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Flood Insurance Coverage in the Coastal Zone of North Carolina

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Executive Summary

We explore behavior and test theory regarding the determinants of flood insurance coverage in the coastal zone using household-level data for Brunswick and Dare Counties, North Carolina in 1998. We use multiple regression analysis to assess the importance and magnitude of insurance cost, risk factors, community characteristics, and household attributes on flood insurance purchase for residential building structures. National Flood Insurance Program rate schedules are utilized to determine marginal insurance premiums (i.e. the price that a customer would pay for an additional \$100 in flood coverage) that reflect specific property attributes (e.g. flood zone, building codes, elevation, presence of basement, etc.). Our baseline empirical models account for both the extensive (whether or not to hold flood insurance) and intensive (how much to hold) margins of flood insurance demand, and include objective flood risk factors (i.e. flood zone) and an estimate of value for the asset at risk (i.e. structure replacement value). The value of asset at risk is imputed by regression analysis, and special procedures (i.e. “bootstrapping”) are utilized to ensure consistent results. Extensions of the model explore the impact of flood insurance subsidies, other risk factors, like coastal erosion and accretion rates, erosion management policies, and household demographics variables.

Fifty-seven percent of near-shore parcels in Brunswick County participated in the National Flood Insurance Program (NFIP) in 1998, compared to 53% in Dare County. Average coverage level for NFIP participants was \$125,490 for Brunswick County and \$155,596 for Dare County. Consistent with previous research, we find evidence a relatively small negative price effect and positive income effect on flood insurance demand; in other words, households do not appear very price sensitive (i.e. demand is “inelastic”), and households with higher income purchase a greater amount of flood insurance (i.e. flood insurance is a “normal good”). Our best estimates of price elasticity are from $\epsilon_p = -0.12$ to $\epsilon_p = -0.49$. That is, a 1% increase in price leads to a roughly 0.12% to 0.49% decrease in flood insurance coverage. We find, however, that households that receive subsidized insurance demand more coverage (on average, about \$43,000, all else being equal) and are much more sensitive to price (i.e. exhibit “elastic demand” — $\epsilon_p = -2.09$, so a 1% increase in price leads to an approximate 2% decrease in coverage demand for subsidized parcels). A 1% increase in household income leads to approximately 0.2% increase in flood insurance coverage, all else being equal.

We find coverage demand higher in the highest risk (V-zone — 100-year flood zone with storm surge) areas, but also relatively high in lower risk (B/C/X-zone — 500-year flood zone or lower risk zone) areas relative to more moderate risk (A-zone— 100-year flood zone) areas. Flood insurance coverage demand is increasing in the value of the asset at risk. A \$1000 increase in replacement value of structure increases flood insurance coverage between \$311 and \$586 (or 0.4% to 0.75% for a 1% increase in structure value). Households that hold mortgages for their coastal property exhibit much higher coverage, approximately \$60,000 more, on average. Flood Insurance coverage is lower in areas that manage coastal erosion through shoreline armoring (approximately \$50,000 lower), suggesting that structural fortification may be seen as a substitute for flood insurance. These results provide an historical baseline for understanding

how flood insurance offers hazard protection vis-à-vis other measures of hazard mitigation in coastal North Carolina.

Keywords: Insurance coverage, flood, hazard, coastal, erosion, Tobit model

Introduction

Over the past 50 years, coastal areas in North Carolina have witnessed a growing populace, an evolving social environment, and increased economic activity. The burgeoning population faces considerable risk from coastal storms (hurricanes and nor'easters) that periodically cause extensive flooding, wind, and erosion damage. Increasing coastal population and rising construction costs have contributed to rising monetary losses due to these natural hazards (Kunreuther 1998a). Nordhaus (2006) estimates the value of capital stock in low-lying coastal areas of North Carolina vulnerable to natural hazards at approximately \$27 - \$45 billion;¹ for perspective, this ranges from 8% - 13% of 2005 state GDP (2005 dollars). Recent predictions suggest that we are entering a period of increased storm activity (Goldenberg et al. 2001; Webster et al. 2005) which could exacerbate coastal risk.

Historically, the catastrophic nature of flood risk has precluded private insurers from voluntarily offering coverage (Anderson 1974, Kunreuther 1998b). Since the late 1960s, the U.S. federal government has played an expanded role in providing protection from flood hazard. The National Flood Insurance Act of 1968 made federal flood insurance available,² through the National Flood Insurance Program (NFIP), to communities that agreed to manage development in floodplains. Due to the large number and diversity of affected communities, however, delineation and estimation of flood risk under the Flood Disaster Protection Act of 1973 proved a laborious task, leading to the development of the NFIP in phases. The "Emergency Phase" of the program offered insurance at subsidized rates to households in communities that agreed to adopt floodplain management ordinances. Subsidized insurance rates applied only until detailed Flood Insurance Rate Maps (FIRMs) could be produced, after which new construction would pay "actuarial" rates determined by location in the flood zone, structural characteristics (e.g., elevation), and the existence of community hazard mitigation projects (in the "Regular Phase" of the program). New construction is required to meet more stringent building standards designed to make structures more flood resistant. Nationwide, 35% of properties in the flood zone were eligible for subsidized insurance in 1997, paying approximately 37% of the actuarial premium (Burby 2001).³

Since its inception, the NFIP has suffered from low levels of participation among homeowners. The Flood Disaster Protection Act of 1973 required communities be enrolled in NFIP in order to qualify for certain types of federal disaster assistance and required flood

¹ Nordhaus estimates exposure using a 15km × 15km grid and selecting all blocks less than 8 meters above sea level with a 2005 capital stock estimate of \$1 billion or greater. The greatest exposures are found in New Orleans, Houston, Miami, Tampa, and New York City (each exceeding \$100 billion). Exposure in coastal North Carolina accounts for roughly 2% - 4% of coastal exposure nationally.

² The NFIP is actually a cooperative venture of federal, state, and local governments, and private insurers. The federal government sets flood insurance premiums, stipulates building standards, designates flood hazard areas, and authorizes hazard mitigation programs. State and local governments can augment building standards, enforce building codes, and administer some hazard mitigation projects. Private insurance companies sell and service flood insurance policies (Burby 2001).

