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RUNNING HEAD: Shore Protection and Beach Development

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To the Water's Edge, and Beyond:

Effects of Shore Protection on Beachfront Real Estate

I. Introduction

The U.S. Army Corps of Engineers ("Corps") shore protection program provides subsidized erosion and storm damage control projects to communities that apply and meet Corps program criteria. Owners of properties, usually residences, in the two or three rows of development closest to the water's edge experience most of the benefits of shore protection as well as the costs of land use restrictions. Primary economic effects occur near the shoreline which is given exogenously and is easily identified both geographically and econometrically (pun intended). This is a specific instance of a general problem arising where government environmental programs have economic effects that are associated with a definite, narrow boundary. We develop a general model of the spatial pattern of economic effects and find that a sharp test for economic effects of environmental programs requires careful estimation of changes in the gradient of land or housing prices as one moves away from the boundary.

Our analysis demonstrates that shore protection projects can have several possible effects. First, the project can encourage development that would have occurred in the area to locate closer to the shore. Second, development may be "displaced" from unprotected shoreline to the protected area. Third, "additional" development could be shifted from inland locations to beach areas. Public debate has focused on the third effect and on the specific possibility that shore protection could increase the risk of storm damage by "inducing" additional development.

However, regulations associated with beach enhancement projects work to offset the private benefits of the additional protection to shorefront property owners and hence the net effect of Corps activity on development is unclear.¹ Overall, shore protection projects appear capable of generating as complex a pattern of development and environmental effects as any other public policy including land use regulations, or other spatially-defined public expenditure programs.

To understand the locational effects of shore protection we adapt models from real estate economics to consider the case of a beach community where the level of beach development is derived from the demand for beach services. This model is used to predict the economic effects of providing additional shore protection benefits. This approach could be applied to a number of alternative instances in which environmental regulations, public expenditure decisions, or land use regulations produce observable spatial patterns of benefits and costs. The model implies that changing housing prices provide a sensitive indicator of the locational effects of shore protection programs. Specifically, the theory implies a sharp test comparing changes in property values in areas proximate to the shoreline with values in areas further inland. The price response to Corps projects depends on distance to the beach and special empirical techniques are needed to distinguish house price changes over both time and down to the water's edge. We propose a simple solution to this problem. The functional form of a repeat-sales housing price index is

¹ Corps participation comes with a number of strings attached. First the community must provide between 50 and 65% of the total reconstruction cost. Second, Corps planning often requires construction of rather high dunes that may block views of the beach. Third, Corps participation requires substantial provision for public access to beaches. Some communities have declined to participate in the program even when shoreline erosion would have qualified them for aid.

modified so that it can be used to project housing price effects to the water's edge.² This approach is potentially applicable to a range of empirical problems in which it is necessary to estimate house price changes along a narrow boundary.

II. A Model of Shore Protection and Beach Development

In order to understand the relation between shore protection projects and the general pattern of beach development, we model land use in a system that allows production at alternative beachfront and inland locations. Comparative static analysis of the effects of implementing a single shore protection project allows us to trace implications for various variables and reveals possibilities for alternative tests, both direct and indirect, for the effects of such projects. This type of formal modeling has been neglected in other papers on valuing localized externalities. We find that empirical tests for economic effects should be based on very localized indicators capable of monitoring price changes over space.

The basis for beach development, which generally takes the form of residential construction in the areas analyzed here, is the underlying demand for beach services. Proximity to the beach differentiates possible locations for beach development. This implies a simple model in which

² Palmquist (1982) first suggested the application of repeat sale price index estimates to issues of environmental valuation. Parsons (1992) has applied the method to the study of land use controls. Our method builds upon his approach. The repeat sale price index may be contrasted with hedonic house price equations applied to land use controls in Parsons (1991). While it would, in theory, be possible to estimate location-specific hedonic equations, no appropriate data for estimating hedonic house price equations were available. In general it is very difficult to find data to estimate hedonic house price equations over time.

