# Valuing Beach Quality with Hedonic Property Models

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## Abstract

This paper explores the influence of beach quality on coastal property values. We hypothesize that beach and dune width provide local public goods in the form of recreation potential and storm/erosion protection, but services are 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, beach and dune width increases property value. We argue that interpretation of MWTP for beach quality depends upon individual understanding of coastal processes and expectations of management intervention.

**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. Unremitting waves and sporadic storms drive sediment flux along the coast. 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). 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 erosion. 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, dunes, and hinterland. In decades to come, few landforms will see changes as distinct as barrier islands, and development on barrier islands will be heavily influenced by this evolution. 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).

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 and recreational aspects.

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 beaches affect the aesthetics of the coastal landscape and provide space for recreation and leisure activities. Local beach width also reflects the amount of erosion risk a property faces and affects flood/storm surge risk. 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 environmental amenities that also reduce risk.

The interpretation of the relationship between housing prices and beach quality is made substantially more difficult by variability in homeowners' i) knowledge of natural coastal evolutionary processes, ii) perceptions of the effectiveness of beaches as storm and erosion buffers, iii) subjective evaluations of nearby beaches for aesthetics, recreation, and leisure, and iv) expectations of future coastal management actions. Information on historical 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 and expectations of future environmental conditions when prospective buyers are bidding on coastal properties. The dynamics of coastal processes can make collection of appropriate data difficult because beach and dune width fluctuate over time; areas can witness periods of erosion and accretion, and periodic beach replenishment can introduce discrete shifts in resource quality. We attempt to address homeowners' perceptions of beach quality, understanding of fundamental beach dynamics, and expectations of community-level intervention in coastal evolutionary processes in our theoretical model and interpretation of empirical results.

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 proximity measures of 500 and 600 meters).

Marginal Willingness-to-pay (MWTP) 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 shoreline 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 MWTP 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, which 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. (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 benefits and costs of beach width.

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, are 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 perceived aesthetic value and their support of recreation and leisure activities.[2]

## *Theory*

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's Hicksian rent function ($\theta$) 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 expectations of coastal management practices. 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:

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

where $r$ is the discount rate, and the asymptotic result 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 in equilibrium (see equation (2) and point A in top panel of figure 1); 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 housing attributes as constant over time. 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 maintained at a constant level 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 $a_i$:

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

This is depicted as point A in figure 1.

[Figure 1 about here.]

For those that expect beaches and dunes to fluctuate, however, equation (1) is incorrect. Define an expected time path for attribute *i* as $\tilde{a}_i(a_i^0, \boldsymbol{\lambda}) = [a_i^0, ..., a_i^T]$, where the superscript indexes time. This expected time path is based on current conditions, $a_i^0$, and reflects individual-level characteristics $\boldsymbol{\lambda}$, such as knowledge of coastal processes and expectations of management interventions. It is reasonable to assume $\partial a_i^t / \partial a_i^0 > 0 \ \forall t$, because higher initial quantity of attribute *i* should be associated with greater expectations of $a_i^t$ conditional on knowledge and expectations and all else being equal. Let expected resource quality be represented as the arithmetic mean of the elements of the attribute time path, $\alpha_i = \frac{\sum_t a_i^t}{T}$. This expectation will vary across *j* bidders, but we suppress the *j* subscript for simplicity.

Under these conditions the Hicksian bid function is:

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

where $\boldsymbol{a}_{\text{-}i}$ is a vector of attributes other than *i* and $a_i^t(a_i^0, \boldsymbol{\lambda})$ represents the expected conditions for attribute *i* in period *t*. This expression does not simplify asymptotically 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 individual specific variables $\boldsymbol{\lambda}$, such as income, risk tolerance, education, knowledge, and expectations.[3] In a competitive equilibrium, utility maximization still 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, because all buyers are bidding on the same observed attribute. Individual preferences, however, reflect expectations of resource quality over time, and we can think of marginal willingness to pay of the bid function being evaluated at $\alpha_i$. More generally, the marginal bid reflects the expected present value of the sequence of marginal rents:

$$\frac{\partial P(\boldsymbol{a})}{\partial a_i^0} = \sum_{t=0}^{T} (1+r)^{-t} \frac{\partial \theta(\boldsymbol{a}_{\text{-}i}, a_i^t(a_i^0, \boldsymbol{\lambda}), y, u, \boldsymbol{\lambda})}{\partial a_i^t} \times \frac{\partial a_i^t}{\partial a_i^0}. \tag{4}$$

