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Flood Hazards, Insurance Rates, and Amenities: Evidence From the Coastal Housing Market

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Abstract

This study employs the hedonic property price method to examine the effects of flood hazard on coastal property values. We utilize Geographic Information System data on National Flood Insurance Program flood zones and residential property sales from Carteret County, North Carolina. Our results indicate that location within a flood zone lowers property value. Price differentials for flood risk and the capitalized value of flood insurance premiums are roughly equivalent—both exhibiting a nonlinear relationship in flood probability. Our results support the conclusion that flood zone designation and insurance premiums convey risk information to potential buyers in the coastal housing market.

Introduction

Hedonic property models provide an intuitive analytical tool for examining the effects of housing attributes and spatially delineated characteristics on housing prices. Rosen (1974) formalized the relationship between the equilibrium price schedule, supplier technology, and household preferences in a competitive market. From the perspective of the household, marginal implicit prices can be interpreted as marginal willingness to pay for housing attributes. In their test of expected utility theory, Brookshire et al. (1985) were the first (to our knowledge) to consider spatially delineated risk factors in the context of the hedonic model, and relate these to household trade-offs. Their analysis suggests that California households are aware of spatial differences in earthquake risk, primarily due to special risk assessments conducted by government authorities in conjunction with disclosure requirements, and that the market capitalizes this risk, discounting properties in the high-risk area.

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A number of hedonic property studies of hazards followed in the environment and risk literature, focusing on earthquake / volcanic hazards (Bernknopf, Brookshire, and Thayer, 1990; Beron et al., 1997), flood hazards (MacDonald, Murdoch, and White, 1987; MacDonald et al., 1990; Bin and Polasky, 2004), hurricane hazards (Hallstrom and Smith, 2005), hazardous waste and Superfund sites (Clark and Allison, 1999; Gayer, Hamilton, and Viscusi, 2000; McClusky and Rausser, 2001), erosion hazards (Kriesel, Randall, and Lichtkoppler, 1993; Landry, Keeler, and Kriesel, 2003), wind hazards (Simmons, Kruse, and Smith, 2002), and wildfire hazards (Donovan, Champ, and Butry, Forthcoming). Some of these articles make use of cross-sectional variation in risk-related attributes of properties to identify risk trade-offs (MacDonald, Murdoch, and White, 1987; MacDonald et al., 1990; Kriesel, Randall, and Lichtkoppler, 1993; Simmons, Kruse, and Smith, 2002; Landry, Keeler, and Kriesel, 2003), others make use of variation in government- or media-provided risk information over time (Brookshire et al., 1985; Bernknopf, Brookshire, and Thayer, 1990; Clark and Allison, 1999; Gayer, Hamilton, and Viscusi, 2000; McClusky and Rausser, 2001; Donovan, Champ, and Butry, Forthcoming), whereas still others utilize quasi-random, natural experiments to induce an exogenous change in risk information (Beron et al., 1997; Bin and Polasky, 2004; Hallstrom and Smith, 2005).[1]

It has recently been acknowledged that the level of risk associated with a property may be correlated with spatial disamenity levels. In their study of water pollution, Leggett and Bockstael (2000) note that pollution levels will tend to correlate with spatial disamenities, such as noise, odor, and unsightliness, associated with pollution emitters. As such, the effect of pollution may be overestimated unless other aesthetic disamenities are controlled. They use Euclidean distance from various emitters and proportional measures of surrounding land use to control for spatial disamenities. Their analysis takes advantage of an irregular coastline that creates considerable variation in pollution levels, breaking the correlation between pollution and emitter effects. Gayer, Hamilton, and Viscusi (2000) encounter a similar problem in their study of hazardous waste sites. They, too, use Euclidean distance to control for visual disamenities independent of perceived health risk. In both of these articles, risks attributable to man-made hazards are correlated with other disamenities associated with the source of such hazards.

In other settings, natural hazards have been shown to be correlated with spatial amenities. Donovan, Champ, and Butry (Forthcoming) examine wildfire risk, which is partially determined by housing and spatial attributes that households may value as amenities. Their results suggest that an education campaign on wildfire hazards is effective in altering the hedonic price of risk-enhancing amenities—whereas wood roofing initially has a positive effect on housing prices and wood siding has no effect, the effect of both attributes becomes negative after an education campaign highlights the wildfire risk inherent in these housing attributes. In the coastal zone, environmental risks, including flood, erosion, and wind hazard, are highly correlated with spatial amenities, such as proximity to water, water-frontage, and view. Taking the correlation between coastal amenities and risk as given, Hallstrom and Smith (2005) use the

[1] Other applications of the hedonic technique to risk include wage models (see, e.g., Smith et al., 2004) and automobile purchase (see, e.g., Andersson, 2005). We focus herein on the hedonic property model.

occurrence of a nearby hurricane to represent a change in information on hazards. The positive correlation between risk and spatial amenities can bias estimates of risk trade-offs downward if amenities are not controlled. Similarly, the value of amenities could be underestimated if risk factors are not accounted. Other settings in which correlation between risk and amenities might be found include hillside properties with views of cityscapes or natural areas, but subject to landslide or avalanche risk, and properties along rivers and streams that are exposed to risk of flooding.

In this article, we examine flood hazards in the coastal housing market of Carteret County, North Carolina. We use a spatial autoregressive model to control for unobservable characteristics of nearby properties and investigate the effects of differential flood risks on property values, controlling for amenities associated with proximity to water. We use National Flood Insurance Program (NFIP) flood zones as a risk measure and include coastal water frontage and distance to sound and Intracoastal waterways as amenity measures. Using NFIP flood zones, we can differentiate between the 100-year floodplain (i.e., a 1.0 percent annual chance of flooding) and the 500-year floodplain (i.e., a 0.2 percent annual chance of flooding), and show that implicit prices for flood classification are sensitive to the presence of coastal amenities. Without controlling for amenities, floodplain location appears to have no effect on housing value. When amenities are included, amenity and risk variables exhibit the expected sign and are statistically significant. Results suggest that location within a floodplain lowers the average property's value by 7.3 percent, or $11,598. Furthermore, we find a significantly larger price discount for locations with higher flood risk. Location within the flood zone with 100-year return interval lowers the average property's value by 7.8 percent ($12,325) whereas location within a 500-year floodplain lowers average property value by 6.2 percent ($9,849).[2] We calculate the flood insurance premiums for the different flood zones and find that the capitalized values of the insurance premiums are in close agreement with the sales price differentials. Several previous studies have documented the price reduction from location in a floodplain and compared the price reduction with the capitalized flood insurance premiums (Shilling, Benjamin, and Sirmans, 1985; MacDonald, Murdoch, and White, 1987; Donnelly, 1989; Harrison, Smersh, and Schwartz, 2001). A common finding in these studies is that location within a floodplain lowers property value from 3 to 12 percent.