there are alternative beach locations, indexed by the subscript i , where beach services may be consumed. It is sufficient for our purposes to consider only two beach locations, i.e. $i=1,2$, and to assume that there is an "inland area," which is far enough from the beach so that it cannot suffer storm damage. Generally, capital letters are used to refer to characteristics of beach areas and small letters are used for the inland area. Thus, the quantity of beach development is Q_i in beach area i and q in the inland area. The quantity of beach services provided in a beach area is assumed to be proportional to the level of beach development. Specifically, beach area i produces $B_i = \tau_i Q_i$ services when it has Q_i units of development, with τ_i reflecting the relation between development and services for a beach area. The inland area produces $b = \tau \Phi q$ services where $0 < \Phi < 1$ is a discount factor reflecting the effect of distance to the beach on the productivity of inland development. The total supply of beach services, B_T , may be written as $B_T = B_1 + B_2 + b = \tau_1 Q_1 + \tau_2 Q_2 + \tau \Phi q$. If beaches 1 and 2 are equally attractive and have the same accessibility to population centers, then $\tau_1 = \tau_2$ and beach development is equally productive in the two beach areas. This type of symmetry is imposed for notational convenience.

Beach development is the result of capital investment in either beach or inland areas. Development is produced by applying "structure" inputs, S , to land inputs, L , according to a simple Cobb-Douglas production function: $Q_i = A_i S_i^\alpha L_i^\beta$ in beach area i , and $q = a s^\alpha l^\beta$ in the inland area. For notational simplicity, we assume that production technology is the same everywhere so that $A_1 = A_2 = a = A$. Given that both the size of areas and the choice of measurement units for land are arbitrary, assume that all areas have one unit of land so that $L_1 = L_2 = l = 1 = \text{unity}$, and the

production function simplifies to $Q_i = AS_i^\alpha$ and $q = As^\alpha$, where $i = 1, 2$. Generally the literature on residential real estate suggests that $0.6 < \alpha < 0.9$.

Land in beach and inland areas has a rental price of R_i and r respectively, which is determined endogenously. The supply price of structure inputs depends on the likelihood of storm damage. In inland areas, structure inputs are supplied at a uniform price of p_s because the probability of storm damage is zero. In beach area i , structure inputs are supplied at a price of $p_{Si} = \sigma_i p_s$, where $\sigma_i = 1 + \Theta_i$, and Θ_i is the probability that a unit of structure in beach area i will suffer storm damage and require replacement. If unsubsidized insurance is available, it is priced at Θ_i per unit S and its availability has no effect on input choice.³ Subsidized insurance would be priced below Θ_i and would effectively reduce P_{Si} in proportion to the amount of the subsidy.

The demand for beach services depends on the distance between population centers and the beaches, income levels of households, the price of beach services, and the price of substitutes for, and compliments to, beach services. Only one of these factors, the price of beach services, is changed by the process of beach protection. The relation between the price of beach services, P_B , and the price at which beach development is supplied follows directly from the expression for B_T above. Specifically, $P_B = P_{Qi}/\tau_i = p_q/\tau\Phi$, where P_{Qi} and p_q are the prices of development in

³ This lack of effect can come about for a number of reasons. First, investors can be risk neutral. Second, storm damage can be a unique risk and hence it is diversified away simply by holding a portfolio of real estate in different beachfront areas.

beach and inland locations respectively. There is an implied equilibrium condition in which the price of beach services is equal at all locations.⁴

The relation between changes in P_B and changes in the quantity of beach services demanded, B_T , determines the manner in which what has been called "induced" development is divided into one portion that is shifted from other beach areas, "relocated development," and another portion that is shifted from other areas, hereafter called "additional development."⁵ This division of economic activity into relocated and additional development is crucial to understanding the effects of shore protection on the location of economic activity. We assume that the market demand function can be expressed as $B_T = \Gamma P_B^\gamma$. In this form, the parameter Γ reflects the geographic distribution of population, income, transportation costs, prices of other goods, etc and γ is the own-price elasticity of beach demand.

Previous models of the economic effects of Corps activity, such as the model of inland flood protection by Stavins and Jaffee (1990), make the strong (implicit) assumption that the demand for the product produced on the land, whether agricultural or manufactured items, is perfectly elastic. In the context of our model, that would amount to assuming that P_B is invariant to shore protection efforts. We believe that such strong assumptions are not warranted. Beaches serve a

⁴ As noted with several other assumptions in this model setup, the assumption of price equality can be relaxed at the expense of greater notational and mathematical complexity.

