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A Hedonic Analysis of Enterococcus in the Long Island Sound

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Abstract:

Hedonic property value studies of water quality conventionally focus on quality levels measured nearest a home. This study examines whether quality at the nearest access point, i.e., a beach, matters more to local residents. We conduct a hedonic analysis focusing on water quality in the Long Island Sound, where an aging infrastructure and heavy precipitation lead to frequent sewage overflows. The analysis focuses on bacteria contamination and beach closures. Results suggest that decreases in water quality measured at the nearest beach yield a larger negative effect and impact homes at a much farther spatial extent than previously suggested in the literature.

JEL Classification: Q24; Q51; Q53

Keywords: beach; enterococcus; hedonic; Long Island Sound; property value; water quality

This paper is an updated draft of an earlier US EPA NCEE working paper #17-08 (Kung et al., 2017).

I. Introduction

Hedonic property value methods are a common approach to estimate the implicit price of local improvements in water quality. Studies typically examine the effect of water quality on home prices by focusing on the portion of a waterbody that is nearest a home. This captures any aesthetic values households may hold for water quality improvements, but may not fully reflect recreational values, particularly for nearby residents that do not live on the waterfront. Although non-waterfront homes may be in view of the nearest part of a waterbody, residents may not have direct access at that point. At the same time, non-waterfront houses have recently received increased attention in the hedonic literature (e.g., Walsh et al. 2011, Netusil et al. 2014, Klemick et al. 2018).

The objectives of this study are to examine how water quality in the Long Island Sound impacts home values, and to compare the estimated price effects under the conventional approach, where water quality is measured based on the nearest monitoring station, to an approach where water quality is measured at the closest point of access for recreation – more specifically, the nearest beach. We conduct a hedonic analysis of residential properties in Westchester County, NY that are within five kilometers of the Long Island Sound. The water quality measure of interest is enterococcus, a type of bacteria and indicator of fecal pollution.

Westchester has long struggled with fecal pollution in the Sound, primarily due to stormwater runoff and sewage overflows. Beginning in 1909 with the construction of the county's first main sewer line (Smith 1912, Harding 1950), the sanitary sewage system was built to keep sewage and stormwater separate. However, cracks in the pipes of this aging infrastructure have led to the intrusion of stormwater into the sewage system during excessive rain events. As a result, the overwhelmed sewage treatment plants must sometimes discharge untreated or partially treated sewage directly into the Sound, leading to reduced water clarity, foul odors, and an increased risk of gastrointestinal illness among swimmers.

Beaches are closed when enterococci levels exceed 104 colony forming units (CFU) per 100mL and are often preemptively closed before heavy rains (LISS 2017). During our study period from 2003 to 2015, the average beach in Westchester was closed for 7% of the summer season, i.e. about one week. Besides the visual cues and foul odors, there are many formal mechanisms keeping residents and potential home buyers well-informed of pollution levels and beach closures.

Briefly, the hedonic results suggest that under the conventional approach of examining enterococci levels at the portion of the Sound nearest a home, prices respond negatively, suggesting a -0.014 elasticity. In other words, a 10% increase in enterococci suggests a 0.14% decrease in home values, which translates to an average depreciation of $1,543. This effect gradually declines with distance, and in line with previous studies (e.g., Klemick et al. 2018, Walsh and Milon 2015), only extends to non-waterfront homes up to about one kilometer from the water.

In contrast, when focusing on water quality levels measured at the nearest beach, we find that the negative price effects associated with enterococci levels in the Long Island Sound are larger and extend much further. Homes nearest the beach face an elasticity of -0.034, an effect that significantly impacts homes up to 2.5 kilometers away. At the same time, when controlling for water quality at the nearest beach, we see that the elasticities with respect to enterococci levels measured nearest the home become statistically insignificant across all distance bins. This result is robust when also explicitly accounting for beach closures, which provide a more observable signal of local water quality levels to nearby residents. We find that the elasticity with respect to beach closures during the summer season has a much more precisely estimated negative effect on house prices, impacting homes up to 3.5 km away.

This is the first study to simultaneously control for water quality measured at the portion of the waterbody nearest the home and at the portion of the waterbody corresponding to the nearest beach. Our findings suggest that water quality at beaches are capitalized in home prices, and that accounting for this demonstrates a farther-reaching impact than previously suggested in the hedonic literature. This finding presents significant implications for defining the extent of the market in benefit-cost analyses of policies to improve water quality and aquatic ecosystem services. Local recreational opportunities are an important component of a neighborhood, and it should be no surprise that the quality of these opportunities can affect nearby home prices.

The paper is outlined as follows. We provide a brief literature review in section II, then a description of our theoretical model in section III, followed by further background about the study location and water quality issues in section IV, and then a description of the data in section V. The empirical methods and results are presented in sections VI and VII, respectively. Section VIII discusses the implications of the findings and provides some concluding remarks.

II. Literature Review

Dating back to David's (1968) report, the literature examining the impacts of surface water quality on residential property values is fairly well-established. The focus, however, has been primarily on price impacts among waterfront homes, particularly in earlier studies (Young 1984, Michael et al. 1996, Boyle et al. 1996, Boyle et al. 1999, Leggett and Bockstael 2000). More recently studies have expanded the analyses to both waterfront and non-waterfront homes and found that water quality can affect homes as far away as about one mile from a waterbody (Walsh et al. 2011, Netusil et al. 2014, Liu et al. 2017, Klemick et al. 2018).

The current study expands on the growing hedonic literature examining the impacts of surface water quality on home prices in four main ways. First, to our knowledge this is the most rigorous study to date to examine how water quality at the nearest point of access for recreation, i.e., the nearest beach, impacts residential property values, and to determine how far this impact may extend. The literature has almost exclusively considered water quality nearest the home, linking residential transactions to water quality levels measured at the nearest monitoring site or nearest few monitoring sites (Boyle et al. 1999, Michael et al. 2000, Gibbs et al. 2002, Poor et al. 2007).

Only a few studies have investigated how water quality at the nearest beach impacts home values. Feenberg and Mills (1980) found significant negative effects from oil contamination and turbidity when interacted with the inverse of distance to the nearest beach. However, their analysis was mainly an illustrative exercise, as it lacked commonly included control variables of the housing structure (e.g., interior square footage, number of bedrooms and bathrooms). Brashares (1985) later found no significant effects across multiple water quality parameters when interacted with distance to the nearest recreation site. A dissertation chapter by Ara (2007) also reported mixed results, but that study did not consider how the impacts of water quality on home prices vary with distance to the beach. Given the relatively small body of literature and mixed results, we set out to investigate whether water quality at the nearest beach has a stronger (and perhaps independent) effect on house prices than water quality measured at the nearest monitoring site.

A second contribution of this study is that by focusing on the Long Island Sound, a large and iconic estuary in the northeast U.S., our study adds to the relatively small subset of hedonic studies of water quality in estuaries. Bin and Czajkowski (2013) examined waterfront properties around the St. Lucie River Estuary in Florida. They found that better water quality in terms of a non-technical location grade summary measure, as well as technical measures (e.g., water clarity, pH), correspond to higher property prices. Leggett and Bockstael (2000) examined the impact of fecal coliform on waterfront homes along the Chesapeake Bay and found significant negative effects. Walsh et al. (2017) and Klemick et al. (2016) analyzed homes in 14 counties adjacent to the Chesapeake Bay and found that home values appreciate significantly with higher levels of water clarity, an effect that extended as far as one kilometer in some counties. Liu et al. (2017) focused on non-waterfront homes around Narragansett Bay and found that chlorophyll concentrations had significant negative effects on homes up to 1,500 meters from the shore.

A third contribution is that, to our knowledge, this is the only hedonic study utilizing measurements of enterococci bacteria counts, despite its common use as an indicator for recreational water safety. Previous studies have examined the impacts of fecal coliform counts (Brashares 1985, Leggett and Bockstael 2000, Ara 2007) and E. coli (Netusil et al. 2014). However, since 1986 enteroccoci has been deemed the appropriate measure for setting federal standards in the U.S. (EPA 2004). Fourth, to our knowledge this is the first hedonic study to explicitly examine the effect of beach closures on residential property values, although several recreation demand models have examined beach closures (Lew and Larson 2005, Parsons et al. 2009, Parsons and Kang 2010)). Beach closures provide a more discrete and perceivable signal of water quality to local residents, and local beaches are an integral component of neighborhood recreation.

III. Theoretical Model

The question of whether water quality at the nearest beach has a greater effect than water quality measured at the nearest monitoring site can be more formally framed in an ecosystem services input versus endpoint construct (Boyd and Krupnick, 2013). Suppose a local resident's utility (U) depends on a composite numeraire good (m), and the water-related recreational (r) and aesthetic (a) services associated with their housing bundle. We posit that both endpoints r and a are functions of the water quality in the local waterbody. More formally, we can think of water quality as an input that contributes to these ecological services. Obviously recreational and aesthetic experiences are affected by other factors unrelated to water quality, but we hold such factors constant here and thus omit them from the theoretical model.

Empirical property value studies have often assumed water quality measured at the monitoring site nearest the home (WQ) is the appropriate measure. Thus, utility would be represented as $U\big(m, r(WQ), a(WQ)\big)$. This may be a reasonable assumption, particularly for waterfront homes where residents have direct access to the portion of the waterbody nearest their home.

However, local residents living in non-waterfront homes do not have direct access to the portion of the waterbody nearest their home, and so the water-related services they receive, especially recreational services, may also be dependent on the quality of the water at the nearest point of access to that waterbody, or beach in our case (WQ_b). Waterfront residents may also care about the quality at the nearest beach, as this may be a more important input to recreation and they may have strong preferences towards this service. An implicit assumption here, and one that generally holds for large waterbodies like the Long Island Sound, is that there is heterogeneity in water quality across different areas of the waterbody, i.e., $WQ \neq WQ_b$.

We hypothesize that the utility function could be a function of both WQ and WQ_b, as follows: $U\big(m, r(WQ, WQ_b), a(WQ, WQ_b)\big)$. This hypothesis is empirically tested based on tests for statistical significance of the coefficients in the hedonic price function. Following Rosen's (1974) seminal framework, the implicit price of water quality at the portion of the waterbody nearest the home and at the nearest beach will equal $\frac{\partial U}{\partial R}\frac{\partial R}{WQ} + \frac{\partial U}{\partial a}\frac{\partial a}{WQ}$ and $\frac{\partial U}{\partial R}\frac{\partial R}{WQ_b} + \frac{\partial U}{\partial a}\frac{\partial a}{WQ_b}$, respectively. Tests of the statistical significance of the corresponding implicit prices will yield insight as to what measures of water quality are important to local residents.

