Economic Value of Multi-peril Coastal Hazard Insurance

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Abstract

Expanding the National Flood Insurance Program to allow policyholders to purchase optional erosion coverage eliminate coverage disputes when erosion and flood both contribute to a loss, and provide affordable national erosion coverage. We examine the household welfare effect of multi-peril hazard insurance coverage by coupling information on NFIP policy in force with a survey data for a sample of coastal households in the US southeast. Our results indicate that the value of multi-peril hazard insurance is substantially higher for households who live in the coastal zone. We also test effect of risk perception (subjective risk assessment) on individuals' decision to purchase multi-peril hazard insurance and find that higher risk perception lead to higher probability of purchasing multi-peril insurance coverage and increases the mean willingness to pay for insurance.

JEL Classification: Q54, D81

1. Introduction

In the aftermath of Hurricanes Katrina and Rita, individuals and businesses in Louisiana, Mississippi, and Alabama protested against perceived inequities and obstacles in the settlement of property damage insurance claims. When insurance adjustors and damage experts assessed the properties damaged by these storms, they were faced with the difficult issue of allocating damages between wind (responsibility of private or state insurance) and flood (responsibility of federal government). Post-Katrina delays in damage assessments and extended litigation of insurance claims generated economic uncertainty and copious ill will among insurance holders and raised concerns about post-event judicial interpretations of the scope of insurance coverage. One insight that emerged from the wind vs. water claims dispute was the potential for expanding hazard coverage to permit policyholders to purchase multi-peril insurance. The idea of broadening hazard exposure for a catastrophe insurance program like the National Flood Insurance Program (NFIP) raises serious concerns among insurance experts due to actuarial difficulties in underwriting diverse catastrophes, practical problems of financial insolvency risk that currently exist for the NFIP, and existing private market insurance for other perils (King 2013). Proponents of multi-peril insurance coverage, on the other hand, argue that such a product would eliminate coverage disputes for correlated hazards (e.g., flood, wind, and coastal erosion) while enhancing marketability and simultaneously allowing for reasonable amounts of cross-subsidization that could improve capital reserves (King 2013).

Currently, the NFIP offers indemnification from flood hazard in communities that agree to regulate development in floodplains. The mapping and regulatory standards of the NFIP, however, do not currently address erosion risk in coastal areas. Flooding and erosion risk are highly correlated along the waterfront; chronic erosion reduces beaches, dunes, and other sediments that maintain a buffer from waves, tides, and storm surge. Though not explicitly indemnifying property loss due to erosion, the NFIP pays an estimated $80 million per year in damages related to erosion (Heinz 2000). This, however, is just a fraction of projected erosion losses, a staggering $500 million per year over the next 60 years. As currently designed, NFIP policies cover erosion damage that occurs in conjunction with flooding, but not erosion losses that occur at other times (e.g. associated with strong waves). Community Rating System (CRS)[1] credit, nonetheless, is granted to coastal communities that include erosion hazard in their regulations, planning, public information, hazard disclosure, and flood warning programs, and this can result in discounted premiums for policy holders in these areas (FEMA 2016).

[1] Community Rating System (CRS) recognize communities for their additional efforts to (1) reduce flood damage to insurable property; (2) strengthen and support the insurance aspects of the NFIP; and (3) encourage a comprehensive approach to floodplain management (FEMA F-084/March 2011).

Since 1) flooding and erosion risk are correlated, 2) the NFIP currently indemnifies flood risk in coastal areas, and 3) there is considerable residual erosion risk for coastal property owners, we examine the potential for multi-peril coastal hazard insurance. We utilize existing survey data to analyze the potential demand for coastal hazard insurance that bundles indemnification of flood and erosion risks. Despite the availability of multi-peril insurance in countries like the UK, France and Germany, and the existence of multi-peril crop insurance in the US, little is known about the economic value of bundled natural hazard insurance. Catastrophe insurance programs like NFIP often have low market penetration, which limits the effectiveness of insurance and mitigation as risk management tools. While there are some potential explanations for low market penetration (Anderson 1974; Pasterick 1998; Wetmore et al. 2006[2]), individual difficulties in assessing risk are a common explanation. Multi-peril insurance contracts can address some of these difficulties by offering a broader range of coverage that could be more marketable (i.e. providing "peace of mind").

To the extent of our knowledge, ours is the first study that combines revealed and stated preference data on different hazard insurance products to estimate welfare effects of bundling. We utilize an older, but unique, dataset on households within approximately 1000 feet of the ocean on the southeast US coast (Atlantic and Gulf). The data include information from the Federal Insurance Administration's policies in force database; field information on parcel-level risk factors collected by contractors for H.J. Heinz III Center for Science, Economics, and Environment; and responses to a household survey

[2] Anderson 1974: inability of insurers to pool insureds with varying degree of exposure to flood losses because lower risks will not purchase coverage at a pooled rate. Wetmore et al. 2006: lack of insurer in the community and less vigorous enforcement of mandatory purchase requirement. Pasterick 1998: opting not to purchase flood insurance due to reliance on federal disaster assistance.

questionnaire administered in 1998. The revealed preference data relate to flood insurance purchase and were previously utilized to analyze NFIP participation (binary outcome) (Kriesel and Landry 2004) and flood insurance coverage levels (censored, continuous outcome) (Landry and Jahan-Parvar 2011). Kriesel and Landry find generally greater flood insurance purchase in coastal areas and in areas with artificial erosion protection (shoreline armoring and/or beach replenishment). They find that distance from the shoreline and lower hurricane risk (as indicated by greater period between historical hurricane landfalls) decrease flood insurance purchase. Landry and Jahan-Parvar also find a positive correlation between erosion rates and flood insurance demand, suggesting that erosion risk may influence flood insurance purchase.

The stated preference data contain contingent valuation responses to offers of hypothetical insurance coverage for erosion damage and were previously analyzed by Keeler, Kriesel, and Landry (2003). They find a negative premium effect, positive income effect, and mixed results for erosion protection (negative for beach replenishment, but positive for shoreline armoring). We build on these studies by combining revealed and stated preference data, permitting correlation amongst purchase decisions, and examining the role of individual risk perceptions derived from survey responses. Our analysis contributes to the literature by investigating household risk perception, multi-peril insurance demand, and welfare effects of bundling hazard insurance. While our empirical focus is on flood and erosion insurance, our intent is to provide insight into the role of risk perceptions and bundling of insurance products for multiple perils on insurance purchase decisions.