⁵ Some readers may note that relocated development is analogous to the concept of trade diversion and additional development to trade creation in the literature on customs unions.

geographically defined market area and variation in the supply of beach services can certainly influence the price of services within such a spatially restricted market area.

III. Solving the Model of Shore Protection and Beach Development

The model may be solved under the initial set of assumptions discussed above for prices and quantities of real property development represented by the Q_i 's, q , P_{Q_i} 's, and p_q , the amounts of structural inputs measured by the S_i 's and s , land rents R_i and r , and quantities of beach services, the B_i 's and b . The effects of shore protection at a given beach are generated by changing the σ_i parameter.⁶ Nourishment changes σ_i by lowering the probability of damage to beach structures at the i^{th} beach.

Solution is achieved by imposing a zero profit equilibrium condition on developers at each location. Developers choose structure inputs to maximize profits subject to given prices for inputs and beach services. For example, the expected profit of a developer operating in beach i is:

- 1) $\Pi_i = P_{Q_i}Q_i - P_{S_i}S_i - R_i = P_B\tau_iQ_i - p_S\sigma_iS_i - R_i$ or
- 2) $\Pi_i = P_B\tau_iAS_i^\alpha - p_S\sigma_iS_i - R_i$

Conversely, the expected profit of a developer in the inland area is:

⁶ Most nourishment projects also raise τ_i by making the beach larger and hence less congested than it would ordinarily be. This second effect is less certain and, in some cases, shore protection or nourishment could raise dune barriers which would make beach location less attractive compared to inland locations.

$$3) \quad \pi = P_q q - p_s s - r = \Phi \tau P_B q - p_s s - r \quad \text{or}$$

$$4) \quad \pi = \Phi \tau P_B A s^\alpha - p_s s - r.$$

Under the assumption that both structures and beach services are provided by perfectly competitive firms under conditions of easy entry, these expressions for expected economic profit may be set equal to zero and analyzed. A bit of manipulation yields the following solutions for levels of structure services, development level, and beach services for these areas:

$$5) \quad S_i = (A\alpha P_B \tau_i / \sigma_i p_s)^{[1-\alpha]} \quad s = (A\alpha P_B \tau \Phi / p_s)^{[1/(1-\alpha)]}$$

$$6) \quad Q_i = A(A\alpha P_B \tau_i / \sigma_i p_s)^{[\alpha/(1-\alpha)]} \quad q = A(A\alpha P_B \tau \Phi / p_s)^{[\alpha/(1-\alpha)]}$$

$$7) \quad B_i = A\tau_i (A\alpha P_B \tau_i / \sigma_i p_s)^{[\alpha/(1-\alpha)]} \quad b = A\tau \Phi (A\alpha P_B \tau \Phi / p_s)^{[\alpha/(1-\alpha)]}$$

These are the demand for structure inputs and supply of development and beach service relations appropriate for each beach or inland area. Interpretation of the equations is aided by recalling that $1 > \alpha > 0$ and hence both $(1 - \alpha) > 0$ and $\alpha/(1 - \alpha) > 0$ so that the effect of P_B on supply is positive in all cases, (i.e., $\partial S_i / \partial P_B, \partial Q_i / \partial P_B, \partial B_i / \partial P_B, \partial s / \partial P_B, \partial q / \partial P_B, \partial b / \partial P_B > 0$).⁷

Imposing a market-clearing equilibrium condition, we set the supply of beach services, the sum of the B_i 's and b , expressed as a function of P_B , equal to the demand for beach services, $B_T = \Gamma P_B^\gamma$, so that $B_T = B_1 + B_2 + b = \tau_1 Q_1 + \tau_2 Q_2 + \tau \Phi q$. Substituting for B_i and b in this relation and setting the result equal to ΓP_B^γ , yields the following reduced form equation for P_B :

$$8) \quad P_B = \{ \Sigma_i (\Gamma / A \tau_i)^{(1-\alpha)/(\alpha + \gamma\alpha - \gamma)} \} \{ \Sigma_i (\sigma_i p_s / A \alpha \tau_i)^{\alpha/(\alpha + \gamma\alpha - \gamma)} + (p_s / A \alpha \tau \Phi)^{\alpha/(\alpha + \gamma\alpha - \gamma)} \}.$$

⁷ Also note that R_i is equal to the value marginal product of land, $P_B \beta S^\alpha / L_i^{\beta-1}$. Given that $\partial S_i / \partial P_B > 0$, it follows that $\partial R_i / \partial P_B > 0$.

