Valuing Beach Quality with Hedonic Property Models

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Abstract

This paper explores the influence of beach quality on coastal residential property values. We hypothesize that beach and dune width provide local public goods in terms of recreation potential and storm/erosion protection, but that this relationship is limited by distance from the shoreline. Our findings support this hypothesis, as extending the influence of beach quality beyond 300 meters from the shore generally results in statistically insignificant parameter estimates. For houses within this proximity bound, high- and low-tide beach width and width of the dune field at the closest beach increases property value. Estimates of marginal willingness to pay (MWTP) range from $421 to $487 ($272 to $465) for an additional meter of high-tide (low-tide) beach, and MWTP for increases in dune width range from $212 to $383 per meter. We argue that interpretation of MWTP for beach quality depends upon individual understanding of coastal processes and expectations of management intervention. If property owners expect beaches and dunes to be maintained either naturally or through management, marginal implicit prices can be interpreted in the conventional manner. If, on the other hand, property owners expect beaches and dunes to degrade over time, MWTP from the hedonic model is an upper bound on true willingness to pay.

Key words: beach, dune, quality, width, coastal, erosion, hedonic, property value

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Introduction

Coastal shorelines are highly dynamic environments; interactions of coastal landforms, ocean, and atmosphere determine the physical characteristics of shorelines, leading to a dynamic equilibrium where rates of change are the result of a combination of physical forcing processes, spatial characteristics, underlying geology, vegetative communities, and physical characteristics of human development. Because the eastern coast of the U.S. lies on a passive geologic margin, much of the coast is characterized by a wide and gently sloping continental shelf and coastal plain. At the intersection of land and ocean exists an extensive barrier island system which spans more than two-thirds of the Southeast Atlantic shore (Morton and Miller 2005). These barrier islands are essentially well developed sand bars, formed as a consequence of wave energy dissipating on land and depositing sediments on the shore. These systems are in constant flux from both regular processes, such as long shore currents, waves and tides, as well as less frequent, high-energy events like hurricanes and nor'easters. Sea level change also plays an important role in barrier island evolution.

The natural appeal of coastal environments has led to extensive development of many coastal areas, including barrier islands. According to the Pew Oceans Commission (2003), between 1998 and 2015 the coastal population of the U.S. will increase by almost 20 percent from 139 million to 165 million. Hazards associated with natural coastal processes pose a risk to the increasing numbers of people and growing amounts of capital and infrastructure. Sediment flux manifests as fluctuating patterns of erosion and accretion along the shoreline. The overwhelming majority of shoreline in the eastern

U.S. (80 to 90 percent), however, has exhibited net erosion in recent decades (Galgano and Douglas 2000). Analysis of existing development suggests that 25 percent of homes within 500 feet of the U.S. coast could be lost to erosion in the next 60 years, at a potential cost of $530 million dollars each year (Heinz Center 2000).

Unremitting waves and sporadic storms drive sediment flux along the coast. Climate change threatens to increase the intensity of storms and raise sea level 18 to 59 centimeters over the next century (IPCC 2007), which would hasten shoreline change and exacerbate coastal erosion. Climatic change affects coastal property and infrastructure through both chronic shoreline erosion as well as discrete devastation due to storms. Beaches and dunes buffer development from coastal storms. While beaches can be decimated by storms, they typically exhibit significant recovery in intervening periods. With sea level rise, chronic erosion could be an increasing threat to beaches and dunes. In decades to come, few landforms will see changes as distinct as barrier islands. Development on barrier islands will be heavily influenced by this evolution.

In light of these hazards, owners and prospective owners of coastal property must decide if the risks are relevant to them and if so, what actions should be taken to mitigate these risks. These decisions are driven by numerous factors including their environmental knowledge, expectations of change in environmental and market conditions, risk preferences, and wealth. Prospective buyers can choose to locate further from the ocean as a form of self-protection, but this can limit recreation potential and visual amenity. For those desiring proximity to the ocean, buyers can search for properties that exhibit favorable environmental risk factors, such as higher elevation above sea level and wide beaches and dunes. The sandy beach also provides for recreation and leisure potential, while dunes may enhance or detract from recreation and leisure depending upon how people perceive them. If market participants view these environmental factors as influencing coastal risk and recreation potential, market prices should reflect implicit values for both protective aspects and recreational amenities.

In this study, we focus on the relationship between residential property values and measures of beach quality – specifically high- and low-tide beach width and dune width. Local beach width reflects the amount of erosion risk a property faces and also affects flood/storm surge risk. Aside from providing space for recreation and leisure activities, wider beaches provide an important buffer for absorbing waves and storm surge during high intensity storm events. Dunes also function as storm buffers. Narrow beaches and dunes often reflect high erosion rates, and thus potential for loss of beachfront or near ocean land and structures due to erosion. We use hedonic property price models to investigate coastal property owners' willingness to pay (WTP) for risk-reducing environmental amenities.

The interpretation of the relationship between housing prices and beach quality is made substantially more difficult by variability in homeowners' i) knowledge of coastal processes, ii) perceptions of the effectiveness of beaches as storm and erosion buffers, iii) value of nearby beaches for recreation and leisure, and iv) expectations of future coastal management actions. Information on rates of coastal erosion is generally available, but often not widely disseminated. Coastal management actions can include construction of shoreline armor to protect property (often at the expense of beach quality) and artificial replenishment of beach and dune sand to bolster the beach. All of these factors will influence subjective value for beaches when prospective buyers are bidding on coastal properties. The dynamics of coastal processes can make data collection difficult because beach and dune width fluctuate over time; areas can witness periods of erosion and accretion, and periodic beach replenishment by government can introduce discrete shifts in resource quality. We attempt to address homeowner perceptions of beach quality and fundamental beach dynamics in both our theoretical and empirical models.