A THEORETICAL FRAMEWORK

Hedonic property models have been used extensively in environmental and natural resource economics as a nonmarket valuation technique.[3] The basic idea underlying the model is that differential property prices reflect the way households value different

[2] The apparent nonlinearity in property value effects may reflect the nonlinearity in flood insurance premiums. It appears that information embedded in insurance premium is used as a signal of the risk to coastal property market participants. Alternatively, our data limitation to control for multi dimensional coastal risks (i.e., shoreline erosion, storm surge, and wind damage) might have caused this nonlinearity. We thank an anonymous referee for pointing this out.

[3] As a nonmarket valuation technique, the hedonic price method has been applied to value spatial attributes, such as pollution or access to recreational resources that are not *explicitly* traded in markets. The case of flood risk is somewhat different in that flood insurance provides

bundles of property characteristics. Residential properties are composite goods with a variety of attributes, and observing how property values change as the level of various attributes change, such as flood hazard, *ceteris paribus*, provides a way of estimating the incremental value of these attributes to property owners. The observed discount on property in an area with high flood risk thus reflects households' willingness to pay to avoid such risk. Multivariate statistics are used to make the *ceteris paribus*, or "all else being equal," assumption operational. The hedonic property price method has an advantage over other assessment techniques in that it makes use of actual market prices to recover value estimates for various nonmarket attributes. Palmquist (2004) provides a useful summary of the theoretical aspects of hedonic price models.

The hedonic price function is typically represented as:

$$Y = Y(s, n, e, r), \tag{1}$$

where Y is the sales price, which is a function of structural characteristics, s, neighborhood characteristics, n, environmental characteristics, e, and risk characteristics, r. Assuming that $Y(\cdot)$ is continuously differentiable, the first derivative of (1) with respect to any continuous attributes produces an estimate of the representative households' marginal willingness to pay for an additional unit of that attribute (Rosen, 1974). Let household utility be represented by $U(s, n, e, q)$, where q is a composite commodity that serves as numeraire. We assume U is bounded, increasing, and strictly concave in all arguments. To incorporate risk, we build upon the expected utility model of Brookshire et al. (1985).

Survey research of Chivers and Flores (2002) suggests that the overwhelming majority of households living in flood prone areas of Colorado was unaware of the risk classification and flood insurance rates at the time they submitted their bid for the property. They view this evidence as supporting hedonic property results that find no influence of risk on housing price (Tobin and Montz, 1997; Chivers, 2001). Our sample is drawn from the low-lying hurricane-prone coastal zone of North Carolina where flood zone disclosure is mandatory. Regulatory requirements coupled with wide dissemination of flood risk and mitigation information make lack of awareness a less likely explanation. As such, we consider the household's expected utility function:

$$\begin{aligned} V = {} & p(r) \cdot U^L[s, n, e, m^L - \alpha \cdot Y(s, n, e, r)] \\ & + (1 - p(r)) \cdot U^{NL}[s, n, e, m^{NL} - \alpha \cdot Y(s, n, e, r)], \end{aligned} \tag{2}$$

a market mechanism for partial indemnification of environmental risks. While flood insurance is not mandatory in general, it is required of any owner of a flood prone property with a mortgage contract backed by the Federal Deposit Insurance Corporation. As such, it is reasonable to expect that housing values reflect flood risks, since such risks entail upfront insurance payments for many homeowners. In the coastal zone, flooding often stems from storms that can potentially destroy a home. Flood insurance contracts associated with the NFIP provide a maximum coverage of $2,50,000 (and entail a deductible for settlements), so for many coastal homes insurance coverage can be far from full. One could also argue that certain nonpecuniary losses associated with flooding (loss of unique personal items or family heirlooms) will not be reflected in insurance market contracts. We interpret our implicit hedonic prices as reflecting the full cost of hazard risks as perceived by homeowners.

where $p(r)$ is the subjective probability of a damage-producing flood event; the utility function is state dependent across loss (superscript L) and no-loss (superscript NL) states; m^L represents expected income in the loss state—income remaining for consumption of the numeraire, including any insurance settlement net of insurance payments, loss from the flood event, and deductible (assuming flood insurance is in force); m^{NL} represents expected income in the no-loss state; and α is a parameter that converts sales price to an annual payment. Flood zones are defined by recurrence intervals (e.g., 100-year flood zone, or 1 percent annual probability) such that subjective assessment of flooding probability should roughly correspond with the objective assessment.

Under competitive market conditions, buyers take the hedonic price schedule $Y(\cdot)$ as given and optimize expected utility through the choice of housing characteristics, with residual income leftover for consumption of a composite commodity. Assuming continuous housing attributes and risk measures, the following first-order conditions characterize the optimal choice of attributes:

$$a : Y_a = \frac{p \cdot U_a^L + (1-p) \cdot U_a^{NL}}{\alpha \left[p \cdot U_m^L + (1-p) \cdot U_m^{NL} \right]}, \tag{3}$$

$$r : Y_r = \frac{p_r (U^L - U^{NL})}{\alpha \left[p \cdot U_m^L + (1-p) \cdot U_m^{NL} \right]}, \tag{4}$$