The remainder of the paper is organized as follows. Section 2 provides a review of the background literature on multi-peril insurance and effect of individual risk perceptions on insurance purchase decisions. Section 3 presents our conceptual model, and Section 4 introduces the study area and data sources. Section 5 describes the econometric model; Section 6 present estimation results and empirical findings, and section 7 concludes.

2. Background

2.1. National Flood Insurance Program and multi-peril insurance

Congress created the U.S. National Flood Insurance Program (NFIP) in 1968 to offer indemnification and guide management of flood hazard in participating communities. Broadly speaking, the NFIP aims to identify and map the nation's floodplains to make the public aware of flood hazards and to address the escalating cost of federal disaster assistance for flood damages. This national program attempts to partner with flood-prone communities to encourage adoption and enforcement of floodplain management measures in the form of guiding development and building practices. In return, households and businesses in participating communities can purchase insurance as protection against flood losses (King 2012).[3]

Since its inception, there have been numerous attempts to improve the performance of the NFIP, in particular to increase accuracy of risk rating, improve actuarial assessments, motivate participation by flood prone communities, and incentivize insurance uptake by individual households. For instance, the Flood Disaster Protection Act of 1973 expanded coverage to flood-related erosion losses, and in 1988 the Upton-

[3] More information on the history and structure of NFIP can be obtained from book written by Kunreuther and Roth (1998).

Jones Amendment provided coverage for relocation or acquisition of properties that were in imminent danger of collapse due to encroaching shorelines. Citing limited effectiveness in incentivizing mitigation and a lack of premium basis to fund such coverage, the Upton-Jones provisions were later rescinded (Simmons 1988; Kunreuther and Roth 1989).

Since Hurricanes Katrina and Rita in 2005, the multi-peril insurance approach has been discussed as a way to address the NFIP's financial solvency problems and to deal with complications in attribution when various hazards contribute to property damages. Since then, attempts to amend the NFIP to cover multiple perils have been unsuccessful. For example, in 2009 Representative Gene Taylor of Mississippi introduced the Multiple Peril Insurance Act in the U.S. Congress, with the goal of adding wind hazard to flood insurance, but this proposal failed to gain attraction. Supply-side concerns surrounding multi-peril insurance include the difficulties in actuarial analysis and simulations that would be required to underwrite correlated catastrophic losses. Additional practical problems revolve around the current financial deficits in government catastrophe insurance programs (like NFIP) and how such programs would affect private insurance products for related perils (King 2013).

Nonetheless, there are potential benefits associated with bundling insurance products. First, multi-peril insurance could enhance efficiency in risk financing through greater pooling and diversification of risk (King 2013). Second, pooling many risks reduces the threats of depleting funds to pay out claims because it is less likely that a deluge of claims will arise out of a single catastrophic event, and paying out claims won't be deterred because there is no need to distinguish between the sources of damages

(Majmudar 2008). Lastly, broad distribution of hazard coverage could result in better market penetration if households view multi-peril protection as a beneficial service that obviates the need for detailed assessment of individual-level risks, provides for overall piece of mind, and enhances the likelihood of quick and easy settlement of claims.

2.2. Risk perceptions and natural hazards

Like other common financial and investment decisions, demand for hazard insurance is influenced by risk perceptions and individual attitudes. Following standard convention, Bubeck et al. (2012) define *perceived risk* as combination of *perceived probability* and *perceived consequences* of an adverse event. A number of conceptual and theoretical frameworks exist for analyzing choice in risky contexts, but implementing these models in an empirical setting is difficult (Gilboa et al. 2008; Charness et al. 2013; Landry et al. 2016). Modeling choice under uncertainty is particularly problematic in the context of natural hazard insurance. Since probabilities are generally low, individuals tend to underestimate the likelihood of catastrophic natural events (Kunruther 1984; Schwarcz 2010; Browne et al. 2015), especially when there is no prior experience with a particular hazard (Kunreuther and Pauly 2004; Kunreuther and Pauly 2006; Siegrist and Gutscher 2006, 2008). This implies that subjective probabilities need to be assessed directly or revealed indirectly, typically via interviews or surveys (Morrison 1967; Schlaifer 1969; Hampton et al. 1973; Norris and Kramer 1990). Collection of primary data also permits analysis of risk perception in relation to socio-demographic factors, such as experience, family history, education, social factors (norms & position), and geographical location (Kogan and Wallach 1964; Harrison et al. 2007).

Risk perceptions (subjective probability) of natural hazards have been studied in recent years by using direct elicitation methods. In an experimental setting, Viscusi and Zeckhauser (2006) measure respondents' perception of 5th, 50th and 95th percentile expected temperature change in degrees Fahrenheit by asking respondents opinion about the upper bound, lower bound and best estimate of change in temperature. Baker et al. (2009) focus on a sample of Hurricane Katrina and Rita evacuees and examine the effect of individual's hurricane risk perception on hypothetical future location decisions. In their study, hurricane risk perception is measured with a graphical scroll bar, bounding hurricane risk between 0 and 100 percent.

Categorical measures of relative risk perception have been used in empirical analysis of wildfire risk mitigation (Martin et al. 2009) and hurricane evacuation (Lazo et al. 2010). Martin et al. (2009) use a composite measure of risk perception, constructed by combining information from five Likert-Scales questions that includes the assessment of both probability and consequences of impacts, to analyze wildfire risk mitigation decisions.[4] In a hypothetical setting, Botzen and van den Bergh (2012) apply Bayesian updating to elicit subjective probability of climate-induced flooding; they find a positive relationship between the insurance demand and risk perception. Petrolia et al. (2013) measure risk perceptions of hurricane return intervals and expected structural damages for a particular strength hurricane along the US Gulf Coast in their analysis of flood insurance demand; they find that individual with higher risk perception and prior experience of flood are more likely to participate in NFIP.

[4] Questions of risk perception and consequence of impacts: ''to what extent do you feel concerned about the effects of wildfire'', ''how serious do you feel the negative consequences of wildfires are to you personally'', ''how vulnerable do you feel about the possibility of wildfire physically affecting you or your family'', ''how vulnerable do you feel about the possibility of wildfire affecting your property and/or possessions'', and ''how severe will the impact of a wildfire be where you live''.

