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Abstract

We use hedonic techniques to measure the impact of improved water quality on inland real estate values. By considering a unique natural experiment setting where consistent and recognizable variation in water quality across two rivers within a small geographic area is well known to market participants, we avoid the major problems inherent in hedonic water quality studies. Controlling for spatial autocorrelation, results show that land and property values increase more substantially with proximity to the non-contaminated river as opposed to the mercury-contaminated river that carries a fish consumption advisory. Results suggest that the value of improving water quality to a level that will remove the advisory is between $7.3 and $12 million.

Introduction

Despite the importance of the nation's waterways and the attraction of U.S. households for living close to water bodies, there is a distinct dearth of hedonic studies examining the impact of water quality on waterfront properties.[1]

[1] To provide an example of some of this research, Epp and Al-Ani (1979) considered rural communities in Pennsylvania and found that an increase in the pH of local streams increased property prices. Young (1984) studied homes adjacent to St. Albans Bay, VT, and found that homes in the polluted bay locations were worth less than comparable properties outside of this area. Steinnes (1992) found a positive correlation between water clarity of Minnesota lakes and property price. Mendelsohn et al. (1992) found that properties affected by a PCB contamination event in New Bedford, MA, fell in value. Leggett and Bockstael (2000) included the distance of the pollution source in a hedonic and found that fecal coliform counts had a significant and negative effect on property values.

In comparison, the literature is rich in air quality hedonic studies.[2] In a review of existing hedonic studies, Boyle and Kiel (2001) examined only seven water quality studies, while in a meta-analysis of air quality hedonic studies, Smith and Huang (1993, 1995) examined over 25 papers. Leggett and Bockstael (2000) queried the disproportionate number of air quality studies, stating that while there is no reason to think that homeowners have a particularly strong desire for clean air, individuals purchasing high-priced waterfront property may self-select into a market based on a desire for water-based recreation.

The most likely explanation for the distinct lack of water quality studies lies in the problems inherent in hedonic modeling when considering water pollution and housing markets. The first potential problem involves the physical nature of water bodies and their relationship to property markets. A hedonic analysis requires variation in ambient environmental conditions within the constraints of a single housing market. As water quality studies are restricted to a single physical resource (a lake, a river, a section of coastline), significant variation in water quality is difficult to observe without expanding the geographic area. This incurs two distinct problems. First, this could induce correlation issues in the hedonic framework as increasing the sample frame increases the possibility that individuals observe other locational attributes that can be expected to influence the hedonic equilibrium. Second, the sample frame is now likely comprised of multiple markets and estimating a single hedonic price function for the whole sample is inappropriate.

There also exists the possibility of measurement error in the hedonic. This could arise for different reasons. First, each characteristic or attribute (including the measure of ambient environmental quality) should be measured in a manner consistent with homeowners'

[2] See for example, Leggett and Bockstael (2000), Anselin and Le Gallo (2006), and Kim et al. (2003).

perceptions of the characteristics. In many instances it is difficult for homeowners to accurately observe water quality measures. Water quality indices can be measured scientifically but are not typically observable by the market participant absent a significant pollution problem, such as a red tide event or high ongoing levels of contamination. Even when local water quality indices are measured and available for public consumption, it is questionable whether homeowners retrieve and digest the information. For example, in arguably the most thorough hedonic water quality study to date, Leggett and Bockstael (2000) examined the impact of fecal coliform contamination on property prices along a portion of the Chesapeake Bay, MD. While the geographical nature of the estuarine coastline provided variation in water quality within an approximate 100-mile stretch coastline, market participants' understanding of the water quality issue assumed they were cognizant of a local water quality hotline. Further, as levels of fecal coliform increased during the summer months, the hotline was only available from Memorial Day to Labor Day, raising the question as to how much knowledge market participants had of the water quality issue outside of this temporal window. For most unobservable cases when homeowners are not informed of the issue, it is then highly problematical to accurately reflect market participants' perceptions of water quality as the measures will not coincide with individuals' perceptions (Poor et al. 2001).