We find that beach and dune quality do influence nearby property values in accord with theory of beaches as local public goods. That is, for coastal properties located close to the shoreline, beaches at that shoreline have an effect on market value. But, as we consider homes located further from the shore, the relationship between beach quality and sales price becomes insignificant. Our data suggest that values for properties within 300 meters are influenced by local beach quality, while those at greater distances are not (with the only exception being an unexpected negative sign on low-tide beach width for 500 and 600 meters proximity models). Marginal WTP for houses in close proximity to the beach ranges from $421 to $487 for an additional meter of high-tide beach, or $272 to $465 for an additional meter of low-tide beach. MWTP for increases in dune width range from $212 to $383 per meter. These welfare measures presumably reflect perceived storm and flood protection as well as recreation opportunity and amenity value that coastal households ascribe to nearby beaches and dunes. Given the beach and dune system's inherent volatility and local government's predilection with attempts at stabilization (e.g. seawalls and beach replenishment), interpretation of marginal implicit prices depends upon property owner's expectations of resource change over time. If property owners expect beaches and dunes to be maintained either naturally or through management, marginal implicit prices can be interpreted in the conventional manner. If, on the other hand, property owners expect beaches and dunes to degrade over time, MWTP from the hedonic model is an upper bound on true willingness to pay.

Coastal Resource Quality and Property Values

Previous Literature

Numerous studies have estimated household values for spatially variable environmental amenities in coastal housing markets. Proximity to water (Shabman and Bertelson 1979; Milon, Gressel, and Mulkey 1984; Edwards and Gable 1991; Pompe and Rinehart 1995a,b, 1990; Earnhart 2001; Parsons and Powell 2001; Landry, Keeler, and Kriesel 2003; Bin, Kruse, and Landry 2008; Pompe 2008), water view (Kulshreshtha and Gillies 1993; Lansford and Jones 1995; Benson et al. 1998; Pompe and Rinehart 1999; Bin et al. 2008), and water quality (Leggett and Bockstael 2000) have all been shown to influence coastal property values, and estimates of marginal WTP for these amenities have been produced using property sales data. Others have used hedonic property models to estimate incremental option price associated with coastal flood hazard (Hallstrom and Smith 2005; Bin, Kruse, and Landry 2008; Bin et al. 2008), erosion hazard (Kriesel, Randall, and Lichtkoppler 1993; Landry, Keeler, and Kriesel 2003; Pompe 2008), or wind hazard (Simmons, Kruse, and Smith 2002).

Likely due to the difficulties in gathering adequate data and interpreting results, less attention has been paid to beach quality. Pompe and Rinehart (1995a) examine coastal South Carolina property sales between 1983 and 1991, including beach width from 1989 as a covariate. They claim that beach width “remained fairly constant” during the study period. Their results suggest a positive relationship between property value and beach width.[1] Similarly, Landry, Keeler, and Kriesel (2003) analyze coastal property sales in Georgia between 1990 and 1997, including beach width measured in 1997 as a covariate in their hedonic regression model. They, too, find a positive relationship, but note the potential for mis-measurement of the beach width effect given the limited information on beach quality and longer period of sales data.

Pompe and Rinehart (1999) make use of time-series beach quality data gathered by a state agency that should provide better accuracy for analysis of property values over a specified time period. Employing a similar specification to their previous analysis (1995a), they examine the impact of high-tide beach width, low-tide beach width, and average beach width at the nearby shore, as well as beach width at a popular recreation site. They find a positive and statistically significant relationship for beach width at nearby beaches, regardless of the specification, but insignificant results for the popular recreation beach. These results suggest that nearby, or local, beaches are of greater import to property owners, likely reflecting recreation value in addition to erosion and flood protection.

The dearth of valuation estimates for beach quality is unfortunate, as these measures can play an important role in benefit-cost analysis (BCA) of beach management strategies. Early attempts at BCA (Bell 1986; Silberman and Klock 1988; Pompe and Rinehart 1995b; Kriesel, Keeler, and Landry 2004; Kriesel, Landry, and Keeler 2005) failed to take account of coastal dynamics. This is problematic, as benefit estimates that do not take beach evolution into account will be biased. Landry (2008) and Smith, et al.

[1] In Pompe and Rhinehart's specification, they include an interaction variable (beach width × distance from the beach) that they claim reflects the recreational aspects of the beach, and include beach width at the nearest shore to account for storm protection benefits. This approach is only valid if the storm protection benefits accruing to homeowners are independent of distance from the shoreline.

(2009) employ dynamic optimization methods that explicitly incorporate coastal geomorphology into the resource management problem. To be applied, however, the models require accurate estimates of beach maintenance benefits and costs.

As recognized by Pompe and Rinehart (1999) and Landry, Keeler, and Kriesel (2003), the interpretation of hedonic price parameters that reflect coastal resource quality depends upon market participants' knowledge of coastal processes and expectations of future coastal management actions. Home buyers who view beaches as static resources and those who expect management agencies to maintain beaches to a certain standard may have a different perspective on beach quality than those expecting that beach width may fluctuate in the future. We note that knowledge and expectations of fluctuations in resource quality are not unique to coastal environments, as pollution levels, urban public goods, and crime (all of which have been shown to influence property values) can also change over time. Fluctuating resources in the coastal zone, however, is perhaps a more salient case, as objective assessment suggests that in most instances beach and dune width are *expected* to change over time. Aside from knowledge and expectations, implicit values for the quality of nearby beaches and dunes will reflect perceptions of their effectiveness as storm and erosion buffers as well as their convenience for recreation and leisure.[2]

Theory

[2] The implicit price for risk mitigating environmental amenities will also reflect individual hazard perceptions. Individuals often behave as if the subjective probability of low probability/ high consequence event is zero, especially if they have not previously experienced a similar event (Kunreuther and Pauly 2006). In addition, Kunreuther and Pauly (2004) find that people are less likely to seek out information on risk when the search costs are high and the event probability is low. If home buyers do not believe that catastrophes are likely to occur, marginal implicit prices of beaches will not reflect risk-mitigation.