³ The Congressional Budget Office estimates that the extent of subsidy has dropped to 25% as of 2005 (Marron 2006).

insurance purchase for federally-backed (FHA) mortgage loans in high-risk areas (Pasterick 1998). Mandatory purchase requirements were strengthened under the National Flood Insurance Reform Act of 1994, and programs were expanded to encourage local hazard mitigation projects. Nonetheless, evidence suggests that mandatory purchase requirements are not aggressively enforced after the initial year of a mortgage contract (Kunreuther 1996, Palm 1998), so that after a loan is secured participation becomes *de facto* voluntary.⁴ In 1997, nationwide market penetration for the NFIP across the U.S. was estimated at 26% of eligible parcels (PricewaterhouseCoopers 1999). Explanations for low market penetration have included ignorance of and lack of experience with flood hazard, subjective misperceptions of the likelihood of flooding and magnitude of loss, lack of awareness of the availability of flood insurance or belief that the price is too high, and “charity hazard” — a reliance on assistance from others (e.g. government) in the event of disaster (Kunreuther 1984, 1996; Browne and Hoyt 2000).

In light of increasing coastal populations and predictions of increasing coastal storm intensity, there is heightened concern about natural hazard exposure in coastal areas and the viability of NFIP. Understanding household demand for coverage is a key element in assessing the viability of the market for flood insurance and the role of market insurance vis-à-vis other forms of indemnification for coastal hazards. In this paper, we focus on hazard perceptions and flood insurance coverage choice in the coastal zone, utilizing household micro-data from 1692 parcels in Dare and Brunswick Counties, North Carolina.

Consistent with previous research, we find evidence of price inelastic demand for flood insurance on average, though households that receive subsidized insurance demand more coverage and exhibit elastic demand. We find coverage demand higher in the highest risk (V-zone) areas, but also high in lower risk (B/C/X-zone) areas relative to more moderate risk (A-zone) areas (controlling for price and value at risk). Flood insurance coverage demand is increasing in the value of the asset at risk. Households that hold mortgages for their coastal property exhibit higher coverage, as do households with greater income. Coverage is lower in areas that manage erosion through shoreline armoring, suggesting that structural fortification may be seen as a substitute for flood insurance.

Empirics of Flood Insurance Demand

There exists little empirical work on demand for flood insurance coverage. Baumann and Sims (1978) find evidence that past experience with disasters motivates insurance adoption, as do social class and personality.⁵ Survey research suggests that lower income and non-white households, women, and elderly all tend to exhibit greater fear of disasters, though it is unclear whether this fear translates into insurance purchase or other types of mitigation and protective

⁴ Recent anecdotal evidence suggests that enforcement of mandatory purchase provisions has improved. For the period over which we have data, however, mandatory purchase provisions were apparently not aggressively enforced.

⁵ Baumann and Sims find that the internal-external locus of control is significantly related to insurance adoption; those who feel that they are in control of their destinies are more likely to hold insurance than those he feel their lives to be directed by external forces.

behavior (Palm 1998). Brown and Hoyt (2000) use state level data to estimate a flood insurance demand model. They find a relatively small negative price effect and positive income effect on flood insurance demand; in other words, households do not appear very price sensitive (i.e. demand is ‘inelastic’), and states with higher average income tend to exhibit greater flood insurance demand. Consistent with previous findings, their results suggest that demand is increasing in flood damages of the prior year. Contrary to expectations, they find that insurance demand is lower in states with more federally-backed (FHA) mortgages and higher in states that receive greater federal disaster assistance.

National data gathered by Dixon et al. (2006) support the finding that rate of market penetration is not sensitive to price, and further suggest that penetration is significantly higher in special flood hazard areas (SFHA — also known as A-zone)⁶ and higher for communities with a larger number of parcels in the SFHA. The authors attribute the latter finding to more aggressive marketing of and more familiarity with flood insurance on the part of insurers in such communities. Dixon et al. (2006) find that the probability of purchasing insurance is substantially higher in communities subject to coastal flooding than in communities that are not — 63 percent versus 35 percent. They speculate that demand for flood insurance may be lower in communities not subject to coastal flooding because there is less appreciation for flood risk or because the type of coverage offered by flood insurance policies is less attractive in inland areas.

Michel-Kerjan and Kousky (2008) examine county-level and individual policy-level data to explore characteristics of the flood insurance market in Florida (which represents approximately 40% of policies in force and total dollars of coverage). They find that the overwhelming majority of policyholders elect the lowest level of deductible (\$500), and that coverage levels have increased in reaction to the floods of 2004, while deductibles have decreased. For most policyholders, the \$250,000 limit on structure coverage is not binding, as their replacement value is less than this limit.

Kriesel and Landry (2004) use household level data from the coastal zone to examine participation in NFIP for nine southeastern U.S. counties. They find price inelastic demand for flood insurance and a positive income effect. Consistent with NFIP requirements their results suggest that mortgaged properties are much more likely to be covered by flood insurance. Further they find that insurance participation is higher in coastal areas that are fortified with artificial erosion protection (shoreline armoring and/or beach replenishment), lower for properties located further back from the shoreline, and lower for geographical areas that have a higher hurricane return period (lower hurricane risk).

Flood Insurance Coverage Data

We make use of data gathered in 1998 by the H.J. Heinz III Center for Science, Economics, and the Environment, under the direction of FEMA, to address issues of flood insurance and erosion in the coastal zone. The population of interest is residential parcels in the

⁶ The SFHA is the flood zone that exhibits a 1 percent chance of flooding each year (i.e. 100-year flood zone).

near-shore zone⁷ of Dare and Brunswick Counties, North Carolina. A stratified random sample of near-shore properties was selected using a T-shaped sampling frame in order to ensure adequate coverage on the oceanfront; weights are used to adjust all reported statistics for representation of the near-shore zone.

Details of the data collection effort are available in Heinz Center (2000). For each parcel, contractors made onsite visits to collect physical information, such as structure elevation above base flood elevation (BFE — height of the 100 year flood), foundation type, etc. Geographic information systems were employed to estimate flood zone and historical erosion rate. Parcel and structure characteristics from the county tax assessor's database were appended to the onsite data. The sample was then merged by address with the Federal Insurance Administration's policies-in-force database in order to provide the most accurate information on market penetration and coverage. Lastly, the dataset was complemented with information from a survey questionnaire sent to the home address of all parcel owners in the sample during 1998-99.