Given $0 > \alpha < 1$ and $0 > \gamma$, $(1 - \alpha)/(\alpha + \gamma\alpha - \gamma) > 0$ and $\alpha/(\alpha + \gamma\alpha - \gamma) > 0$.⁸ It follows from (8) that $dP_B/d\Gamma$, dP_B/dp_S , and $dP_B/d\sigma_i$ are all > 0 . The third result, that an increase in expected storm damage raises P_B , is expected as higher costs of production raise the price of beach services.

Equation (8) for P_B along with the input demand and development and beach service supply functions (5 through 7) determine the effects of a variety of economic policies regarding beach development. For example, a shore protection project in beach area 1 should lower σ_1 but leave all other parameters of the model unchanged. The total effect on the B_i 's, b , Q_i 's, q , S_i 's and s , can be determined by noting that $dX_j/d\sigma_i = \partial X_j/\partial\sigma_i + (\partial X_j/\partial P_B)(dP_B/d\sigma_i)$, where X_j could be any one of the variables indicating changes in the level of development. The total change in any variable, $dX_j/d\sigma_i$, can be decomposed into what could be termed a "direct effect," $\partial X_j/\partial\sigma_i$, and an "indirect effect" due to any change in market price of beach services caused by the direct effect, $(\partial X_j/\partial P_B)(dP_B/d\sigma_i)$. From the equation for P_B , we can sign $(dP_B/d\sigma_i) > 0$, because a fall in σ_i lowers P_B given that $\alpha/(\alpha + \gamma\alpha - \gamma) > 0$. Now consider the effect of the fall in σ_1 on beach area 2 and the inland area. In both cases $\partial B_2/\partial\sigma_1 = \partial b/\partial\sigma_1 = \partial Q_2/\partial\sigma_1 = \partial q/\partial\sigma_1 = \partial S_2/\partial\sigma_1 = \partial s/\partial\sigma_1 = 0$ and there is no "direct effect" of the fall in σ_1 on these areas. But there is an indirect effect because $\partial B_2/\partial P_B$, $\partial b/\partial P_B$, $\partial Q_2/\partial P_B$, $\partial q/\partial P_B$, $\partial S_2/\partial P_B$, $\partial s/\partial P_B$ are all < 0 . Given that $dP_B/d\sigma_1 > 0$, it follows that $dB_2/d\sigma_1$, $db/d\sigma_1$, $dQ_2/d\sigma_1$, $dq/d\sigma_1$, $dS_2/d\sigma_1$, $ds/d\sigma_1$ are all < 0 .

⁸ Further insight into the expression for P_B above is obtained by considering the case in which the own price elasticity of demand for beach services is equal to $-1 = \gamma$, so that:

$$P_B = \{\Sigma_i(\Gamma/A\tau_i)^{(1-\omega)}\} \{(\sigma_i p_S/A\alpha\tau_i)^\alpha + (p_S/A\alpha\tau\Phi)^\alpha\}.$$

In the case of beach 1, it is easily seen, from equations 5, 6, and 7, that $\partial B_1/\partial \sigma_1$, $\partial Q_1/\partial \sigma_1$, $\partial S_1/\partial \sigma_1$ are all negative and hence the direct effect of the fall in σ_1 is to raise B_1 , Q_1 , and S_1 . In contrast, the indirect effect of the fall in P_B is negative. This is seen by noting that $dP_B/d\sigma_1 > 0$, and $\partial B_1/\partial P_B$, $\partial Q_1/\partial P_B$, $\partial S_1/\partial P_B$ are all positive so that a fall in σ_1 tends to lower P_B which has the indirect effect of lowering B_1 , Q_1 , and S_1 . We know that the direct effect must be larger than the indirect effect because the fall in P_B in the reduced form requires a rise in B_T which must come from beach 1 given that production elsewhere is known to fall. Thus, we conclude that $dB_1/d\sigma_1$, $dQ_1/d\sigma_1$, $dS_1/d\sigma_1$ are all negative and that a fall in σ_1 due to a shore protection project in beach area 1 will raise output of beach services, induce development, and expand structure inputs in beach area 1.