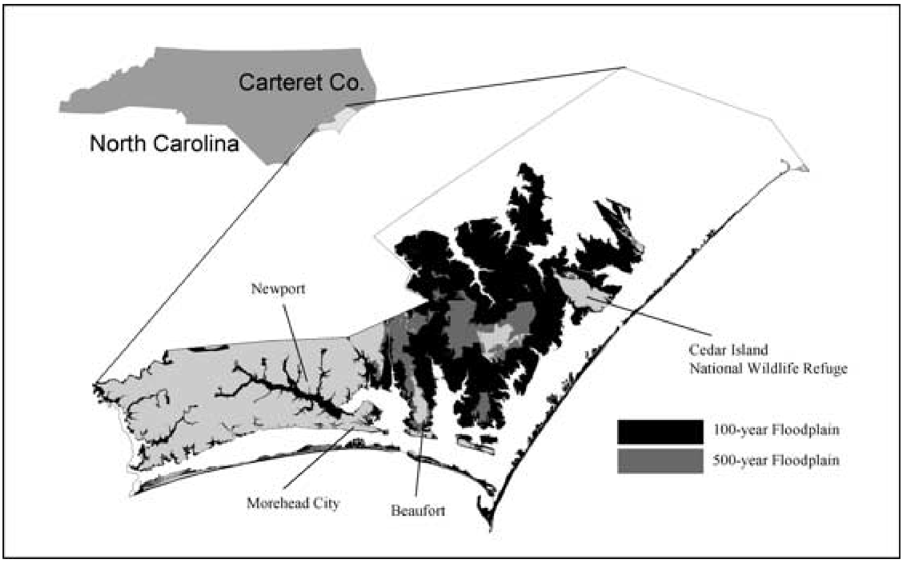
where $a = s, n, e$, and subscripts on U, Y, and p denote partial derivatives. Equation (3) indicates that the marginal implicit hedonic price for amenities reflects the expected amenity value. Equation (4) indicates that the marginal implicit price for risk attributes reflects marginal probability of the incremental utility difference across states, $p_r(U^L - U^{NL})$. Dividing by the expected marginal utility of income, $p \cdot U_m^L + (1 - p)U_m^{NL}$, produces a measure of marginal willingness to pay. We use the framework of (2) and the results in (3) and (4) to guide our formulation of the hedonic price model and interpretation of the parameter estimates.

STUDY AREA AND DATA

Data for this study come from Carteret County, located on the coast of the Atlantic Ocean in eastern North Carolina. It has a total population of 59,383. The largest town in the county, Morehead City, has a population of 7,691. Given its coastal location, the county has substantial access to water, including the Atlantic Ocean, the Pamlico Sound, the Intracoastal Waterway, back-barrier lagoons, the White Oak and Newport rivers, and numerous streams, creeks, and wetlands. With an elevation of 51 feet above sea level at its highest point, a large proportion of Carteret County is low lying and prone to flooding. The map of Carteret County shown in Figure 1 provides the geographic distribution of the floodplains. As shown in Figure 1, the 100-year floodplains are common along the coastline, rivers, and streams, whereas the 500-year floodplains tend to locate on other low-lying areas further inland.

The data for this study came from real estate transactions from 2000 to 2004. This followed a decade of relatively active North Carolina hurricane seasons. North Carolina was exposed to six named storms in the 1990s (Gordon in 1994, Bertha and Fran in

FIGURE 1
Floodplains of Carteret County, North Carolina, USA



Notes: The mainland and the barrier islands of Carteret County are separated by the Atlantic Ocean and Intracoastal waterways. Dark-shaded areas denote 100-year floodplains and light-shaded areas represent 500-year floodplains.

1996, Bonnie in 1998, and Dennis and Floyd in 1999). Hurricane Isabel made landfall September 2003 at Drum Inlet along the Outer Banks. Although Isabel caused major flooding and loss of power in the mid-Atlantic region, the impacts on Carteret County were relatively minor.[4] Hurricane Charley did affect the region in August 2004, although it had weakened to tropical storm classification by the time it reached North Carolina (National Oceanic & Atmospheric Administration–National Hurricane Center, 2005).

Multiple GIS-based data sets are utilized for this study: property parcel data from Carteret County Tax Office, NFIP digital flood maps and other GIS layers from North Carolina Floodplain Mapping Program, and county/coastline boundary data from North Carolina Center for Geographic Information and Analysis. Data from these sources are merged so that each parcel had information on flood hazard and coastal amenities as well as standard structural and neighborhood attributes.

[4] To further test whether additional hurricane activity carried new information on property risk, we performed a quasi-random experiment using Hurricane Isabel as the treatment variable, following the approach suggested by Meyer (1995). The results indicate that Hurricane Isabel had no significant effect. People appear to be well aware of flood risks in this area that has experienced a spate of storms associated with varying degrees of flooding. Hurricane Isabel did not seem to provide any new information to property owners. We thank an anonymous referee for suggesting this test.

Carteret County Tax Office maintains detailed sales records for all properties in the county. Carteret County is composed of mainland plus coastal barrier islands. The barrier islands are primarily a recreational area with many rental properties. We maintain that the housing market on the barrier islands is quite different from that of the mainland.[5] Property sales data from the barrier islands are excluded in this study. This study utilizes a total of 3,106 residential property sales records from September 2000 to September 2004. Sales prices were inflation-adjusted using a Consumer Price Index to report figures in September 2004 dollars. The average home sales price in the data set was $163,911. The data also include a series of structural attributes such as the number of bathrooms, age of the house, square footage of the house, the lot size, and whether a house is sold within a year of construction. The homes are on average 24 years old and have about 1,633 total square feet. About 16 percent of the properties are classified as new (sold within a year from the date built).

The NFIP digital flood maps are obtained from the North Carolina Floodplain Mapping Program and used to identify properties within flood zones. Flood zone maps provide the location and extent of floodplains in the county. We denote two major categories based on the recurrence interval. A 100-year floodplain (or A-zone) corresponds to an area that has a 1 percent annual probability of flooding. Due to the relatively high risk of flooding in this area, flood insurance is mandatory for homeowners who finance their purchase through federally regulated lenders. About 13 percent of the homes in our sample were located in the in the A-flood zone.[6] A 500-year floodplain (or X-zone) is an area outside the 100-year floodplain but associated with a lower level of flood risk (annual probability 0.2 percent). About 4 percent of the homes in our data set locate within the X-flood zone.