The theory of hedonic prices originates with Rosen (1974), but is based on the intuitive notion that the competitive market price of a differentiated commodity reflects the implicit value of attributes of the commodity. We focus here on the consumer side of the housing market. A home buyer Hicksian rent function (θ) for a property with a vector of attributes $\boldsymbol{a} = (a_1, \ldots, a_n)$ is implicitly defined as: $U(y - \theta, \boldsymbol{a}, \boldsymbol{\lambda}) = u$, where U is a strictly concave utility function with the usual properties, y is normalized (by price of numeraire good x) annual household income, and $\boldsymbol{\lambda}$ is vector of variables representing demographic factors, knowledge of coastal processes, and coastal management expectations. This structure gives rise to a family of indifference curves $\theta(\boldsymbol{a}, y, u, \boldsymbol{\lambda})$ in attribute/rent space that define household annual WTP for a_i (Palmquist 2004). The Hicksian bid function is then:

$$B(\boldsymbol{a}, y, u, \boldsymbol{\lambda}) = \sum_{t=0}^{\infty}(1+r)^{-t}\,\theta(\boldsymbol{a}, y, u, \boldsymbol{\lambda}) = \frac{\theta(\boldsymbol{a}, y, u, \boldsymbol{\lambda})}{r}, \qquad (1)$$

where r is the discount rate, and the last equality holds by the rules governing sum of an infinite geometric series. In a perfectly competitive environment, all consumers take the hedonic price schedule, $P(\boldsymbol{a})$, as given. Maximizing utility subject to a continuous housing price schedule implies equality of the gradient of the individual's bid function and the gradient of the hedonic price schedule, each in attribute space, in equilibrium; this is the genesis of the hedonic price function when housing supply is taken as fixed (a common assumption in the short run and for situations where existing housing stock dominates the market (Palmquist 2004)).

Conventional applications of the hedonic price method take the vector of attributes as fixed. A notable exception is housing age (Clapp and Giaccotto 1998), which evolves along a simple and known trajectory, but can exhibit discontinuities in implicit prices due to countervailing forces (obsolescence versus vintage effects). For those individuals that view barrier islands as static environments, equation (1) may be a reasonable representation of preferences for beach and dune quality. Likewise, for individuals that expect beaches and dunes will be reasonably maintained by some external authority over the relevant period they occupy a unit of housing, equation (1) could be accurate. In this case, the gradient of an estimated hedonic price equation can provide an estimate of marginal willingness to pay for attribute a_i:

$$\frac{\partial P(\boldsymbol{a})}{\partial a_i} = \frac{\partial B(\boldsymbol{a}, y, u, \boldsymbol{\lambda})}{\partial a_i} = \frac{1}{r}\frac{\partial \theta(\boldsymbol{a}, y, u, \boldsymbol{\lambda})}{\partial a_i}. \tag{2}$$

For those that expect beaches and dunes to fluctuate, however, equation (1) is incorrect. Given some expected time path for attribute i based on current conditions and individual characteristics $\boldsymbol{\lambda}$, $\tilde{a}_i(a_i^0, \boldsymbol{\lambda}) = [a_i^0, ..., a_i^\infty]$, the Hicksian bid function is:

$$\tilde{B}(\boldsymbol{a}_{\text{-}i}, \tilde{a}_i(a_i^0, \boldsymbol{\lambda}), y, u, \boldsymbol{\lambda}) = \sum_{t=0}^{\infty}(1+r)^{-t}\,\theta(\boldsymbol{a}_{\text{-}i}, a_i^t(a_i^0, \boldsymbol{\lambda}), y, u, \boldsymbol{\lambda}), \tag{3}$$

where $\boldsymbol{a}_{\text{-}i}$ is a vector of attributes other than i. This expression does not simplify as in (1), because the scale factor of the infinite sum ($\theta(\bullet)$) is not constant. All else being equal, we would expect an individual that expects a_i to decay (grow) to bid less (more) than and individual that expects a_i to remain constant. The bid, however, will also be influenced by income and individual specific parameters, $\boldsymbol{\lambda}$, such as education, knowledge, and expectations. In a competitive equilibrium, utility maximization implies equality of the gradient of the individual's bid function and the gradient of the hedonic price schedule. With respect to the dynamic characteristics associated with housing, this equality holds at the current attribute level, a_i^0, on the hedonic price schedule, but the marginal bid reflects the expected present value of the sequence of marginal rents:

$$\frac{\partial P(\boldsymbol{a})}{\partial a_i^0} = \frac{\partial \widetilde{B}(\boldsymbol{a}_{\text{-}i}, \widetilde{a}_i(a_i^0, \boldsymbol{\lambda}), y, u, \boldsymbol{\lambda})}{\partial a_i^0} = \sum_{t=0}^{\infty} (1+r)^{-t} \frac{\partial \theta(\boldsymbol{a}_{\text{-}i}, a_i^t(a_i^0, \boldsymbol{\lambda}), y, u, \boldsymbol{\lambda})}{\partial a_i^0}. \quad (4)$$

In essence, the home buyers is not paying for current attribute level in perpetuity, but the expected sequence of future attribute levels.

The last element of RHS of equation (4) is the current value marginal rent or willingness to pay, $\partial\theta / \partial a_i^t \times \partial a_i^t / \partial a_i^0$, which is non-negative if both partial derivatives are assumed to be greater than or equal to zero. Since the rent function is strictly concave in utility-bearing attributes of $\boldsymbol{a}$ (Palmquist 2004), the marginal willingness to pay is diminishing in a_i^t. Thus, the interpretation of marginal willingness to pay depends upon individual beliefs about attribute a_i, $\widetilde{a}_i(a_i^0, \boldsymbol{\lambda}) = [a_i^0, ..., a_i^\infty]$. For individuals that expect a_i to decay (grow) the marginal willingness to pay in (4) is increasing (decreasing) over time. The discount factor is diminishing exponentially over time, which should ensure that the index in (4) is decreasing over time. The implications are that present discounted value of marginal willingness-to-pay in (4), $\partial \widetilde{B}(\boldsymbol{a}) / \partial a_i^t \times \partial a_i^t / \partial a_i^0$, reflects expected future attribute levels. The gradient of the hedonic price function, $\partial P(\boldsymbol{a}) / \partial a_i^0$, then, will be an upper (lower) bound to the true marginal value because the expected characteristic level (a weighted average, in which the weights are given by the discount factor in (4)) is less (greater) than the current level under the assumption that the characteristic is decaying (growing). Thus, the interpretation of hedonic prices for beach and dune width depends upon individual perceptions and beliefs of durability of the beach and dune system.