Related to this issue, other problems may arise if there is variation in homeowners' knowledge and expectations of environmental issues (Landry and Hindsley, 2010). For example, if homeowners' knowledge of local pollution levels or understanding and expectations of current and future local management actions vary then this will influence the individuals' valuation of local environmental amenities and future environmental conditions. As the homeowner is purchasing a waterfront property based, not on the current environmental characteristics in perpetuity, but rather expected attribute levels over time, households' marginal willingness to pay for amenities depends on their expectation regarding the attributes. This raises a timing issue. As the sample of properties used in the hedonic is drawn over time, if expectations regarding the quality of the resource change, and these are capitalized into current housing prices, then different implicit prices will be estimated depending upon the years chosen for the sample. A final potential source of measurement error concerns the use of a single pollutant in the analysis. Research typically includes one type of pollutant (such as a high concentration of nutrients or toxic contamination). If the observed pollutant is correlated with other types of pollutant, then this could result in omitted variable bias and biased parameter values. Taylor (2003) also discussed the importance of improving the measurement of this one ambient environmental quality variable to reduce the bias in all coefficients. Work by Graves et al. (1988) supports this point by finding that even a small measurement error in ambient quality measures leads to unstable coefficient estimates.

The unique geographical setting provides a unique opportunity to analyze differences in housing values that arise from variation in water quality without incurring the typical issues inherent in other hedonic water quality analyses. Specifically, this study considers a small geographic area of Augusta, VA, through which two rivers (Middle River and South River) flow in close proximity to one another. The Middle River is an unpolluted water body while the South River has been contaminated with high levels of mercury for several decades, prompting a fish consumption advisory since 1977. Its contamination is well-known with biannual newsletters, fact sheets, posters highlighting the contamination issue to local residents and recreationists. As such, we have a small geographical area with a well-established discrete variation in water quality. Carbone (2006) discussed that when an analysis involves economic outcomes such as housing values that arise from differences in non-market environmental amenities, two important assumptions are required to be sure that the natural experiment isolates the effect being measured. First, market participants know the amount of the amenity and respond to it. Second, there is consistent and recognizable variation in the amenity of interest. This natural experiment satisfies both of these assumptions. The variation in water quality across rivers is well known and has remained constant for several decades. This implies that we can accurately reflect market participants' perceptions of water quality in the hedonic framework. The discrete difference in pollution levels also avoids measurement error problems inherent in other water quality hedonic studies as we are not examining the cross sectional variation of a single pollutant, and therefore risking potential omitted variable bias. Rather, we consider the impacts of a polluted versus non-polluted water body on property and land values.

Through a spatial hedonic analysis and controlling for structural and neighborhood variables, we measure the marginal willingness to pay (WTP) to locate closer to the polluted and non-polluted rivers. Using a "bundle of sticks" argument – reasoning that any difference in WTP, having controlled for other structural and neighborhood characteristics, is due to the variation in water quality – we estimate the potential benefits of improving the environmental quality of the polluted river to a level that would lift the fish consumption advisory.

Another important component of the research is that we include a dichotomous variable in the hedonic to capture the effect of properties located within Special Flood Hazard Area (SFHA). The SFHA denotes the 100-year floodplains (that is a 1% annual chance of flooding). Some studies have examined the effect of SFHA designation on coastal properties.[3] However, to our knowledge, only one hedonic analysis (Shultz and Fridgen, 2001) considers the effect of a SFHA designation on inland property valuations. They found that property prices within the SFHA are $9,000 lower, on average, than prices of properties outside the SFHA. Our results will therefore add more evidence to the sparse economic literature regarding the impact of SFHA designation on inland property values.

Contamination, Monitoring and Public Awareness

Between 1929 and 1950, mercuric sulfate, used as a catalyst in the manufacture of acetate fiber by E. I. DuPont de Nemours and Company (DuPont), entered the South River from a manufacturing plant in Waynesboro, VA. Mercury analysis taken in 1976, immediately after the discovery of the contamination, for sediment samples downstream of the plant exceeded 240 parts per million (ppm), in comparison to readings of less than 1 ppm upstream from the plant (Carter, 1977). Mercury analysis of fish downstream of the DuPont plant, at 0.86 ppm, substantially exceeded the Food and Drug Administration (FDA) "action level" of 0.5 ppm, while the mercury content in bass caught as far as 77 miles downstream were more than twice as high as the FDA standard (Carter, 1977). On the basis of these sediment and fish samples, Virginia Governor Mills E. Godwin Jr., on June 6, 1977, pronounced the South River below Waynesboro as well as the entire South Fork closed to the taking of all fish species for eating

[3] For example, Harrison et al. (2001) found that a SFHA designation reduced the value of a property by about $2,100 in Alachua County, FL, while Bin and Kruse (2006) estimated that North Carolina coastal properties sold for between 5% to 10% less if they are within a SFHA compared to those outside.

(Carter, 1977). Presently, the South River remains under a no-consumption advisory for the general public for all fish, except stocked trout, starting in Waynesboro and ending in Port Republic, VA (USEPA, 2009).

