Vulnerability Analysis and Risk Management for Water-Related Hazards

PART II: "Socio-economic valuation of risk perception"

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Content of "Economic approaches to risk valuation"

1. Overview of economic approaches to risk valuation
2. Revealed vs stated preference methods
3. Revealed preferences methods
   - Hedonic price
   - Travel cost
4. Stated preferences methods
   - Contingent valuation
   - Choice experiments
5. Case studies

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3. Revealed preferences methods

A. Hedonic pricing

B. Travel cost

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A. Hedonic pricing

- The hedonic pricing (HP) method is used to estimate economic values for non-market goods and services (including risk protection) that directly affect market prices. HP is based on market transactions for differentiated goods in order to estimate the value of specific characteristics.
- It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. Seminal paper: Rosen (1974) developed the theoretical framework.
- It can be used to estimate benefits or costs associated with risk protection and the value of alternative risk management plans

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A. Hedonic pricing

- The basic premise of HP method is that the price of a marketed good is related to its characteristics or the services it provides.
- The most common application of hedonic pricing in risk valuation involves housing markets. The choice of housing location and, therefore, neighborhood amenities, is observable.
- Often, location choice is directly linked to an environmental amenity of interest. For example, housing locations can offer different scenic vistas, or they can impose greater perceived risks by placing a household closer to perceived hazards
- As such, the choice of a house and its associated price implies an implicit choice over the environmental amenities (or disamenities) proximate to the house and their implicit prices.

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A. Hedonic pricing

- The price of a house reflects its characteristics either in terms of proximity to services (school, hospital, etc.), proximity to environmental amenities (forest, park, lake, etc.) or exposure to risk
- The individual characteristics of a house or other good can be valued by looking at how people are willing to pay for its changes. The HP method is most often used to value non-market characteristics that affect the price of residential properties
- Hedonic pricing is an "indirect" valuation method because we infer the value people place on the characteristics from observable market transactions, rather than making a straightforward estimate

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A. Hedonic pricing

- The aim is to estimate a hedonic price function where the prices of properties (i.e. houses) are a function of some characteristics of the structure and some risk attributes of the houses (air quality, lake water quality, proximity to a forest):

$$P = \alpha_1 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \gamma_1 z_1 + \gamma_2 z_2 + \ldots \gamma_n z_n$$

- where the dependent variable *(P)* is the sales price of a property, the independent variables are the structural characteristics (x) and the risk characteristics (z) of the commodity.

- Ex. size (square meters) of the property and a risk index of the area where the property is located

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Example of hedonic price function

- Boyle, Poor, and Taylor (1999) estimated hedonic price functions for lakefront properties in Maine.

- Sales prices of summer cottages were analyzed as a function of the characteristics of the structure on the property, its location and the water quality of the lake.

- Maine lakes are known for their high water quality, however this quality is being compromised in many lakes by eutrophication resulting from nonpoint pollution. An effect of eutrophication is reduced water clarity.

- Hence, water clarity is the measure of lake water quality that is used by the authors in the hedonic price function.

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Example of hedonic price function

$$P = 25{,}899 + 6{,}790 \bullet \ln(SQFT) + 83 \bullet FRONT - 1{,}516 \bullet DIST + 11{,}572 \bullet HEAT + 23{,}465 \bullet BATH + 2.057 \bullet WQ$$

Dependent variable: sales price of a property

Independent variables:

- SQFT: area of the structure on the property
- FRONT: length of the property's frontage on the lake
- DIST: the distance between property and nearest town
- HEAT: dummy variables whether or not the structure has central heating
- BATH: a full-bath
- WQ water quality (expressed in terms of water clarity)

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Estimation of the Hedonic pricing function

The hedonic price function allows to calculate implicit prices, that is marginal willingness to pay for the attributes of the house.

The following steps can be followed to estimate the hedonic price function:

1. data to be collected (part 1): property values
2. data to be collected (part 2): property attributes & risk attributes
3. sampling
4. model estimation: choice of the functional form
5. welfare measures

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Data 1: Property values

Property prices are the dependent variables.

