, and Graham (2002) found that the price of mitigation improvements sufficient to protect a home against Category 3 hurricane wind speeds is approximately $3,000-$5,000. If homeowner estimates of mitigation costs are similar to those of Burrus, Dumas, and Graham, then homeowners may not believe that mitigation improvements costing $1,500 are of comparable quality.

In an attempt to isolate the respondents who received a price of $1,500, a dummy variable (PRICEDUM) was added to the model in equation (7). PRICEDUM takes on the value 1 if the respondent received a price of $3,000 or $6,000 and 0 if the respondent received a price of $1,500. The coefficient estimates for the new model are reported under Model 2 in Table 4. In Model 2, the coefficient estimate on PRICE is negative, and the coefficient on PRICEDUM is positive which indicates a difference in the cohort that received a price of $1,500 that is not captured by the other independent variables. Again, the perceived quality of the improvements across price categories may be the explanation.

Other model results remained largely unchanged by the addition of the PRICEDUM variable except that the INDEX coefficient estimate is now insignificant; the inclusion of the PRICEDUM variable diminishes the power of the INDEX factor. A likelihood ratio test leads to the conclusion that the PRICEDUM variable should not be excluded from the model ($\chi^2 = 12.074$).

Willingness to pay, using the findings of the second model, is computed using equation (7). If owners face current deductible levels (DEDUC = 0, NOINS = 0), an average homeowner who received a survey price in the $1,500 range (PRICEDUM = 0) requires a subsidy of approximately $26,000 (WTP is negative) to purchase mitigation devices that would defend against a category 3 hurricane. Even if deductibles are 5 times the current level (DEDUC = 1, NOINS = 0)) or if insurance is completely unavailable (DEDUC = 0, NOINS = 1), the owner requires a $14,000 subsidy or a $10,000 subsidy, respectively. For owners facing current deductibles who were queried with mitigation prices of either $3,000 or $6,000 (PRICEDUM = 1), subsidies of $15,000 and $2,275 are required. The WTP estimate is positive only when insurance is completely unavailable; WTP is $1,662 when insurance is not an option. Each of these estimates of WTP is significant.[4]

## CONCLUDING COMMENTS

The primary goal of this paper is to investigate the impacts of insurance deductibles and hurricane damage expectations on homeowners' structural mitigation purchase decisions. The National Flood Insurance Program and the Florida Windstorm Underwriters Association currently write policies giving premium reductions for mitigation purchases. Burrus, Dumas and Graham (2002) theoretically show that mitigation purchase behavior may be more sensitive to increases in insurance deductible levels than to decreases in insurance premium levels; we provide the earlier-absent empirical support for their model.

Mitigation devices must reduce damages to a level below the insurance deductible for mitigation to provide financial benefits, and higher deductibles make mitigation purchases more attractive. Survey results indicate that increased insurance deductibles do increase the probability of structural mitigation purchases. If anything, mitigation purchases are even more sensitive to deductive levels than indicated by Burrus, Dumas and Graham (2002). Knowledge of strike probabilities, however, does not significantly change mitigation behavior.

Patterns among insurance regulators in such hurricane-prone states as Florida to dramatically increase potential deductibles due to damages caused by "named storms" bring our findings into stark relief: Whereas a homeowner contemplating total damages in a strong category 2 or category 3 hurricane might have earlier not been motivated by total dollar damages equal to a deductible of only $500 to $2,500, that same homeowner, according to our findings, would mitigate where she is facing out-of-pocket expenses of 10% of a several hundred thousand dollar loss. Where deductibles are allowed to increase so dramatically within our model, losses to all stakeholders (including insurers, local and state and federal governments, lenders and property owners) are reduced as homeowners respond to significantly increased incentives to mitigate.

Homeowner choices to mitigate to a far greater extent given the unavailability of insurance is intuitive; whereas the homeowner who does not mitigate, but has insurance, is allowed to share her losses with the insurer, she suffers the entire loss if the insurance option is unavailable (this ignores special government programs such as those developed after Katrina). Given that, and consistent with our model, mitigation increases as insurance is removed.

We find also that the impact of mitigation price on mitigation purchases appears to vary; increasing the price of mitigation from low to moderate levels appears to increase purchases (perhaps because homeowners associate low prices with poor quality), while increasing price from moderate to high levels appears to decrease purchases (as would be expected). Larger household income increases the probability of purchasing mitigation, while higher levels of pre-existing, installed mitigation are sometimes associated with additional mitigation purchases.