IV. Background

Westchester County is located just north of New York City and next to the Long Island Sound. The Sound offers many aesthetic and recreational amenities, such as swimming, fishing, and boating. As of 2015, the county was home to about 967,000 people. It is a relatively affluent area, with 2015 Census data showing a median household income of $83,958, which is notably higher than the national median of $53,889 (U.S. Census Bureau 2015).

Westchester has long struggled with fecal pollution in the Sound, primarily due to stormwater runoff and sewage overflows. The county's sanitary sewage system, which started in 1909 with the construction of the Bronx Valley main sewer line, was built to keep sewage and stormwater separate. In other words, the system is *not* a combined sewage system (Smith 1912, Harding 1950). However, cracks in the pipes of this aging infrastructure cause stormwater to leak into sewage pipes during excessive rain events, resulting in raw sewage flowing into the Sound through several pathways. Sewage can overflow from manholes and ultimately run into the Sound, or it can leak out of pipes and into groundwater and the Sound. Moreover, excess water flows to the county's sewage treatment plants sometimes causes the need to discharge untreated or partially treated sewage directly into the Sound.

The county found in 2013 that the flow of stormwater into sewage pipes contributes up to half of the water volume flowing to sewage plants (Westchester County Department of Public Works and Transportation 2013). As part of the response to this problem, the county constructed two overflow retention facilities in 2004 to take in extra wastewater and minimize untreated discharges. But as recently as 2015, a nonprofit group called Save the Sound sued Westchester County for failing to stop the overflows (Garcia 2015a).

Exposure to fecal bacteria in water can lead to a variety of health problems, including gastrointestinal, skin, eye, ear, and respiratory illnesses (EPA 2015). Because enterococci are often found in fecal waste, jurisdictions commonly use counts of enterococci to determine whether waters are suitable for recreation. Westchester's policy is to close beaches when enterococci counts exceed 104 colony forming units (CFU) per 100mL. The county also closes both public and private beaches preemptively in anticipation of excessive rain events and pollution concerns. The county generally closes beaches for one day if there is at least half an inch of rain, and two days if there is at least one inch of rain. If it rains more than two inches, the county decides the appropriate length of time to close the beaches (Westchester County Department of Public Health 2017).

There are a number of ways the public is informed of water quality in the Sound. For example, beach closures are announced on the county website. The nonprofit group Save the Sound e-mails beach closure alerts and provides an interactive map of general water quality on its website [1]. The local media report on beach closures and sewage overflows, and signs are posted at the beaches (Daily Voice 2013, NBC 4 New York 2013, News 12 Westchester 2003, New York State Department of Health 2012).

V. Data

Property Data

Property sales data in Westchester County from 2003 to 2015 were obtained from the New York State Department of Taxation and Finance. We limit our study to arms-length sales of single family homes and townhomes within five kilometers of the Long Island Sound, resulting in a final dataset of 16,926 transactions.[2] Home prices are normalized to 2015 dollars using the Consumer Price Index for All Urban Consumers.[3] The property sales data includes variables for structural and parcel characteristics, such as square footage, number of bedrooms and bathrooms, age, the presence of a basement, and parcel acreage.

We controlled for a number of locational factors by using Geographic Information Systems (GIS) to generate variables for distances of homes to primary roads, New York City, and the Long Island Sound.[4] We also included distance to the nearest sewage treatment plant[5] to control for other polluter effects besides pollution, such as noise and unsightly aesthetics, which Leggett and Bockstael (2000) found to be significant in their study of a similar iconic estuary (the Chesapeake Bay). Socioeconomic variables of the neighborhood (census block group) were obtained from the U.S. Census Bureau and were included as covariates in the hedonic regressions. Variables include median household income, race, population density, and percent owner-occupied housing.[6] Data of local school ratings were obtained from GreatSchools.org,[7] which the real estate website Zillow displays alongside their home listings. The full list of control variables in our model and the corresponding descriptive statistics can be found in Table 1.

Water Quality Data

Data on enterococci levels in the Sound were obtained from the Water Quality Portal.[8] The vast majority of enterococcus sampling occurs during the beach season, from May to September. During these months in our study period there were 5,210 samples from 32 different monitoring sites located along Westchester's shoreline (see Figure 1). Enterococci levels were measured and expressed in terms of CFU (colony-forming units) per 100mL. We find that enterococci levels vary both temporally and spatially, but the majority of the observed variation tends to be spatial in nature (see Kung et al. (2017) for details).

At each monitoring site we averaged enterococci levels by month, and then averaged the monthly means for each monitoring site and for each beach season. Homes sold during and after May were matched to the average enterococci levels for the beach season that year. Homes sold before May were matched to the average enterococci levels for the beach season of the previous year.

Home transactions were spatially matched to water quality monitoring sites in two ways. First, we identified the closest three monitoring sites for each home. Of the three monitoring sites, homes were then matched to the nearest one where enterococcus was sampled and measured for the summer season corresponding to when a transaction took place. Second, we matched homes to the average water quality measure at the nearest beach.[9] Most beaches had only one monitoring site, but some had multiple sites. For beaches with multiple sites, we averaged water quality values across all monitoring sites within 150 meters of the beach. Descriptive statistics of the water quality variables can be found in Table 1.

Beach Data

In our study area there are 22 beaches along the Long Island Sound, of which 17 are private and 5 are public. Beach closure data came from EPA's BEACON (Beach Advisory and Closing Online Notification) database.[10] The data indicate that the length of the beach season was 107 days for most beaches, but for some private beaches the seasons were slightly longer. For consistency, we only accounted for beach closures within the 107-day season, which begins about a week before Memorial Day in May and ends about a week after Labor Day in September. Closures are measured as the number of days the beach is closed. As shown in Table 1, a beach is closed for about 7 days each beach season on average.[11]

It is possible that beaches with better water quality (and hence less beach closures and lower levels of enterococci) tend to have other desirable characteristics. If that is the case, then not controlling for heterogeneity in the various features offered by different beaches could present an omitted variable bias. To control for beach heterogeneity and better minimize the potential for such confounding effects, we obtained GIS data on beaches and boat launches from the Westchester County Geographic Information Systems Data Warehouse.[12] These data are used to derive two variables – the length of the beach and whether a boat launch is present. Multiple studies on beach erosion have shown that beach width is capitalized in nearby home prices (Edwards and

Gable 1991, Landry and Hindsley 2011, Landry and Allen 2016). Although we only have the data to measure beach length, the aforementioned studies on beach erosion suggest that people place greater value on beaches with greater area. In addition, we also control for whether a beach is publicly or privately owned and later examine heterogeneity in the price impacts of water quality in this regard. Nearly all of the 17 private beaches along the Sound are owned by country clubs. The five public beaches provide similar features to visitors, including restroom facilities, lifeguards, and parking lots.

VI. Empirical Methods

We estimate a series of hedonic property value regressions where the dependent variable $\ln p_{ijt}$ is the natural log of the real transaction price for home *i*, in neighborhood *j,* when it was sold in year *t*. This is estimated as a function of characteristics of the parcel, the home itself, and the surrounding neighborhood, all denoted as $\mathbf{x}_{ijt}$. A vector of year and quarterly dummy variables $\mathbf{M}_t$ is included to control for broader housing market trends and seasonal effects.

To account for spatial dependence and absorb any otherwise confounding spatially correlated unobservables (Anselin and Le Gallo 2006) we estimate a general spatial model (referred to as the SAC model by LeSage and Pace (2009)), as shown below. Robust Lagrange multiplier tests of spatial dependence indicate both error and lag spatial dependence, supporting the use of the SAC model. Let $wp_{[ijt]}$ denote the corresponding element from the n × 1 vector obtained after multiplying the spatial weight matrix (SWM) $\mathbf{W_1}$, by the price vector **P**. In other words, $wp_{[ijt]}$ is the spatially and temporally weighted average of neighboring prices allowed to influence the price of home *i* sold in period *t*.[13] Similarly, $w\varepsilon_{[ijt]}$ is the corresponding element from the n × 1 vector obtained after multiplying $\mathbf{W_2}$ by the vector of error terms $\boldsymbol{\varepsilon}$. The random component of the error term is denoted as $u_{ijt} \sim N(0,\sigma^2)$.

Our base hedonic specification, Model 1, is:

$$\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{D_i}\boldsymbol{\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \boldsymbol{Beach_{ib}}\boldsymbol{\theta_2} + \varepsilon_{ijt}$$
$$\text{where } \varepsilon_{ijt} = \lambda w \varepsilon_{[ijt]} + u_{ijt} \quad (1)$$

and $\boldsymbol{\beta}$, $\boldsymbol{\alpha}$, $\boldsymbol{\theta_1}$, $\boldsymbol{\theta_2}$, $\boldsymbol{\gamma_1}$, ρ, and λ are all coefficients to be estimated. In particular, ρ is the spatial lag parameter and λ is the spatial error parameter.

The variables of primary interest are $\boldsymbol{D_i}$ and WQ_{it}. $\boldsymbol{D_i}$ is a vector of dummy variables denoting distance of house i to the nearest portion of the Long Island Sound, measured using incremental 500-meter bins, starting with 0 to 500 meters and extending out to five kilometers. The last 500-meter bin (4,500 to 5,000 meters) is the omitted category. The choice of 500-meter distance bins is based on consideration of two opposing factors, the desire for high spatial resolution when estimating the price gradient with respect to water quality versus having a reasonable sample size within each bin for statistical identification. Ultimately, we believe the 500-meter bins provide the best balance, but the results subsequently presented are robust to smaller 250-meter wide bins.

The parameter vector $\boldsymbol{\theta_1}$ captures the price gradient associated with being in close proximity to the Long Island Sound. This price gradient captures features like access to the resource and aesthetic views, as well as all other time-invariant unobserved factors associated with each 500-meter bin. $\boldsymbol{D_i}$ is also interacted with the natural log of water quality measured at the portion of the waterbody closest to home *i*, in period *t* (WQ_{it}). We control for distance to the nearest beach (*b*), again using a vector of dummy variables denoting 500-meter bins extending out to five kilometers, $\boldsymbol{Beach_{ib}}$. The vector $\boldsymbol{\theta_2}$ captures the price gradient associated with proximity to a beach. Again, this price gradient will reflect the net effect of access to the resource, aesthetic views, and all other time-invariant unobserved factors associated with each 500-meter bin.