Three types of data can be used as property values:

1. market prices
2. homeowner or tax authorities estimates of value
3. rental prices

The most common dependent variable is market prices, but values assessed by homeowners or tax authorities can also be taken into account as substitutes

The choice among these crucially depends on their availability and reliability within the studied country. For instance, information provided by tax authorities is not reliable in Italy

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Data 2: Property attributes

Data that can be used as independent variables may be:

1. property characteristics;
2. neighborhood characteristics;
3. environmental characteristics (including risk);

There is no straight way to select the variables for the hedonic regression, knowledge of the market is one of the main tools.

Property characteristics may include the size of the plot (he or acres), size of the building, n. bedrooms and bathrooms (squared meters or feet), age of the building.

Data on property characteristics are generally gathered from tax authorities records or homeowner surveys

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Data 2: Property attributes

Neighborhood characteristics deal with:

1. quality: quality of local school, level of crime, average income. Source: government census.
2. location: distance (km) to the town centre, nearest shopping centres, train station, nearest light rail or bus stop, nearest motorway exit . GIS software packages can be of help.

Environmental amenities/disamenities deal with:

1. quality: pollution level of the area, clarity of the water of the lake where the property is located, risk measures. Scientific measures of the variables provided by local environmental authorities are used.
2. location: distance (km) to open spaces, forests, urban parks, lakes, landfills or quarries. GIS are often used.

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Sampling

- Two main issues need to be carefully defined:
  a) geographic area;
  b) period of time.
- The size of the area is crucial because one needs to ensure enough variation for the risk characteristics across observations. It is easier to allow for variation in location (for example the distance to a river) rather than quality variation (for example index of air quality or flood risk).
- If there is variation in the period of time, one needs to account for prices to be deflated, by means of a price index or by including some dummy variables

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Model estimation: choice of the functional form and implicit price

The choice of the functional form to estimate the hedonic price function can have a substantial impact on the results.

Several functional forms are available:

1. linear;
2. semi-log;
3. double-log;
4. quadratic
5. quadratic Box-Cox

There is no specific rule to follow in choosing the functional form.

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Model estimation: choice of the functional form and implicit price

Functional form	Equation	Implicit prices
Linear	$P = \alpha_0 + \sum \beta_i z_i$	$\partial P / \partial z_i = \beta_i$
Semi-log	$\ln P = \alpha_0 + \sum \beta_i z_i$	$\partial P / \partial z_i = \beta_i \cdot P$
Double-log	$\ln P = \alpha_0 + \sum \beta_i \ln z_i$	$\partial P / \partial z_i = \beta_i \cdot P / z_i$
Quadratic	$P = \alpha + \sum_{i=1}^{N} \beta_i z_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \delta_{ij} z_i z_j$	$\partial P / \partial z_i = \beta_i \cdot P / z + \sum_{j \neq 1}^{N} \delta_{ij} z_j + \delta_{ii} z_i$
Quadratic Box-Cox	$P^{(\theta)} = \alpha + \sum_{i=1}^{N} \beta_i z_i^{(\lambda)} + \frac{1}{2} \sum_{i,j=1}^{N} \delta_{ij} z_i^{(\lambda)} z_j^{(\lambda)}$	$\partial P / \partial z_i = \left(\beta_i z_i^{(\lambda)} + \sum_{j=1}^{N} \delta_{ij} z_i^{(\lambda-1)} z_j^{(\lambda)} \right) P^{1-\theta}$

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Model estimation: choice of the functional form and implicit price

- The linear functional form is straight: it allows the implicit price for any specific attribute (structural or property characteristics, neighborhood issues and risk attributes) to equal the respective estimated coefficients.
- The price of the house differs for each specific attribute but is constant within each attribute. This raises an issue: the influence some risk characteristics have on the price might be non-linear.
- Sales prices of contaminated sites are of course negatively impacted, but the price of sales decreases at an increasing rate with shorter distance. Hence, linear hedonic approaches should be avoided, because of their inability to allow for incremental changes.