Table 1 displays insurance, physical, and parcel characteristics for the 1692 properties that were selected for the study. Dare County provides 61% of the data, and Brunswick makes up the remaining 39%. Fifty-seven percent of near-shore parcels in Brunswick County participate in NFIP (in 1998), compared to 53% in Dare County. While these measures of market penetration are lower than those reported for coastal areas by Dixon et al. (2006) (63%), our data are older (1998 versus 2003) and there is a general belief that demand for flood insurance has been increasing in recent years. Average flood insurance coverage for structure (including zeros for non-participants) is \$68,600 in Brunswick County and \$78,700 in Dare County, with a minimum of zero and a maximum of \$250,000.⁸ Average coverage for NFIP participants (excluding zeros for non-participants) is \$125,490 for Brunswick County and \$155,596 for Dare County. Marginal premiums (i.e. the price for an additional \$100 flood insurance coverage) were calculated using descriptive information on the property and detailed NFIP rate tables from 2004 (adjusted back to 1998 levels).⁹ At the parcel level, flood insurance premiums depend upon a number of factors, including: flood zone, elevation above BFE, year of construction relative to publication of FIRM, presence of basement or obstruction below a property, type of structure, CRS score, the level of coverage, and chosen deductible.¹⁰ We discuss each of the factors in turn.

We see considerable variability in physical risk factors across counties. Most of the near-shore properties in Brunswick County (81%) are located in the V flood zone (100-year flood zone with additional risk due to high-velocity waves associated with storm surge) while only

⁷ For the purposes of this study, the near-shore zone is defined as the parcels within approximately 1000 feet of the ocean.

⁸ Consistent with the findings of Michel-Kerjan and Kousky (2008) only 5% elect for the maximum coverage of \$250,000.

⁹ Flood insurance rates have been generally increasing over time. Between 1998 and 2004 there were three targeted rate increases that we had to factor into our marginal premium calculations.

¹⁰ Total premium also includes a \$30 Federal Policy Fee that applies to high-risk areas, an Increased Cost of Compliance coverage premium, and a Probation Surcharge (if applicable). These additional fees do not affect the marginal premium, but may induce price differences in total premium paid.

32% of Dare County near-shore properties are located in the V-zone. Fourteen percent of Brunswick County properties are located in the standard SFHA or A-zone (100-year flood zone), while 59% of Dare County properties are located in this zone. The remaining near-shore properties (5% for Brunswick and 9% for Dare) are located in lower flood risk zones (e.g., 500-year flood zone). Properties in Dare County also exhibit greater average elevation above BFE — 7.86 feet compared to 0.55 feet in Brunswick. Elevation above BFE ranges from -9.95 to 29.81 feet in Dare County, compared to -12.42 to 97.26 feet in Brunswick County. The majority of properties in Dare County are oceanfront — 63%, versus 45% in Brunswick.

The tax assessor's database provides information on assessed building and land values, recent sales price, year of construction, year of sale, and other structural variables. Building and land assessed values are unreliable measures of value due to differences in assessment and updating across municipalities. Since information on sales price is limited (N = 678), we employ hedonic price regression analysis to produce imputed current property values, which provide a measure of the value of the asset at risk (more on this below). The average housing sales price is \$160,000 for Brunswick County and \$167,000 for Dare County (current \$). The average near-shore property in Brunswick (Dare) County has 1528 (2220) square feet, was built in 1976 (1978), and purchased in 1988 (1986).

Year of construction is used to determine whether a structure was built before the publication of a flood insurance rate map (FIRM) in the community. Forty percent of the homes in Brunswick County and 24% of the homes in Dare were built before publication of FIRMs. Pre-FIRM structures and those built in the V-zone built between 1975 and 1981¹¹ are “grandfathered” in the NFIP and pay subsidized insurance rates. Sixty-four percent of the parcels in Brunswick County and 33% of the parcels in Dare qualify for subsidized insurance under these provisions. The proportion of subsidies in Brunswick County is considerably higher than the 1997 national average of 35% (Burby 2001). Subsidized and regular flood insurance premiums vary by flood zone, with structures in the V-zone paying the highest rates and structures in the X-zone (outside the 500-year flood zone) paying the lowest rates. Subsidized rates vary according to whether a basement or other obstruction is present and by type of structure (single or multiple-family). Regular rates vary by number of building stories, presence of basement or obstruction, structure type, and elevation above BFE. Post-FIRM structures with greater elevation pay lower rates. Around 85% of structures in our dataset are elevated on piles, and less than 10% have obstructions below the property.

The National Flood Insurance Reform Act of 1994 established the Community Rating System (CRS) to evaluate and summarize mitigation projects in a community. The CRS score ranges from 1 (many mitigation projects, low flood risk) to 10 (little or no mitigation projects, baseline flood risk); a lower CRS score lowers flood insurance premiums. The average CRS score for Brunswick is 8.7 (low of 8 and high of 9), while for Dare it is 7.8 (low of 7 and high of 10). Flood premiums are adjusted to reflect the CRS score for the community, with discounts ranging from 0% (for a score of 10) to 45% (for a score of 1).

¹¹ Post-FIRM structures in the V-zone built between 1975 and 1981 are “grandfathered” because building standards did not take account of damage due to wave heights. The level of the subsidy is different for pre-FIRM structures and these “grandfathered” V-zone structures.

Premiums vary by amount of coverage and deductible elected. A basic lower rate applies to the first \$50,000 of coverage on structure, while a higher rate applies to additional coverage up to the \$250,000 limit on structure.¹² Knowing coverage level, we are able to apply the marginal rate in our empirical analysis of demand for flood insurance coverage. The standard deductible for NFIP structure coverage is \$500. Reduced premiums are awarded for those opting for a higher deductible, up to \$5,000 deductible on single-family structures. Premiums for post-FIRM structures in the V-zone built after 1981 (approximately 14% of our data) depend upon the ratio of coverage level to replacement value (replacement cost ratio). Unfortunately, our data contain limited information (N = 761 for policy holders) on deductible level¹³ and no information on replacement value.¹⁴

To make full use of the available data, we consider two measures of marginal premium — a high and a low version — in order to assess the responsiveness of coverage demand to insurance price. The high premium model assumes all households elect the standard \$500 deductible¹⁵ and that post-FIRM structures in the V-zone built after 1981 select a level of coverage that is less than 50% of the structure replacement cost. The price elasticity (i.e. measure of price sensitivity) from the coverage model that employs the high marginal premium will be a lower bound on the true value. The low premium model assumes all households take a \$1000 deductible and that post-FIRM structures in the V-zone built after 1981 select a level of coverage that is greater than or equal to 75% of the replacement cost. The price elasticity from the coverage model that employs the low marginal premium will be an upper bound on the true value.