3. Conceptual framework

The decision to purchase insurance can be cast in the framework of utility maximization under uncertainty (Smith 1968). If we condition this decision upon subjective evaluation of risk, then it is equivalent to the concept of "Subjective Expected Utility" (Savage 1954). Consider a consumption prospect (x) that reflects current wealth (w) and the possibility of flood damage (d^f) and/or erosion damage (d^e) to a residential structure: $x_i = w_i - d_i^f - d_i^e$. Likelihoods of flood and erosion loss vary spatially according to trends in precipitation and sub-tropical storms, topography, geomorphology, as well as physical attributes of structures at risk and surrounding public infrastructure. Subjective perceptions of risk also reflect individual factors, such as knowledge, experience, and beliefs.

Individual decisions on managing flood and erosion risk thus reflect subjective risk perceptions, utility levels associated with consumption prospects, availability and pricing of insurance and mitigation projects, and risk preferences. Packaging these elements in the subjective expected utility framework, we specify a decision model as (suppressing individual subscripts, i):

$$SEU(x) = \sum_{j \in f,e,fe} [p^j\,(h,z)U\big(w - d^j + n^j - \pi; \alpha\big)] + p^o(h,z)U(w - \pi; \alpha) \qquad [1]$$

where $p^j(h,z)$ is the subjective perception of event j = flood damage (f), erosion damage (e), flooding and erosion damage (fe), or no damage (o) (which depends upon localized physical conditions (h) and individual characteristic (z)); n^j is insurance cover for damage $j = f, e, fe$; π is the price of hazard insurance, and α indexes individual risk tolerance. Optimal choice of insurance cover thus represents a tradeoff between consumption in the no-loss state and the loss ($j = f, e, fe$) states. Demand for insurance n^j will be influenced by subjective perceptions of flood and erosion losses, conditional damages, wealth level, insurance premiums, and risk tolerance.

In this study, we focus on the role of empirically estimated subjective probability parameters ($\tilde{p}_i^j$) on individual decisions to purchase flood and erosion insurance coverage. Based on both theoretical (Kunreuther, 1984) and empirical studies in the literature (Martin et al. 2009; Botzen and van den Bergh, 2012; Petrolia et al., 2013), we expect that higher risk perceptions increase insurance demand. We utilize first-stage regressions that map indicators of latent risk perceptions into the unit interval, while permitting correlation among perception of flood and erosion risk. While not a structural model, utilizing survey data to estimate subjective risk perceptions improves the model and incorporates structural parameters in estimation. Unfortunately, information on other structural parameters in equation [1], such as expected losses and indictors of risk aversion, are not available in this study.

We posit individual risk perceptions as a function of physical risk factors—flood zone and shoreline erosion rate—and an indicator of hazard mitigation efforts (presence of shoreline stabilization structures such as seawalls, rip-rap, groin, break water or utilization of beach replenishment). Households located in the Special Flood Hazard Area (SFHA, also known as the 100-year floodplain) face federal flood insurance requirements for the majority of mortgage contracts and are exposed to flood-risk disclosure provisions in some areas. Perceptions of risk can also be influenced by public infrastructure projects that are designed to mitigate hazards (Botzen, Aerts, and van den Bergh, 2009; Bubeck, Botzen, and Aerts, 2012; Peacock, 2003). The influence, however, is ambiguous, as mitigation projects can convey a sense of security (reducing risk perception) or heighten saliency of vulnerability (increasing risk perception).

Individual factors affecting risk perception include prior experience with hazards and demographic factors like age and education. Previous research has found that prior personal experience with natural hazard losses increase risk perception (Browne and Hoyt 2000; Lindell and Perry 2004; Peacock et al. 2005). This pattern is consistent with the Bayesian learning model of Viscusi (1991) in which individuals may exhibit overly optimistic expectations of disaster loss prior to experiencing an event (Palm et al. 1990; Kunreuther et al. 1987). Experience can foster learning, which may influence risk perceptions. For instance, Martin et al. (2009) found relatively high correlation between the risk perception and subjective knowledge about wildfires. Other individual characteristic such as age and education can also play a role in risk perception and evaluation. In a general context, Savage (1993) illustrates that for four common hazards (aviation accidents, fires in the home, automobile accidents, and stomach cancer) younger people have significantly higher "dread" of hazards than older people.

4. Study area and data

The dataset in this study includes information from Federal Insurance Administration's policies in force database; parcel-level field data collected information by H.J. Heinz III Center for Science, Economics, and Environment under the direction of FEMA; and household-level survey questionnaire responses collected in 1998.[5] Combining these information sources, we make use of both revealed and stated preference data on insurance purchase decisions in coastal counties, seeking insight into economic value of

[5] As of march 1998, 18,760 communities out of 21,000 flood-prone communities, had joined the NFIP with approximately 4 million policies in force (Pasterick, 1998)

multi-peril insurance products[6]. The coastal counties are located in North Carolina (Brunswick and Dare), South Carolina (Georgetown), Florida (Brevard and Lee), Texas (Brazoria and Galveston) and Delaware (Sussex), with North Carolina, Texas, and Florida providing the bulk of survey respondents (41, 29, and 12 percent, respectively)[7]. Galveston and Brazoria counties in Texas have the highest number of residents in high flood risk areas (V-Zone), while most of residents in Lee and Brevard Counties locate in moderate (A-Zone) and low risk areas (B/X/C Zone). It should be noted that to ensure adequate coverage on the oceanfront, which was focus an important aspect of the original study, stratified sampling was used. Thus summary statistics and econometric estimation must employ sampling weights. In the remainder of this section, variables from various data sources are introduced. Table 1 presents the description and source of data and table 2 presents the descriptive statistics of variables used in our analysis.

4.1. Revealed preference information on flood insurance purchase

Revealed preference information on flood insurance purchase is available from both the Federal Insurance Administration's policies in force database and the household survey questionnaire. The policies-in-force database contains accurate information on coverage levels, deductibles, and other aspects of NFIP insurance contracts.

The field data permit accurate assessment of parcel-level risk factors and flood insurance prices (which depend upon elevation above base flood, among other things). Information on structure elevation, ocean frontage, distance from shoreline, flood zone (V-Zone, A-Zone, and B/C/X-Zone) and erosion and accretion rates are provided from

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[6] All counties in this study are participating in the NFIP.

[7] Based on the study by Dixon et al. (2006) nearly 60 percent of single-family homes (SFHs) in the SFHAs nationwide are in the south, and market penetration rate of SFHs is considerably higher in South and West of U.S (approximately 60 percent). Besides, under plausible assumptions, the compliance rate with the mandatory purchase requirement in the south is 80 to 90 percent. This gives us confident that results of this study would hold for the NFIP eligible property owners that may experience erosion.