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Case Study 1:
The effects of landslide hazard on property value in Woomyeon Nature Park area, South Korea
(Kim J. et al., 2017)

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Motivation

- An urban nature park, which generally includes environmentally valuable natural landscape such as forests, mountains, rivers, and beaches, provides valuable benefits for the public in urban areas such as recreational opportunities and an aesthetic landscape.
- However, residents near nature parks could be more vulnerable to natural disasters like floods, tsunamis, and landslides
- Understanding the trade-off between the amenity and hazard effects of nature parks is key to successful landscape and urban planning, for both open spaces and disaster management

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Motivation

- The study explores the effects of mountains as both amenity and hazard factors on property values before and after a landslide event in Woomyeon Nature Park (WNP) in Seoul.
- During a long rainy season from June 22 to July 17, 2011, the Seoul are recorded the second-highest precipitation since 1973, weakening the slopes of Woomyeon Mountain. This led to a landslide on Woomyeon Mountain on July 27th. The landslide resulted in property damage of more than 16 billion won (equivalent to 16 million U.S. dollars), 18 deaths, and 21 injuries, which was one of the largest natural disasters in Seoul since 2000
- After the investigation into the causes of the landslide, the Seoul Government finished the restoration, including the reinforcing slopes, in July 2012. The path of the debris flow was repaired by constructing several debris barriers and stone-channels.

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Motivation

a) Before the restoration work | b) After the restoration work

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Sample

- A total of 5758 transactions in Seoul from 2008 to 2014, based on the sales data of the Ministry of Land, Infrastructure, and Transport (MLIT).
- Only apartment-type housing according to the the Korean Building code, defined as high-rise condominiums or multifamily housing with five stories or more, are included.
- Only transactions of apartments located within a distance of one kilometer from the boundary of the WNP in order to control the effects of different housing submarkets.

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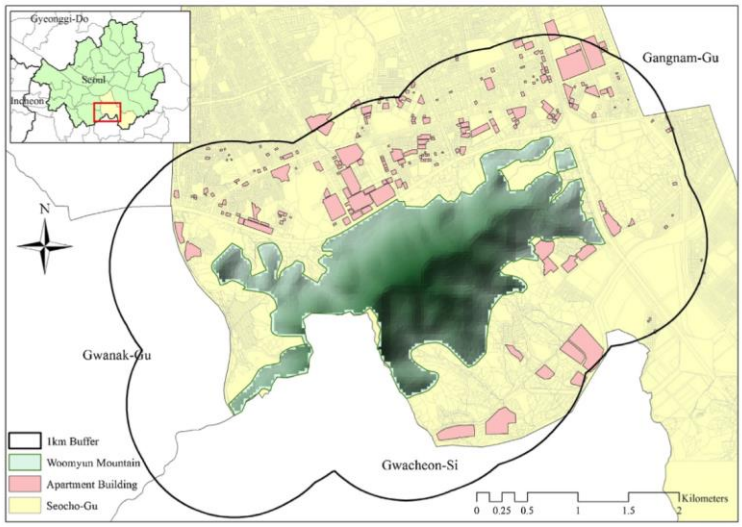
Sampling map



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Risk measure

- The hazard of landslide was reviewed using the landslide risk map of the Korea Forest Service. The risk of landslide is mainly determined by the gradient, length and location of a slope, types of ground, depth of soil, conditions of forest, and other factors.
- The Korea Forest Service classifies the risk of landslide into five classes: 1st (very high), 2nd (high), 3rd (low), 4th (very low), and 5th (no risk).
- The potential landslide hazard areas depend on the total travel distance of a debris flow which is affected by the height of a landslide starting point, the amount of precipitation, slopes, barriers, and many other factors, implying that quantifying the landslide hazard for nearby housing is complex.

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Risk measure

- In fact, the damage from the landslide of the Woomyeon Mountain in July 2011 was observed in apartment complexes having various landslide risks ranging from 1st to 4th class, and the travel distances of debris varied depending on location.
- Therefore, the measures the hazard effect of the WNP indirectly using the differences in coefficients of WNP proximity variables before and after the landslide.

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Dataset (1/2)

Variables	Description	Expected results
Log(Sale price)	Log value of housing sale price adjusted for the market trend	Dependent variable
Property characteristics		
AREA	Area of exclusive use of a housing unit in an apartment complex (m^2)	(+). Larger houses are more expensive
STORY	Story of a housing unit	(+). Housing on higher stories is more expensive due to the view and better daylight
FIRST	First floor = 1; otherwise = 0	(−). First floor housing units are less attractive due to security, daylight, and privacy issues.
AGE	Years since construction	AGE(−), AGESQ(+). Older housing is less expensive, but the potential of reconstruction (30 years old or later) increases the housing value
AGESQ	Square of the property age	
HIGHEST	The highest story in an apartment complex	(+). Apartment complexes having higher stories are preferred because these apartments are relatively new and provide a better site design due to the lower building-coverage ratio.
MIXED	Mixed-use building = 1; otherwise = 0	(−). Mixed-use apartments have a relatively lower exclusive use area, thus having a lower price.