In this study we measure water quality (WQ_{it}) as the natural log of enterococci counts (CFU per 100mL). The impact of a marginal change in enterococci on home values may vary at different baseline levels, and so, as assumed in previous studies (e.g., Michael et al. 2000, Gibbs et al. 2002, Walsh et al. 2011), WQ_{it} enters the hedonic models in its natural log form.[14] The parameter of primary interest is $\boldsymbol{\gamma_1}$, a vector where each element reflects the elasticity of house prices with respect to enterococci counts at the monitoring site closest to a home (and among homes in the corresponding distance bin). In other words, $\boldsymbol{\gamma_1}$ captures how the elasticity of house prices, with respect to water quality at the portion of the waterbody nearest the home, varies with proximity to the waterbody.

Subsequent models build on Model 1 by explicitly accounting for water quality at the nearest beach in that same waterbody, controlling for beach closures in response to poor water quality, and accounting for other features of the nearest beaches, including whether the beach is publicly accessible or considered private.

Model 2 separately controls for water quality at the portion of the waterbody nearest the home (WQ_{it}) and at the nearest beach (WQ_{ibt}). The variable of particular interest here is $\boldsymbol{\gamma_2}$, a vector of house price elasticities with respect to enterococci counts at the nearest beach, where each element corresponds to a 500-meter distance bin. More formally:

$$\begin{aligned}\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{D_i\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \\ +\boldsymbol{Beach_{ib}\theta_2} + \{\boldsymbol{Beach_{ib}} \times ln(WQ_{ibt})\}\boldsymbol{\gamma_2} + \varepsilon_{ijt} \qquad (2)\end{aligned}$$

Model 3 builds on the previous model by explicitly accounting for beach closures in response to actual or anticipated high enterococci counts. Beach closures ($Closures_{ibt}$) are expressed as the number of summer season days closed. More formally:

$$\begin{aligned}\ln p_{ijt} = \rho w p_{[ijt]} + \mathbf{x}_{ijt}\boldsymbol{\beta} + \mathbf{M}_t\boldsymbol{\alpha} + \boldsymbol{D_i\theta_1} + \{\boldsymbol{D_i} \times ln(WQ_{it})\}\boldsymbol{\gamma_1} + \\ +\boldsymbol{Beach_{ib}\theta_2} + \{\boldsymbol{Beach_{ib}} \times ln(WQ_{ibt})\}\boldsymbol{\gamma_2} + \\ +\{\boldsymbol{Beach_{ib}} \times ln(Closures_{ibt})\}\boldsymbol{\gamma_3} + \varepsilon_{ijt} \qquad (3)\end{aligned}$$

The vector $\boldsymbol{\gamma_3}$ reflects the elasticity of home prices with respect to closures at the nearest beach. Model 4 builds on Model 3 by including additional characteristics of the nearest beach *b*. This allows us to better control for the possibility that other desirable or undesirable features of a beach may be correlated with water quality, which if not otherwise controlled for would present the possibility of omitted variable bias.

In subsequent models, we examine potential heterogeneity in the impacts of beach closures on home values, depending on whether a beach is privately owned or accessible by the public. Interaction terms between $\boldsymbol{Beach_{ib}}$ and dummy variables denoting whether a beach is public or private are added, allowing the price gradient with respect to beach proximity $(\boldsymbol{\theta_2})$ to vary across public versus private beaches. The public and private beach dummy variables are then interacted with $Closures_{ibt}$, thus allowing us to test for heterogeneity in the price impacts of beach closures $(\boldsymbol{\gamma_3})$.

VII. Results

In the following presentation of results only the estimates of interest are presented, but the full hedonic regression results are provided in an online appendix. The majority of the omitted coefficient estimates have the expected sign and are statistically significant. For example, home prices increase with higher square footage, better school ratings, and a lower population density.[15]

The coefficient estimates of interest for Models 1 through 4 are presented in two different tables to distinguish between water quality nearest the home versus at the nearest beach, but these estimates are from the same hedonic regressions. As described in section VI, the elasticity estimates presented are based only on the coefficient estimates. Any indirect “feedback” effects through the spatial lag are not included. Such indirect effects are miniscule in our results, and as discussed by Anselin and Lozano-Gracia (2008), in this context we view the spatial lag as a means to absorb spatially correlated omitted variables, and thus the inclusion of these indirect effects in the implicit price estimates of interest would be inappropriate. Note that all rho values are small, so that the difference between the coefficients, direct effects, and total effects are extremely small.

The results show that home prices generally respond negatively to increased enterococci levels, and that the effect is strongest among homes within close proximity to the water and then diminishes with distance. First consider Model 1, which follows the conventional approach in the literature and links homes to the water quality measures at the closest monitoring site. As shown in Table 2, the results suggest a negative elasticity that is greatest in magnitude among homes located in the nearest distance bins (0-500 m and 500-1,000 m). We can see that homes within 500 meters of the Sound are affected the most, which on average experience a decrease in sales price of 0.14% for every 10% increase in enterococci. For these homes, this translates to an average decrease in home value of $1,543. This negative effect diminishes at farther distances but remains significant out to 1,000 meters, as visually depicted in the Model 1 column in Figure 2. The magnitude of the effect in the first two buffers is quite similar and t-tests suggest that they are not significantly different from each other.

In Models 2 through 4 we deviate from the conventional approach and explicitly account for water quality at the nearest beach. In doing so, we see in Table 2 that the water quality price gradient associated with enterococci levels at the portion of the waterbody nearest the home becomes much smaller in magnitude and statistically indistinguishable from zero.

In contrast, as seen in Table 3, when we consider water quality at the closest beach conditional on water quality measured nearest the home, there is a strong negative effect that is larger in magnitude and spatial extent than the estimates corresponding to water quality levels measured at the monitoring site nearest the home. Model 2 shows that among homes in the nearest 0-500 meter bin from the beach that a 10% increase in enterococci decreases house prices by 0.34%. As shown in Table 3 and Figure 2, the negative elasticity associated with water quality at the nearest beach remains statistically significant in most 500-meter bins out to 2,500 meters. These results translate to average implicit prices of $4,730 for homes within 500 meters of a beach and $1,845 for homes in the farthest significant distance bin, 2,000-2,500 meters. The coefficients for the last three significant distance bins are close in magnitude, and t-tests do not find significant differences between the effects, suggesting that the price effect is fairly constant before dropping off at greater distances.

In Model 3 we account for the number of beach closure days in the corresponding summer season. The results suggest that home buyers and sellers do, on average, seem to respond more to beach closures than enterococci levels. This is reasonable given that beach closures and notifications are a more direct and salient signal to local residents regarding water quality. When comparing estimates across Models 2 and 3 in Table 3, we see that accounting explicitly for beach closures decreases the magnitude of the estimated elasticities corresponding to beach enterococci levels. It also results in beach enterococci estimates becoming statistically insignificant, at least among homes in the nearest distance bins. The estimated elasticities with respect to enterococci do remain fairly robust in the farther bins (1,000 to 2,500 meters). The estimated elasticities with respect to beach closures are of the expected negative sign, with statistically significant effects extending out to the 3,000-3,500-meter bin.

Similar results are found in Model 4, where we control for size of the beach and presence of amenities, like a boat ramp.[16] Figure 2 graphically compares the estimates for beach water quality and beach closures from Model 4. We highlight two features of this graph. First, the elasticity estimates corresponding to the more direct and salient beach closure measure are much more precise, as can be seen by the relatively tight 95% confidence intervals around the estimates and the consistently negative price gradient. Second, the statistically significant negative effects of beach closures extend to homes as far as 3,000 meters from the beach. The estimates translate to an average decrease in home values of $162 for homes in the 0-500 meter bin and $77 for homes in the 2,500-3,000 meter bin for one additional beach day closed each summer season. Although these numbers do not seem economically significant, they suggest that if the nearest beach is closed an additional week every year, there would be an average price decrease of $1,134 for homes in the 0-500 meter bin and $539 for homes in the 2,500-3,000 meter bin. This is a plausible scenario given that the average number of beach days closed per season is seven, and there have been instances where beaches were closed for most of, or even the entire, season.[17]

The hedonic models estimated thus far assume that enterococci counts and beach closures enter in natural logged form, thus allowing the price impact of an incremental change in water quality to vary at different baseline water quality levels. Although we believe this is the most appropriate functional form in this context (Michael et al. 2000), the sensitivity of results to such assumptions has received considerable attention in the literature (Cropper et al. 1988, Kuminoff et al. 2010). Re-estimating the hedonic regression models with the water quality variables entering in levels yields similar results in terms of sign and spatial extent. Beach closures still seems to yield the strongest decline in property values, suggesting that one additional beach closure day yields a 0.18% decline in the value of homes located 1,500 to 2,000 meters from the beach, and a marginally significant 0.22% decline among homes within 3,000 to 3,500 meters. In contrast to our main results, however, the inner distance bins are not statistically significant. The sensitivity of our results to the functional form is an important caveat to keep in mind, but we argue that the double-log specification is most appropriate because it implies that the incremental price effects vary across baseline water quality levels.

In the remaining models, we continue with the double-log specification and draw further focus to the more salient measure of beach water quality – beach closures. We now disregard beach enterococci levels to circumvent potential multicollinearity issues, particularly when examining impact heterogeneity across private versus public beaches. Model 5 (Table 4) is the same as Model 4, but excludes enterococci levels at the nearest beach. Comparison of these models demonstrates that the other results of interest are robust to the exclusion of beach enterococci levels. Figure 2 visually shows the declining magnitude of the negative price effects of beach closures, as estimated by Model 5, with statistically negative price effects extending as far as 3,500 meters.