The average high marginal premium is \$1.43 per \$100 coverage for Brunswick County, with a minimum of \$0.072 and a maximum of \$5.70. For Dare County, the average high marginal premium is much lower at \$0.52 per \$100 coverage (min = \$0.068, max = \$5.40). Since premium schedules are set at the federal level, the cross-county disparity in average premium likely reflects the lower proportion of V-zone properties and higher average elevation above BFE in Dare County. We note, paradoxically, that Brunswick County has a higher proportion of subsidized parcels, which might lead one to expect lower average premiums in Brunswick. Pre-FIRM subsidies, however, apply only to the first \$35,000 of structure coverage. The average low marginal premium for Brunswick County is \$1.17 per \$100 coverage (min = \$0.069, max = \$3.70), while for Dare it is \$.042 (min = \$0.065, max = \$3.51).

¹² Basic contents coverage rates apply to the first \$20,000 in insurance, with higher rates applying to additional coverage up to the \$100,000 limit on contents. We do not consider contents coverage in this paper.

¹³ Of these data, 71% claim structure deductible of \$500 and 93% claim deductible of \$1000 or less.

¹⁴ Building assessed values are often outdated and housing sales prices reflect both structure and land values.

¹⁵ The data of Michel-Kerjan and Kousky (2008) suggest that 98% of Florida policyholders select a deductible less than the maximum and 80% choose the lowest deductible of \$500. Thus, this assumption probably provides more reliable results than the low-premium assumptions.

As these data were collected to analyze the effect of coastal erosion on NFIP and flood insurance demand, measures of erosion risk are available. A similar proportion of properties in each county are located in actively eroding zones — 75% for Brunswick County and 72% for Dare County. The average historical erosion rate, however, is higher in Dare County at 2.69 feet per year, compared to 1.3 feet per year in Brunswick. The highest historical erosion rates were 6.38 feet per year for Brunswick and 18.27 feet per year for Dare. Much smaller proportions of properties in each county are located in coastal zones that are accreting — 5% in Dare County (average accretion rate of 0.02 feet per year) and 23% in Brunswick County (average accretion rate of 0.007 feet per year). The remaining proportions of parcels (2% of Brunswick and 22% of Dare) are classified as being in neither an erosion nor accretion zone.¹⁶

Kriesel, Randall and Lichtkoppler (1993) use a variable transformation, *geotime*, to measure erosive pressure on a parcel. *Geotime* is defined as the ratio of setback (or distance from the shoreline) to erosion rate, providing an estimate of the number of years a parcel is expected to remain in the face of constant, deterministic shoreline erosion. The average distance from the shore is 255 feet in Brunswick County and 313 feet in Dare County. Average *geotime* in Brunswick County is 3269 years, while in Dare County it is 840 years. These numbers are somewhat misleading, however, as more than a quarter of the properties in each county had less than 10 years *geotime*, indicating that they are prone to erosional undermine in the very near future.

We turn next to survey data gathered from the mail questionnaire. The response rate for Brunswick County is 45%; for Dare County it is 53%, for an overall response rate of 50%. Descriptive statistics are presents in table 2. Household income is measured by a nominal response to 8 income categories, with the mid-point utilized as an estimate. Average income in Brunswick County is \$85,000, and Dare is somewhat higher at \$109,000. The majority of near-shore Brunswick residents are college educated (50%), while the majority of near-shore Dare residents possess a graduate degree (43%). A considerable proportion of residents are retirees — 55% in Brunswick and 39% in Dare. The average age is around 60 years, and the average household has less than one child.

The majority of survey respondents (56% in Brunswick and 58% in Dare) indicate that they would have purchased their coastal home regardless of whether flood insurance was available, and a small proportion (3% in Brunswick and 6% in Dare) indicate that they have allowed their flood insurance to lapse at some time in the past. Around 13% (7%) of property owners in Brunswick (Dare) indicate that they have submitted a claim for flood insurance damages in the past. Interestingly, a minority of properties are mortgaged (32% in Brunswick and 49% in Dare), and only a fraction of those (17% and 12% overall in Brunswick and Dare, respectively) claim that they were required to purchase flood insurance by their mortgage lender. Around one-third of respondents (31% in Brunswick and 34% in Dare) claimed to be aware of the rate of coastal erosion nearest shore. Brunswick County property owners indicate a much higher incidence of coastal engineering at the nearest shore — 14% shoreline armoring and 52% beach replenishment — in comparison to Dare County residents — 3% shoreline armoring and

¹⁶ The erosion rates were calculated by state coastal zone managers. In some cases, managers set the erosion rate to zero if structural fortification (i.e. seawalls) were in place.

16% beach replenishment. The majority of respondents in the near-shore zone (46% and 56% in Brunswick and Dare, respectively) utilize their property as a part-time rental/part-time vacation home. A considerable amount of owners uses the property as an exclusive vacation home (29% in Brunswick and 26% in Dare), while some rent their property full-time (29% in Brunswick and 26% in Dare). A much smaller proportion of owners are full-time residents — 7% in Brunswick and 5% in Dare.

A subset of respondents (N = 63 overall) provided information regarding why they did not hold flood insurance. The majority (27%) indicated that they were not required to purchase flood insurance. Twenty-two percent indicated that they perceived the risk of flooding as very low, and 21% claimed that flood insurance was too expensive — these two results taken together suggest that almost half of property owners likely have overly optimistic assessments of coastal flood risk. Eight percent indicated that flood insurance was unavailable in their area.