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

The current value marginal rent or willingness to pay, $\partial\theta / \partial a_i^t \times \partial a_i^t / \partial a_i^0$, is non-negative; since the rent function is strictly concave in utility-bearing attributes of ***a*** (Palmquist 2004), the marginal willingness to pay is diminishing in $a_i^t$, as shown in the bottom panel of figure 1. Thus, the interpretation of marginal willingness to pay depends upon individual expectations regarding attribute $a_i$, $\tilde{a}_i(a_i^0, \boldsymbol{\lambda}) = [a_i^0, \ldots, a_i^T]$. Let expectations of the current quality in perpetuity be given by $\alpha_i^c$ - standard interpretation of hedonic price parameters implies that MWTP is evaluated at $\alpha_i^c$ (point A in figure 1). Ignoring the discount factor for the moment, for individuals that expect $a_i$ to decay (expected value denoted $\alpha_i^d < \alpha_i^c$) the marginal rent in (4) is increasing with diminishing resource quality over time, all else being equal. For those that expect resource quality to improve (expected value denoted $\alpha_i^g > \alpha_i^c$), on the other hand, the marginal rent in (4) is decreasing over time with improving resource quality. In either case, the discount factor is diminishing exponentially over time, which should ensure that the overall index in (4) is decreasing over time.

The implications are that present discounted value of marginal rent, or marginal bid, in (4) reflects the value of expected future attribute levels. In this case, the gradient of the hedonic price function, $\partial P(\boldsymbol{a}) / \partial a_i^0$, will provide only a bound on the true marginal value. If the housing attribute (beach or dune quality in our case) is decaying over time, the gradient of the hedonic price function will be an upper bound to the true marginal value because the expected characteristic level, $\alpha_i^d$, is less than the constant level, $\alpha_i^c$.

This case is depicted as point B in figure 1. The bias in marginal willingness to pay is labeled in the bottom panel b, as '*Bias*$^d$'. Under the assumption that the attribute is growing, the gradient of the hedonic price function will be a lower bound on the true value because the expected characteristic level, $\alpha_i^g$, is greater than the constant level, $\alpha_i^c$. This case is depicted as point C in figure 1, and bias in estimation of MWTP is labeled in panel b as '*Bias*$^g$'. Thus, the interpretation of hedonic prices for beach and dune width depends upon individual knowledge and expectations of trends in quality of the beach and dune system.

We note that bias is not completely analogous to the classic errors-in-variables problem (see, e.g., Wooldridge (2002), pg. 74), as one might presume. We assume that current beach and dune quality, $a_i^0$, are completely observable. We do not, however, observe people's expectations of $a_i$, for which we assume $\alpha_i$ is a sufficient statistic. If expectations were observable, we could include their average in the hedonic price regression equation. In doing so, we would obtain unbiased estimates of marginal willingness to pay, as both marginal value and quantity of the attribute would be expressed in comparable units - present-value for marginal WTP and expected value for attribute level.[4]

Without information on individual expectations, we can only focus on the relationship between sales price and observed quality levels. In some sense this is reasonable, as bidding among potential home buyers reflects competition over the array of existing conditions across property locations. The parameters of the estimated equation should be useful for predicting sales prices, conditional on the distribution of expectations in the bidder population. The problem persists, however, in attempting to interpret marginal implicit prices for beach and dune quality as a point on an individual MWTP function. As bids reflect expectations of resource change and management interventions, the present value of MWTP will reflect some expected level of resource quality, which can differ from the current observed level in some cases. This implies that MWTP is potentially being evaluated a different level of resource quality than currently observed, as indicated at points B and C in the bottom panel of figure 1. We also note that this complication is in addition to other difficulties associated with identifying individual preferences in the "second stage" of hedonic estimation (Palmquist 2004).

## 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 a given 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, $\varepsilon$ 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,[5] so we focus attention upon the spatial lag model:

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

where $\rho$ is the spatial autoregressive parameter, $\boldsymbol{\Psi}P$ is the vector of spatially lagged dependent variables for weights matrix $\boldsymbol{\Psi}$, $\beta$ is a vector of unknown parameters to be estimated, and $\varepsilon$ 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 cutoff distances greater than 300 meters were statistically insignificant.[6] 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. For our dataset, the proportions of properties that fall within these cutoff distances are 21%, 39%, and 50%, respectively.