Model 6 includes terms interacting dummy variables denoting private versus public beaches with the corresponding distance bins, as well as the beach closures variable. This allows us to examine whether the magnitude and spatial extent of the impact of beach closures on home prices varies based on ownership and ease of access for local residents. A likelihood ratio test rejects the restricted model (Model 5), indicating that Model 6 is preferred. In line with this finding, the results in Table 4 suggest noticeable heterogeneity. The elasticities for beach closures in the nearest distance bins are very similar, but as we move further away, the estimates start to diverge. Among the nearest distance bins (0-500, 500-1000, and 1000-1500 meters), a series of t-tests (Kennedy 2001) fail to reject the null hypothesis that the negative price impacts are statistically equal, suggesting that closures at private versus public beaches have a similar impact on homes in relatively close proximity. At around 1,500 meters, closures at public beaches have a noticeable and statistically greater impact on home prices than those at private beaches, with significant negative price impacts extending as far as 4,000 meters. In contrast, closures at a nearby private beach only seem to significantly impact home prices out to about 2,000 meters.[18]

The empirical estimates are in line with intuition and economic theory – public beaches are a more widely accessible amenity, and so it makes sense that closure of a more widely accessible resource would have a broader impact on property values and surrounding residents. In contrast, private beaches are a more localized amenity, only accessible to members of the corresponding country club and/or those that live in close proximity, and so it seems reasonable that private beach closures have a more local effect on property values. This has implications for policymakers when choosing how to allocate resources for pollution abatement and restoration. Such efforts at public beaches may provide greater benefits to local constituents than similar efforts at private beaches.

VIII. Conclusion

As the number of hedonic property value studies examining water quality has grown, the focus has expanded to include impacts to both waterfront and non-waterfront residents living near a waterbody. This study utilizes data on residential transactions near the Long Island Sound in Westchester County, NY, where sewage overflows caused by an aging infrastructure have been a longstanding problem. Our results are the first to show that when we consider water quality at the nearest recreational access point (a beach in our case), the negative price impact of pollution can extend to homes beyond what has been previously suggested in the literature. This has important implications for benefit-transfer and in defining the "extent of the market" for benefit-cost analyses of policies and projects aimed at improving surface water quality.

In our conventional hedonic specification, where homes are linked to enterococci counts measured at the nearest portion of the waterbody, irrespective of a resident's ability to access the waterbody at that nearest point, we find negative price effects that extend up to one kilometer from the Long Island Sound. This result is largely in line with the magnitude and spatial extent of estimates previously suggested in the literature (e.g., Walsh et al. 2011, 2017, Netusil et al. 2014, Klemick et al. 2018, Liu et al. 2017). However, when we examine enterococci counts at the closest beach, the negative effects extend much farther out to 2.5 kilometers.

When focusing on beach closures, a more perceivable signal of water quality, we find a more precisely estimated and even farther extending effect, impacting homes out to 3.5 kilometers. One could attribute this stronger effect to beach closures being a less complicated non-technical measure of water quality that is easier for local residents to understand. In this case our results would be in contrast to those of Bin and Czajkowski (2013), who find technical water quality measures to be better predictors of housing values. However, in the current context we believe beach closures are a stronger driver of price impacts because closures are more directly communicated to and observed by residents.

Local stakeholders can make better informed decisions by comparing our results to the costs of policies and projects to improve water quality in the Long Island Sound. Purely as an illustrative back-of-the-envelope example, consider a hypothetical program that reduces the number of beach closures each summer season from the average of seven days a year to zero. This would yield a total increase in value of the 24,834 single-family homes and townhomes within 3.5 km of a beach by about $14.5 million. We emphasize that these estimated property value impacts reflect only a portion of the benefits to local stakeholders because households further away who use these beaches will also benefit. Nonetheless, as a rough comparison, a project to repair the sewer infrastructure and prevent stormwater infiltration and subsequent sewage overflows in one Westchester city, New Rochelle, costs about $20 million (Garcia 2015b).

In summary, accounting for water quality and closures at the nearest beach may better capture recreational and aesthetic values held by nearby residents, compared to the conventional approach of only accounting for water quality at the portion of the waterbody nearest the home, as reflected by measurements at the nearest monitoring site. Our results suggest that in order to more fully account for water quality benefits, future analyses, at least those of large iconic waterbodies like the Long Island Sound, should consider homes and residents at farther distances and account for water quality levels at key access points.

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Tables and Figures

Table 1. Home transaction and water quality descriptive statistics.

	Count	Mean	St Dev	Min	Max
Home price (2015$)	16,926	934,298.10	611,056.20	142,168.50	4,320,623.00
Structural variables					
Age of home (years)	9,452	67.43	28.57		
Dummy: age missing	16,926	0.44	0.50	0.00	312.00
Home square footage	9,425	2,384.92	1,006.46	0.00	1.00
Dummy: home square footage missing	16,926	0.44	0.50	10.00	10,110.00
Parcel acreage	16,926	0.22	0.44	0.00	1.00
Dummy: townhome	16,926	0.16	0.37	0.01	40.06
Bedrooms	9,642	3.39	1.69	0.00	1.00
Dummy: bedroom missing	16,926	0.43	0.50	0.00	10.00
Bathrooms	9,132	2.85	1.18	0.00	1.00
Dummy: bathrooms missing	16,926	0.46	0.50	1.00	9.00
Dummy: pool	7,015	0.04	0.18	0.00	1.00
Dummy: pool missing	16,926	0.59	0.49	0.00	1.00
Dummy: porch	7,015	0.83	0.37	0.00	1.00
Dummy: porch missing	16,926	0.59	0.49	0.00	1.00
Dummy: A/C	3,177	1.00	0.00	0.00	1.00
Dummy: A/C missing	16,926	0.81	0.39	1.00	1.00
Dummy: basement	9,642	0.68	0.47	0.00	1.00
Dummy: basement missing	16,926	0.43	0.50	0.00	1.00
				0.00	1.00
Location variables					
Distance to primary road (m)	16,926	818.06	577.94		
% Developed by block group	16,926	65.63%	24.51%	21.61	3,162.98
Distance to NYC (km)	16,926	28.85	4.80	13.97%	100%
Distance to sewage plant (m)	16,926	3,672.02	2,157.56	22.25	42.48
School rating	13,190	6.66	2.73	91.52	9,403.98
Dummy: school rating missing	16,926	0.22	0.41	1.00	10.00
Dummy: in 100-yr flood plain	16,926	0.03	0.18	0.00	1.00
Distance to Sound (m)	16,926	2,038.85	1,456.05	0.00	1.00
Distance to beach (m)	16,926	3,767.86	2,170.00	0.00	4,999.99
Distance to public beach (m)	9,507	3,844.83	2,118.24	44.24	8,730.98
Distance to private beach (m)	7,419	3,669.23	2,230.83	171.60	8,730.98
Length of closest beach (m)	16,926	219.60	104.03	44.24	8,681.24
Dummy: boat launch at closest beach	16,926	0.55	0.50	29.00	430.00
				0.00	1.00
Neighborhood variables by block group					
Median household income	16,926	94,428.41	61,078.17		
Dummy: median income > $250k	16,926	0.13	0.33	0.00	244,118.00
% Hispanic	16,926	13.31%	13.61%	0.00	1.00
% Black	16,926	15.48%	25.04%	2.10%	87.05%
% Owner occupied	16,926	72.16%	23.50%	0.00%	93.70%
Pop. density (Pop/sq km)	16,926	3,448.06	2,935.42	0.00%	98.71%
				27.94	15,560.81
Water quality variables					
Ent. at closest monitor	16,926	250.73	821.07		
Ent. at closest beach	14,852	146.85	211.14	0.00	11,000.00
Ent. at closest public beach	7,910	218.43	243.10	3.78	1,473.00
Ent. At closest private beach	6,942	65.28	124.71	3.78	1,453.70
Days closed at closest beach	16,540	7.16	10.35	4.35	1,473.00
Days closed at closest public beach	9,507	11.27	11.24	0.00	107.00
Days closed at closest private beach	7,033	1.59	5.26	0.00	46.00
				0.00	107.00

Table 2. Hedonic Regression Results: Elasticities with respect to Enterococci levels measured closest to Home.

	Model 1	Model 2	Model 3	Model 4
Home Ent.				
0-500m	-0.0137***	0.0029	0.0043	0.0047
	(0.004)	(0.0066)	(0.0065)	(0.0065)
500-1000m	-0.0124***	0.0022	0.0028	0.0034
	(0.0041)	(0.0052)	(0.0052)	(0.0052)
1000-1500m	-0.0046	-1.8x10^-5	-0.0007	0.0001
	(0.003)	(0.0032)	(0.0033)	(0.0033)
1500-2000m	-0.0023	-0.0002	-0.0005	-0.0006
	(0.0025)	(0.0026)	(0.0026)	(0.0027)
2000-2500m	0.0006	0.0015	0.0011	0.001
	(0.0032)	(0.0033)	(0.0033)	(0.0033)
2500-3000m	0.0019	0.0024	0.003	0.0029
	(0.003)	(0.003)	(0.003)	(0.003)
3000-3500m	0.0047	0.005	0.0054*	0.0053*
	(0.0031)	(0.0032)	(0.0032)	(0.0032)
3500-4000m	-0.0003	0.0005	0.001	0.001
	(0.0031)	(0.0033)	(0.0033)	(0.0033)
4000-4500m	0.005	0.0062	0.0057	0.0056
	(0.0038)	(0.0044)	(0.0044)	(0.0044)
rho	0.0373***	0.0300***	0.0270***	0.0260***
	(0.0048)	(0.0003)	(0.0003)	(0.0003)
lambda	0.7810***	0.8020***	0.7850***	0.7720***
	(0.0008)	(0.0023)	(0.0007)	(0.0008)
Beach Ent. Interactions	No	Yes	Yes	Yes
Beach Closures Interactions	No	No	Yes	Yes
Beach Attributes	No	No	No	Yes
Observations	16,926	14,852	14,845	14,845
R-squared	0.7853	0.7858	0.7867	0.7865

Note: Dependent variable: *ln(price).* Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The sample is smaller in Model 2 because residential transactions where water quality measurements at the nearest beach are missing are dropped from the estimating sample. For Models 3 and 4, an additional seven transactions are dropped due to missing values for beach closures. The full regression results are provided in the online appendix.

Table 3. Hedonic Regression Results: Elasticities with respect to Enterococci levels and closures at nearest Beach.

	Model 1	Model 2	Model 3	Model 4
Beach Ent.				