Beach area 2 and the inland area experience the fall in P_B due to a fall in σ_1 and this leads unambiguously to a fall in B_2 and b , S_2 and s , Q_2 and q . These areas experience no positive direct effect, only the negative indirect effect resulting from the fall in P_B as σ_1 falls. The fall in P_B , S_2 , and s implies a fall in R_2 and r . Most important for the empirical testing discussed in the next section, we reach the strong conclusion that a fall in σ_1 associated with shore protection applied to beach 1 will raise the density of development, the structure input to land ratio, and land rents at beach 1 compared to either the inland area or neighboring unprotected beaches. Even if demand for beach services is relatively inelastic, so that changes in P_B are consequential, the differential effect of shore protection on shoreline real estate compared to inland areas holds. This differential effect of changes in σ_1 on beach 2 and the inland area compared to beach 1 is strong

and unambiguous. It arises because beach 2 and the inland area experience only the negative indirect effect while beach 1 experiences both positive direct and negative indirect effects. Thus our sharp empirical test for the economic effects of shore protection activities rests on the differential effects associated with distance from the water's edge. Testing will require a model capable of monitoring spatial price responses before and after protection projects.

IV. Estimating Economic Effects At The Margin Using A Repeat-Sales Index

This section presents the results of a test for the economic effects of shore protection projects on induced development using a spatial house price change approach. Based on the theory developed above, a sharp test for the economic effects of shore protection programs should be based on an increase in property values and levels of development proximate to the water's edge compared to areas further inland. But, as noted elsewhere in this paper, shore protection projects undertaken by the Corps have several features that could lower beachfront property values. Large dunes constructed as part of beach enhancement may block scenic vistas and requirements for public access may increase beach congestion. Thus, although Corps projects reduce σ at the protected beach by lowering expected losses from storms, these projects may also lower τ by reducing the amount of beach services that can be produced from a given amount of beachfront development. The net effect of a Corps project on a beachfront community is thus theoretically ambiguous, and must be determined empirically.

The first step in this empirical effort is the estimation of spatial house price change indexes for three Florida counties in which the Corps has been active. Then tests are performed to determine if the differential between inland and beach house price changes is related to the level of shore protection activity. Estimates of spatial house price changes should be particularly sensitive to measures of shore protection effects. First, it is possible to estimate price changes out to the limit of development, i.e. in the "first row" of residences. Second, price changes are more flexible and immediate than changes in new construction. Even if coastal development regulations severely limit the ability to increase development along the beach and effectively prevent significant amounts of induced development, spatial house price index measures will still show the effects of shore protection on expected future losses as shorefront land values rise.

Given the need to estimate changing house prices over time and continuous space, data limitations force us to use the repeat-sales method, first introduced by Bailey, Muth, and Nourse (1963), which produces an index by examining the price changes of homes that sell repeatedly during the time interval being studied.⁹ The method, and its refinements, have been "rediscovered" as a means to avoid the omitted variables bias problems often associated with traditional hedonic models (e.g., Palmquist (1980), Case and Shiller (1989), and Case and Quigley (1991)). This method assumes that housing quality is held constant between the transaction

⁹ The data requirements for hedonic regression far exceed those for repeat sale price indexes. It is particularly difficult to find data on both housing prices and characteristics with precise locational detail needed to proximate distance to the water's edge.

dates; hence, the difference between the two transaction prices is a function of the intervening time period.

The primary advantage of the repeat-sales approach is that it does not require the researcher to identify and control for the differing physical attributes of the properties sold. It only requires two sale prices and their respective sale dates for each observation. However, Haurin and Hendershott (1991) and Gatzlaff and Haurin (1996) have criticized the repeat-sales approach because: (1) property improvements occurring between the sale dates will bias the estimate, (2) prices of characteristics may change over time, and (3) the repeat-sales sample may not be representative of the stock.¹⁰ To mitigate these potential limitations, the sample used in this study has been carefully screened to eliminate substantially improved or renovated properties.¹¹ To reduce the effects of potential sample selectivity, the data are selected from the population of properties in each county and a relatively long time period (21 years) is used.¹²

The following steps were employed to construct a repeat-sales database suitable for this study. Data were acquired from the Florida Department of Revenue's (DOR) property tax records for Dade County (Miami), Duval County (Jacksonville), and Pinellas County (St. Petersburg). These

¹⁰ Changes in characteristic prices over time and sample selectivity are, of course, also concerns in traditional hedonic price estimation.