Study Area and Data

Tybee Island, the northernmost barrier island on the Georgia coast, is located roughly 19 miles east of Savannah, Georgia. The island has a relatively small year-round population of 3,392 people (2000 estimate). Tybee Island became a tourist destination in the late 1800's, leading to residential and commercial development on the island. The Island now offers the region, which includes Savannah and Atlanta, a popular beach resort destination.

Tybee Island has experienced numerous shoreline engineering modifications over the past hundred years. Historically, Tybee Island has eroded on its northeastern portion and accreted on its southeastern portion (Oertel, Fowler, and Pope 1985). Much of the historical erosion can be attributed to harbor dredging on the Savannah River (Griffin and Henry 1984). Erosion on the island has been addressed using numerous stabilization projects, including sea walls, groins, and riprap. Also, between 1976 and 2000, there were five major beach replenishment projects.

Our dataset includes 372 real estate transactions for single-family residences that occurred between January 1990 and December 1999. All property sales records with complete information on "arms length" transactions were gathered from the county tax assessor database. Descriptive statistics for the dataset are presented in table 1. The average real home sales price is \$151,906 (1999\$). The data also include numerous structural attributes such as heated square footage (mean = 1703), lot square footage (mean = 8345), number of bedrooms (mean = 2.8) and bathrooms (mean = 2.1), presence of garage (mean = 0.18), presence of air conditioning (mean =0.86), and the age of the home at the time of sale (mean = 30 years). Spatial characteristics include oceanfront homes (mean = 0.06), inlet front homes (mean = 0.03), homes bordering marsh (mean = 0.04), and distance from the nearest beach (mean = 332 meters).

[table 1 about here]

The original beach quality measurements used in this analysis reflect conditions existing in spring of 1997. Thirty-two transects were measured using an electronic range finder, and an additional eight transects were interpolated to provide regular and complete coverage of Tybee's beach. Given the length of Tybee Island, we collected measurements, on average, in 140 meter intervals. Thus, beach quality measures for 1997 reflect conditions at a maximum of approximately 70 meters from the nearest beach for all Tybee Island properties. For each transect, high- and low-tide beach and dune widths were recorded. For the 1997 measurements, the mean high-tide beach width is 26.4 meters, and the mean low-tide beach width is 75.9 meters. The average dune field width is 67.6 meters.

In order to control for temporal variability in beach quality, we combine four sources of information: the observed beach width calculations from 1997, U.S. Geological Survey (USGS) shoreline transects depicting the erosion rate between 1970 and 1999, historic beach replenishment data for Tybee Island, and anecdotal evidence from local government documents. We utilize these sources of information to estimate shoreline change during our study period (1990 – 1999).

USGS contains archival data on shoreline erosion rates, in meters per year, between 1970 and 1999 using 95 transects that cover Tybee Island from the Northern Groin to the Southern tip of the island (Miller et al. 2005). These data cover most of the shoreline, except for the narrow beaches on the north side of Tybee along the Savannah River. While these data reflect the rate of shoreline change over this period, they also incorporate fluctuations in shoreline position resulting from beach replenishment projects. As these projects bolster shoreline position, implied erosion rates will be inaccurate estimates of the natural erosion rate. To correct for this, we recalculate the annual erosion rate for each transect taking into account changes in shoreline position resulting from beach replenishment.

Our adjustments are accomplished using secondary data for beach replenishment projects on Tybee Island (U.S. Army Corps of Engineers 1994; Applied Technology and Management, Inc., 2002). These data allow us to control for large discrete changes in beach width due to sand replenishment activities. Between 1970 and 1999, Tybee Island witnessed six beach replenishment operations for a total of nine projects on different reaches. Of these nine projects, one utilized poor fill material and did not produce an appreciable effect on beach quality, so we omitted it from our calculations. For each project, we had information on the volume of sand (in cubic yards), the berm elevation, the depth of closure, and the project's shoreline length. We were able to estimate the change in beach width resulting from replenishment using the following formula:

$$W = \frac{V}{(B + D_C)} \tag{5}$$

where W is beach width, V is sand volume, B is the berm elevation, and D_C is the depth of closure (USACE 2008). Table 2 gives the change in beach width for each project. Estimated incremental width, W in equation (5), is used to adjust USGS shoreline position measures in order to produce an adjusted shoreline erosion rate. For those reaches of shoreline that have received replenishment sand, the adjusted erosion rate is greater than the implied rate, and should more accurately reflect the historical rate of shoreline change.

[table 2 about here]

Annual beach width for each transect and year from 1990 to 1999 are estimated using the adjusted annual erosion rate, the change in width resulting from a given beach replenishment project (if applicable), and the 1997 beach width measurements. For reaches that were replenished in 1995, we subtracted the total amount of the change in beach width due to replenishment for years 1990 – 1994. For reaches that were replenished in 1999, we added the total amount of change in beach width for 1999. To verify our beach width estimates, we referred to anecdotal information and shoreline maps from the Tybee Island Beach Management Plan (Elfner 2005) and the Savannah Harbor Beach Erosion Study (Applied Technology and Management 2002). The original USGS data suggest that 67.5% of the shoreline is eroding, while the remaining 32.5% was accreting between 1970 and 1999. The average adjusted high-tide (low-tide) beach width was 26.5 (76.1) meters. The maximum adjusted erosion rate was 3.35 meters/year and the maximum adjusted accretion rate was 5.95 meters per year. As indicated in table 1, the average adjusted erosion rate is 1.03 meters/year, and the average adjusted accretion rate is 0.56 meters/year.