By law, a property is considered "in a flood zone" if any part of the structure falls within a floodplain. Since our GIS data contain only an outline of the land parcel (i.e., not the footprint of the structure), we define presence within a flood zone as the center of the parcel being located within a floodplain. Although this definition does create the potential for error, in the overwhelming majority of cases location in reference to the floodplain was unambiguous. In addition, a binary indicator—post-FIRM—identifies properties that are constructed on or after the effective date of

[5] We consider the mainland and the barrier islands of Carteret County as separate housing markets because they vary in a number of important ways. Mainland property is not likely to be considered a close substitute for barrier-island property. Barrier island properties provide direct access to beach amenities and command much higher prices than mainland parcels. Further, barrier island properties are exposed to more diverse risk factors, such as hurricane force winds, nor'easters, storm surge, and coastal beach erosion. Results from the Chow test indicated that the coefficients in the regression model are collectively different between the mainland and the Outer Banks housing markets.

[6] Generally speaking, some properties in the 100-year floodplains are also located in the Special Flood Hazard Area, also known as the V-zone, in which homes are subject to additional vulnerability associated with high velocity wave action (and thus higher insurance rates). This type of flood zone is common in the coastal communities adjacent to ocean beaches (i.e., primarily barrier islands on the East Coast). Our sample contains six houses (less than 0.2 percent of the total observations) located in V-zones. Therefore, analysis of V-zone areas is beyond the scope of this study.

the initial Flood Insurance Rate Map (FIRM) for the community (or after December 31, 1974, whichever is later). Post-FIRM properties within a floodplain are likely to have higher elevation and exhibit structural characteristics designed to make them flood resistant but are also subject to more expensive flood insurance premiums than otherwise equivalent pre-FIRM properties. This binary variable will indicate whether post-FIRM properties are valued differently from pre-FIRM properties, all else being equal.

Flood insurance premiums are calculated using the NFIP Flood Insurance Manual (May 2004) guidelines. The current version of the manual establishes a rate structure that depends on the recurrence interval (100-year or 500-year return interval), the date of construction, and presence of a Community Rating System (CRS). The NFIP was developed with the goal of meeting two challenges: to contain the rising cost of damage caused by disasters and to provide economically feasible relief to victims to help fuel recovery (Pasterick, 1998). In 1968, Congress passed the National Flood Insurance Act, which created the NFIP. Prior to this legislation, the federal government routinely paid large sums for disaster relief after floods. Under current provisions, the NFIP insurance is available only in the approximately 20,000 U.S. communities with approved community floodplain management plans. The NFIP provides a maximum flood coverage limit of $250,000 on single-family homes.

Amenities such as the proximity to coastal water (i.e., ocean, sound, and Intracoastal waterways), water frontage, and boat access are highly valued in the coastal housing market. In order to account for these amenities, we measure the distance to nearest coastal water for each residential property. The distance is measured as the Euclidean distance in feet from the centroid of each property to the nearest coastal water.[7] The average distance to nearest coastal water is less than 1 mile in our data set (4,882 feet). A binary indicator for first row from coastal water is created to proxy for water frontage and access. About 10 percent of homes sold during the period of our analysis have water frontage. We also control for neighborhood characteristics using distance to nearest central business district (downtown Morehead City), nearest highway, and nearest park, forest, or game land. We control for heterogeneity across townships using a set of dummy variables representing the fifteen townships in the county. Table 1 provides the definition and description of the variables used in this study. Summary statistics are presented in Table 2.

EMPIRICAL ANALYSIS

There has been a tremendous increase in the availability of spatial data and spatial analysis functionality in recent years. Considerable attention has been given to examining spatial dependence in estimated hedonic equations (Pace and Gilley, 1997; Basu and Thibodeau, 1998; Bowen, Mikelbank, and Prestegaard, 2001; Paterson and Boyle, 2002; Kim, Phipps, and Anselin, 2003). Spatial dependence arises because residential properties sharing common features tend to cluster in space. Sales prices tend to cluster in space because houses in a neighborhood share similar location amenities (e.g.,

[7] An alternative to the approach reported here is to construct an objective measure representing the "view" amenity. Constructing a view variable within GIS requires detailed data on the location and physical dimensions of coastal structures. These data were not available for the mainland of Carteret County at the time of this study.

TABLE 1
Definition and Description of the Variables

Variable	Description
PRICE	House sales price adjusted to September 2004 dollars
BATHRM	Number of bathrooms
AGE	Year house was built subtracted from 2004
SQFT	Total structure square footage
LOTSIZE	Total lot size measured in acres
NEWHOME	Dummy variable for new home (1 if sold within a year after built, 0 otherwise)
POSTFIRM	Dummy variable for post-FIRM properties (1 if post-FIRM, 0 otherwise)
FLOOD	Dummy variable for house within any floodplain (1 if inside, 0 otherwise)
FLOOD100	Dummy variable for house within a 100-yr floodplain (1 if inside, 0 otherwise)
FLOOD500	Dummy variable for house within a 500-yr floodplain (1 if inside, 0 otherwise)
COASTFRONT	Dummy variable for the first row from coastal water (1 if on, 0 otherwise)
COASTDIST	Distance in feet to the sound or Intracoastal waterways
CBD	Distance in feet to downtown Morehead City
HIGHWAY	Distance in feet to nearest highway
PARK	Distance in feet to nearest park, forest, or game land
TOWN1	Dummy variable for a township (1 if Morehead, 0 otherwise)
TOWN2	Dummy variable for a township (1 if White Oak, 0 otherwise)
TOWN3	Dummy variable for a township (1 if Atlantic, 0 otherwise)
TOWN4	Dummy variable for a township (1 if Cedar Island, 0 otherwise)
TOWN5	Dummy variable for a township (1 if Davis, 0 otherwise)
TOWN6	Dummy variable for a township (1 if Harkers Island, 0 otherwise)
TOWN7	Dummy variable for a township (1 if Harlowe, 0 otherwise)
TOWN8	Dummy variable for a township (1 if Marshallberg, 0 otherwise)
TOWN9	Dummy variable for a township (1 if Merrimon, 0 otherwise)
TOWN10	Dummy variable for a township (1 if Newport, 0 otherwise)
TOWN11	Dummy variable for a township (1 if Sea Level, 0 otherwise)
TOWN12	Dummy variable for a township (1 if Smyrna, 0 otherwise)
TOWN13	Dummy variable for a township (1 if Stacy, 0 otherwise)
TOWN14	Dummy variable for a township (1 if Straits, 0 otherwise)
TOWN15	Dummy variable for a township (1 if Beaufort (County Seat), 0 otherwise)
YEAR00	Dummy variable for sales year (1 if sold in 2000, 0 otherwise)
YEAR01	Dummy variable for sales year (1 if sold in 2001, 0 otherwise)
YEAR02	Dummy variable for sales year (1 if sold in 2002, 0 otherwise)
YEAR03	Dummy variable for sales year (1 if sold in 2003, 0 otherwise)
YEAR04	Dummy variable for sales year (1 if sold in 2004, 0 otherwise)