**TABLE 1A**

**Hurricane History for the Study Region in Southeastern North Carolina**

| Hurricane Name | Month and Year of Landfall | Category |
|---|---|---|
| Bertha | July of 1996 | 1 |
| Fran | September of 1996 | 3 |
| Bonnie | August of 1998 | 1 |
| Floyd | September of 1999 | 2 |
| Charley | August of 2004 | 1 |
| Ophelia | September of 2005 | 1 |
| Ernesto | August of 2006 | Trop Storm |
| Hanna | September of 2008 | Trop Storm |

**TABLE 1B**

**Tropical Weather Wind Speed Categories for TABLE 1A**

| Saffir-Simpson Storm Category | Category Wind Speed Ranges |
|---|---|
| Tropical Storm | 39-73mph |
| Category 1 | 74-95mph |
| Category 2 | 96-110mph |
| Category 3 | 111-130mph |
| Category 4 | 131-154mph |
| Category 5 | 155+mph |

**TABLE 2**

**Variable Names and Definitions and Mean Values**

| Variable Name | Definition | Mean | St. Dev. |
|---|---|---|---|
| MIT | 1='Yes' respondent purchases mitigation; 0 = 'No' or 'Don't Know' | 0.3 | 0.016 |
| PRICE (in 1000's) | Price of mitigation (takes on the values $1,500, $3,000, or $6,000) | $3.49 | 0.663 |
| DEDUC | 1=deductible at 5 times original level; 0=otherwise | 0.33 | 0.16 |
| NOINS | 1=no insurance available; 0=otherwise | 0.33 | 0.16 |
| $P_3$ | Probability of a Category 3 hurricane strike | 0.38 | 0.01 |
| INDEX | The number of the following features the home is equipped with: roof reinforcements, window coverings, door coverings, garage door coverings, raised on fill dirt, raised on crawl space, raised on pilings, and raised outdoor appliances. | 2.48 | 0.57 |
| INCOME (in 1000's) | Homeowner income: categories are $0 - $10,000; 10,001 - 15,000; 15,001 - 20,000; 20,001 - 25,000; 25,001 - 30,000; 30,001 - 40,000; 40,001 - 50,000; 50,001 - 60,000; 60,001 - 75,000; 75,001 - 150,000; above $150,000. Incomes are coded as the midpoint of the income categories. | $48.69 | 11.64 |

**TABLE 3**

**Comparison of the Three Cohorts**

| Variable | *$1,500 Cohort* | | *$3,000 Cohort* | | *$6,000 Cohort* | |
|---|---|---|---|---|---|---|
| | *Mean* | *St. Dev.* | *Mean* | *St. Dev.* | *Mean* | *St. Dev.* |
| MIT | 0.24 | 0.03 | 0.35 | 0.03 | 0.31 | 0.03 |
| $P_3$ | 0.35 | 0.02 | 0.39 | 0.02 | 0.40 | 0.02 |
| INDEX | 2.05 | 0.76 | 2.59 | 0.96 | 2.79 | 0.12 |
| INCOME (in 1000's) | 47.14 | 20.23 | 50.86 | 17.18 | 48.03 | 22.80 |

**TABLE 4**

**Probit Results**

| | *Model 1* | | | *Model 2* | | |
|---|---|---|---|---|---|---|
| *Variable* | *Coefficient* | *b/St.Er.* | *P-value* | *Coefficient* | *b/St.Er.* | *P-value* |
| Constant | -15.382 | -5.137 | 0.000 | -22.442 | -3.256 | 0.001 |
| PRICE | 0.538 | 3.514 | 0.001 | -0.556 | -2.619 | 0.009 |
| PRICEDUM | | | | 6.619 | 3.558 | 0.000 |
| DEDUC | 3.350 | 4.714 | 0.000 | 6.080 | 2.729 | 0.007 |
| NOINS | 4.654 | 3.783 | 0.000 | 7.094 | 3.152 | 0.002 |
| $P_3$ | 2.469 | 2.935 | 0.004 | 9.283 | 3.025 | 0.003 |
| INCOME | 0.091 | 4.766 | 0.000 | 0.104 | 3.329 | 0.001 |
| INDEX | 0.314 | 1.996 | 0.047 | 0.042 | 0.304 | 0.761 |
| $\rho$ | 0.985 | 166.242 | 0.000 | 0.994 | 288.677 | 0.000 |
| Ending LL | -273.189 | | | -267.255 | | |
| Beginning LL | -483.295 | | | -483.295 | | |
| Count $R^2$ | 0.696 | | | .717 | | |

## ENDNOTES

1. The survey was conducted after Hurricane Floyd struck North Carolina, but before the Hurricane Isabel passed nearby.

2. Simmons, Kruse, and Smith (2002) found that approximately 30 percent of homes in an unnamed gulf coast city were equipped with storm shutters.

3. Most defensive measures are rated to protect against no more than a category 3 hurricane. The set of improvements that would protect against a category 3 hurricanes would be roughly equivalent to anchoring rafters to wall top plates, reinforcing the wall sheeting attachment to the bottom plate/mud sill, and installing angle brace anchors between the bottom plate/mud sill and footings and plywood coverings for windows and doors (Burrus, Dumas, and Graham, 2002).

4. A log-linear model with the PRICE and INCOME variables individually omitted to form a new variable ln[(INCOME – PRICE)/INCOME] was also estimated. Median WTP results from this model generally confirmed the findings of the linear model. For respondents who received an original mitigation price of $1,500, subsidies of around $34,000, $21,000, and $14,000 were required for respondents with normal deductibles, increased deductibles, and no insurance availability, respectively. For other respondents, subsidies of $12,000 and $3,600 were required for current deductibles and increased deductibles. When insurance was unavailable, WTP was positive and equal to $1,665. As in the preceding model, these WTP results were statistically different from zero.

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