Methods of Analysis

We employ multiple regression analysis to explore determinants of flood insurance coverage choice for residential building structures in the near-shore coastal zone of North Carolina. Flood insurance coverage is a censored variable because it cannot be below \$0 and cannot exceed the \$250,000 limit. We use the Tobit model (Wooldridge 2001), which assumes that the continuous portion of the error distribution is normally distributed, while the censored values are represented with discrete probability masses. The method of estimation is maximum likelihood.

Economic theory provides guidance on the specification of our regression model (Smith 1969, Mossin 1969). The marginal price of flood insurance (i.e. the amount charged for additional \$100 coverage) is a primary parameter in the specification of demand, as is household income. Risk factors, such as presence in a flood zone, should affect demand; we hypothesize that households in higher risk zones will demand greater coverage, but the higher cost of insurance in these zones makes the effect uncertain. We also explore erosion hazard factors, such as the erosion/accretion rate and the presence of erosion mitigation projects (shoreline armoring or beach replenishment) in the nearby area. Households may view such projects as substitutes or complements to formal flood insurance depending upon their own assessment of the protection offered. Other covariates in the model include property usage and household demographic factors.

Theory and intuition suggest that the value of the asset at risk should affect insurance demand. Unfortunately, we have limited information on property values. We employ hedonic price regression analysis to produce imputed current property values, and take a proportion of the imputed value as an estimate of the value at risk. We run a bootstrapping procedure to correct for sampling variation in the imputation process (Shao and Sitter 1996) which requires multiple estimations (1000 iterations) with subsets of the data, but an example of the hedonic price regression parameters is included in table 3. The estimation utilizes a semi-log functional form (that is the dependent variable is the natural logarithm of sales price) and includes all housing

sales between 1950 and 1998.¹⁷ Due to missing data, the specification is fairly restricted, including only square footage and lot size (in quadratic form), a dummy variable for missing information on square footage, the age of the structure at time of sale, and dummy variables for oceanfront and vacant lots at time of sale. Decadal dummy variables are used to identify sales in the 50's, 60's, and 70's, and yearly dummy variables are included for 1980 - 1996 (the excluded category being 1997 — parameter estimates for time effects not shown). The R^2 indicates that the included covariates explain 48% of the variation in housing sales prices, and the F-statistic for the model is statistically significant at the 5% level. All parameters are statistically significant at the 5% level for a Type I error, except lot size, missing square footage, and five of the time dummies. The estimated model is used to predict housing sales price in 1998, and 51% of the estimated sales price provides a proxy for the structure asset value.¹⁸

Let y_i be the amount of flood insurance coverage elected; this is the dependent variable in our insurance demand model. The dependent variable for a Tobit model can be censored as follows:

$$y_i = \begin{cases} UL; y_i^* > UL \\ y_i^*; LL \leq y_i^* \leq UL, \\ LL; y_i^* < LL \end{cases} \quad (1)$$

where y_i is the observed response variable (coverage level), y_i^* is the latent response variable, UL is the upper limit on coverage (\$250,000) and LL is the lower limit (\$0). The log-likelihood function for the Tobit model is:

$$LLF = \sum_{i \in \{y_i = LL\}} \ln \Phi\left(\frac{LL - x_i' \beta}{\sigma}\right) + \sum_{i \in \{LL < y_i < UL\}} \ln \phi\left(\frac{y_i - x_i' \beta}{\sigma}\right) / \sigma + \sum_{i \in \{y_i = UL\}} \ln \Phi\left(-\frac{UL - x_i' \beta}{\sigma}\right) \quad (2)$$

where $\phi(\bullet)$ represents the normal probability density function, $\Phi(\bullet)$ represents the normal cumulative distribution function, x is a vector of covariates hypothesized to effect demand for coverage, and β and σ parameters to be estimated. Marginal effects are transformations of (2) that provide an estimate of the effect that a unit change in an element of the vector x have upon the response variable (insurance coverage). Marginal effects for the double-censored Tobit model are calculated as:

$$\frac{\partial E(y|x)}{\partial x_j} = \Phi\left(\frac{x' \beta}{\sigma}\right) \beta_j + 2500 \phi\left(\frac{x' \beta - 2500}{\sigma}\right) \frac{\beta_j}{\sigma} \quad (3)$$

for each continuous element j of the vector x , where $E(\bullet)$ is the expectations operator.¹⁹ Marginal effects for discrete covariates are calculated as:

¹⁷ The long time series included in a single model is a very demanding specification; as our goal is imputation, rather than testing hypotheses regarding parameters, we employ this specification to make use of all available sales data.

¹⁸ Fifty-one percent is the value of the ratio of building assessed value to total assessed value in our dataset.

¹⁹ For the double-censored Tobit, $E(y|x) = \Phi\left(\frac{x' \beta}{\sigma}\right) x' \beta + \sigma \phi\left(\frac{x' \beta}{\sigma}\right) + 2500 \Phi\left(\frac{x' \beta - 2500}{\sigma}\right)$

$$\frac{\Delta E(y|x)}{\Delta x_h} = E(y|x_{-h}, x_h = 1) - E(y|x_{-h}, x_h = 0) \quad (4)$$

Elasticities transform marginal effects into unit-free, percentage change effects, and are typically calculated as:

$$\varepsilon_j = \frac{\partial E(y|x)}{\partial x_j} \times \frac{\bar{x}_j}{\bar{y}} \quad \text{or} \quad \varepsilon_h = \frac{\Delta E(y|x)}{\Delta x_h} \times \frac{\bar{x}_h}{\bar{y}} \quad (5)$$

where \bar{x} and \bar{y} are means of the independent and response variable, respectively.

Results

Model (2) is estimated by method of maximum likelihood. Tables 4 and 5 display results for the high and low estimate of marginal premium, respectively. Each table includes 3 specifications, the first of which serves as a baseline and includes marginal premium, indicators for high and low flood risk (presence in the V-zone and B/C/X zones, respectively — the excluded category is A-zone), imputed value of the asset at risk, and a dummy variable for Brunswick County. Asymptotic standard errors are produced via bootstrapping procedure to address the imputed regressor problem associated with *asset_val* variable. An asterisk indicates covariates which are *not* statistically significant at the 5% level for a Type I error (i.e. for these parameter estimates, we cannot reject the hypothesis that the estimated effect is zero at a 95% level of confidence).