0-500m		-0.0336**	-0.0187	-0.0182
		(0.0132)	(0.014)	(0.0141)
500-1000m		-0.0141	-0.006	-0.0059
		(0.0095)	(0.0097)	(0.0098)
1000-1500m		-0.0217**	-0.0167*	-0.0174**
		(0.0084)	(0.0086)	(0.0086)
1500-2000m		-0.0236***	-0.0214***	-0.0216***
		(0.0075)	(0.0078)	(0.0078)
2000-2500m		-0.0197***	-0.0218***	-0.0225***
		(0.0072)	(0.0076)	(0.0076)
2500-3000m		-0.0027	0.0054	0.0058
		(0.0089)	(0.0096)	(0.0096)
3000-3500m		-0.0143	-0.0102	-0.0102
		(0.0091)	(0.0099)	(0.0099)
3500-4000m		0.0011	-0.0002	-0.0003
		(0.0092)	(0.0098)	(0.0098)
4000-4500m		0.0054	0.0069	0.007
		(0.0091)	(0.0099)	(0.0099)
Beach Closures				
0-500m			-0.0127***	-0.0123***
			(0.0044)	(0.0046)
500-1000m			-0.0145***	-0.0145***
			(0.0028)	(0.0029)
1000-1500m			-0.0105***	-0.0096***
			(0.0022)	(0.0024)
1500-2000m			-0.0051**	-0.0055**
			(0.0023)	(0.0023)
2000-2500m			-0.0013	0.0007
			(0.0025)	(0.0026)
2500-3000m			-0.0077***	-0.0077***
			(0.0024)	(0.0024)
3000-3500m			-0.0056**	-0.0043
			(0.0027)	(0.0028)
3500-4000m			-0.0013	-0.0001
			(0.0029)	(0.0031)
4000-4500m			-0.0023	-0.0029
			(0.0028)	(0.003)
rho	0.0373***	0.0300***	0.0270***	0.0260***
	(0.0048)	(0.0003)	(0.0003)	(0.0003)
lambda	0.7810***	0.8020***	0.7850***	0.7720***
	(0.0008)	(0.0023)	(0.0007)	(0.0008)
Home Ent. Interactions	Yes	Yes	Yes	Yes
Beach Attributes	No	No	No	Yes
Observations	16,926	14,852	14,845	14,845
R-squared	0.7853	0.7858	0.7867	0.7865

Note: Dependent variable: *ln(price).* Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The sample is smaller in Model 2 because residential transactions where water quality measurements at the nearest beach are missing are dropped from the estimating sample. For Models 3 and 4, an additional seven transactions are dropped due to missing values for beach closures. The full regression results are provided in the online appendix.

Table 4. Hedonic Regression Results: Elasticities with respect to Enterococci levels measured closest to Home and Closures at the Nearest Beach..

	Model 5	Model 6
Home Ent		
0-500m	-0.0055	-0.0048
	(0.0042)	(0.0042)

500-1000m	-0.0075*	-0.0063	
	(0.0041)	(0.0042)	
1000-1500m	-0.0034	-0.0026	
	(0.0031)	(0.0031)	
1500-2000m	-0.0028	-0.0027	
	(0.0026)	(0.0026)	
2000-2500m	0.0005	0.0007	
	(0.0033)	(0.0033)	
2500-3000m	0.0026	0.0028	
	(0.0029)	(0.0029)	
3000-3500m	0.0052*	0.0053*	
	(0.0031)	(0.0031)	
3500-4000m	-0.0001	-0.0001	
	(0.0031)	(0.0031)	
4000-4500m	0.0046	0.0045	
	(0.0038)	(0.0038)	
Beach Closures		Public	Private
0-500m	-0.0152***	-0.0154*	-0.0133***
	(0.0041)	(0.0083)	(0.0047)
500-1000m	-0.014***	-0.0147***	-0.0121***
	(0.0025)	(0.0041)	(0.0032)
1000-1500m	-0.0103***	-0.0146***	-0.0086***
	(0.0022)	(0.004)	(0.0025)
1500-2000m	-0.0083***	-0.0193***	-0.0044*
	(0.0021)	(0.0038)	(0.0026)
2000-2500m	-0.0018	-0.0107***	0.0047
	(0.0023)	(0.0039)	(0.0031)
2500-3000m	-0.0073***	-0.0187***	-0.0038
	(0.0022)	(0.005)	(0.0026)
3000-3500m	-0.0055**	-0.0216*	-0.0047
	(0.0026)	(0.0115)	(0.0031)
3500-4000m	-0.001	-0.0288**	-0.002
	(0.0029)	(0.0129)	(0.0034)
4000-4500m	-0.0037	-0.0048	-0.0046
	(0.0025)	(0.005)	(0.003)
rho	0.02600***	0.0259***	
	(0.0003)	(0.0003)	
lambda	0.7660***	0.7610***	
	(0.0008)	(0.0009)	
Beach Attributes	Yes	Yes	
Observations	16,540	16,540	
R-Squared	0.7883	0.7888	

Note: Dependent variable: *ln(price).* Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Regressions include variables for structural, location, and neighborhood characteristics, as well as dummy variables for year and quarter. The full regression results are provided in the online appendix. Note that models 5 and 6 exclude 386 observations because beach closure data for the corresponding summer season were missing.

Figure 1. Study area in Westchester County, NY with beaches and average enterococci counts at monitoring sites.

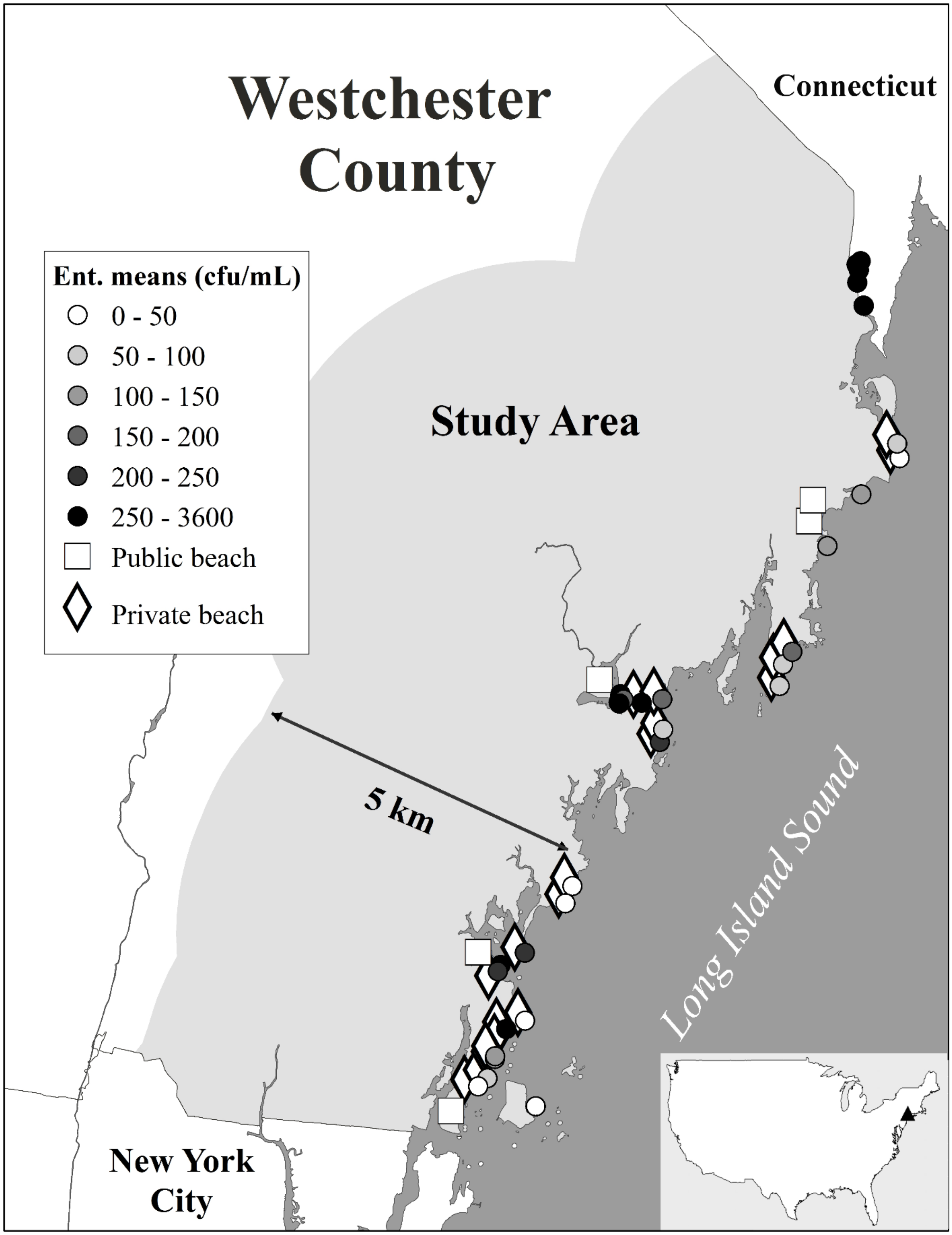
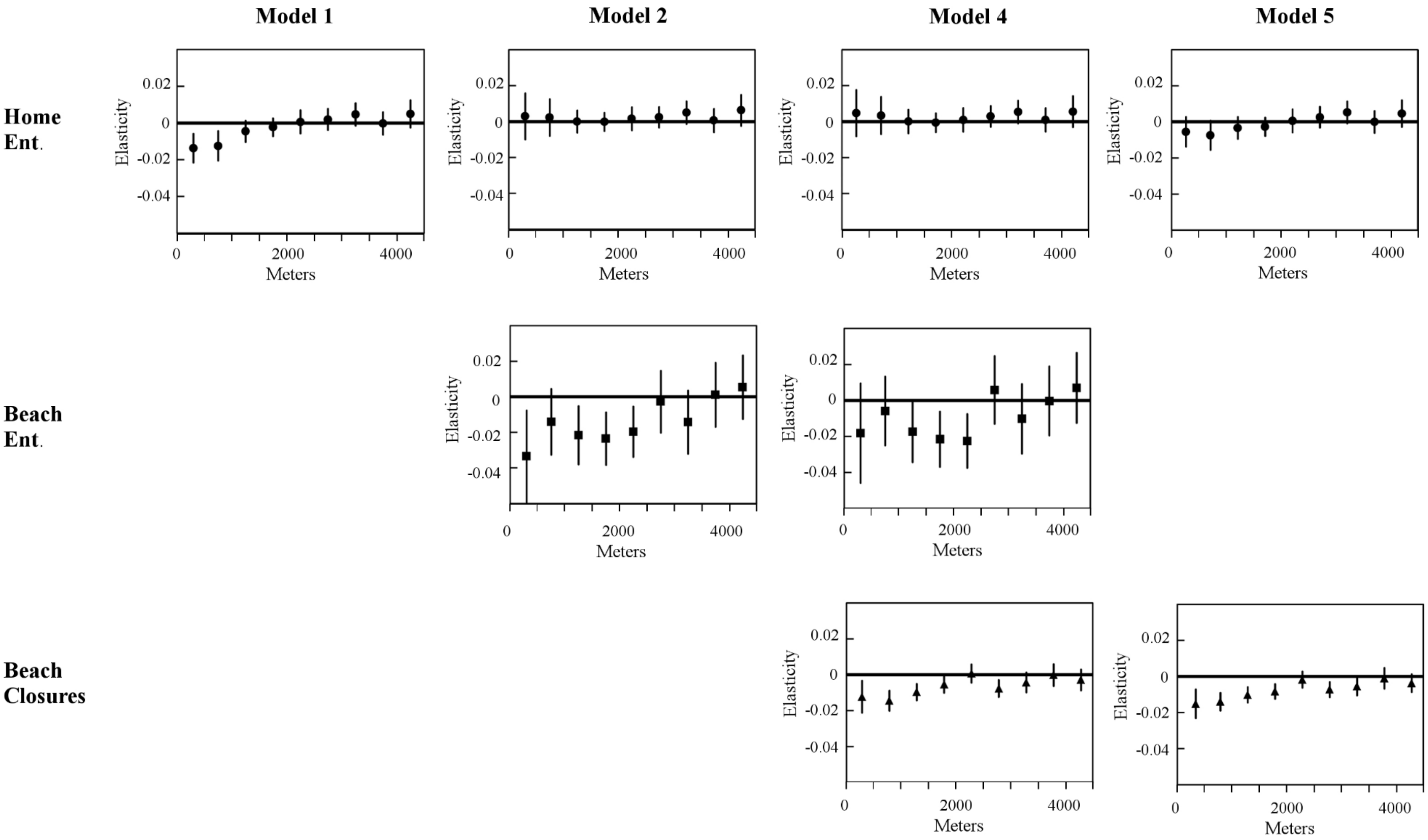