¹¹ Substantial property renovations are identified by a year-built variable within the dataset. This variable is updated for properties that have obtained a building permit. In the areas studied, building permits are required for property improvements of \$500 or more.

¹² Using similar data, Gatzlaff and Haurin (1996) find that homes sold vary by quality over the business cycle. While they report evidence of sample selectivity, the effect on the estimated repeat-sale price index is small.

data are collected for all parcels in each county and maintained by the local county property appraiser's office for use in updating the annual property tax assessments. The data record for each parcel includes: a land use code, the most recent sales price and closing date, the second most recent sales price and closing date, the homestead status, the assessed land and property values, and several other property-specific variables, including owner's street address.

All owner-occupied, single-family, detached housing units were initially identified by land use code and homestead status. Following Gatzlaff and Ling (1994), a series of steps were conducted to delete incomplete and incompatible observations (e.g. homes transferring ownership for \$1, homes lacking year built, or sale date information, etc), or apparent data errors. Paired repeat-sales observations were identified for the period 1971-1992, because the repeat-sale method requires data containing the previous two transactions. This procedure yielded data sets of 43,898 (Dade), 20,315 (Duval), and 50,258 (Pinellas) observations for the three counties examined.

Using the street address information, each observation was geo-coded with latitude/longitude location variables. An algorithm was then developed to compute the minimum distance from each observation to the nearest shoreline point based on the latitude/longitude location of the water's edge. Finally the shoreline distance values were match-merged with the sales data to produce the final repeat-sales database.

Ordinary least squares regression techniques were used to estimate a modified repeat-sales regression model of house prices for each of the three counties over the January 1971 to

December 1992 period. The key modification to repeat-sales models found elsewhere in the literature was to estimate a flexible functional form that allowed distance from the shoreline to be a partial, piecewise linear, determinant of price. Using this method, house price indices and rates of change in those indices could be computed for various distances from the water's edge for each of the counties. Specific indices were constructed for housing units located (1) at the shoreline, (2) one-half mile from the shoreline, (3) five miles from the shoreline, i.e. for the inland areas discussed in the model.¹³ While the specific application of this approach is to effects on the spatial pattern of shoreline real estate prices, we believe that the techniques can be applied generally to analyze house price effects associated with a variety of environmental issues.

Following Bailey, Muth and Nourse (1963) and the extended subsequent literature, estimation of a repeat-sales price index is based on the assumption that the sales price of property i , P_{2i} which is sold for a second time at time T_{2i} can be expressed as a function of the initial sales price, P_{1i} , and the time of initial sale, T_{1i} , by first assuming that $P_{2i} = P_{1i}(1 + r_1)^{D_{1i}}(1 + r_2)^{D_{2i}}(1 + r_3)^{D_{3i}} \dots (1 + r_n)^{D_{ni}}$ where r_t is an index of cumulative appreciation through period t , and D_t is an exponent equal to -1 if period $t = T_{1i}$, equal to $+1$ if $t = T_{2i}$, and equal to 0 for all other values of t . Dividing through this equation by P_{1i} and taking the natural logarithm of both sides yields an expression for the sales price ratio:

¹³ Unfortunately, the number of transactions using solely beachfront properties is not adequate to estimate reliable repeat sales house price indexes over a 21-year period, as required by this study.

$LN(P_{2i}/P_{1i}) = D_{1i}LN(1 + r_1) + D_{2i}LN(1 + r_2) + \dots + D_{ni}LN(1 + r_n)$. Given that the sales prices and dates can be observed for each property, it is possible to estimate:

$LN(P_{2i}/P_{1i}) = \beta_1D_{1i} + \beta_2D_{2i} + \dots + \beta_nD_{ni} + \varepsilon_i$ where ε_i is an identically and independently distributed normal random variable. The β 's are parameters to be estimated which reflect the compound appreciation between period 1 and subsequent periods, and the D's are as defined above.