[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.[7]

[table 4 about here]

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 further 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 ranges 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 (as shown in the lower panel of figure 1, point B). Since the marginal bid is decreasing in beach width, the hedonic gradient will provide an upper bound on true willingness-to-pay (with bias indicated in the lower panel of figure 1 as '$Bias^d$'). 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 (as shown in the lower panel of figure 1, point C, with bias '$Bias^g$'). 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

Coastal areas have been witness to expanding development the last several decades, and these areas face considerable risk due to myriad forces that shape and continually reshape the coastal landscape. This is especially true for barrier islands. Chronic shoreline erosion and storm risk pose serious threats to private property investments and public infrastructure on barrier islands. Options for indemnification of these hazards are somewhat limited, as insurance is restricted in terms of coverage, hazards, and availability. Elements of the natural terrain and construction quality, however, can also affect risk. For example, ground elevation above sea level, distance from the shoreline, and elevation of housing structure can help to alleviate flood risk. For erosion risk, on the other hand, options for self-protection are somewhat more limited. For those that want to live in close proximity to the shore, selecting a location with a low historical erosion rate, a wide beach, and robust dune field are options for protecting property investments for erosion.

In this paper, we use hedonic property models to estimate economic value of beach quality – beach and dune width. Such estimates are insightful in gaining an understanding of property owners' preferences for environmental quality, and are informative for policy analysis of coastal erosion management options (Landry 2008; Smith, et al. 2009). We find that beach and dune quality do influence property values, but that this relationship is limited by proximity to the shoreline. This finding provides support for our contention that beach quality is most likely to be a local public good, because nearby beaches afford protection and provide recreation potential to houses in close proximity. For houses located further away from the shoreline, storm, flood, and erosion risk are likely to be considerably lower, and beach recreation choices are likely to be influenced by road networks, access points, and available parking. These factors suggest that beach quality at the nearest shore would be less important for houses located further away, and our data support this notion. Methods for augmenting property data with information on accessibility in order to learn something about the value of beach recreation for homes located further from the shore is a topic for future research.

As coastal sediments are given to seasonal and chronic fluctuation due to the various forces that shape the shoreline, beach quality is somewhat unique as a housing attribute. Unlike structural characteristics, beach quality is expected to undergo exogenous change in the future. While change could also be expected for neighborhood and environmental attributes of residential property, beach quality seems to be a more salient dynamic characteristic because expert assessment predicts that it is expected to change over time. Building upon this idea, we incorporate dynamic housing characteristics into the conventional hedonic property price framework. Theory indicates that if property owners expect beaches and dunes to be maintained as static attributes, either as a result of natural forces or through management interventions, marginal implicit prices can be interpreted in the conventional manner. If, on the other hand, property owners expect beaches and dunes to change over time, MWTP derived from the hedonic price function provides only a bound on true willingness to pay. In the case of expected future erosion, MWTP for beach and dune width provide an upper bound on economic value because individual bids reflect a lower expected attribute level in perpetuity than is currently available. Marginal willingness to pay estimated from the hedonic price function is being evaluated at the lower expected attribute level, which implies the marginal value associated with the current, observed quality level is less, by strict concavity of the bid function (as shown in figure 1, point B). We note that economic value for other attributes of coastal housing markets, such as distance from the shore and ocean front status, could also suffer from a similar type of bias. Lastly, the influence of perceptions, beliefs, and expectations on economic value of beaches can potentially complicate policy analysis because implicit values derived from market prices may reflect expectations of certain policies being implemented over others (e.g. beach replenishment over shoreline retreat). In such cases, these values may not be relevant for analyzing other management approaches.

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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:** Beach Replenishment Projects on Tybee Island, GA