Heinz Center (2000) field survey. Overall, 47% of the properties are located in the V-zone (100-year flood zone), which is among the "Special Flood Hazard Areas" (SFHA), but with additional risk of high-velocity waves due to storm surge. Another 31% of the properties are located in A-zone, which is the standard SFHA or 100-year flood zone. Other properties are located in moderate or minimal flood risk area referred as B/C/X zone, which is the reference category in our estimation.[8] The vertical and horizontal distances in this study ranges from 10 feet below to 29 feet above the sea level, and 0 to 1700 feet from shoreline, respectively. Thirty-two percent of properties are classified as ocean front properties, and 94% are located along an eroding shoreline (with average erosion rate of 3.8 feet per year). The small minority of properties is located in accreting areas, with average accretion rate of 1.8 feet per year. The erosion variable in our analysis takes negative values for the accretion and positive values for erosion.

Full coverage premium for each property is estimated using NFIP rate tables and detailed property characteristics, such as year of construction relative to release of Flood Insurance Rate Maps (FIRM), being located in the Special Flood Hazard Area (SFHA), structure value,[9] and physical characteristics, like having a basement, elevation on piles, etc.[10] The average estimated full coverage premium is $1,018 hundred dollars. Full coverage premium is divided by the structure value so that normalized flood insurance price is expressed in units of coverage and also be comparable with the erosion coverage premium that will be explained later. The flood insurance coverage premium ranges from $0.07 to $4.20 per $100 covered assessed asset value.

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[8] To ensure adequate coverage on the oceanfront and reporting representative statistics, stratified sampling and weights are used.

[9] We used the assessed value of structure estimated by hedonic regression model from Landry and Jahan-Parvar (2011).

[10] Detailed explanation on the underlying assumptions of estimating full coverage premium is available in Landry and Jahan-Parvar and can be provided upon request (2011).

4.3. Survey data and stated preference information on erosion insurance purchase

The survey data collected through mail questionnaire provide detailed information on flood and erosion risk perceptions; previous experience with flood damage or filing of flood insurance claims; socio-demographic characteristics including age, education, and income; and a stated preference question inquiring about individual willingness to purchase additional insurance for erosion damage. The stated preference scenario was described as follows:

> *Suppose that the National Flood Insurance Program were expanded to cover erosion damages, regardless of whether a flood had occurred. To avoid being subsidized by tax dollars, the Program would have to charge policyholders more for this expanded coverage.*
> *Suppose that this expanded erosion damage coverage were offered to you for an additional $_____________ per year above what you now pay.*
> *Would you purchase this coverage?*

Offer prices were expressed as an annual payment, varying randomly in 30 increments from $25 to $24,000, and were defined as an additional payment to current premium (which is zero for NFIP non-participants). Following procedures with flood insurance price, the offer price for erosion coverage is divided by the assessed structure value so that erosion insurance price is expressed in units of asset value covered; proposed erosion insurance coverage premium ranges from approximately $0 to $104.5 per $100 covered assessed asset value (table 2). Fifty-four percent of households in our sample are NFIP participants, and 28% of them are willing to pay for the addition of erosion coverage to the NFIP. Nineteen percent of NFIP non-participants elect to pay additional premium for the optional erosion coverage. Thirteen percent of respondents perceive that they are required to purchase the flood insurance provided by NFIP, and our data suggest that 80% comply.

Regarding our interest in investigating the impact of risk perception on insurance purchase decision, two questions in the survey data provide information on individuals' risk perception for flood and erosion damages that enable us to estimate a model of individual "joint flood-erosion risk perceptions". In the flood section of the survey questionnaire, individuals provide a binary respond to the question, "*would you have purchased coastal property regardless of whether flood insurance were available?*" We interpret *no* response as reflecting high flood risk perception and *yes* response as reflecting low flood risk perception. For individual perceptions of erosion risk, we utilize responses to the question, "*how likely do you expect it is that erosion occurring over the 30 next year will significantly reduce the price for which your property could be resold by you or your heirs?*" Respondents that indicated *no chance* or *unlikely* are identified as having low erosion risk perception, whereas those answering *likely* or *highly likely* are identified as having high erosion risk perception. For simplicity, we refer to these two nominal risk perception variables as flood risk perception and erosion risk perception, and we use them to determine the parameter of joint flood-erosion risk perception.

We use indicator of filing a flood insurance claim, as the proxy for the personal prior experience of the natural disaster. Among all respondents, 10% state that they have experienced flood damage and filed insurance claim. To capture impact of erosion mitigation measure at community level on risk perception we use an indicator variable that takes value one when any of erosion mitigation measure (*sea wall, rip-rap, groin/jetty, break water, sand nourishment, dune fences/dune grasses, raised walkways, others*) has been attempted during the time that respondent own the property. Sixty percent of respondents claim that at least one of the above erosion mitigation measures has been used in their community to protect against erosion.

5. Econometric model

In this paper, we utilize a two-step regression analysis. First, we estimate the joint risk perception of individuals for flood and erosion using bivariate Probit, and then we estimate flood and erosion insurance demand conditional on the results of the first step estimation and determine the marginal effects of relevant covariates (e.g., insurance price, risk perception) and mean willingness to pay for the multi-peril insurance product.

5.1. First step: Joint flood-erosion risk perception

Empirical approach for solving subjective expected utility maximization problem is to set up a reduced form specification for the Marshallian-type demand function with assuming linear approximation of subjective expected utility.