With the exception of model 3, table 4, all model specifications indicate significantly higher flood insurance coverage in the V-zone (100-year flood zone with high velocity waves during storms) relative to the A-zone (standard 100-year flood zone). For example, results from model 1, table 4 suggest that location within the V-zone increases flood insurance coverage by \$39,800 (or 27%) relative to A-zone, all else being equal. The estimated mean effect ranges from \$51,300 (or 34%, model 2 table 4) to \$19,400 (or 13%, model 3, table 4). Interestingly, results for location in lower risk flood zones (B, C, and X — 500-year flood zone or lower risk) are mixed, with the full model (N = 1579) indicating higher coverage relative to A-zone and models that utilize the subsample of survey data (N=533) indicating lower coverage. Estimated asset value is statistically significant in all specifications, and increases the level of flood insurance coverage. Referring to Model 1, table 4 again, a \$1000 increase in estimated asset value leads to a \$446 increase in flood insurance coverage, on average. Models provide estimated marginal effects between \$311 and \$586 per \$1000 increase in asset value. Elasticity estimates range from 0.4% to 0.75% increase in coverage for a 1% increase in asset value.

Average price elasticity estimates for the high premium models range from $\varepsilon_p = -0.12$ (model 3) to -0.49 (model 1). Results from model 2 suggest that those households that face subsidized rates purchase substantially higher flood insurance coverage (marginal effect = \$43,000), and thus also exhibit higher price elasticity, $\varepsilon_p = -2.09$. The price elasticity for non-subsidized properties in model 2 is fairly low in absolute value, $\varepsilon_p = -0.26$.

Price elasticities for the low premium models are significantly larger for model 1, indicating elastic demand on average ($\varepsilon_p = -2.03$). Subsidized property owners demand about \$40,300 more coverage than other property owners, and exhibit highly elastic demand ($\varepsilon_p = -$

6.79), though one should bear in mind that this is an upper bound on the true effect. Price elasticity for non-subsidized properties is $\varepsilon_p = -0.72$. Results for model 3, which utilizes the subset of survey data, indicate inelastic demand on average ($\varepsilon_p = -0.22$).

According to the results in models 3, community hazard mitigation projects affect demand for flood insurance, with shoreline armoring reducing demand by \$50,800 (high premium model) to \$49,700 (low premium model), on average. Beach replenishment projects have an estimated positive impact on flood insurance coverage, but the effect is not statistically significant (i.e. we cannot reject the hypothesis that the effect is zero with any conventional degree of confidence). Models exploring the direct effect of shoreline erosion (results available on request) found a positive effect for erosion rate (i.e. increasing flood insurance demand) and a negative effect for accretion rate (i.e. decreasing flood insurance demand), but neither of the estimated effects were statistically significant. Likewise, alternative specifications that explored the effect of recent purchase found no statistically significant effect of new ownership on flood insurance coverage.

Models 3 explore the effect of household-level demographic factors on the demand for flood insurance. Those with a mortgage hold higher flood insurance coverage, with a marginal effect of \$57,700 (\$60,800) in the high (low) premium model. Consistent across both models, a \$1000 increase in household income increases average flood insurance demand only modestly, by approximately \$137. The income elasticity in the high (low) premium model is $\varepsilon_I = 0.22$ ($\varepsilon_I = 0.19$). Other household level covariates, such as property usage (vacation home vs. primary residence vs. rental unit), educational attainment, and retirement status, did not have a statistically significant effect on flood insurance coverage.

Discussion

Consistent with previous research (U.S. GAO 1983; Browne and Hoyt 2000; Kriesel and Landry 2004; Dixon et al. 2006), our findings suggest inelastic demand for flood insurance in coastal North Carolina in 1998. Given the evidence of low chosen deductibles (our data and Michel-Kerjan and Kousky 2008) the high premium model is arguably the better specification. Price elasticities in this model ranged from $\varepsilon_p = -0.12$ to $\varepsilon_p = -0.49$. That is, a 1% increase in price leads to a roughly 0.12% to 0.49% decrease in coverage. Our results also provide some insight into the differences in coverage and elasticity across subsidized and non-subsidized properties. Properties that face subsidized rates purchase significantly more coverage (on average, about \$43,000, all else being equal), and are more sensitive to price, $\varepsilon_p = -2.09$. A 1% increase in price leads to an approximate 2% decrease in coverage demand for subsidized parcels. Price elasticity for non-subsidized properties is estimated at $\varepsilon_p = -0.26$ — demand goes down by one-quarter % if price increases by 1%. We believe that our estimates may be more accurate than previous estimates due to the fact that we employ marginal measures of insurance premium and utilize household-level data. Our results, however, are limited to coastal properties in North Carolina. Landry and Jahan-Parvar (2008) provide a more complete analysis for nine counties in the southeast.

The Congressional Budget Office (Marron 2006) estimates that flood insurance premium payments make up about 60% of the actuarial balance, leaving the general taxpayer responsible

for an estimated \$1.3 billion per year. Our results support the contention that moderate increases in flood insurance premiums will not induce wholesale cancellation of policies, but the reduction in demand is likely to be greater for subsidized than non-subsidized policyholders. To the extent that mortgage requirements mandate a specified level of flood insurance coverage, price increases will have little effect on demand but will clearly induce negative welfare effects on coastal households.²⁰ Positive mortgage status induces a large marginal effect in our models (on the order of \$60,000).