The conventional repeat sale estimation procedure was modified given the special needs of this research for estimates of appreciation effects in beach areas. The modified approach to estimation of a repeat sale price index considers distance from the coast as a determinant of housing prices. The relation between distance to the coast and housing prices is complicated by the possibility that shore protection projects may cause prices first to fall with distance and then rise again with distance as one approaches inland urbanized areas. This is particularly likely for the three counties chosen here because in each case a large urban area is located inland from the coast. Specifically the sample includes Dade County (Miami), Duval County (Jacksonville), and Pinellas County (St. Petersburg). Indeed, the housing markets in all these beach areas are influenced by urban sprawl from the large cities and many beach residents are commuters who work in the city. In order to insure sufficient property transactions to estimate a repeat sales price index, it was necessary to sample beach areas that were part of larger urbanized areas.

The general equation estimated using ordinary least squares techniques has the form:

$$LN(P_{2i}/P_{1i}) = \beta_1D_{1i} + \beta_2D_{2i} + \dots + \beta_nD_{ni} + [\gamma_1D_{1i} + \gamma_2D_{2i} + \dots + \gamma_nD_{ni}] * \ln(DIST) + \gamma_{0.5}S_{0.5} * \ln(DIST) + \varepsilon_i$$

where: $\text{LN}(P_2/P_1)$, the D's and β 's are as defined above, $S_{0.5}$ is a dummy variable equal to 1 if distance to the shore is > 0.5 miles and 0 otherwise, $\text{ln}(\text{DIST})$ is the logarithm of distance to the shoreline and the γ 's are parameters to be estimated reflecting the effect of distance on the housing price index for properties located less than 0.5 miles from the coast. This functional form allows the relation between distance to the coast and the price index to be different within a half mile of the coast than it is as property location moves further inland.

Estimates of the repeat-sales house price index discussed above are computed by substituting various specific distances into the estimated function along with two time periods, the base year of 1971 and the alternative year for which the index is being computed. For simplicity, the index was computed at three specific distances, $\text{DIST} = 0$ (the water's edge), $\text{DIST} = 0.5$ (one-half mile from the water's edge), and $\text{DIST} = \text{the mean value of DIST in the sample}$ (the inland location). Specifically, the value of the index at time T in area i, at distance $\text{DIST} = 0$ (the shoreline), INDEX_{T_i} , would be computed as:

$\text{INDEX}_{T_i} = \text{EXP} [-\beta_{1i} + \beta_{T_i} + (-\gamma_{1i} + \gamma_{T_i}) \text{LN}(0)] + \gamma_{0.5} \text{LN}(0)$. Note that, because distance = 0, the $S_{0.5}$ dummy variable equals zero. The value of the index can be computed for each year, for each of the three locations in each of the three counties.

Figures 1, 2, and 3 show the pattern of house price indexes for each of the three counties over the 1971 to 1992 period. All indexes have been normalized so that the inland price index in 1971 equals 1.0. Overall, the computed price indexes follow a similar pattern that agrees well with expectations. For all three counties, the rate of price appreciation for the beach areas are highest

so that the price index is uniformly highest for the beach areas by 1992. Figures 4, 5, and 6 display changes in the house price index at the three locations in the three counties over the 1971 to 1992 period. The rate of appreciation in the price index for beach areas often differs significantly from that of either the off-coast or inland areas. There is a high variation in the rate of change in house prices over the period, including periods of very rapid appreciation and even some periods when prices fell slightly. It appears that the beach real estate market is subject to some influences that do not characterize either off-coast or inland areas. This is consistent with the possibility that differences in rates of appreciation could be due to shore protection efforts.

The relation between the house price index at the shore and the level of Corps shore protection activity is estimated by applying ordinary least squares to the following equation:

$$\text{Shore} = \alpha_0 + \alpha_1 \text{Inland} + \alpha_2 \text{Active} + \alpha_3 \text{Tcost} + \alpha_4 \text{Storm} + \beta_1 \text{Dade} + \beta_2 \text{Duval} + \varepsilon$$

where Shore is annual percentage change in estimated house prices at the shoreline, Inland is the estimate of the annual percentage change for inland areas, Active is a dummy variable equal to unity during the period after the Corps project became active and zero otherwise, Tcost is the annual dollar expenditure for Corps projects, Storm is a variable supplied by the Corps indicating the presence of storm damage in each year, Dade and Duval are dummy variables for those two counties, and ε is an identically and independently distributed random error term.