Notes: A 100-year floodplain denotes an area of the 1 percent annual chance of flooding that is determined in the Flood Insurance. Study: A 500-year floodplain includes an area outside the 1 percent annual chance floodplain, or an area of the 1 percent annual chance floodplain where average depths are less than 1 foot or where the contributing drainage area is less than 1 square mile.

school district) or because they have similar structural characteristics due to similar timing of construction (e.g., alike design features). The existence of spatial dependence implies that a sample contains less information than an uncorrelated one, and that the loss of information should be acknowledged in estimation to properly carry out statistical inference. If the relevant spatial dependence is ignored in estimation of the hedonic price function, then the resulting estimates could be inefficient or even

TABLE 2
Summary Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
PRICE	163,911.45	113,578.35	10,640.00	1,150,000.00
BATHRM	1.92	0.61	1.00	6.00
AGE	24.38	24.02	0.00	103.00
SQFT	1,632.85	573.60	288.00	6,108.00
LOTSIZE	0.67	1.46	0.03	46.30
NEWHOME	0.16	0.36	0.00	1.00
POSTFIRM	0.68	0.47	0.00	1.00
FLOOD	0.17	0.38	0.00	1.00
FLOOD100	0.13	0.33	0.00	1.00
FLOOD500	0.04	0.20	0.00	1.00
COASTFRONT	0.10	0.30	0.00	1.00
COASTDIST	4,882.16	7,671.97	2.11	36,762.16
CBD	50,561.76	35,012.50	378.60	158,071.29
HIGHWAY	6,038.45	6,662.40	54.50	62,729.16
PARK	9,952.99	7,590.77	4.02	41,962.51
TOWN1	0.38	0.48	0.00	1.00
TOWN2	0.21	0.40	0.00	1.00
TOWN3	0.01	0.10	0.00	1.00
TOWN4	4.2e-03	0.06	0.00	1.00
TOWN5	0.01	0.09	0.00	1.00
TOWN6	0.03	0.16	0.00	1.00
TOWN7	0.02	0.15	0.00	1.00
TOWN8	0.01	0.09	0.00	1.00
TOWN9	0.01	0.08	0.00	1.00
TOWN10	0.14	0.35	0.00	1.00
TOWN11	3.2e-03	0.06	0.00	1.00
TOWN12	0.01	0.09	0.00	1.00
TOWN13	2.9e-03	0.05	0.00	1.00
TOWN14	0.04	0.19	0.00	1.00
TOWN15	0.14	0.34	0.00	1.00
YEAR00	0.01	0.12	0.00	1.00
YEAR01	0.20	0.40	0.00	1.00
YEAR02	0.23	0.42	0.00	1.00
YEAR03	0.31	0.46	0.00	1.00
YEAR04	0.25	0.43	0.00	1.00

Note: Number of observations is 3,106.

inconsistent, and any inference based on the estimates may result in misleading conclusions (Anselin and Bera, 1998).

The first step in this estimation process is to create a spatial weights matrix that defines a relevant "neighborhood set" for each observation. We use a contiguity matrix that identifies properties within 325 feet in a binary fashion. That is, $w_{ij} = 1$ when i and j are located within 325 feet, and $w_{ij} = 0$ otherwise. The specification of the spatial weights matrix is based on our observations of the spatial extent that may share unobserved characteristics generating spatial dependence. We have experimented with different weight matrices, but the primary results are largely insensitive to different weight matrices.[8] Regression diagnostics based on ordinary least squares (OLS) estimation and the Lagrange multiplier (LM) test statistics indicated that the spatial error model is preferred.[9] As a result, the following first-order spatial error hedonic model is estimated:

$$\begin{aligned} \ln Y &= \alpha + \sum_i \beta_i x_i + \sum_j \gamma_j z_j + \sum_k \phi_k f_k + \varepsilon \\ \varepsilon &= \lambda W \varepsilon + u, \end{aligned} \tag{5}$$

where ln Y is the log of sales price, x_i is a dichotomous variable for the ith housing attribute, z_j is a nondichotomous variable for the jth housing attribute, f_k is a dichotomous variable equal to 1 for location within the flood zone k and 0 otherwise, λ is the spatial autoregressive coefficient, W is the spatial weights matrix, and u is a vector of independent and identically distributed random error terms. This model assumes that one or more omitted variables in the hedonic equation vary spatially, and thus the error terms are spatially autocorrelated. In this specification, the OLS estimator remains unbiased but is no longer efficient due to the nonspherical error covariance. Efficient estimators are obtained by utilizing the particular structure of the error covariance implied by the spatial process. The spatial autoregressive error models are estimated via maximum likelihood. The estimation is implemented within the GeoDa v.0.9.5-i (2004) environment in conjunction with ArcView GIS 3.3 extensions.

We use quadratic specifications for nondichotomous structural variables such as age of the house and total structure square footage. The effect of these attributes on property values is assumed to decline as the level of the attributes increase. We also use the log of the distance to coastal water to capture the diminishing marginal returns for the proximity as the distance increases. Distance to nearest central business district, nearest highway, and nearest park, forest, or game land are also log transformed. The primary results were robust across several alternative specifications, and the current specification provided the overall best fit.