We incorporate flood risk perception (R_{fl}) and erosion risk perception (R_{er}) in a bivariate probit model, to utilize all the available information that affects individual risk assessment, and generate a subjective risk measure for multi-peril coastal hazard using non-nested seemingly unrelated regressions.

$$R_{er}^{*} = F(X)\beta_1 + \varepsilon_1, \quad R_{er} = 1 \; if \; R_{er}^{*} > 0\,, 0 \; otherwise \qquad [2]$$

$$R_{fl}^{*} = F(X)\beta_2 + \varepsilon_2, \quad R_{fl} = 1 \; if \; R_{fl}^{*} > 0\,, 0 \; otherwise \qquad [3]$$

$$[\varepsilon_1 \quad \varepsilon_2 |\, F(X)\,] \sim N[(0,0), (1,1), \rho], \qquad [4]$$

where R_{fl}^{*} and R_{er}^{*} are latent variable representations for individual risk perception of flood and erosion risk, with, for example, $R_{fl} = 1$ and $R_{er} = 1$ if we interpret responses as indicating high flood and erosion risk perception, respectively. Evaluating the bivariate normal CDF (Equations [5]) gives us conditional estimates of individuals' subjective probability of flood and erosion loss:

$$\pi_{11}(\hat{\theta}) = \Pr\left(R_{fl} = 1, R_{er} = 1 \mid \mathrm{F(X)}\right), \qquad [5]$$

where $\theta = (\beta_1 \quad \beta_2 \quad \rho)$ is vector of regression and correlation coefficients for flooding and erosion risk perception equations. In a general setting, for a binary variable, we assume normality and utilized the Probit model in order to estimate the reduced form; therefore, the perceived predicted probability of flood and erosion for each individual is the evaluated joint probability distribution obtained from bivariate estimation of flood and erosion risk perception, conditional on vector of linear combinations of the individual characteristic variables and location determinants, $F(X)$. X includes age, level of education, having filed an insurance claim, distance to shore, indicator for property located in the 100-year flood zone-SFHA, taking mitigation measures for erosion. We reduce the dimensionality of vector X by using the Multiple Correspondence Analysis (MCA). Using MCA method, we obtain the common trends of variation behind influential regressors, avoid loss of degree of freedom in the first step regression, and deal with the multicollinearity problem between estimated risk perception parameter and vector X in the second stage regression. With a significant correlation coefficient between flood and erosion risk perception equations, the natural conditions for well-behaved probability distribution and the underlying assumption of normality provide reasonable conditions for identification. Fitting latent risk perception response data with a bivariate normal cumulative distribution function confines all the conditional probabilities between 0 and 1 and guarantees the sum of the probabilities for occurrence of each mutually exclusive event (i.e. no loss; flood loss; erosion loss; erosion & flood loss) equals one (Anderson et al. 1977) – desirable conditions for a subjective probability distribution function. While it is difficult to find instrumental variables that would permit clear identification of the subjective probability function, these natural conditions for well-behaved probability distribution and the assumption of normality provide reasonable conditions for identification.

Incorporating individual risk perceptions in the estimation of the multi-peril insurance demand allows us to explore the effects of subjective probability perception on insurance purchase decisions (for both flood and erosion) and mean willingness to pay for multi-peril hazard insurance. The use of an initial regression equation, however, introduces a generated regressor problem (Wooldridge 2002), which complicates inference. To produce reliable coefficient estimates we use a parametric bootstrap procedure introduced by Efron and Tibshirani (1986).

5.2. Second step: Multi-peril hazard insurance demand

We permit interdependence of demand for flood and erosion insurances by modeling the binary responses simultaneously in a bivariate Probit framework and define $y_{1i} = 1$ if a household participates in the NFIP (equivalent to "yes" response to flood insurance bid price per \$100 coverage, and zero otherwise) and $y_{2i} = 1$ if individual response to the erosion stated preference scenario is affirmative (indicating WTP for the offered premium per \$100 coverage, and zero otherwise). Using bivariate Probit likelihood function, defining $d_{1i} = 2y_{1i} - 1$ and $d_{2i} = 2y_{2i} - 1$, the i^{th} observation contribution to the likelihood function is:

$$L_i(\mu_i|d_{1i}, d_{2i}) = \Phi_{\varepsilon_1,\varepsilon_2}\left(d_{1i}\left(\frac{bid_{fl,i} - \mu_{1i}}{\sigma_1}\right), d_{2i}\left(\frac{bid_{er,i} - \mu_{2i}}{\sigma_2}\right), d_{1i}d_{2i}\rho\right) \tag{6}$$

where $[\varepsilon_1 \quad \varepsilon_2 | \mathrm{X}_1, \mathrm{X}_2] \sim \mathrm{N}[(0,0),(1,1),\rho]$ in the stochastic part of utility and μ_{ji} is means for the response that depends on the individual covariates ($\mu_{ji} = \mathrm{X}_{ji}\beta_j$) (Haab and McConnell 2002). X_{ji} are determinants of insurance demand function as it is introduced in equation [4] including the estimated joint risk perception parameter in the first-step regression. Generated regressor problem that rise due to inclusion of an imputed variable in the regression can be dealt with by applying bootstrapping procedure (Efron and Tibshirani, 1986) in estimation of coefficients.

The mean willingness to pay for flood and erosion insurance is estimated using the parameters of each equation; If $WTP_{ji} = \mu_{ji} + \varepsilon_{ji}$, WTP_{ji} represents the i[th] respondent's willingness to pay and j=1,2 represents answer to participation question for flood and erosion insurance. The estimated mean WTP facilitate analysis of welfare gain/loss from bundling flood and erosion insurance products. The initial assessment of distribution of the erosion purchase price illustrates that assuming normal distribution for the error term will lead to mean willingness to pay outside the realm of feasible values (negative mean WTP). Therefore, we also estimate the exponential WTP ($WTP_{ji} = e^{\mu_{ji}+\varepsilon_{ji}}$) and report the median WTP for insurance products.

To find the population of interest that has higher willingness to pay for the proposed multi-peril insurance, we investigate two subsamples in this study. First, we hypothesize that residents of oceanfront properties are more likely to have willingness to pay for the bundled insurance product and experience larger welfare gain if the erosion insurance market introduced to NFIP. As we discussed before, bundled insurance product can improve risk pooling for the insurer, if erosion insurance seems appealing to residents of erosion-prone areas who are not required to purchase flood insurance. Therefore, second subsample of interest investigate portion of households who are not required to participate in NFIP.

6. Results

Table 3 presents the result of first step regression to identify influential regressors to estimates the individual joint risk perception parameters. Living in high and moderate hazard areas (V-Zone and A-Zone) increases the probability of stating high flood and erosion risk perception and consequently lead to higher joint risk perception. Consistent with previous studies, prior flood experience leads to higher individual risk perception, and erosion mitigating measures undertaken by the local government in the community increases prior knowledge about the erosion and develop higher erosion risk perception. Attending graduate school compare to high school can lead to higher level of flood nominal risk perception, but not erosion. Utilizing the MCA method, we reduce the dimensionality of variables that determine risk perception and use two dimensions that explain 65% of the variation in the data. These two dimensions are mainly explained by the association between location determinants such as being located in vzone and b/c/x zone and county fixed effects, as well as the binary variable of experiencing a flood and filing insurance claim. Figure 1 shows the cumulative density functions of joint risk perception parameter that is estimated using a linear combination of location determinants and individual characteristic variables. From CDF of π_{11}, joint risk perception of approximately 40% of respondents is lower than 0.2.