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Dataset (2/2)

Time variables		
SHORT	Dummy for the landslide restoration period: from August 2011 to July 2012 = 1; otherwise = 0;	Controlling changes in the housing market after the landslide (short-term and long-term)
LONG	Dummy after completion of the restoration work: From August 2012 to December 2014 = 1; otherwise = 0;	
TREND	Monthly time dummies (reference: December 2014)	Controlling changes in the housing market over time
WNP effect		
WNP100 ~WNP400	Dummy variables for distance to WNP – WNP100: 100 m or less – WNP200: 100.1 ~ 200 m – WNP300: 200.1 ~ 300 m – WNP400: 300.1 ~ 400 m (reference: more than 400 m)	(+): Proximity to WNP increases housing price. The premium of WNP proximity is close to zero at 400 m (roughly one-quarter mile).
WNP dummies * SHORT	Interaction variable between WNP proximity dummies and SHORT	(−): Proximity to WNP increases the hazard of landslide.
WNP dummies * LONG	Interaction variable between WNP proximity dummies and LONG	(−): Proximity to WNP increases the hazard of landslide. This effect is smaller than the short-term effect (WNP dummies * SHORT) because the restoration work reduces the vulnerability of landslide.
Locational characteristics		
SCHDIS	Distance to the closest school (100 m)	(−). Proximity to schools increases housing price.
SUBDIS	Distance to the closest subway station (100 m)	(−). Proximity to subway stations increases housing price.
MTSTATION	Transfer station (2 or more subway lines) = 1; otherwise = 0	(+). Proximity to transfer station means better accessibility to transit services, thus increasing housing price.

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The Hedonic pricing model

$$\ln(SP) = \beta_0 + \beta_1 * P + \beta_2 * L + \beta_3 * TREND + \beta_4 * WNPDIS + \beta_5 * WNPDIS * SHORT + \beta_6 * WNPDIS * LONG + \varepsilon$$

ln(SP) = the log-transformed value of the adjusted sale price
P and L = are the vectors of property and locational characteristics, respectively.
TREND = the monthly time dummy variable vector
WNPDIS = dummy variable vectors for the proximity to WNP
SHORT and LONG = measure the short- and long-term effect of the landslide event with the WNPDIS variable. If the transactions were made between August 2011 and July 2012, the value of SHORT is 1, otherwise 0. When the transactions were made after August 2012, the value of LONG is 1, otherwise 0.

The effects of the landslide event are measured using the interaction variables between WNPDIS's interaction variables and SHORT and LONG.

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The Hedonic pricing results

Property characteristics		*Amenity/Hazard effect*	
AREA	0.011***	WNP100	0.367***
STORY	−0.003***	WNP200	0.299***
FIRST	−0.083***	WNP300	0.210***
AGE	−0.048***	WNP400	0.010
AGESQ	0.001***	WNP100*SHORT	−0.137***
HIGHEST	0.005***	WNP200*SHORT	−0.101***
MIXED	−0.220***	WNP300*SHORT	−0.062***
Locational characteristics		WNP400*SHORT	−0.091***
SCHDIS	−0.013***	WNP100*LONG	−0.175***
SUBDIS	−0.027***	WNP200*LONG	−0.153***
MSTATION	0.122***	WNP300*LONG	−0.200***
constant	10.284***	WNP400*LONG	−0.031
Rho (Intra-class correlation)			
Adjusted-R2	0.8096		

Note: *. **. *** are 10%, 5%, 1% significance, respectively.