Figure 2. Elasticities with respect to Enterococcus (Ent.) and Beach Closures.



Note: Water quality price gradients based on results from Tables 2, 3, and 4. The 95% confidence intervals are denoted by vertical lines corresponding to each point estimate.

Online Appendix

Table A. 1. Full Hedonic Regression Results.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-1.2686**	10.2639***	-9.9159***	-15.039***	-8.9912***	-9.5185***
	(0.55)	(0.0077)	(0.5682)	(0.0065)	(0.5799)	(0.0134)
Home Ent 0-500m	-0.0137***	0.0029	0.0043	0.0047	-0.0055	-0.0048
	(0.004)	(0.0066)	(0.0065)	(0.0065)	(0.0042)	(0.0042)
Home Ent 500-1000m	-0.0124***	0.0022	0.0028	0.0034	-0.0075*	-0.0063
	(0.0041)	(0.0052)	(0.0052)	(0.0052)	(0.0041)	(0.0042)
Home Ent 1000-1500m	-0.0046	-1.8x10^-5	-0.0007	0.0001	-0.0034	-0.0026
	(0.003)	(0.0032)	(0.0033)	(0.0033)	(0.0031)	(0.0031)
Home Ent 1500-2000m	-0.0023	-0.0002	-0.0005	-0.0006	-0.0028	-0.0027
	(0.0025)	(0.0026)	(0.0026)	(0.0027)	(0.0026)	(0.0026)
Home Ent 2000-2500m	0.0006	0.0015	0.0011	0.001	0.0005	0.0007
	(0.0032)	(0.0033)	(0.0033)	(0.0033)	(0.0033)	(0.0033)
Home Ent 2500-3000m	0.0019	0.0024	0.003	0.0029	0.0026	0.0028
	(0.003)	(0.003)	(0.003)	(0.003)	(0.0029)	(0.0029)
Home Ent 3000-3500m	0.0047	0.005	0.0054*	0.0053*	0.0052*	0.0053*
	(0.0031)	(0.0032)	(0.0032)	(0.0032)	(0.0031)	(0.0031)
Home Ent 3500-4000m	-0.0003	0.0005	0.001	0.001	-0.0001	-0.0001
	(0.0031)	(0.0033)	(0.0033)	(0.0033)	(0.0031)	(0.0031)
Home Ent 4000-4500m	0.005	0.0062	0.0057	0.0056	0.0046	0.0045
	(0.0038)	(0.0044)	(0.0044)	(0.0044)	(0.0038)	(0.0038)
Beach Ent 0-500m		-0.0336**	-0.0187	-0.0182		
		(0.0132)	(0.014)	(0.0141)		
Beach Ent 500-1000m		-0.0141	-0.006	-0.0059		
		(0.0095)	(0.0097)	(0.0098)		
Beach Ent 1000-1500m		-0.0217**	-0.0167*	-0.0174**		
		(0.0084)	(0.0086)	(0.0086)		
Beach Ent 1500-2000m		-0.0236***	-0.0214***	-0.0216***		
		(0.0075)	(0.0078)	(0.0078)		
Beach Ent 2000-2500m		-0.0197***	-0.0218***	-0.0225***		
		(0.0072)	(0.0076)	(0.0076)		
Beach Ent 2500-3000m		-0.0027	0.0054	0.0058		
		(0.0089)	(0.0096)	(0.0096)		
Beach Ent 3000-3500m		-0.0143	-0.0102	-0.0102		
		(0.0091)	(0.0099)	(0.0099)		
Beach Ent 3500-4000m		0.0011	-0.0002	-0.0003		
		(0.0092)	(0.0098)	(0.0098)		
Beach Ent 4000-4500m		0.0054	0.0069	0.007		
		(0.0091)	(0.0099)	(0.0099)		
Beach Closures 0-500m			-0.0127***	-0.0123***	-0.0152***	

		(0.0044)	(0.0046)	(0.0041)	
Beach Closures 500-1000m		-0.0145***	-0.0145***	-0.014***	
		(0.0028)	(0.0029)	(0.0025)	
Beach Closures 1000-1500m		-0.0105***	-0.0096***	-0.0103***	
		(0.0022)	(0.0024)	(0.0022)	
Beach Closures 1500-2000m		-0.0051**	-0.0055**	-0.0083***	
		(0.0023)	(0.0023)	(0.0021)	
Beach Closures 2000-2500m		-0.0013	0.0007	-0.0018	
		(0.0025)	(0.0026)	(0.0023)	
Beach Closures 2500-3000m		-0.0077***	-0.0077***	-0.0073***	
		(0.0024)	(0.0024)	(0.0022)	
Beach Closures 3000-3500m		-0.0056**	-0.0043	-0.0055**	
		(0.0027)	(0.0028)	(0.0026)	
Beach Closures 3500-4000m		-0.0013	-0.0001	-0.001	
		(0.0029)	(0.0031)	(0.0029)	
Beach Closures 4000-4500m		-0.0023	-0.0029	-0.0037	
		(0.0028)	(0.003)	(0.0025)	
Beach Closures (Pub) 0-500m					-0.0154*
					(0.0083)
Beach Closures (Pub) 500-1000m					-0.0147***
					(0.0041)
Beach Closures (Pub) 1000-1500m					-0.0146***
					(0.004)
Beach Closures (Pub) 1500-2000m					-0.0193***
					(0.0038)
Beach Closures (Pub) 2000-2500m					-0.0107***
					(0.0039)
Beach Closures (Pub) 2500-3000m					-0.0187***
					(0.005)
Beach Closures (Pub) 3000-3500m					-0.0216*
					(0.0115)
Beach Closures (Pub) 3500-4000m					-0.0288**
					(0.0129)
Beach Closures (Pub) 4000-4500m					-0.0048
					(0.005)
Beach Closures (Prv) 0-500m					-0.0133***
					(0.0047)

Beach Closures (Prv) 500-1000m						-0.0121***
						(0.0032)
Beach Closures (Prv) 1000-1500m						-0.0086***
						(0.0025)
Beach Closures (Prv) 1500-2000m						-0.0044*
						(0.0026)
Beach Closures (Prv) 2000-2500m						0.0047
						(0.0031)
Beach Closures (Prv) 2500-3000m						-0.0038
						(0.0026)
Beach Closures (Prv) 3000-3500m						-0.0047
						(0.0031)
Beach Closures (Prv) 3500-4000m						-0.002
						(0.0034)
Beach Closures (Prv) 4000-4500m						-0.0046
						(0.003)
Dist. to Sound 0-500m	-0.1213**	-0.2207***	-0.1564**	-0.1609***	-0.1541***	-0.1692***
	(0.0534)	(0.0581)	(0.061)	(0.0573)	(0.053)	(0.049)
Dist. to Sound 500-1000m	-0.0864*	-0.1939***	-0.1275**	-0.1319**	-0.1061**	-0.1215***
	(0.051)	(0.0531)	(0.0559)	(0.0524)	(0.0504)	(0.0466)
Dist. to Sound 1000-1500m	-0.0981**	-0.1477***	-0.0904*	-0.0912*	-0.1004**	-0.1146***
	(0.0481)	(0.0482)	(0.0509)	(0.047)	(0.0472)	(0.0437)
Dist. to Sound 1500-2000m	-0.1478***	-0.1811***	-0.1483***	-0.1368***	-0.1341***	-0.145***
	(0.0452)	(0.0451)	(0.047)	(0.043)	(0.0438)	(0.0407)
Dist. to Sound 2000-2500m	-0.1456***	-0.1586***	-0.1367***	-0.1196***	-0.1286***	-0.1374***
	(0.0437)	(0.0442)	(0.0452)	(0.0419)	(0.0424)	(0.0399)
Dist. to Sound 2500-3000m	-0.1311***	-0.1342***	-0.1195***	-0.1041***	-0.1176***	-0.1254***
	(0.0406)	(0.0417)	(0.0418)	(0.0392)	(0.0392)	(0.0374)
Dist. to Sound 3000-3500m	-0.104***	-0.1195***	-0.1015**	-0.0885**	-0.0899**	-0.0949***
	(0.0383)	(0.0403)	(0.0397)	(0.0379)	(0.037)	(0.0358)
Dist. to Sound 3500-4000m	-0.0605*	-0.0766**	-0.0601	-0.05	-0.0475	-0.0492
	(0.0355)	(0.0382)	(0.0375)	(0.0361)	(0.0344)	(0.0336)
Dist. to Sound 4000-4500m	-0.0408	-1.2899	-0.0364	-0.0302	-0.0294	-0.0295
	(0.0339)	(0.0374)	(0.0368)	(0.0361)	(0.0331)	(0.0327)
Dist. to Beach 0-500m	0.2331***	0.3925***	0.2458***	0.2214**	0.2066***	
	(0.0607)	(0.091)	(0.0947)	(0.1085)	(0.0792)	
Dist. to Beach 500-1000m	0.2418***	0.2948***	0.1784**	0.1693**	0.1735***	
	(0.0544)	(0.0738)	(0.0744)	(0.0802)	(0.0641)	