First four columns of table 4 illustrate the regression results of joint estimation of flood and erosion insurance demand before controlling for the impact of individual risk perception. Alternative specification with the logarithm of the insurance premium is presented in columns 3 and 4. Wald statistics of correlation between errors of flood and erosion insurance equations is statistically insignificant, which denotes the independence of flood and erosion insurance decision for this sample (Wald test of rho=0, Chi-squared (1)= 2.20235, Prob > chi2= 0.1378).

Consistent with previous studies, coefficients of insurance premiums for flood and erosion equations are statistically significant (Browne and Hoyt, 2000; Kriesel and Landry 2004; Landry and Jahan-Parvar, 2011), with the marginal effect of (MWTP) 0.20 and 0.11 per $100 asset value covered for flood and erosion insurance, respectively. We find equal positive income effect of 0.20 for flood and erosion insurance demand. As expected, mandatory flood insurance is one of the main determinants of flood insurance decision with the marginal effect of 0.82. Consistent with the result of Botzen and van den Bergh (2012), we find no significant relationship between the elevation of property relative to flood plain and the insurance decision. Locating in high risk and moderate risk areas contribute to both higher risk perception (table 3) and a larger probability of purchasing flood insurance (table 4). Despite insignificant impact of proximity to shoreline on flood insurance decision, owners of properties closer to shoreline have a higher probability of buying erosion insurance.

In the second panel of table 4, we add the estimated joint flood-erosion risk perception parameters (π_{11}) to flood and erosion insurance demands for two specifications of linear and exponential WTP. The estimated coefficients of insurance price show no significant change from the base specification (left panel of table 4) across all specifications.

As we hypothesized, the estimated coefficient of joint flood-erosion risk perception parameter is significant across all specifications with a positive impact, which means risk perception contributes to higher penetration rate in the insurance market. The estimated elasticities of insurance demand with respect to risk perception are 2.40% and 2.44 % for flood a %2.45 and %3.24 for erosion in linear and exponential model respectively.

The addition of joint flood-erosion risk perception to the model leads to a slight increase in the partial effect of insurance price on insurance demand. A possible explanation for this result is that although the risk perception can increase the responsiveness of individual to change in insurance premium, it can't be a driving force in the multi-peril insurance market, as individuals may not be able to distinguish the risk of two perils when one already exists.

Comparing estimated marginal effects of risk perception variable in column 1 and 2 with 5 and 6 shows that including joint flood-erosion risk perception parameter in the model slightly increases the marginal effect of flood insurance premium from $0.20 to $0.25 per $100 covered asset value but reduce the marginal effect of erosion insurance premium from $0.11 to $0.032 per $100 covered asset value. This illustrates how higher risk perception reduces the elasticity of erosion insurance demand and provides justification on adding erosion to NFIP and offering multi-peril insurance products. Taking risk perception into account in the second panel of table 4, we find substantially higher positive income effect for flood (marginal effect: 0.169) compare to erosion (marginal effect: 0.050) insurance demand.

Table 5 summarizes the mean and median willingness to pay for two bundled insurance products for four specifications in table 4. The choice between mean and median willingness to pay is important when mean and median of the distribution of WTP does not coincide. As Hanemann (1989) suggests in his paper, "the choice between the two, indeed, can be nontrivial" as mean is "more sensitive to skewness or kurtosis in the original data". Therefore we present mean and median WTP for linear and exponential

WTP model, respectively. We also investigate the mean and median willingness to pay of oceanfront residents and individual who are not mandated to buy flood insurance. We find larger and statistically different willingness to pay for residents of oceanfront properties for flood and erosion, as well as trivial differences between those who are not required to buy insurance and the whole sample.

In the linear specifications, we find negative mean willingness to pay for erosion insurance, while median in the exponential specifications sits in a reasonable range for both products. As we expected, except residents of oceanfront properties, higher risk perception increased WTP for both flood and erosion, with substantially larger WTP for the flood insurance. Comparing the WTP statistics from with and without π_{11} provides an insight on the importance of bundling and diversifying insurance products that can reduce the uncertainty associated with multi-peril hazards and reduce the associated welfare loss.

7. Conclusion

The multi-peril coastal hazard insurance is a useful mitigation measure to address the erosion hazard in coastal areas. Especially multi-peril coastal hazard insurance is an important mitigating tool because weather-related coastal hazards such as flood, hurricanes and other severe storms contain a series of events and it is a complicated issue for both the insurer and the insured to split the total damages between different sources of damage such as flood and wind or flood and erosion hazards. In this study, we estimate the economic value of a flood and erosion bundled insurance product to reduce the risk of multi-peril natural hazards. Focusing on erosion hazard in the coastal areas is specially relevant, as it can undermine waterfront houses, businesses, and public facilities over time. Currently, there are many shortcomings in addressing and incorporating erosion risk into insurance markets and there is no evidence of the existence of a private insurance market that provides indemnification against erosion risk. Evaluation of erosion hazards illustrates that risk of erosion and flooding are comparable and erosion may be responsible for the destruction of one out of four houses within 500 feet of U.S. shoreline in a 60-year time horizon (H.J Heinz 2000). NFIP as it stands today does not map erosion hazard areas, and the insurance premiums of homeowners in erosion-prone areas do not differ from other NFIP policyholders. Regarding the lack of private insurance markets for erosion hazard and high erosion risk in coastal areas, we show that residents of coastal regions demand multi-peril coastal hazard insurance and they would be willing to pay for the addition of erosion insurance to NFIP. This result can inform policy makers that bundled insurance product can be offered to population of interest in coastal areas after addressing shortcomings of NFIP in including the erosion risk.

Our investigation illustrates that homeowners whose properties are located in Special Flood Hazard Area, those who have filed insurance claims, as well as those who live in communities with local erosion mitigation measures have higher joint flood-erosion risk perception, and their higher risk perception can lead to larger probability of buying bundled insurance products.