In the following section, we report the estimation results and discuss the marginal effects of housing attributes on sales price. As suggested by Halvorsen and Palmquist (1980), the marginal effect for dummy variables is calculated by $Y \cdot \{\exp(\beta) - 1\}$, where Y is the sales price and β is the coefficient of a dummy variable. For distance-related variables, which are log-transformed, the marginal effect is price times the

[8] Anselin and Bera (1998) note that the spatial weights should be truly exogenous to the model, and the range of dependence allowed by the structure of the weights matrix should be constrained to avoid identification problems. Alternative spatial weights based on social network, distance decay, and k nearest neighbors have been considered in the literature.

[9] Spatial dependence can be also incorporated using a spatially lagged dependent variable model, which assumes that the spatially weighted sum of neighborhood housing prices enters as an explanatory variable in the hedonic price function. When both types of spatial dependence occur, the general model that includes both the spatial error and spatial lag terms can be considered. Failing to account for spatial lag dependence leads to biased and inconsistent parameter estimates, whereas failing to account for spatial error dependence leads to inefficiency.

distance coefficient divided by the distance. All marginal effects are evaluated at the observed mean values.

Estimation Results

The estimation results of spatial autoregressive error models are reported in Table 3. We estimate four different models based on the flood-risk zone variables and the inclusion of coastal amenity variables. In models (1) and (2), we do not differentiate between the levels of flood risk (i.e., 100-year floodplain vs. 500-year floodplain). The flood hazard variable represents the location within any type of floodplain. Model (1) excludes the coastal amenity variables (distance to coastal water and coastal waterfront indicator) whereas model (2) controls for these variables. In models (3) and (4) we differentiate between the high-flood-risk areas (100-year floodplains) and the low-flood-risk areas (500-year floodplains). Similarly, model (3) excludes the coastal amenity variables whereas model (4) controls for these variables. Most structural and neighborhood characteristics are statistically significant and have expected signs that are stable across specifications.

Knowing that proximity to water is highly desirable in coastal housing markets, model (1), which does not include amenity levels, is something of a "straw man." However, considering these parameter estimates juxtaposed to a more complete specification illustrates how an incomplete accounting of risks and amenities can lead to biased inferences. The flood risk variable in model (1) has the expected negative sign, but the effect is not statistically significant. The insignificant coefficient on the flood risk variable likely reflects the compounded effects of coastal amenities (proximity to coastal waterways and water access) and flood hazards. Such correlation, if present, would attenuate the coefficient on flood risk and increase the estimated variance of the parameter due to additional noise in the data. After controlling for the distance to coastal water and the coastal water frontage in model (2), the flood variable has a negative sign and becomes significant at any conventional level. The difference in the log-likelihood functions between model (1) and model (2) is large enough to conclude that the coastal amenity measures are important in the hedonic function specification. The result suggests that location within a floodplain lowers the average property's value by 7.3 percent. The marginal effect estimate suggests that location in a floodplain results in an \$11,598 discount evaluated at the mean property value (\$163,911).

The coefficient on distance to coastal water has a statistically significant and negative sign, implying that proximity to coastal water is desirable. As expected, coastal water frontage is also highly valued. The floodplains in a coastal setting are likely to be found adjacent to water, and in some areas almost all waterfront properties fall in a flood zone. Our data suggest that coastal amenities such as proximity to coastal water or water frontage are highly correlated with coastal hazard risks, and omitting coastal amenities in hedonic models may result in biased estimates of the effects of hazards on property values (and vice versa). However, this correlation is not perfect, and thus accounting for amenities allows for identification of the differential effects. After controlling for coastal amenities, our findings with regard to flood hazard are consistent with previous findings in the literature that have evaluated the effect of flood hazard on housing values in noncoastal settings (Shilling, Benjamin, and Sirmans, 1985; MacDonald, Murdoch, and White, 1987; Donnelly, 1989; MacDonald et al., 1990; Harrison,

TABLE 3
Estimation Results—Spatial Autoregressive Error Models

	(1)			(2)			(3)			(4)		
	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value
Intercept	10.725	0.196	0.000	11.337	0.218	0.000	10.728	0.196	0.000	11.337	0.218	0.000
BATHRM	0.095	0.046	0.038	0.109	0.050	0.029	0.099	0.046	0.031	0.108	0.050	0.030
BATHRM^2	−0.010	0.010	0.315	−0.011	0.011	0.293	−0.010	0.010	0.285	−0.011	0.011	0.298
AGE	−0.006	0.001	0.000	−0.010	0.002	0.000	−0.006	0.001	0.000	−0.010	0.002	0.000
AGE^2	5.9e−05	1.2e−05	0.000	9.4e-05	1.3e-05	0.000	6.0e-05	1.2e-05	0.000	9.4e-05	1.3e-05	0.000
SQFT	0.001	4.8e-05	0.000	0.001	5.0e-05	0.000	0.001	4.8e-05	0.000	0.001	5.0e-05	0.000
SQFT^2	−6.8e-05	1.2e-05	0.000	−1.1e-04	1.2e-05	0.000	−6.9e-05	1.2e-05	0.000	−1.1e-04	1.2e-05	0.000
LOTSIZE	0.027	0.007	0.000	0.030	0.008	0.000	0.027	0.007	0.000	0.030	0.008	0.000
LOTSIZE^2	−5.6e-05	2.4e-04	0.815	2.0e-04	2.6e-04	0.457	−4.1e-05	2.4e-04	0.864	1.9e-04	2.6e-04	0.465
NEWHOME	−0.053	0.021	0.012	−0.060	0.023	0.010	−0.054	0.021	0.011	−0.059	0.023	0.010
POSTFIRM	−0.030	0.029	0.303	−0.022	0.031	0.468	−0.031	0.029	0.284	−0.022	0.031	0.474
FLOOD	−0.028	0.020	0.170	−0.073	0.022	0.001						
FLOOD100							−0.010	0.023	0.654	−0.078	0.025	0.002
FLOOD500							−0.072	0.032	0.026	−0.062	0.035	0.074
COASTFRONT				0.313	0.030	0.000				0.314	0.030	0.000
ln(COASTDIST)				−0.106	0.009	0.000				−0.106	0.009	0.000
ln(CBD)	−0.008	0.013	0.501	−4.0e−04	0.014	0.976	−0.009	0.013	0.497	−3.8e-04	0.014	0.978
ln(HIGHWAY)	0.023	0.007	0.001	0.005	0.007	0.491	0.022	0.006	0.001	0.005	0.007	0.493
ln(PARK)	0.009	0.008	0.251	−0.001	0.008	0.899	0.009	0.008	0.253	−0.001	0.008	0.900
TOWN1	−0.268	0.067	0.000	−0.478	0.072	0.000	−0.272	0.067	0.000	−0.478	0.072	0.000
TOWN2	−0.082	0.099	0.409	−0.518	0.105	0.000	−0.096	0.100	0.334	−0.515	0.106	0.000