| Project Location | Year(s) | Distance (meters) | Volume Cubic Meters | Beach Width Meters |
|---|---|---|---|---|
| N. Term Groin to 18th Street | 1975-6 | 3960 | 1682020.69 | 41.04 |
| Between Terminal Groins | 1986-7 | 4080 | 917465.83 | 21.73 |
| South of S. Term Groin | 1986-7 | 360 | 120035.11 | 32.22 |
| N Term. Groin to 3rd Street | 1993-4 | 1600 | 1146832.29 | 69.25 |
| 13th street and S Groin | 1995 | 960 | 217898.13 | 21.93 |
| Between S Term Groin and S L-Groin | 1995 | 360 | 38227.74 | 10.26 |
| Between Terminal Groins | 1999-00 | 4080 | 1146832.29 | 27.16 |
| Between S. Term Groins and S. L-Groin | 1999-00 | 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*** | 0.00003 | .00022*** | 0.00003 | .00022*** | 0.00003 |
| lot_sqft | 1.05E-06 | 2.40E-06 | 9.67E-07 | 2.39E-06 | 8.89E-07 | 2.39E-06 |
| tbath | .09638*** | 0.03085 | .09311*** | 0.03085 | .09480*** | 0.03085 |
| gar | 0.04369 | 0.05081 | 0.03641 | 0.05093 | 0.03917 | 0.05094 |
| ac | .22556*** | 0.05709 | .22126*** | 0.057 | .22714*** | 0.05699 |
| age | -.00390*** | 0.00078 | .00386*** | 0.00078 | -.00403*** | 0.00078 |
| ocn | .32523*** | 0.08327 | .36119*** | 0.07948 | .37675*** | 0.07942 |
| inlt | .60731*** | 0.10674 | .61127*** | 0.10636 | .59648*** | 0.1069 |
| mrsh | 0.17255 | 0.10734 | 0.16503 | 0.10718 | 0.16651 | 0.10738 |
| dist | -.00055*** | 0.0001 | -.00047*** | 0.00011 | -.0004*** | 0.00012 |
| d_hbeach | .00294** | 0.00148 | .00320** | 0.00131 | .00276** | 0.00125 |
| constant | 11.43662*** | 0.11881 | 11.40309*** | 0.12059 | 11.3848*** | 0.12418 |
| rho | .00021*** | 0.00007 | .00022*** | 0.00007 | .00021*** | 0.00007 |
| Year fixed effects | Yes | | Yes | | Yes | |
| lnL | -119.823 | | -118.81 | | -119.358 | |
| Obs. | 372 | | 372 | | 372 | |

*** - 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*** | 0.00003 | .00020*** | 0.00003 | .00021*** | 0.00003 |
| lot_sqft | 9.46E-07 | 2.37E-06 | 2.63E-07 | 2.36E-06 | 6.47E-07 | 2.39E-06 |
| tbath | .08950*** | 0.0305 | .09148*** | 0.03029 | .10141*** | 0.0306 |
| gar | 0.06319 | 0.04993 | 0.04425 | 0.04965 | 0.04691 | 0.05035 |
| ac | .21030*** | 0.05663 | .19694*** | 0.05658 | .22674*** | 0.05681 |
| age | -.00398*** | 0.00077 | -.00402*** | 0.00077 | .00416*** | 0.00078 |
| ocn | .22742*** | 0.08856 | .34707*** | 0.07837 | .38865*** | 0.07934 |
| inlt | .58727*** | 0.1057 | .61327*** | 0.10474 | .6075*** | 0.10622 |
| mrsh | 0.14111 | 0.10659 | 0.11856 | 0.10646 | 0.13925 | 0.10818 |
| dist | -.00045*** | 0.00011 | -.00027** | 0.00013 | -.00035** | 0.00014 |
| d_hbeach | .00306*** | 0.00085 | .00294*** | 0.0007 | .00178*** | 0.00066 |
| constant | 11.43612*** | 0.11619 | 11.40156*** | 0.11634 | 11.35334*** | 0.1253 |
| rho | .00018*** | 0.00007 | .00019*** | 0.00006 | .00018*** | 0.00006 |
| Year fixed effects | Yes | | Yes | | Yes | |
| lnL | -115.426 | | -113.174 | | -118.189 | |
| Obs. | 372 | | 372 | | 372 | |

*** - 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 | .00022*** | 0.00003 | .00020*** | 0.00003 | .00021*** | 0.00003 |
| lot_sqft | 9.46E-07 | 2.37E-06 | 2.63E-07 | 2.36E-06 | 6.47E-07 | 2.39E-06 |
| tbath | .08950*** | 0.0305 | .09148*** | 0.03029 | .10141*** | 0.0306 |
| gar | 0.06319 | 0.04993 | 0.04425 | 0.04965 | 0.04691 | 0.05035 |
| ac | .21030*** | 0.05663 | .19694*** | 0.05658 | .22674*** | 0.05681 |
| age | -.00398*** | 0.00077 | -.00402*** | 0.00077 | .00416*** | 0.00078 |
| ocn | .22742*** | 0.08856 | .34707*** | 0.07837 | .38865*** | 0.07934 |
| inlt | .58727*** | 0.1057 | .61327*** | 0.10474 | .6075*** | 0.10622 |
| mrsh | 0.14111 | 0.10659 | 0.11856 | 0.10646 | 0.13925 | 0.10818 |
| dist | -.00045*** | 0.00011 | -.00027** | 0.00013 | -.00035** | 0.00014 |
| d_hbeach | .00306*** | 0.00085 | .00294*** | 0.0007 | .00178*** | 0.00066 |
| constant | 11.43612*** | 0.11619 | 11.40156*** | 0.11634 | 11.35334*** | 0.1253 |
| rho | .00018*** | 0.00007 | .00019*** | 0.00006 | .00018*** | 0.00006 |
| Year fixed effects | Yes | | Yes | | Yes | |
| lnL | -115.426 | | -113.174 | | -118.189 | |
| Obs. | 372 | | 372 | | 372 | |