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Tables

Table 1: List of Variables

Variable	Source	Description
Location variables		
Dare, North Carolina	Survey	Indicator of the county
Brunswick, North Carolina	Survey	Indicator of the county
Georgetown, South Carolina	Survey	Indicator of the county
Brevard, Florida	Survey	Indicator of the county
Lee, Florida	Survey	Indicator of the county
Galveston, Texas	Survey	Indicator of the county
Brazoria, Texas	Survey	Indicator of the county
Sussex, Delaware	Survey	Indicator of the county
X/B/C-Zone	Heinz Center	SFHA- Minimal risk area
V-Zone	Heinz Center	SFHA-higher risk area
A-Zone	Heinz Center	SFHA-Moderate risk area
Elevation (feet)	Field survey	Structure elevation
Distance from shore (100 feet)	Field survey	Structure distance from the shoreline in feet
Oceanfront	Field survey	Dummy: 1= building is ocean front
Erosion or accretion (feet/year)	Heinz Center	Erosion or accretion rate
Flood and erosion related variables		
NFIP participant	Survey	Dummy: 1=participating in NFIP
Willing to pay for addition of erosion coverage to NFIP	Survey	Dummy: 1=yes response to the erosion bid
Flood coverage premium (annual per $100 covered assessed asset value)	Estimated using Federal Insurance Administration's policies in force database	Assuming full coverage, this price is derived by dividing the full insurance coverage by the asset value

Erosion coverage premium (annual per $100 covered assessed asset value)	Survey	Assuming full coverage, this price is derived by dividing the erosion insurance bid by the asset value
Mandatory flood insurance	Survey	Dummy: 1= If individual is required to participate in NFIP
Assessed asset value ($10000)	Estimated in Jahan parvar and landry 2009	Estimated using Hedonic Price Regression Model
Flood nominal risk perception	Survey	Binary choice variable: 1= individual would buy the insurance regardless of any obligation from NFIP (flood risk is high), 0= would not buy the insurance (flood risk is low)
Erosion nominal risk perception	Survey	Binary choice variable: 1= individual expects property value loss because of erosion (erosion risk is high), 0= individual does not consider erosion as a serious problem (erosion risk is low)
Filed insurance claim	Survey	Dummy: 1= filed insurance claim
Erosion mitigation measure	Survey	Dummy: 1= engaging in measures that prevent erosion including seawall, rip-rap, groin, jetty, break water, sand nourishment, dune fences, dune grasses, raised walkways
Socio-demographic variables		
Graduate school degree	Survey	Dummy: 1= attend graduate school
College degree	Survey	Dummy: 1= attend college
Age	Survey	Respondent age
Income	Survey	Annual Household income

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Location variables				
Dare, North Carolina	0.30	0.46	0.00	1.00
Brunswick, North Carolina	0.11	0.31	0.00	1.00
Georgetown, South Carolina	0.04	0.21	0.00	1.00
Brevard, Florida	0.12	0.32	0.00	1.00
Lee, Florida	0.05	0.23	0.00	1.00
Galveston, Texas	0.24	0.43	0.00	1.00
Brazoria, Texas	0.05	0.21	0.00	1.00
Sussex, Delaware	0.08	0.27	0.00	1.00
B/C/X Zone	0.22	0.42	0.00	1.00
V-Zone	0.47	0.50	0.00	1.00
A-Zone	0.31	0.46	0.00	1.00
Elevation	3.60	6.48	-9.97	28.71
Distance from shore	3.94	2.69	0.00	17.00
Oceanfront	0.32	0.47	0.00	1.00
Erosion or accretion	2.56	3.49	-22.99	18.27
Flood and erosion related variables				
NFIP participant	0.54	0.50	0.00	1.00
Willing to pay for addition of erosion coverage to NFIP	0.28	0.45	0.00	1.00
Flood coverage premium	0.83	0.78	0.07	4.19
Erosion coverage premium	7.84	13.00	0.00	83.14
Assessed asset value	1,693.19	1,957.86	201.23	23,619.30

Mandatory flood insurance	0.13	0.33	0.00	1.00
Flood nominal risk perception	0.33	0.47	0.00	1.00
Erosion nominal risk perception	0.51	0.50	0.00	1.00
Filed insurance claim	0.10	0.30	0.00	1.00
Erosion mitigation measure	0.60	0.49	0.00	1.00
Socio-demographic variables				
Graduate school degree	0.37	0.48	0.00	1.00
College degree	0.44	0.50	0.00	1.00
Age	60.04	11.86	25.00	91.00
Income	161,020	225,757	15,000	780,627

Table 3: First Step Regression; Joint Flood-Erosion Risk Perception

	(1) Flood nominal risk perception	(2) Erosion nominal risk perception
Distance from shoreline	-0.018	-0.043
	(0.023)	(0.026)
V-zone	0.535***	0.779***
	(0.169)	(0.182)
A-zone	0.364**	0.304*
	(0.164)	(0.176)
Flood insurance claim	0.285**	-
	(0.120)	-
Erosion mitigating measure	-	0.410***
	-	(0.112)
Graduate school	0.495***	0.090
	(0.160)	(0.171)
College degree	0.260	0.197
	(0.159)	(0.164)
Age	-0.016***	-0.001
	(0.004)	(0.005)
Constant	-0.134	-0.573
	(0.326)	(0.386)
Observations	1231	1231

Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Second Step Regression: Multi-peril Insurance Demand