(continued)

TABLE 3
(Continued)

	(1)			(2)			(3)			(4)		
	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value	Coeff. Est.	Std. Error	*p*-value
TOWN3	−0.308	0.069	0.000	−0.458	0.074	0.000	−0.326	0.070	0.000	−0.453	0.075	0.000
TOWN4	−0.027	0.046	0.552	−0.081	0.050	0.103	−0.034	0.046	0.464	−0.080	0.050	0.112
TOWN5	−0.188	0.043	0.000	−0.377	0.047	0.000	−0.189	0.043	0.000	−0.377	0.047	0.000
TOWN6	−0.235	0.068	0.001	−0.442	0.074	0.000	−0.253	0.069	0.000	−0.437	0.075	0.000
TOWN7	−0.268	0.081	0.001	−0.366	0.086	0.000	−0.289	0.081	0.000	−0.361	0.087	0.000
TOWN8	−0.098	0.023	0.000	−0.115	0.024	0.000	−0.102	0.023	0.000	−0.114	0.024	0.000
TOWN9	−0.213	0.034	0.000	−0.013	0.042	0.748	−0.218	0.034	0.000	−0.012	0.042	0.783
TOWN10	−0.149	0.105	0.155	−0.509	0.114	0.000	−0.157	0.105	0.133	−0.508	0.114	0.000
TOWN11	−0.299	0.070	0.000	−0.489	0.074	0.000	−0.319	0.071	0.000	−0.484	0.075	0.000
TOWN12	−0.142	0.112	0.203	−0.528	0.121	0.000	−0.156	0.112	0.165	−0.525	0.121	0.000
TOWN13	−0.181	0.039	0.000	−0.268	0.041	0.000	−0.196	0.040	0.000	−0.264	0.042	0.000
TOWN14	−0.067	0.028	0.017	−0.120	0.030	0.000	−0.072	0.028	0.011	−0.119	0.031	0.000
YEAR01	0.020	0.051	0.701	0.020	0.056	0.717	0.018	0.051	0.722	0.021	0.056	0.712
YEAR02	0.044	0.051	0.391	0.067	0.055	0.223	0.043	0.051	0.401	0.068	0.055	0.221
YEAR03	0.067	0.051	0.190	0.096	0.055	0.081	0.066	0.051	0.194	0.096	0.055	0.080
YEAR04	0.068	0.051	0.188	0.111	0.055	0.044	0.066	0.051	0.197	0.112	0.055	0.044
LAMBDA	0.571	0.013	0.000	0.192	0.019	0.000	0.570	0.013	0.000	0.192	0.019	0.000
Observations			3,106			3,106			3,106			3,106
Log-likelihood			−1,418,.01			−1,11,9.81			−1,416.46			−1,119.79

Notes: Dependent variable is the log of sales price. Category omitted for township is Beaufort (county seat). Omitted year is 2000.

Smersh, and Schwartz, 2001; Bin and Polasky, 2004). These studies have found that location within a floodplain lowers property values from 3 percent to 12 percent.

Models (3) and (4) provide the estimation results for distinguishing flood risks between location within a 100-year floodplain and location within a 500-year floodplain. Given a chi-square distribution with two degrees of freedom, the likelihood ratio test statistic is significant at any conventional level of significance. The result suggests that exclusion of the coastal amenity measures may lead to the biased conclusions on the valuation of risk in a coastal setting. Most coefficient signs are identical to those of models (1) and (2). In model (3) where we do not control for coastal amenities, the variable for the location within a 500-year floodplain has a significant, negative sign, whereas the location within a 100-year floodplain is insignificant. However, after controlling for the coastal amenities in model (4), both flood risk variables become significant and have negative signs. As seen in Figure 1, the 500-year floodplains are usually located in low-lying inland areas and not associated with coastal water. Hence, the 500-year flood risk variable is less affected by the omission of coastal amenity measures than the 100-year flood risk variable. Results indicate that the price discount from locating within a higher flood risk area is significantly larger than the price discount for a lower risk area. The location within a 100-year floodplain lowers the property values by 7.8 percent whereas the location within a 500-year floodplain lowers the property values by 6.2 percent. The average price discount for being in a flood zone is estimated to be $12,325 and $9,849 for the 100-year and 500-year flood risk areas, respectively. It is interesting to note that the discount for flood risk that is presumably five times higher (100-year zone) than the 500-year flood zone is only about 30 percent higher. However, the nonlinearity of relative marginal values of differential flood risks appears to be in close agreement with the calculated flood insurance premiums as shown below.

We calculate flood insurance premiums and compare capitalized insurance premiums with sales price differentials in Table 4. We use three housing values: low ($75,000), average ($150,000), and high ($225,000). Reported insurance premiums are based on the NFIP insurance rates in May 2004. Insurance premiums depend on the value of insured structure and contents, deductibles, as well as the type of flood zone. The annual flood insurance premium for each type of house is given in the second column of Table 4. The annual insurance premiums are discounted in perpetuity using discount rates of 3 percent, 5 percent, and 7 percent. For an "average" valued house, assuming a 5 percent discount rate, the capitalized premium value of flood insurance is $13,500 and $9,320 for the location within a 100-year and 500-year floodplain, respectively. For the average valued house, the sales price differential between inside and outside these flood zones is quite comparable to the capitalized value of the flood insurance. Using a 5 percent discount rate, we find that for a high-valued house the sales price differentials are larger than the capitalized insurance premiums whereas they are the opposite for a lower valued house. The results suggest that nonmonetary losses that cannot be covered by insurance, and possibly the disutility of being displaced seem to matter for a higher valued property.