Methods

For our purposes, we consider local beach conditions as those at the shoreline that is the shortest Euclidean distance from any particular parcel. For most parcels, these beaches are located along the ocean, but for a few parcels on Tybee Island's extreme north side, these beaches are on the Savannah River. We assume that quality of the nearest beach is a local public good, but that this relationship is limited by distance from the shoreline. For those houses in close proximity to the shore, the nearest beach can provide protection from storm surge and erosion, in addition to providing for convenient recreation and leisure opportunities. For houses located a significant distance from the shore, however, beach conditions at any particular point are arguably less important. For these households, storm surge and erosion are much less of a concern. Moreover, for households located away from the beach, significant distance must be traveled in order to engage in beach recreation, such that many will bike or drive, and thus their recreation site choices are limited less by what is nearby and more by what is accessible (via road networks and access points, and given parking availability). To model beaches as local public goods, we incorporate distance from the shoreline into our hedonic price models by interacting a proximity dummy variable with beach quality. As we are uncertain *a priori* what distance represents and appropriate cut-off for beaches as local public goods, we estimate a series of models with the cutoff varying from 100 meters to 600 meters in one-hundred meter increments.

Our beach quality measures of interest – high- and low-tide beach width and dune width – exhibit significant correlation, as could be expected. High-tide beach width, low-tide beach width, and dune width are positively correlated, with pair-wise correlation coefficients significantly different from zero (ranging between 0.629 – 0.819). As such, if we include all beach quality measures in a single model, standard errors will be large due to multicollinearity. In what follows, we estimate separate models for high- and low-tide beach width and dune width.

The problem of spatial dependence has garnered increasing interest in the hedonic valuation literature (Dubin 1988; Kim, Phipps, and Anselin 2003; Bin, Kruse, and Landry 2008; Bin et al. 2008), and can be thought of as a clustering of property values based on location or common proximity. Sales prices can cluster in space due to common, unobserved location factors (such as school quality, local crime rate, local government services, and other intangible neighborhood characteristics) or because surrounding parcels have similar structural characteristics (such as architectural design, dwelling and lot size, and unobserved housing characteristics) that reflect style or common practice at the time of neighborhood development/housing construction. Our regression model takes the form:

$$P = P(\boldsymbol{a}, \varepsilon, \boldsymbol{\Psi}), \tag{6}$$

where $\boldsymbol{a}$ is a vector of structural and environmental housing attributes, ε is a random error term, and $\boldsymbol{\Psi}$ is a spatial weights matrix that explicitly defines the spatial structure of sales price dependence.

We use a contiguity matrix that identifies properties within 400 meters as "neighbors"; $\psi_{ij} = 1$ when i and j are located within 400 meters of one another, and $\psi_{ij} = 0$ otherwise. Theory dictates that the structure of $\boldsymbol{\Psi}$ be treated as exogenous to the model (Anselin and Bera 1998), and primary results of the paper are not sensitive to the choice of distance. Preliminary regression model diagnostics indicated the presence of spatial dependence in sales prices,[3] so we focus attention upon the spatial lag model:

$$\ln P = \rho \boldsymbol{\Psi} P + \beta \boldsymbol{a} + \varepsilon \,, \tag{7}$$

where ρ is the spatial autoregressive parameter, $\boldsymbol{\Psi} P$ is the vector of spatially lagged dependent variables for weights matrix $\boldsymbol{\Psi}$, β is a vector of unknown parameters to be estimated, and ε is a vector of independent and identically distributed random error terms (Anselin and Bera 1998). The presence of the spatially lagged dependent variable induces correlation with the error term, which renders ordinary least squares biased and inconsistent. Marginal effects in a spatial lag hedonic model reflect induced values on neighboring parcels stemming from the spatial autocorrelation structure. For continuous variables, the marginal effect is given by $\left(\frac{\beta}{1-\rho}\right) \cdot P$. For binary variables, the marginal effect is $\frac{P \cdot \{\exp(\beta) - 1\}}{1-\rho}$ (Halvorsen and Palmquist 1980).

Results

We explore the influence of coastal resource quality on housing prices with three types of specifications. The first two include high-tide and low-tide beach width, respectively, and the third includes dune width. For each specification, we explore an array of effects varying by distance from the shoreline for the influence of beach quality on local property values. Our distance cutoffs range from 100 meters to 600 meters from the shore (in 100 meter increments). Across most specifications, estimated parameters for

[3] All robust Lagrange Multiplier tests for $\rho = 0$ are statistically significant, with p-values less than 0.01.

cutoff distances greater than 300 meters were statistically insignificant.[4] Thus, we present results for beach and dune quality interacted with dummy variables representing parcels 100 meters, 200 meters, and 300 meters from the shoreline.

[table 3 about here]

Results for high-tide beach width are presented in table 3. All structural and location characteristics (such as ocean frontage, inlet frontage, and marsh frontage) have the expected sign. Most of the estimated parameters are statistically significant for 1% chance of Type I error, except for lot square footage, presence of garage, marsh frontage, and high-tide beach width. Beach width, however, is statistically significant at the 5% level. The parameter on high-tide beach width is positive, indicating that the natural log of property value is increasing in beach width. The spatial lag parameter is significantly different from zero, and the likelihood ratio test rejects restricting this parameter to zero. The coefficient on inlet frontage indicates that this location is more highly valued than ocean frontage, but both are valued above inland properties. The log-likelihood value is the largest for the 200 meter cutoff model, suggesting that this specification could provide a better fit to the data.[5]

[table 4 about here]

[4] The exceptions are low-tide beach width, which for distances of 500 and 600 meters we obtain counter-intuitive negative signs on beach width.

[5] As all models have the same number of parameters, we eschew the calculation and comparison of information criteria.