Variables	(1) Flood insurance demand	(2) Erosion insurance demand	(3) Flood insurance demand	(4) Erosion insurance demand	(5) Flood insurance demand	(6) Erosion insurance demand	(7) Flood insurance demand	(8) Erosion insurance demand
Flood coverage premium	-0.206*				-0.270***			
	(0.105)				(0.053)			
Erosion coverage premium		-0.119***				-0.127***		
		(0.023)				(0.009)		
Log (Flood coverage premium)			-0.394***				-0.464***	
			(0.116)				(0.059)	
Log (Erosion coverage premium)				-0.403***				-0.424***
				(0.032)				(0.019)
Graduate school	0.143	0.030	0.152	-0.060	-0.094	-0.054	-0.089	-0.183
	(0.171)	(0.186)	(0.172)	(0.196)	(0.101)	(0.116)	(0.101)	(0.123)
College degree	0.204	0.043	0.218	-0.089	-0.095	-0.063	-0.083	-0.242**
	(0.159)	(0.182)	(0.161)	(0.189)	(0.098)	(0.114)	(0.099)	(0.12)
Age	-0.026***	-0.008	-0.026***	-0.009	-0.031***	-0.009***	-0.03***	-0.011***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)
Log (income)	0.200**	0.199***	0.182**	0.185***	0.221***	0.213***	0.192***	0.201***
	(0.083)	(0.061)	(0.084)	(0.063)	(0.035)	(0.036)	(0.035)	(0.038)
Mandatory flood insurance	0.828***		0.837***		0.91***		0.917***	
	(0.202)		(0.200)		(0.112)		(0.112)	
Distance from shoreline	-0.039	-0.054*	-0.042	-0.078**	0.032	-0.030	0.030	-0.040**
	(0.031)	(0.032)	(0.032)	(0.037)	(0.02)	(0.021)	(0.02)	(0.023)
Ocean front	0.241	0.045	0.215	0.051	0.16*	0.009	0.128	0.017
	(0.177)	(0.155)	(0.177)	(0.171)	(0.09)	(0.091)	(0.091)	(0.097)
Elevation	0.009	-0.006	-0.002	-0.008	0.014**	-0.003	0.003	-0.003
	(0.016)	(0.015)	(0.016)	(0.015)	(0.007)	(0.008)	(0.008)	(0.009)
V-zone	0.882***	0.221	1.049***	0.119	0.097	-0.050	0.300**	-0.215
	(0.306)	(0.276)	(0.311)	(0.301)	(0.162)	(0.173)	(0.165)	(0.188)
A-zone	0.712***	0.422*	0.632***	0.306	0.754***	0.491***	0.692***	0.385***
	(0.223)	(0.254)	(0.224)	(0.277)	(0.119)	(0.137)	(0.121)	(0.15)

Erosion rate	0.015	-0.003	0.009	0.003	0.005	-0.004	-0.004	0.0001
	(0.020)	(0.022)	(0.020)	(0.024)	(0.01)	(0.011)	(0.01)	(0.011)
Estimated joint risk perception ($\widehat{\pi_{11}}$)					9.471***	3.384***	9.608***	4.569***
					(0.998)	(0.872)	(1.001)	(0.927)
Constant	-0.687	-2.487**	-0.989	-2.614**	-1.582	-3.019	-1.936***	-3.363***
	(1.152)	(0.998)	(1.144)	(1.054)	(2.069)	0.536	(0.517)	(0.581)
Observation	1105	1105	1105	1105	1105	1105	1105	1105

Standard errors in parentheses. Estimated parameters and standard errors obtained from 500 replications using bootstrap procedure (Efron and Tibshirani , 1986). All regressions include county fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Welfare Change Analysis

	Mean WTP (Linear WTP function)			Median WTP (Exponential WTP function)		
	All	Ocean front =1	Mandatory flood insurance =0	All	Ocean front =1	Mandatory flood insurance =0
Flood w/o π_{11}	2.20	4.85	1.89	1.21	4.69	1.02
Erosion w/o π_{11}	-2.15	-0.03	-1.77	0.13	0.26	0.15
Flood with π_{11}	2.63	3.26	2.09	1.77	2.48	1.25
Erosion with π_{11}	-1.55	-0.73	-1.44	0.17	0.20	0.17

Figures

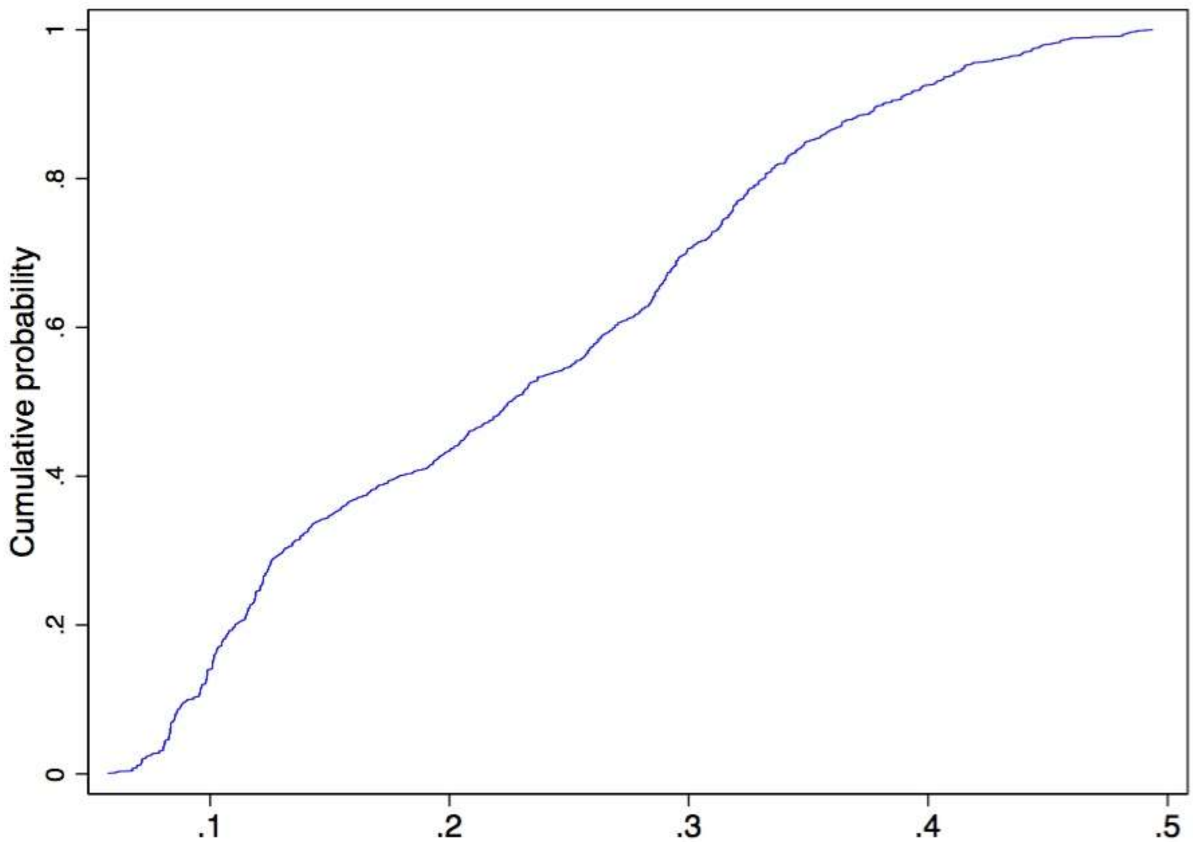

Figure 1: Cumulative Density Function of Joint Risk Perception