Dist. to Beach 1000-1500m	0.168***	0.2583***	0.1732***	0.1379*	0.0784	
	(0.0505)	(0.0671)	(0.0667)	(0.0719)	(0.0591)	
Dist. to Beach 1500-2000m	0.0786*	0.1727***	0.1234**	0.0902	-0.0073	
	(0.0465)	(0.0618)	(0.0618)	(0.0707)	(0.059)	
Dist. to Beach 2000-2500m	0.0597	0.1482**	0.1335**	-0.016	-0.1001*	
	(0.0427)	(0.0577)	(0.0578)	(0.07)	(0.0584)	
Dist. to Beach 2500-3000m	0.1216***	0.1174**	0.0511	-0.0945	-0.1035*	
	(0.0392)	(0.0575)	(0.0598)	(0.0859)	(0.0629)	
Dist. to Beach 3000-3500m	0.081**	0.1385**	0.096	-0.0993	-0.1454**	
	(0.0364)	(0.0559)	(0.0587)	(0.0864)	(0.0706)	
Dist. to Beach 3500-4000m	0.0006	-0.0755	-0.0171	-0.1497*	-0.1545**	
	(0.032)	(0.0527)	(0.0553)	(0.0851)	(0.0712)	
Dist. to Beach 4000-4500m	0.0023	-0.1023	-0.0296	-0.0538	-0.0035	
	(0.026)	(0.0493)	(0.0531)	(0.082)	(0.0643)	
Age of Home	-0.0027***	-0.003***	-0.003***	-0.003***	-0.0027***	-0.0027***
	(0.0003)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Age of Home - squared	1.2x10^-5***	1.5x10^-5***	1.5x10^-5***	1.6x10^-5***	1.3x10^-5***	1.3x10^-5***
	(1.6255x10^-6)	(2.3108x10^-6)	(2.0490x10^-6)	(2.1775x10^-6)	(1.7386x10^-6)	(1.7328x10^-6)
Age Missing	-0.3858***	-0.387***	-0.394***	-0.3947***	-0.3876***	-0.3867***
	(0.0192)	(0.0221)	(0.0216)	(0.0216)	(0.0191)	(0.0191)
Home Sq. Footage	0.0002***	0.0001***	0.0001***	0.0001***	0.0002***	0.0002***
	(4.7344x10^-6)	(5.0812x10^-6)	(5.0970x10^-6)	(5.0868x10^-6)	(4.7230x10^-6)	(4.7327x10^-6)
Home Sq. Footage Missing	0.4853***	0.4705***	0.4685***	0.4681***	0.4874***	0.4861***
	(0.0208)	(0.0223)	(0.0223)	(0.0223)	(0.0207)	(0.0207)
Ln(Parcel Acreage)	0.147***	0.1396***	0.1392***	0.1389***	0.1437***	0.143***
	(0.0047)	(0.0049)	(0.0049)	(0.0049)	(0.0047)	(0.0047)
Townhome	0.0799***	0.0807***	0.0811***	0.0805***	0.0816***	0.0819***
	(0.0071)	(0.0076)	(0.0076)	(0.0076)	(0.0072)	(0.0072)
Bedrooms	-0.0036	-0.0053**	-0.0057**	-0.0057**	-0.0045*	-0.0047**
	(0.0024)	(0.0025)	(0.0025)	(0.0025)	(0.0024)	(0.0024)
Bathrooms	0.0477***	0.0487***	0.0483***	0.0485***	0.0473***	0.0475***
	(0.0038)	(0.004)	(0.004)	(0.004)	(0.0038)	(0.0038)
Bathrooms Missing	0.138***	0.1444***	0.1382***	0.1386***	0.1331***	0.1326***
	(0.0162)	(0.0177)	(0.0177)	(0.0177)	(0.0161)	(0.0161)
Pool	0.0545***	0.0498***	0.0493***	0.0484***	0.0559***	0.0582***
	(0.0179)	(0.0187)	(0.0187)	(0.0187)	(0.018)	(0.018)
Porch	0.0087	0.6675	0.0034	0.0034	0.0088	0.0104
	(0.0081)	(0.0085)	(0.0085)	(0.0085)	(0.0081)	(0.0081)
A/C	0.011	0.0129*	0.013*	0.0137*	0.0111	0.012
	(0.0073)	(0.0078)	(0.0078)	(0.0078)	(0.0073)	(0.0073)
Basement	-0.0291***	-0.0254**	-0.0344***	-0.0348***	-0.0298***	-0.0266**

	(0.011)	(0.0116)	(0.0116)	(0.0116)	(0.0109)	(0.0109)
Dist. to Primary Road	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
	(1.8083x10^-5)	(2.0256x10^-5)	(1.9154x10^-5)	(1.8547x10^-5)	(1.7641x10^-5)	(1.7397x10^-5)
% Developed by Block Group	-0.0021***	-0.0021***	-0.002***	-0.002***	-0.0021***	-0.002***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Dist. to NYC	1.3018***	0.1758***	2.1367***	2.6194***	2.042***	2.1167***
	(0.0249)	(0.015)	(0.0248)	(0.0118)	(0.0273)	(0.0119)
Dist. to NYC - squared	-0.0395***	-0.0028***	-0.0655***	-0.0807***	-0.0625***	-0.065***
	(0.0003)	(0.0003)	(0.0002)	(4.7911x10^-5)	(0.0002)	(0.0001)
Dist. to NYC - cubed	0.0004***		0.0007***	0.0008***	0.0006***	0.0007***
	(1.6155x10^-6)		(3.2147x10^-6)	(1.8336x10^-6)	(3.0922x10^-6)	(1.5098x10^-7)
Ln(Dist. to Sewage Plant)	0.0172	0.4377	0.0269	0.04*	0.0353	0.0119
	(0.027)	(0.024)	(0.0287)	(0.022)	(0.0263)	(0.0204)
School Rating	0.0218***	0.0189***	0.0183***	0.0183***	0.021***	0.0203***
	(0.0035)	(0.0037)	(0.0036)	(0.0035)	(0.0034)	(0.0034)
School Rating Missing	0.1059***	0.0944***	0.0899***	0.0934***	0.1038***	0.1012***
	(0.0248)	(0.0262)	(0.0257)	(0.0251)	(0.0245)	(0.0242)
100-Year Flood Plain	0.006	0.5348	0.0096	0.0086	0.0061	0.0053
	(0.0156)	(0.0166)	(0.0165)	(0.0165)	(0.0156)	(0.0156)
Median Household Inc.	1.0x10^-6***	1.0x10^-6***	1.0x10^-6***	1.0x10^-6***	1.0x10^-6***	1.0x10^-6***
	(9.2867x10^-8)	(7.5471x10^-9)	(8.5254x10^-8)	(8.5839x10^-8)	(9.4088x10^-8)	(9.6279x10^-8)
Median Household Inc. > $250k	0.2646***	0.2664***	0.2587***	0.2572***	0.2584***	0.2546***
	(0.0071)	(0.019)	(0.0106)	(0.0099)	(0.0074)	(0.0067)
Ln(% Hispanic)	-0.0131	0.0403	-0.0051	-0.0057	-0.0065	-0.0052
	(0.0125)	(0.0135)	(0.0132)	(0.0129)	(0.0124)	(0.0122)
Ln(% Black)	-0.0329***	-0.0409***	-0.0429***	-0.0416***	-0.0336***	-0.0312***
	(0.0056)	(0.0061)	(0.006)	(0.0059)	(0.0055)	(0.0055)
% Owner Occupied	-0.1884***	-0.1682***	-0.1892***	-0.1832***	-0.1763***	-0.168***
	(0.0458)	(0.05)	(0.0483)	(0.048)	(0.046)	(0.0457)
Pop. Density	-8.0x10^-6***	-6.x10^-6**	-6.x10^-6**	-6.x10^-6**	-7.x10^-6**	-6.x10^-6**
	(2.7506x10^-6)	(3.0346x10^-6)	(2.7890x10^-6)	(2.7670x10^-6)	(2.8226x10^-6)	(2.7719x10^-6)
Year 2004	0.088***	0.0847***	0.0758***	0.0769***	0.0773***	0.0742***
	(0.0088)	(0.0093)	(0.0094)	(0.0094)	(0.0091)	(0.0091)
Year 2005	0.1732***	0.1678***	0.1518***	0.1536***	0.1513***	0.1469***
	(0.0087)	(0.0093)	(0.0096)	(0.0097)	(0.0094)	(0.0095)
Year 2006	0.1794***	0.1668***	0.1509***	0.1529***	0.1577***	0.1549***
	(0.0092)	(0.01)	(0.0103)	(0.0104)	(0.0098)	(0.0099)
Year 2007	0.1211***	0.1088***	0.0919***	0.0944***	0.1***	0.0964***
	(0.0101)	(0.0108)	(0.0112)	(0.0112)	(0.0107)	(0.0108)
Year 2008	0.0534***	0.0428***	0.0258**	0.028**	0.0338***	0.0312***
	(0.0106)	(0.0113)	(0.0116)	(0.0116)	(0.0112)	(0.0112)
Year 2009	-0.0835***	-0.0923***	-0.1036***	-0.102***	-0.0992***	-0.1018***
	(0.0114)	(0.0122)	(0.0123)	(0.0123)	(0.0117)	(0.0118)