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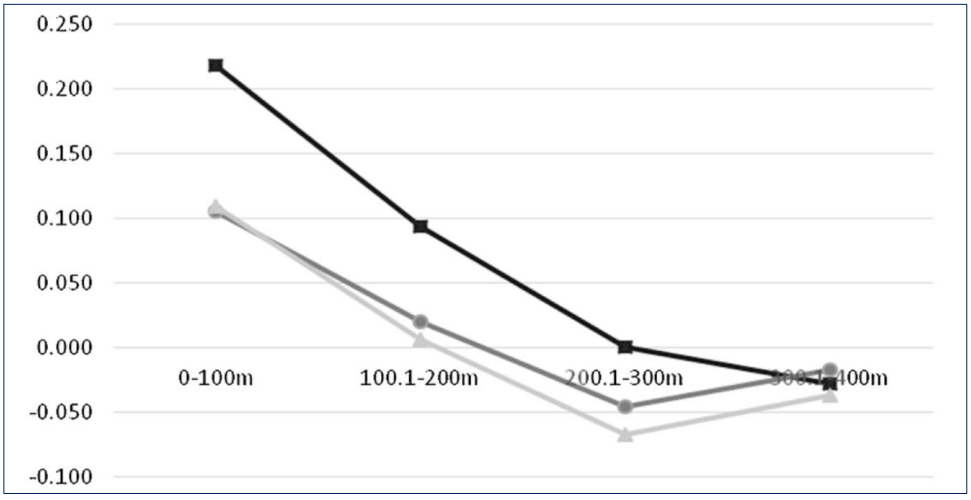
Estimated premium by distance to WNP



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Implications of the study

- The fact that an urban nature park can have a hazard effect suggests the importance of disaster prevention efforts in urban open spaces. Such successful prevention efforts could reduce this hazard effect.
- Therefore, the design and management process of urban nature parks should incorporate disaster management planning to develop safe and pleasant urban open spaces.
- Specifically, local and central government should implement real-time mountain landslide hazard monitoring and prediction to provide hazard warnings in time to avoid or reduce losses.
- Local government should also develop and implement guidelines and training for planners and decision-makers in the use of accurate landslide hazard maps, assessments, and technical information for planning, preparedness, response, and mitigation.

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Implications of the study

- Following these suggestions, the Seoul Metropolitan Government recently approved a Master Plan of Parks and Urban Green Spaces for 2030, which includes disaster management and prevention strategies in urban open spaces.
- In preparing this plan, safety and risk factors for all slopes in mountain-type urban parks in Seoul were inspected and landslide mitigation planning was incorporated with park management planning (Seoul Metropolitan Government, 2015).

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Case Study 2:
Costs of beach erosion and flood risk in Hilton Head Island (US) (Catma S., 2021)

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Motivation

- Coastal living has been preferred by many Americans because of sandy beaches and warmer climate.
- Hilton Head Island (HHI), a foot-shaped barrier island located in South Carolina, USA, experienced a similar population increase of almost 18% from 2007 to 2017. In addition, in 2019, 2.68 million travelers visited HHI, contributing a total of $1.17 billion to the local economy
- HII is exposed to climate change risks, specifically accelerated shoreline changes and elevated risks of flooding cause by increasing sea levels
- According to Vousdoukas et al. (2020), Beaufort County, where HHI is located, has experienced a cumulative shoreline change of −189 m.

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Motivation

- As coastal population has been increasing rapidly in the US, there is an urgent need for effective policy prescriptions to combat coastal hazards.
- The results of the study provide valuable information to policy makers, since the costs of beach erosion and coastal flooding need to be determined accurately so that optimal adaptive strategies to lessen the impact of sea-level rise can be enacted.
- As such, the study explores how the risks associated with beach erosion and coastal flooding are capitalized into residential property prices.

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Sample

- 495 properties sold between 2011 and 2016 and located within 1500 feet (457 m) of the ocean

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Dataset

Variables included in the hedonic pricing model

Variable	Description	Source
singfam	1 if property is a single-family home; 0 otherwise	Beaufort County Assessor's Office (BCAO)
pbaccess	Distance to nearest public beach access point (meters)	ArcGIS Pro
footage	Size of the living space in the property (square feet)	BCAO
numbed	Number of bedrooms	Zillow
numbath	Number of bathrooms	Zillow
garage	1 if property has garage space; 0 otherwise	Zillow
mstory	1 if property is single-storied; 0 otherwise	Zillow
gated	1 if property is located in a gated community; 0 otherwise	Zillow
waterfr	1 if property is oceanfront or marshfront; 0 otherwise	ArcGIS Pro
shrate	Change in shoreline position (in meters) per year.	USGS [12]
shdum	1 if annual change in shoreline position is negative; 0 if positive.	USGS [12]
dbeach	Distance to the nearest beach (in meters)	ArcGIS Pro
disteros	shrate*dbeach (in square meter)	ArcGIS Pro
flrisk	1 if the property is located where flood risk is high or very high; 0 if the flood risk is low or very low.	Federal Emergency Management Agency (FEMA)
year	Year of sale, 1 (2011) to 6 (2016)	BCAO