Results for low-tide beach width models, presented in table 4, are similar to high-tide model, in terms of parameter signs and patterns of statistical significance. The exceptions are that distance from the shoreline is significant at the 5% level in the 200 and 300 meter models, while low-tide beach width is statistically significant at the 1% level in all models. Thus, property values appear to be increasing in low-tide beach width, and the results are stronger than the case of high-tide beach width. As noted in footnote 5, however, for models that consider 500 and 600 meters proximity to the shoreline as an appropriate specification for local beach quality, we obtain negative and statistically significant parameters on low-tide beach width. We are uncertain what could be driving these unexpected results. The log-likelihood value for these series of models is also largest for the 200 meter cutoff specification.

[table 5 about here]

Table 5 presents parameters for the dune width model. Again, the pattern of parameter signs and statistical significance is similar to the beach width models. The parameter estimate for dune width is positive and statistically significant at the 1% level in each model, suggesting that property values in close proximity to the beach (100 – 300 meters from the shoreline) are increasing in the width of the dune field at the nearest beach. Again, of the three models estimated, the log-likelihood value is the largest for the 200 meter cutoff model.

Estimates of marginal willingness-to-pay (MWTP) for beach and dune width are presented in table 6. Standard errors are calculated using the delta method. MWTP for high-tide beach width is $71 per meter (95% confidence interval (CI): $1 - $114) for the

100M model, $168 per meter (95% CI: $32 - $302) for the 200M model, and $196 per meter (95% CI: $22 - $369) for the 300M model. The standard errors for high-tide beach width are somewhat larger than other models, giving rise to rather wide confidence intervals. These are average welfare measures for all coastal properties. MWTP estimates for high-tide beach width conditional on proximity to the shore (i.e. being located within the cut-off distance) are $447 per meter for the 100M model, $487 per meter for the 200M model, and $421 per meter for the 300M model.

[table 6 about here]

MWTP estimates for low-tide beach width are $74 per meter (95% CI: $34 - $114) for the 100M model, $154 per meter (95% CI: $82 - $226) for the 200M model, and $126 per meter (95% CI: $34 - $218) for the 300M model. These are roughly similar to high-tide estimates, with slightly lower point estimates for 200M and 300M models. The confidence intervals are tighter, reflecting higher p-values for beach width parameters in the low-tide models. MWTP estimates for low-tide beach width conditional on proximity to the shore are $465 per meter for the 100M model, $447 per meter for the 200M model, and $272 per meter for the 300M model.

Welfare estimates for dune width are the most precise. MWTP for dune width is $52 per meter (95% CI: $18 - $85) for the 100M model, $132 per meter (95% CI: $73 - $191) for the 200M model, and $98 per meter (95% CI: $27 - $170) for the 300M model. MWTP for dune width conditional on proximity to the shore are $325 per meter for the 100M model, $383 per meter for the 200M model, and $212 per meter for the 300M model. Other welfare measures of interest from the hedonic property models include ocean frontage (WTP ranging from \$39,000 to \$75,000 across all models), inlet frontage (WTP ranging from \$121,000 to \$128,000 across all models), and distance from the shoreline (MWTP ranging from -\$41 to -\$84 per meter across all models)

Discussion

Using spatial lag hedonic price regression models, we find evidence that coastal resource quality affects market values of nearby properties. Our results suggest that high- and low-tide beach width and width of the dune field have a significant positive effect on property values within 300 meters of the shoreline. We do, however, find contradictory results for low-tide beach width at distances of 500 and 600 meters from the shore. For high-tide beach width and dune width, estimated values for models of proximity greater than 300 meters are statistically insignificant. Overall, we interpret this pattern of results as supporting our specification of coastal beach quality as a local public good, influencing the value of property in close proximity to the shore. Across all specifications, 200 meter proximity to the shore as a measure of local beach quality provided the best fit to the data (based on log-likelihood values). While we attempted other specifications for the distance-beach quality relationship (such as, Pompe and Rinehart's (1995a,b; 1999) approach of included beach width and an interaction term for beach width and distance from the shore), our results did not support these models, as beach quality variables were statistically insignificant. More research is necessary to explore the proximity-beach quality relationship, and to investigate the contradictory results we find for low-tide beach width.

Theory suggests that the interpretation of MWTP estimates depends upon individual property owners' perceptions of the durability of coastal resource quality and expectations of future beach management activities. For property owners that are ignorant of coastal dynamics, beaches may be viewed as a static resource that can provide storm protection and recreation opportunity in perpetuity. In this case, hedonic parameter estimates for beach quality can be interpreted as parameters for conventional structural attributes, like square footage, number of bedrooms, etc. Likewise, for those that expect beach quality to fluctuate but believe that coastal management practices (e.g. beach replenishment) can maintain the beach over some relevant time period, parameters can be similarly interpreted. Under these circumstances, coastal property owners are willing to pay, on average, $71 to $196 for an additional meter of high-tide beach width, with estimates differing based upon the definition of local beach width (i.e. proximity measure employed). For those properties located in close proximity, average MWTP ranges from $421 to $487 for an additional meter of beach width at high tide. These MWTP measures are estimated at current average high-tide beach width of 26.5 meters.

Estimates of average MWTP for increases in low-tide beach width range from $74 to $154, evaluated at the current average low-tide beach width of 76 meters. For those properties located in close proximity, average MWTP ranges from $272 to $465 for an additional meter of beach width at low tide. For beaches, these welfare measures reflect perceived storm and flood protection benefits, as well as recreational and leisure value of local beaches. Average MWTP for increases in dune width range from $52 to $132 per meter, evaluated at current average of 68 meters. For properties in close proximity to the shoreline, average MWTP ranges from $212 to $383 for an additional meter of dune width. These welfare measures reflect perceived storm and flood protection afforded by sand dunes and any amenity value that coastal households ascribe to the dunes.