*** - 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<br>(35.74) | $167.6<br>(68.36) | $195.63<br>(88.54) |
| Low-tide beach width | $73.84<br>(20.52) | $153.84<br>(36.63) | $126.43<br>(46.92) |
| Dune width | $51.58<br>(17.17) | $132.07<br>(29.89) | $98.42<br>(36.30) |

## Endnotes

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[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.

[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.

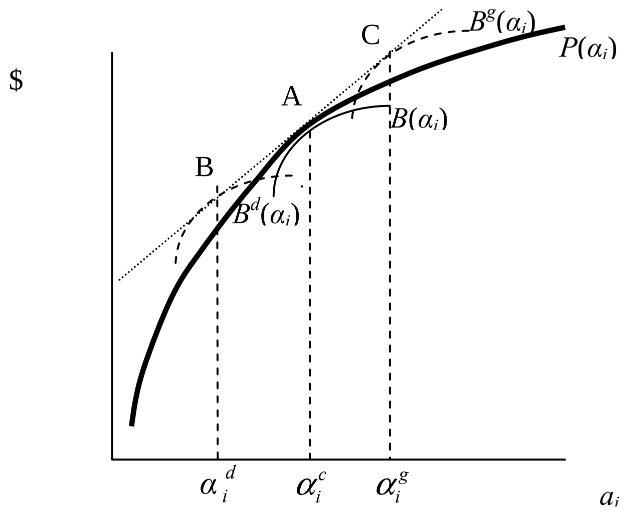
[3] As an anonymous reviewer notes, there is potential for selection and sorting in this model based on expectations of coastal evolution, management interventions, income, or risk tolerance. We agree with this point, but consider this a course of inquiry that would require much additional work and is thus beyond the scope of this paper.

[4] We thank an anonymous referee for helping us to clarify this point.

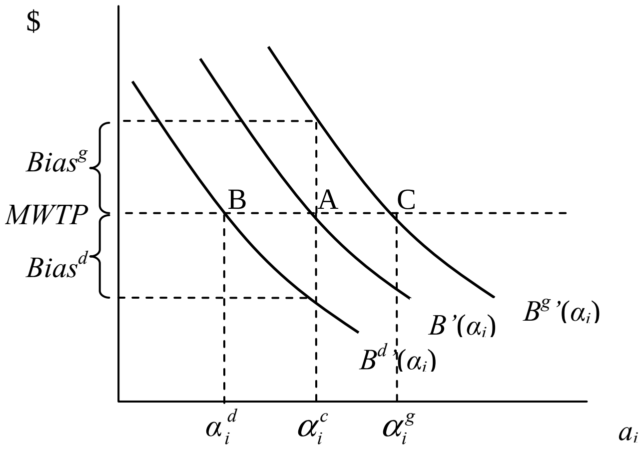
[5] All robust Lagrange Multiplier tests for $\rho = 0$ are statistically significant, with p-values less than 0.01.

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

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



a) Hedonic Price and Bid Functions



b) Marginal Willingness to Pay

**Figure 1:** Hedonic Price Function and Marginal Willingness to Pay for attributes that are (A) constant over time ($\alpha_i^c$), (B) decaying over time ($\alpha_i^d$), or (C) growing over time ($\alpha_i^g$). Figure 1a shows the tangency between the hedonic price function (in bold) and the bid function, both as a function of $a_i^0$. The straight line in 1a represents this tangency and indicates that the tangency is evaluated at an overall lower (higher) level of quality on the bid function when the resource is expected to decay (grow). Figure 1b depicts marginal willingness to pay under the three resource conditions and bias in MWTP when the resource is expected to decay ($B^d(\alpha_i^d) - B^d(\alpha_i^c) = Bias^d$) or grow ($B^g(\alpha_i^g) - B^g(\alpha_i^c) = Bias^g$).