Increasing distance from the coastline has a strong negative impact on property values. Evaluated at the mean distance (4,882 feet), decreasing the distance to coastal water by 1,000 feet results in an increase in the property values by $3,540. Water frontage also commands a substantial premium and raises the property values by 31.3 percent.

TABLE 4
Comparison Between the Present Value of Flood Insurance Premiums and House Price Differentials

Property Value	Annual Insurance Premium	Present Value of Insurance Premium			Sales Price Differential
Properties Within a 100-Year Floodplain					
		3%	5%	7%	
Low ($75K)	$615	$20,500	$12,300	$8,786	$5,863
Avg. ($150K)	$675	$22,500	$13,500	$9,643	$11,726
High ($225K)	$735	$24,500	$14,700	$10,500	$17,589
Properties Within a 500-Year Floodplain					
Property Value	Annual Insurance Premium	3%	5%	7%	Sales Price Differential
Low ($75K)	$361	$12,033	$7,220	$5,157	$4,648
Avg. ($150K)	$466	$15,533	$9,320	$6,657	$9,295
High ($225K)	$571	$19,033	$11,420	$8,157	$13,943

Notes: Flood insurance premium estimates are based on the post-FIRM (Flood Insurance Rate Maps) for single-family houses without basement and enclosure. A standard deductible $500 applies. Premiums include the federal policy fee and the increased cost of compliance.

Evaluated at the sample mean, it provides a premium of $60,324 over an otherwise equivalent house. Milon, Gressel, and Mulkey (1984) estimated a large positive value from being close to the shore. They found that property values declined 36 percent in moving 500 feet from the Gulf of Mexico. Other studies have also found positive values for water proximity (Shabman and Bertelson, 1979; Earnhart, 2001).

Most structural housing characteristics are statistically significant and have expected signs across the models. The quadratic specifications capture the diminishing marginal effects of house age and structure square footage. Evaluated at the average house value, the results indicate that house price increases by $93 per additional square foot. An additional year of age of a house lowers the estimated sales price by $865 evaluated at observed mean values. A new house sold within a year after construction is estimated to lower sales price by $9,491. After controlling for the age effect, a new house may be discounted for other reasons such as lack of landscaping at the time of sale. Our results indicate that post-FIRM properties are not valued differently from pre-FIRM properties. Coefficients for the distance to central business district, nearest highway, and nearest park, forest, or game land have expected signs but are statistically insignificant.

CONCLUDING REMARKS

This study examines the effects of flood hazards on coastal residential property values. In general, the estimation results indicate that the price of a residential property located within a floodplain is significantly lower than an otherwise similar house located outside the floodplain. On average, location within a floodplain lowers estimated sales value $11,598, which represents a 7.3 percent reduction of the average house sales price. In addition, the data allow us to examine the marginal effects of different flood risks. The difference in the estimated discount between the higher-risk (100-year floodplain) and the relatively lower-risk (500-year floodplain) designation is also statistically significant. In a model that differentiates between 100-year and 500-year return interval, the estimated discounts are $12,325 and $9,849, respectively.

We find that the estimated sales price differentials associated with location in a floodplain are consistent with the capitalized value of flood insurance for different levels of risk. Focusing on barrier islands, Kriesel and Landry (2004) estimate that only 49 percent of coastal households maintain flood insurance, despite mandatory purchase requirements for those households that hold a federally backed mortgage. Assuming a similar proportion holds in the flood zone of the coastal mainland, the correspondence between implicit sales price differentials and capitalized insurance rates is noteworthy. That the average household may choose to forego formal flood insurance, but the market price of coastal properties reflects the capitalized insurance value, suggests that flood zone designations do convey useful information about flood risk that affect buyer bidding behavior. It appears that the NFIP flood zone designation (and / or the associated insurance premium) may signal the differential flood risk associated with alternative locations regardless of whether flood insurance is purchased or not.

We find evidence of a strong positive correlation between coastal amenities and flood hazard. Our results suggest researchers interested in analysis of amenities and / or hazards in coastal housing markets must be cognizant of the high degree of correlation between such attributes. Failure to control for both hazard risk and amenities will likely lead to biased results that inaccurately identify the sources of value. Fortunately, there is sufficient variation in our data that we can separately identify the effects of amenities and hazards; however, in some coastal settings this may not be the case. Coastal barrier islands, for example, which exhibit complex and potentially confounding effects of amenities and multiple hazards, present a challenging environment for hedonic modeling.

Current and future work includes exploring the possibility of employing GIS-based spatial indicators of property amenity values that are otherwise hard to quantify (Paterson and Boyle, 2002). A *viewshed* is defined as the surface area visible from a vantage point in a three-dimensional space. A viewshed can be derived for each property by quantifying differing degrees of ocean or beach views while accounting for natural topography and built obstructions. Spatial accessibility can similarly be quantified as network travel distances (as opposed to straight-line distance) from properties to public beaches or beach access points. Analysis that uses the GIS-based variables described above may help to unravel the influence of amenity and risk on the value of highly desirable locations such as barrier island properties. This is the direction of future analysis.

The size of the population along the U.S. coast has expanded rapidly in the last several decades with growth rates that are more than double the national rate of population growth (Rappaport and Sachs, 2003). One element driving such growth is the desire for access to unique coastal amenities. However, widespread coastal development has increased overall exposure to natural disasters, such as hurricanes, flooding, and erosion. This combination of growth and vulnerability has been seen as an explanation for the long-term trend of rising insured disaster losses. With over half of the U.S. population now residing in coastal counties, the need for public policy analysis of hazards that affect these locations is compelling and urgent. As this research agenda develops, the spatial complexity of the coastal setting must be carefully considered in order to prescribe the appropriate policy instruments that sustain economic growth and manage the inherent hazard risks of coastal areas.

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