All previous papers that have employed hedonic property models to value beach quality (Pompe and Rinehart 1995a, b; Pompe and Rinehart 1999; Landry, Keeler, and Kriesel 2003) have interpreted parameters in a straightforward and conventional manner. We argue that the interpretation of marginal implicit prices depends upon individual perceptions of beach quality. Current expertise on barrier island systems identifies beach conditions as highly variable over time, responding to waves, currents, storms, and changes in sediment supply. As such, an informed buyer would expect changing beach conditions over the time that they occupy a coastal property. We show that for those who expect beach and dune conditions to degrade over time, marginal implicit price estimates provide an upper bound on true willingness to pay. We obtain this result because marginal prices are derived from the gradient of the hedonic price function, evaluated at the current level of resource conditions, but individual bid functions will reflect the present discounted marginal value for expected level of conditions over time. Thus, the bid function is evaluated at a lower expected level of resource quality than the hedonic price function. Since the marginal bid is decreasing in beach width, the hedonic gradient will provide an upper bound on true willingness-to-pay. The opposite result obtains for those that expect resource quality to improve over time, and the marginal implicit price estimated from the hedonic price function will be a lower bound on true willingness-to-pay. Unfortunately, little information is available that might elucidate individual coastal homeowners' perceptions of the durability of coastal beach resources or their knowledge of coastal processes. This remains an important area for future research.

Conclusions

Beach erosion is a significant problem along America's coastline, and the prospects of sea level rise offer more complications and higher stakes. There is a large amount of property and infrastructure exposed to coastal hazards, including flooding, storm surge, and wind damage, in addition to beach erosion. Current efforts Landry (2008) and Smith, et al. (2009) employ dynamic optimization methods that explicitly incorporate coastal geomorphology into the erosion management problem. To be applied, however, the models require accurate estimates of beach replenishment benefits and costs.

We find that beach and dune quality do influence nearby property values in accord with theory of beaches as local public goods. That is, for coastal properties located close to the shoreline, beaches at that shoreline have an effect on market value. But, as we consider homes located further from the shore, the relationship between beach quality and sales price becomes insignificant. Our data suggest that values for properties within 300 meters are influenced by local beach quality, while those at greater distances are not (with the only exception being an unexpected negative sign on low-tide beach width for 500 and 600 meters proximity models). Marginal WTP for houses in close proximity to the beach ranges from $421 to $487 for an additional meter of high-tide beach, or $272 to $465 for an additional meter of low-tide beach. MWTP for increases in dune width range from $212 to $383 per meter. These welfare measures presumably reflect perceived storm and flood protection as well as recreation opportunity and amenity value that coastal households ascribe to nearby beaches and dunes. Given the beach and dune system's inherent volatility and local government's predilection with attempts at stabilization (e.g. seawalls and beach replenishment), interpretation of marginal implicit prices depends upon property owner's expectations of resource change over time. If property owners expect beaches and dunes to be maintained either naturally or through management, marginal implicit prices can be interpreted in the conventional manner. If, on the other hand, property owners expect beaches and dunes to degrade over time, MWTP from the hedonic model is an upper bound on true willingness to pay.

The dearth of valuation estimates for beach quality is unfortunate, as these measures can play an important role in benefit-cost analysis (BCA) of beach management strategies. Early attempts at BCA (Bell 1986; Silberman and Klock 1988; Pompe and Rinehart 1995b; Kriesel, Keeler, and Landry 2004; Kriesel, Landry, and Keeler 2005) failed to take account of coastal dynamics. This is problematic, as benefit estimates that do not take beach evolution into account will be biased.

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The topological data generated from the use of the TLS integrated instrument suite will be utilized to analyze the benefits of coastal resource quality. Measures of beach quality at the level of individual coastal parcels will be gathered in conjunction with property sales data and MLS data in order to provide an accurate assessment of the influence of beach width on property values and, possibly, the number of days that a property is offered for sale (or "sits on the market"). Both transacted price and time-to-sell could reflect the value of beach quality. Analysis of property markets will include an exploration of the influence of dune quality (e.g. height, width, presence of vegetation), as previous research has been inconclusive (Landry and Hindsley 2009). In addition, survey data can be gathered to assess buyers' and sellers' perceptions of the stability of coastal resources and relate these constructs to geomorphological phenomena, such as beach width, dune width, erosion scarps, and perhaps others. The combination of coastal topological data at a fine spatial and temporal scale with information on coastal property markets will allow for a detailed and nuanced exploration of the influence of coastal resources on coastal development that will provide insight into human behavior in the coastal zone and coastal resource management.

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Table 1: Descriptive Statistics for Tybee Island Property Dataset

Variable	Observations	Mean	Std. Dev.	Min	Max
Sales Price (1999)	372	151906.60	85669.00	21564.01	715264.80
Heated Sqft	372	1703.27	651.66	585.00	4096
Lot Sqft	372	8345.07	8518.68	997.90	120000
Bedrooms	372	2.82	0.84	1	6
Bathrooms	372	2.10	0.74	1	6
Garage	372	0.18	0.39	0	1
AC	372	0.86	0.35	0	1
Age	372	30.08	25.40	0	89
Ocean Front	372	0.06	0.25	0	1
Inlet Front	372	0.03	0.18	0	1
Marsh	372	0.04	0.20	0	1
Distance	372	332.94	218.72	0	1036
High Tide Beach (1997)	372	26.37	17.03	0	92
Low Tide Beach (1997)	372	75.94	22.66	25	105
Dune Width	372	67.64	41.48	0	148
Erosion Rate	372	1.04	1.07	0	3.35
Accretion Rate	372	0.56	1.19	0	5.95
Adjusted High Tide Beach	372	26.55	16.63	0	108.60
Adjusted Low Tide Beach	372	76.07	25.19	7	135.71
y1990	372	0.08	0.28	0	1
y1991	372	0.05	0.21	0	1
y1992	372	0.09	0.28	0	1
y1993	372	0.09	0.28	0	1
y1994	372	0.12	0.33	0	1
y1995	372	0.07	0.26	0	1
y1996	372	0.15	0.35	0	1
y1997	372	0.15	0.36	0	1
y1998	372	0.11	0.31	0	1
y1999	372	0.09	0.29	0	1