Year 2010	-0.1085***	-0.1149***	-0.131***	-0.1291***	-0.1296***	-0.1329***
	(0.0107)	(0.0113)	(0.0116)	(0.0116)	(0.0112)	(0.0112)
Year 2011	-0.1489***	-0.1624***	-0.1785***	-0.1774***	-0.1692***	-0.172***
	(0.0107)	(0.0113)	(0.0115)	(0.0116)	(0.0111)	(0.0111)
Year 2012	-0.1907***	-0.208***	-0.2286***	-0.2272***	-0.2149***	-0.2175***
	(0.0111)	(0.0117)	(0.0121)	(0.0121)	(0.0116)	(0.0117)
Year 2013	-0.1628***	-0.1849***	-0.2016***	-0.1997***	-0.1858***	-0.1891***
	(0.0108)	(0.0117)	(0.012)	(0.012)	(0.0114)	(0.0114)
Year 2014	-0.1276***	-0.151***	-0.1682***	-0.166***	-0.1478***	-0.1507***
	(0.0105)	(0.0113)	(0.0116)	(0.0117)	(0.0111)	(0.0112)
Year 2015	-0.1257***	-0.1565***	-0.1763***	-0.1752***	-0.1536***	-0.1579***
	(0.0175)	(0.019)	(0.0192)	(0.0193)	(0.018)	(0.0181)
Quarter 2	0.0261***	0.028***	0.0261***	0.0263***	0.0244***	0.0233***
	(0.0063)	(0.0066)	(0.0066)	(0.0066)	(0.0063)	(0.0063)
Quarter 3	0.0432***	0.0425***	0.0401***	0.0403***	0.0404***	0.0389***
	(0.0061)	(0.0065)	(0.0065)	(0.0065)	(0.0062)	(0.0062)
Quarter 4	0.0156**	0.0182***	0.0156**	0.0157**	0.013*	0.012*
	(0.0066)	(0.007)	(0.007)	(0.007)	(0.0067)	(0.0067)
Bch Length x Bch Dist. 0-500m				0.0002	-3.4x10^-5	0.0007*
				(0.0003)	(0.0002)	(0.0004)
Bch Length x Bch Dist. 500-1000m				0.0002	0.0002	0.0008***
				(0.0002)	(0.0002)	(0.0003)
Bch Length x Bch Dist. 1000-1500m				0.0003*	0.0004***	0.0007***
				(0.0002)	(0.0002)	(0.0002)
Bch Length x Bch Dist. 1500-2000m				0.0003	0.0004**	0.0005**
				(0.0002)	(0.0002)	(0.0002)
Bch Length x Bch Dist. 2000-2500m				0.0008***	0.0008***	0.0009***
				(0.0002)	(0.0002)	(0.0002)
Bch Length x Bch Dist. 2500-3000m				0.0008**	0.001***	0.0009***
				(0.0003)	(0.0002)	(0.0003)
Bch Length x Bch Dist. 3000-3500m				0.001***	0.0011***	0.001***
				(0.0003)	(0.0003)	(0.0003)
Bch Length x Bch Dist. 3500-4000m				0.0007**	0.0007**	0.001**
				(0.0003)	(0.0003)	(0.0004)
Bch Length x Bch Dist. 4000-4500m				0.0001	1.1x10^E-5	0.0003
				(0.0003)	(0.0003)	(0.0003)
Boat Launch at Closest Beach				-0.0017	-0.0017	0.0217
				(0.0235)	(0.0244)	(0.0223)
Dist. to Beach (Pub) 0-500m						-0.1037
						(0.1477)

Dist. to Beach (Pub) 500-1000m						-0.0612
						(0.0994)
Dist. to Beach (Pub) 1000-1500m						-0.0572
						(0.0812)
Dist. to Beach (Pub) 1500-2000m						-0.0584
						(0.073)
Dist. to Beach (Pub) 2000-2500m						-0.1606**
						(0.07)
Dist. to Beach (Pub) 2500-3000m						-0.1182
						(0.0731)
Dist. to Beach (Pub) 3000-3500m						-0.1238
						(0.0812)
Dist. to Beach (Pub) 3500-4000m						-0.13
						(0.0841)
Dist. to Beach (Pub) 4000-4500m						-0.0455
						(0.0702)
Dist. to Beach (Prv) 0-500m						0.1502*
						(0.0846)
Dist. to Beach (Prv) 500-1000m						0.1221*
						(0.0668)
Dist. to Beach (Prv) 1000-1500m						0.0495
						(0.0614)
Dist. to Beach (Prv) 1500-2000m						0.01
						(0.0618)
Dist. to Beach (Prv) 2000-2500m						-0.0479
						(0.065)
Dist. to Beach (Prv) 2500-3000m						-0.0361
						(0.0755)
Dist. to Beach (Prv) 3000-3500m						-0.1197
						(0.0944)
Dist. to Beach (Prv) 3500-4000m						-0.262**
						(0.1116)
Dist. to Beach (Prv) 4000-4500m						-0.1083
						(0.1012)
rho	0.0373***	0.03***	0.027***	0.026***	0.026***	0.0259***
	(0.0048)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
lambda	0.781***	0.802***	0.785***	0.772***	0.766***	0.761***
	(0.0008)	(0.0023)	(0.0007)	(0.0008)	(0.0008)	(0.0009)

Observations	16,926	14,852	14,845	14,845	16,540	16,540
R-squared	0.7853	0.7858	0.7867	0.7865	0.7883	0.7888

Note: Dependent variable: ln(price). Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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[1] Sound Health Explorer. Accessed November 6, 2017. http://soundhealthexplorer.org/.

[2] Homes with prices in the lowest percentile (less than \$152,613) and highest percentile (greater than \$3,638,694) were dropped from our dataset to eliminate outliers, leaving 20,079 home transactions. An additional 3,153 sales were dropped due to missing water quality data from the three nearest monitoring stations during the summer season corresponding to the date of transaction, leaving a final sample size of n=16,926 transactions. In some specifications additional observations are dropped due to missing values for enterococci counts and closure information at the nearest beach. When house structure variables not of primary interest are missing, we code the missing values as zero and include a corresponding missing value dummy. Although more than 7,000 observations are missing values for key characteristics of the house structure, a sensitivity analysis omitting these observations yielded similar results.

[3] Bureau of Labor Statistics. 2016. Accessed March 28, 2016. http://www.bls.gov/cpi/cpid1602.pdf.

[4] Respective data sources are: U.S. Census Bureau. 2010. "Topographically Integrated Geographic Encoding and Referencing (TIGER)/Line Primary and Secondary Road Shapefiles." Accessed September 16, 2013. http://www.census.gov/geo/maps-data/data/tiger-line.html; U.S. Census Bureau. 2010. "Gazeteer Shapefiles of Major U.S. Cities." Accessed September 16, 2013. http://www.census.gov/geo/maps-data/data/gazetteer2010.html.; and U.S. Geological Survey. 2015. "NHD High Resolution Dataset." Accessed August 2015.

[5] Westchester County Geographic Information Systems Data Warehouse. Accessed October 25, 2016. http://giswww.westchestergov.com/wcgis/datawarehouse.htm.

[6] Data generally from the 2010 decennial census, but information on household income was not collected as part of the 2010 decennial census in Westchester County. Median household income from the 2013 American Community Survey was used instead. Income greater than \$250,000 was coded as \$250,000+ in the raw data, hence a dummy variable for income greater than \$250,000 was created.

[7] GreatSchools. Accessed March 21, 2017. https://www.greatschools.org.

[8] Sponsored by the United States Geological Survey, Environmental Protection Agency, and National Water Quality Monitoring Council. Accessed April 3, 2015. https://www.waterqualitydata.us/.

[9] An extension of this approach is to explore additional substitutes, or nearby beaches. However, that is likely better captured in studies of recreation demand, and is not easily modeled with home prices.

[10] BEACON 2.0. Accessed October 12, 2016. https://watersgeo.epa.gov/beacon2/.

[11] According to Westchester County's website, and as discussed in section IV, many of the beach closures are due to heavy rain and/or stormwater issues, and the subsequent concerns regarding water quality and high levels of harmful bacteria (https://health.westchestergov.com/beach-closures, accessed Dec. 2, 2018). It is possible, however, that closures also occur on occasion due to hazardous swimming conditions.

[12] Westchester County Geographic Information Systems Data Warehouse. Accessed July 10, 2017. http://giswww.westchestergov.com/wcgis/datawarehouse.htm.

[13] To reflect local spatial dependence in neighborhoods, particularly as a result of the use of "comparable sales" for real estate appraisal by real estate agents and mortgage lenders, we use an inverse-distance based SWM on the spatial lag that includes homes sold 6 months before and three months after each home transaction. A distance radius of a half mile is also applied. To control for remaining spatial autocorrelation, the spatial error term uses a 20 nearest neighbor SWM (Lesage and Pace, 2009, Walsh et al. 2017).

[14] Alternative semi-log models constrain the price impacts of enterococci counts to be constant across different baseline pollution levels. This is likely an overly stringent assumption. Nonetheless, as a sensitivity analysis we re-estimate our models using a semi-log specification, where WQ_{it} enters in levels (see the results section for details).

[15] There is one counterintuitive result warranting brief discussion. We find a negative price gradient associated with proximity to the Long Island Sound in general, irrespective of water quality, as suggested by the negative signs on the dummy variables for closer proximity to the Long Island Sound. We believe this may reflect that the omitted distance bin, which comprises homes 4500-5000 meters from the Sound, covers relatively wealthy neighborhoods in Bronxville and Scarsdale, which both ranked among America's top 10 richest places by Bloomberg (who based their ranking on 2015 Census data www.bloomberg.com/graphics/2017-hundred-richest-places/, accessed September 5, 2017). The inclusion of the distance bin vector helps absorb such factors that could otherwise confound the water

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quality parameters of primary interest. It is also reassuring that the coefficients corresponding to the distance bins denoting proximity to the nearest beach suggest a distance gradient of the expected sign – i.e., homes closer to the beach sell at a higher price.

[16] More specifically, we include an intercept term denoting whether the closest beach has a boat ramp, and interact beach length with each of the 500-meter distance bins. The signs on the beach length variables are positive and significant as expected, suggesting that larger beaches covering more shoreline are more desirable. The coefficient on the boat ramp variable is insignificant, but was found to be negative and significant in earlier OLS models – a result that has been found previously in the literature (Brashares, 1985).

[17] Estimating variants of Models 1 through 4 that include tract-level fixed effects yield results qualitatively similar to those discussed, but the estimates are often statistically insignificant. Including coarser municipal-level fixed effects, however, leads to similar results as our SAC models in terms of sign, magnitude, and statistical significance. In fact, the estimated elasticities with respect to beach closures were even stronger in magnitude, suggesting statistically significant impacts as far as 4,500 meters. The results of these models are provided by Kung et al. (2017). In any case, we believe the use of spatial fixed effects may be inappropriate in the current context. Variation in annual enterococcus levels are primarily based on variation over space, as opposed to time (see Appendix B in Kung et al. (2017) for details). Spatial fixed effects absorb much of the price variation of primary interest. Instead, we include a spatio-temporal lag of the dependent variable in our spatial autoregressive combined (SAC) models to help control for any spatially correlated omitted variables.

[18] Although we do not believe such models are appropriate in the current context, we must note that this finding is sensitive to the inclusion of municipal-level fixed effects (see Kung et al. 2017).