Table 1 presents estimation results for a series of equations in which Shore is the dependent variable. The first equation estimated in Table 1 shows that beach appreciation is largely a function of inland appreciation, that is changes on the shore reflect inland economic growth.

There are no significant differences in the relation between beach appreciation and inland appreciation associated with location in Duval or Dade counties, as opposed to Pinellas. Given that the distances between beach and inland real estate have been standardized to be the same for all three areas, this result is not surprising.

Adding the two variables reflecting the presence and level of Corps activity, Active and Tcost, and the Storm variable indicating significant storms adds essentially nothing to the predictive power of the model. These variables are added sequentially in a series of estimates reported in columns 3, 4, and 5 of TABLE 1. While the estimated coefficients of Active and Tcost generally have the expected positive sign, they are always non-significant. Similarly, the estimated coefficient of Storm is a negative and non-significant. Even if the estimated coefficients of all three variables were statistically significant, their combined effect on the rate of beach housing price appreciation would be modest economic significance compared to the average rate of appreciation of beach real estate. The failure to have a single hurricane strength storm hit any of the three counties during the 1971-1992 sample period limited the opportunity to observe effects of a major storm in the data. However, Corps activity on these beaches was not trivial during this period and yet there is no significant observable effect on the differential between price appreciation in inland and at the water's edge due to this activity.

V. Conclusions

We have undertaken the ambitious task of evaluating the locational effects of a rather complex policy, Corps shore protection projects. Based on a theoretical model of land use adjustments to Corps projects, we identify a sharp test for environmental effects based on changes in the relative price of housing between the shoreline and interior. Implementing the test suggested by theory requires that we observe variation in house prices over time, before, during, and after projects are undertaken and across space, specifically based on proximity to the water's edge. This strongly suggests estimation of repeat sales house price indexes adapted to identify variation of prices by location.

The repeat sale price index allows us to project price effects to the boundary most influenced by shore protection policy, i.e. the water's edge. The finding that introduction of Corps protection activity had no significant effect on prices is surprising at first.¹⁴ However, it may be the result of program size and regulatory structure. Over the past five years, the total Corps budget for shore protection has averaged only about 40 million dollars per year. Furthermore significant land use regulations are attached to shore protection which may offset the benefits provided by the reduction in expected storm damage. Indeed, there are cases in which communities have explicitly refused Corps beach enhancement projects in response to the land use regulations which would likely be imposed.

¹⁴ Cordes and Yezer (forthcoming, 1998) reach a similar conclusion using an entirely different approach that involves estimating small region econometric models of housing starts in a substantial panel data set of beachfront communities.

This examination of the locational effects Corps shore protection programs is a specific example of the more general problem of evaluating the effects on location of economic activity of spatially defined environmental regulation and land use policies. The techniques used in this study should be helpful in modeling and empirical analysis of these other issues.

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Table 1
Determinants of Beach Housing Price Change
Dependent Variable: Annual Percentage House Price Change

	Effects of inland price change		Add effects of corps activities and storms		
	(1)	(2)	(3)	(4)	(5)
Constant	2.007* (3.297)	2.082* (2.068)	1.873* (1.808)	1.920* (1.818)	1.957* (1.848)
Dade		0.200 (0.146)	-0.259 (-0.176)	-0.396 (-0.255)	-0.460 (-0.296)
Duval		-0.422 (-0.307)	-0.226 (-0.162)	-0.309 (-0.215)	-0.401 (-0.278)
Inland	1.012* (39.176)	1.012* (38.561)	1.006* (37.266)	1.009* (35.739)	1.011* (35.625)
Active			1.316 (0.886)	0.912 (0.454)	0.531 (0.258)
Tcost				0.000 (0.300)	0.000 (0.682)
Storm					-2.341 (-0.911)
R-square	0.9639	0.9637	0.9642	0.9643	0.9648
Adj.R-square	0.9630	0.9618	0.9616	0.9610	0.9609

Note. No. of observation=60

Numbers in parentheses are t values.

*indicates that the estimated coefficient is statistically significant at the 90% level