Table 2:

Project Location	Distance (meters)	Volume Cubic Meters	Beach Width Meters
N. Term Groin to 18th Street	3960	1682020.69	41.04
Between Terminal Groins	4080	917465.83	21.73
South of S. Term Groin	360	120035.11	32.22
N Term. Groin to 3rd Street	1600	1146832.29	69.25
13th street and S Groin	960	217898.13	21.93
Between S Term Groin and S L-Groin	360	38227.74	10.26
Between Terminal Groins	4080	1146832.29	27.16
Between S. Term Groins and S. L-Groin	360	152910.97	41.04

Table 3: Spatial Lag Hedonic Regression Model Results – High-tide Beach Width

	100 Meter Cutoff		200 Meter Cutoff		300 Meter Cutoff	
Variables	**Parameter**	**Std Err**	**Parameter**	**Std Err**	**Parameter**	**Std Err**
hsqft	.00022***	.00003	.00022***	.00003	.00022***	.00003
lot_sqft	1.05E-06	2.40e-06	9.67e-07	2.39e-06	8.89e-07	2.39e-06
tbath	.09638***	.03085	.09311***	.03085	.09480***	.03085
gar	.04369	.05081	.03641	.05093	.03917	.05094
ac	.22556***	.05709	.22126***	.05700	.22714***	.05699
age	-.00390***	.00078	.00386***	.00078	-.00403***	.00078
ocn	.32523***	.08327	.36119***	.07948	.37675***	.07942
inlt	.60731***	.10674	.61127***	.10636	.59648***	.10690
mrsh	.17255	.10734	.16503	.10718	.16651	.10738
dist	-.00055***	.00010	-.00047***	.00011	-.0004***	.00012
d_hbeach	.00294**	.00148	.00320**	.00131	.00276**	.00125
constant	11.43662***	.11881	11.40309***	.12059	11.38485***	.12418
rho	.00021***	.00007	.00022***	.00007	.00021***	00007
Year fixed effects	Yes		Yes		Yes	
lnL	-119.823		-118.810		-119.358	
*** - statistically significant for 1% chance of Type I error; ** - statistically significant for 5%; * - statistically significant for 10%.						

Table 4: Spatial Lag Hedonic Regression Model Results – Low-tide Beach Width

	100 Meter Cutoff		200 Meter Cutoff		300 Meter Cutoff	
Variables	**Parameter**	**Std Err**	**Parameter**	**Std Err**	**Parameter**	**Std Err**
hsqft	.00022***	.00003	.00020***	.00003	.00021***	.00003
lot_sqft	9.46e-07	2.37e-06	2.63e-07	2.36e-06	6.47e-07	2.39e-06
tbath	.08950***	.0305	.09148***	.03029	.10141***	.03060
gar	.06319	.04993	.04425	.04965	.04691	.05035
ac	.21030***	.05663	.19694***	.05658	.22674***	.05681
age	-.00398***	.00077	-.00402***	.00077	.00416***	.00078
ocn	.22742***	.08856	.34707***	.07837	.38865***	.07934
inlt	.58727***	.10570	.61327***	.10474	.6075***	.10622
mrsh	.14111	.10659	.11856	.10646	.13925	.10818
dist	-.00045***	.00011	-.00027**	.00013	-.00035**	.00014
d_lbeach	.00306***	.00085	.00294***	.00070	.00178***	.00066
constant	11.43612***	.11619	11.40156***	.11634	11.35334***	.12530
rho	.00018***	.00007	.00019***	.00006	.00018***	.00006
Year fixed effects	Yes		Yes		Yes	
lnL	-115.426		-113.174		-118.189	
*** - statistically significant for 1% chance of Type I error; ** - statistically significant for 5%; * - statistically significant for 10%.						

Table 5: Spatial Lag Hedonic Regression Model Results – Dune Width

	100 Meter Cutoff		200 Meter Cutoff		300 Meter Cutoff	
Variables	**Parameter**	**Std Err**	**Parameter**	**Std Err**	**Parameter**	**Std Err**
hsqft	.00021***	.00003	.00021***	.00003	.00021***	.00003
lot_sqft	9.71e-07	2.38e-	1.04e-07	2.36e-06	5.29e-07	2.39e-06
tbath	.08720***	.03091	.07787**	.03059	.09345***	.03075
gar	.05348	.05014	.03442	.04969	.04046	.05055
ac	.21737***	.05681	.20239***	.05624	.21811***	.05695
age	-.00390***	.00078	-.00391***	.00077	-.00407***	.00078
ocn	.30411***	.08237	.37967***	.07792	.40084***	.07975
inlt	.59282***	.10622	.60235***	.10453	.60451***	.10625
mrsh	.15255	.10700	.12812	.10576	.14940	.10756
dist	-.00050***	.00010	-.00033***	.00012	-.00041***	.00012
d_dune	.00214***	.00071	.00252***	.00057	.00139***	.00051
rho	.00018***	.00006	.00016***	.00006	.00016***	.00007
constant	11.47722***	.11621	11.45795***	.11472	11.42582***	.11803
Year fixed effects	Yes		Yes		Yes	
lnL	-117.328		-112.271		-118.151	
*** - statistically significant for 1% chance of Type I error; ** - statistically significant for 5%; * - statistically significant for 10%.						

Table 6: Welfare Estimates for Coastal Resource Quality

	100 Meter	**200 Meter**	**300 Meter**
High-tide beach width	$70.95 ($35.74)	$167.60 ($68.36)	$195.63 ($88.54)
Low-tide beach width	$73.84 (20.52)	$153.84 ($36.63)	$126.43 (46.92)
Dune width	$51.58 (17.17)	$132.07 (29.89)	$98.42 (36.30)