The raw data, however, suggest that only 42% of North Carolina coastal properties are mortgaged in 1998, and surprisingly only 14% claim that they were required to hold flood insurance despite the federal mandate for FDIC-backed mortgage securities. Moreover, 5% state that their flood insurance has lapsed as some time in the past. These results are consistent with the assertion that lenders have not been especially zealous in enforcing insurance purchase requirements as required by law (Kunreuther 1984; Kunreuther 1996; Pasterick 1998), but anecdotal evidence suggests that more recent data may not show a similar tendency. Also, we find no evidence that new homeowners are more likely to hold greater flood insurance coverage than other households in the coastal zone—a result we might expect if homeowners enroll in the flood insurance program at the time of house purchase to satisfy mortgage lender requirements, but subsequently let their coverage lapse. The subset of survey data providing information on why those that have foregone flood insurance have made such a choice indicates that subjective assessments of flooding tend to be lower than objective estimates, as 43% of respondents claim that the price of insurance is too high or that the risk of flooding is very low. Assessing the extent to which the mandatory purchase provisions are enforced and analyzing household perceptions of hazard and methods to encourage insurance purchase remain important areas for future research.²¹

Our results provide some support for rational decision making with regard to flood risk in the coastal zone. Estimated asset value is statistically significant in all specifications, and increases the level of flood insurance coverage. A \$1000 increase in value of the exposed structural asset increases flood insurance between \$311 and \$586 (or 0.4% to 0.75% increase in coverage demand for a 1% increase in asset value). We find evidence of significantly higher insurance coverage in the V-zone (100-year flood zone exposed to storm surge), on the order of tens of thousands of dollars, relative to the A-zone (standard 100-year flood zone), despite the fact that flood insurance is more expensive in the V-zone. This pattern of results suggests that, conditional on the price of flood insurance and the value of the asset at risk, homeowners anticipate higher damage and thus purchase greater coverage in the 100-year flood zone with storm surge relative to the standard 100-year flood zone. Evidence is mixed on flood insurance coverage in lower risk zones B/C/X (500-year or greater flood zones), but results we expect to be more reliable (full dataset) suggest higher average flood insurance coverage in lower risk zones

²⁰ The reduction in public funds for flood-related payouts will induce countervailing welfare increases for the general populace (assuming that the savings in public expenditures are utilized for other programs that people value or rebated to tax payers in tax cuts).

²¹ The Natural Hazards and Human Dynamics (HHD) component of The Renaissance Computing Initiative at East Carolina University (RENCI@ECU) is a longitudinal study attempting to address some of these issues (<http://www.ecu.edu/renci/>).

relative to A-zone, ranging from \$9100 to \$29,500. Generally, one would expect lower flood insurance coverage in lower risk zone, but because expected loss and price are lesser in lower risk zones, households may view insurance as a better deal, and thus purchase higher coverage. Consistent with previous research (Browne and Hoyt 2000; Kriesel and Landry 2004) we find a positive and statistically significant income elasticity, around $\varepsilon_I = 0.21$.

Lastly, consistent with the findings of Kriesel and Landry (2004), we find evidence that community level erosion hazard mitigation projects influence flood insurance holdings. Contrary to Kriesel and Landry, however, we find asymmetry across the type of project, with shoreline armoring appearing to act as a substitute for flood insurance (reducing coverage by around \$50,000) and beach replenishment having a positive but insignificant effect on demand. This distinction is important as communities often apply for credit within the context of the Community Ratings System for hazard mitigation projects in order to reduce their flood insurance premiums. The NFIP may be more inclined to recognize and award credit for projects that are seen as complementary to flood insurance purchase.

Conclusions

We use multiple regression analysis to explore behavior and test theory regarding the determinants of flood insurance coverage using micro-level data for two counties in coastal North Carolina. Unlike previous research, we incorporate both the extensive (whether or not a household holds flood insurance) and intensive margin (how much insurance) of demand and employ measures of marginal insurance premium to assess price elasticity. For our preferred specifications, we find evidence of price inelastic demand, but subsidized policyholders hold greater coverage and exhibit elastic demand.

We find support for rational choice in the coastal zone, with flood insurance coverage increasing in the estimated value of the asset at risk. We find higher average coverage in the V-flood zone (100-year flood zone with additional risk due to storm surge), but also find higher coverage in lower risk zones, both relative to A-zone (100-year flood zone, or SFHA). Consistent with expectations, results suggest that properties that are mortgaged hold greater flood insurance coverage. Though, less than half of the properties in our dataset are mortgaged. We find a positive and statistically significant income elasticity that is significantly less than one indicating the flood insurance is a normal good; higher average income is associated with higher flood insurance coverage, but the percentage increase in coverage is less than the percentage increase in income.

We find limited evidence that erosion risk affects flood insurance demand. A household facing higher erosion risk demands greater insurance coverage, but the effect is not statistically significant. Lastly, we find evidence that community level erosion hazard mitigation projects influence flood insurance holdings, with shoreline armoring appearing to act as a substitute for flood insurance. Unfortunately, we are unable to address the importance of “charity hazard”, or a reliance on third-party assistance in the event of natural disaster. Finding data that will allow for an assessment of charity hazard vis-à-vis other determinants of flood insurance demand remains an important topic for future research.

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Table 1: Insurance, Physical, and Parcel Descriptive Statistics

Var	Definition	Brunswick			Dare		
		N	Mean	Std dev	N	Mean	Std dev
part*	NFIP participation indicator	623	0.570	0.580	1069	0.533	0.598
flcov	NFIP flood insurance coverage (\$100)	587	686.43	887.75	1007	787.75	1085.38
condcov	NFIP flood insurance coverage (\$100) for participants	326	1254.90	670.12	495	1555.96	790.08
vzone*	V flood zone indicator	623	0.813	0.456	1069	0.325	0.561
azone*	A flood zone indicator	623	0.145	0.413	1069	0.591	0.589
elev	Elevation above base flood elevation (BFE)	623	0.555	6.303	1069	7.862	6.047
ocean*	Oceanfront property indicator	623	0.456	0.583	1069	0.632	0.577
hp	Housing sales price (1000s current \$)	282	160.308	619.430	396	167.445	201.975
sqft	Square footage	367	1528	2022	1027	2220	2647
yearbuilt	Year structure built	493	1976	14.582	1002	1978	18.447
yearsold	Year parcel sold	484	1988	10.394	500	1986	13.255
pfirm*	Indicator for structure built before FIRM	623	0.397	0.573	1069	0.240	0.511
subsidy*	Indicator for subsidized insurance	623	0.638	0.563	1069	0.328	0.5630
brkwy*	Indicator for breakaway walls present below structure	623	0.027	0.190	1069	0.007	0.102
obstet*	Indicator for obstructions present below structure	623	0.094	0.342	1069	0.047	0.256
piles*	Indicator for structure on piles	623	0.845	0.424	1069	0.868	0.405
crs	Community Ratings System classification (1998)	623	8.711	0.530	1069	7.822	0.883
prem_hi	Marginal flood insurance premium (high)	623	1.433	1.383	1069	0.516	0.693
prem_lo	Marginal flood insurance premium (low)	623	1.172	1.143	1069	0.416	0.546
er	Erosion rate (feet/year)	623	1.305	2.061	1069	2.691	4.495
ar	Accretion rate (feet/year)	623	0.016	0.059	1069	0.007	0.064
geotime	Number of years expected before erosion reduces setback to zero	623	3269	18636	1069	840.8	9475
distance	Distance from the shore (feet)	623	255.01	187.29	1069	313.62	263.19

* - dummy variable; descriptive statistics are weighted to correct for T-scale sampling scheme.