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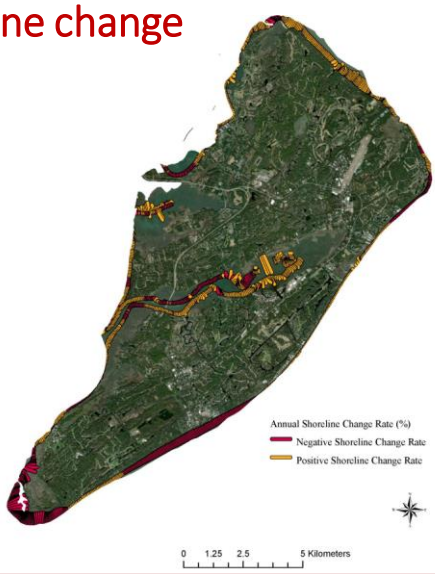
Risk characteristics: shoreline change

- Information obtained from the U.S. Geological Survey (USGS), which provides estimates of 30-year change in shoreline positions
- Shoreline change rates in meters per year were spatially joined with the property data using ArcGIS
- The mean annual shoreline change rate (*shrate*) in the study area is, 0.15 with the values ranging from –1.83 to 5.2.



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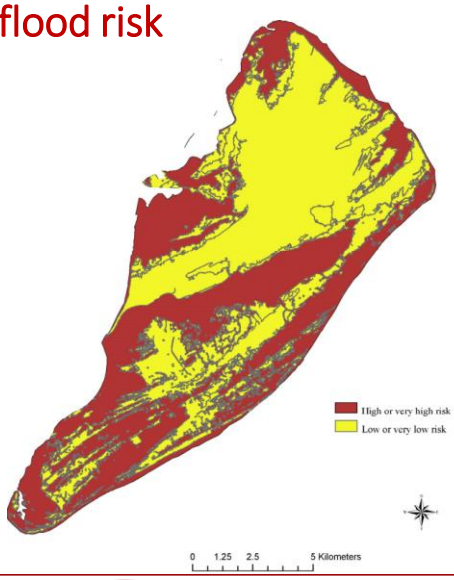
cs: flood risk



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The hedonic pricing estimates

Variable	Parameter	Standard Error
spatial	-	-
singfam	0.16516 ** (0.17958)	0.08162
Pbaccess (meters)	0.00004 ***	0.00001
Footage (square feet)	0.00004 ***	0.00001
numbed	0.05296 ** (0.05438)	0.02322
numbath	0.15054 *** (0.16246)	0.01998
garage	0.07195 (0.0746)	0.04751
mstory	−0.09457 ** (−0.09024)	0.03777
gated	0.20917 *** (0.23265)	0.05844
waterfr	*0.64862 *** (0.9128)*	*0.67407*
shdum	*−0.35015 *** (−0.2954)*	*0.08787*
Disteros (square meters)	−0.00027 ***	0.00006
flrisk	−0.15888 *** (−0.1469)	0.04126
location effects		yes
year fixed effects		yes
ln L		−280
R^2	0.605	
Observations		495

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

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Implications of the study

- Capitalization of erosion risk is an important first step to produce an accurate cost benefit analysis of best management practices to combat this problem.
- Hard stabilization and beach nourishment projects are some of the practices that provide not only recreational benefits to the residents and the property owners but also protection to the nearby properties serving as buffers from beach erosion.
- It is critical to know the true cost of coastal erosion or benefit of reducing its risk so optimal policy strategies and programs can be implemented.

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Implications of the study

- For example, the burden of a potential tax program to finance an adaptive strategy to lower beach erosion risk can be allocated based on the quantification of the benefits taxpayers would receive in exchange.
- The property owners who own oceanfront or nearby properties could pay more in taxes to finance a stabilization program that would lower the risk of property damage.
- Such policy would ensure that those who benefit the most from owning a property in a coastal location also endure the associated risks of shoreline change

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