Table 2: Household Descriptive Statistics from Mail Questionnaire

Var	Definition	Brunswick			Dare		
		N	Mean	S.D.	N	Mean	S.D.
income	Categorical income variable	246	85.268	86.721	400	109.129	98.539
gradsch*	Graduate school indicator	257	0.361	0.666	412	0.431	0.672
college*	College graduate indicator	257	0.495	0.693	412	0.405	0.666
hschool*	High school graduate indicator	257	0.143	0.486	412	0.163	0.501
parttime*	Part-time employed indicator	259	0.029	0.235	408	0.032	0.240
retired*	Retired indicator	259	0.547	0.690	408	0.394	0.663
age	Age of respondent	255	62.418	15.538	407	59.361	15.907
children	# children in the household	272	0.393	1.287	429	0.569	1.551
wo_ins*	Individual would have purchased property regardless of flood insurance availability	248	0.557	0.691	388	0.576	0.677
laps_ins*	Flood insurance has lapsed in past	238	0.031	0.248	376	0.061	0.326
claim*	Previous flood insurance claim has been submitted and settled	272	0.128	0.469	429	0.073	0.362
mort*	Property is mortgaged	264	0.320	0.644	419	0.487	0.681
requ*	Mortgage lender required flood insurance purchase	264	0.168	0.519	410	0.122	0.438
ero_kno*	Respondent has seen information on the erosion rate at the nearest shore	272	0.306	0.647	429	0.337	0.657
armor*	Shoreline armoring employed at the nearest shore	272	0.144	0.492	429	0.028	0.230
nourish*	Beach replenishment employed at the nearest shore	272	0.519	0.701	429	0.162	0.512
primary*	Coastal property is primary residence	263	0.073	0.352	411	0.052	0.299
vacation*	Coastal property is vacation home	263	0.292	0.613	411	0.262	0.593
pt_rent*	Coastal property is part-time rental	263	0.461	0.672	411	0.560	0.668
rental*	Coastal property is full-time rental	263	0.172	0.509	411	0.124	0.445
- Explanations for not holding flood insurance (subset)							
norisk*	Indicates respondent thinks the risk of flooding is very low	21	0.210	1.256	42	0.220	1.024
notreq*	Indicates flood insurance not required	21	0.353	1.473	42	0.230	1.039
too_exp*	Indicates respondent thinks flood insurance is too expensive	21	0.261	1.354	42	0.184	0.956
notavail*	Indicates that flood insurance is perceived as not available	21	0.058	0.721	42	0.086	0.694
* - dummy variable; descriptive statistics are weighted to correct for T-scale sampling scheme and over-representation of flood insurance participants.							

Table 3: Hedonic Price Regression Model

Variable	Coeff	Std Error
sqft	0.000236*	0.000049
sqft ²	-6.11281E-9*	1.758388E-9
no_sqft	-0.2133	0.1776
lotsize	0.0000167	0.0000106
lotsize ²	-3.2468E-10	1.72351E-10
house age	-0.0088*	0.0035
vacant lot	-0.3144*	0.0856
oceanfront	0.4746*	0.0765
brun	-0.0653*	0.0807
constant	11.558	0.17655
Year dummy variables	YES	
R ²	0.4813	
F (<i>p</i> -value)	25.15 (<i>p</i> < 0.0001)	
N	816	
* - indicates statistical significance at the 5% level; dependent variable = ln(house price)		

Table 4: Tobit Model Results (High Premium)

Variable	Model 1		Model 2		Model 3	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
premium	-882.79	320.748	-543.72	211.076	-442.93	172.273
subsidy			848.27	284.229		
prem×sub			-2309.16	851.474		
vzone	773.22	246.757	1051.26	332.976	138.75*	130.523
xzone	502.86	190.212	402.23	170.581	-1082.66	448.432
asset_val	9.20	3.193	7.64	2.687	13.08	4.917
armor					-902.31	399.158
nourish					208.04*	147.776
vacation					145.19*	153.369
primary					358.41	168.892
mort					808.08	265.816
income					5.66	1.964
retired					-244.08*	151.982
college					-158.87*	142.575
hschool					-427.28*	220.799
brun	624.99	207.149	715.8	231.765	316.59	151.499
constant	-694.73	305.801	-544.34	261.748	-794.94	391.277
sigma	2347.63	766.171	2241.43	730.412	1547.08	479.525
state fx	YES	YES	YES	YES	YES	YES
N	1579		1579		533	

* - not statistically significant for 5% probability of Type I error.

Table 5: Tobit Model Results (Low Premium)

Variable	Model 1		Model 2		Model 3	
	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
premium	-2655.77	946.31	-1394.07	537.95	-952.36	340.96
subsidy			2540.35	845.31		
prem×sub			-4321.7	1598.52		
vzone	1618.97	524.23	1610.47	519.99	267.53	134.467
xzone	661.60	283.57	538.42	261.99	-1010.96	422.345
asset val	7.09	2.66	6.54	2.51	12.36	4.671
armor					-906.38	395.544
nourish					259.32*	151.976
vacation					148.21*	149.236
primary					300.35*	163.398
mort					802.25	263.555
income					5.42	1.893
retired					-147.18*	129.892
college					-133.46*	133.895
hschool					-345.81*	196.321
brun	1400.97	463.59	1278.82	423.17	440.61	172.162
constant	-3646.74	1282.45	-3963.13	1391.38	-663.08*	352.087
sigma	3657.04	1192.41	3570.54	1162.15	1508.26	468.012
state fx	YES	YES	YES	YES	YES	YES
N	1579		1579		533	

* - not statistically significant for 5% probability of Type I error.