Mercury is a naturally occurring element that cycles in the environment with no known benefit to biological organisms and is considered potentially hazardous to organisms in which it is present (Tchounwou et al., 2003; USNAS, 1978; Eisler, 2006). The toxicity of mercury largely depends on its conversion from an inorganic form to an organic form, called methylmercury (CH_3Hg^+), in a process known as methylation.[4]

Due to methylmercury's high stability, lipid solubility and membrane permeability, it is highly toxic and more bioavailable than any other forms of mercury and readily accumulates in biological tissues and biomagnifies (Beijer and Jernelov, 1979; Hamaski et al. 1995; USEPA, 1997b; Morel et al., 1998). Methylmercury bioaccumulates when mercury uptake exceeds rates of elimination and biomagnifies, or increases in concentration, up the food chain with each trophic level (Huckabee et al., 1979; Wiener et al., 2003). Intestinal absorption of methylmercury can reach 100%, as opposed to only a few percent for inorganic mercury, and once absorbed, methylmercury passes into cells and selectively concentrates in the brain, liver and kidney

[4] Methylation occurs naturally in aquatic environments through biotic and abiotic processes under either aerobic or anaerobic conditions; however, most methylation occurs via anaerobic bacteria, such as sulfate-reducing bacteria and iron-reducing bacteria (Celo et al., 2006; Flemming et al., 2006). The rate of methylation depends predominantly on the amount of bioavailable mercury and on microbial activity, which in turn depends on abiotic factors, such as temperature, pH, redox potential, nutrient content and others (Holmes and Lean, 2006; Celo et al., 2006).

(Scheuhammer, 1987; Weech et al., 2006; Wolfe, et al., 1998). Methylmercury has the ability to cross the blood-brain barrier, earning it a reputation as a potent neurotoxin (Wolfe et al., 1998). Finally, if ingested in sufficient amounts by humans, methylmercury can cause a severe disorder of the nervous system, known as Minimata disease (Carter, 1977).

The mercury that leaked into the river between 1929 and 1950 continues to contaminate the South River, though 60 years have passed.[5][6] Mercury's great weight and liquid form allow it to shelter in nooks and crannies in the irregular limestone bottom of the South River, making it difficult to dislodge (Carter, 1977). Furthermore, microorganisms abundant in the sediment and other conditions of the South River efficiently methylate the inorganic industrial mercury to methylmercury, which aquatic organisms in the river uptake to begin the processes of bioaccumulation and biomagnification throughout the food chain (Carter, 1977).

The discovery of mercury contamination in the South River prompted a number of actions to monitor and evaluate the condition of the tributary and to promote awareness of the contamination throughout the community. For example, in the early 1980s, DuPont and the

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[5] The use of mercury as a catalyst at the DuPont plant was suspended in 1950, thus, most if not all of the mercury entered the South River in the 1930s and 1940s. Additionally, Edward T. Ruehl, the Waynesboro plant's manager for health, safety and environmental affairs, speculated that not much more mercury spilled into the river than could fill a "Volkswagen gas tank" (Carter, 1977).

[6] Many factors contribute to the persistent presence of mercury in the South River. According to Mason et al. (2004), the atmospheric transport of mercury is the predominant mechanism for mercury deposition at the Earth's surface, where factors such as seasons, foliage, wind and moisture content then affect the transport and transformation of mercury from the atmosphere into aquatic environments (Mason et al., 2000; Guentzel et al., 2001; Wang et al., 2004; Fang et al., 2001; Lindqvist and Rodhe, 1985). Mercury contaminated soil is also an important source of contamination in aquatic systems through surface runoff, river bed and bank erosion, and flooding (Wang et al., 2004; Quemerais et al., 1999; Carroll and Warwick, 2001). Finally, factors such as soil temperature, solar radiation and soil moisture affect the emission of mercury from contaminated soil into the atmospheric mercury cycle, resulting in a cycling process among the atmosphere, terrestrial systems and aquatic systems that prolongs the impact of anthropogenic mercury (Carpi and Lindberg, 1998; Wang et al., 2004; Mason et al., 2004).

Virginia Department of Environmental Quality (VDEQ) established a trust fund to monitor mercury contamination and saturation in water, fish and sediments in the Shenandoah River basin for a 100-year period (VDEQ, 2000). In 2000, the trust fund was utilized to create the South River Science Team (SRST), a collaborative team of researchers, tasked with monitoring mercury levels and understanding the effects of mercury on the local human population. Since its inception, the SRST has worked to raise awareness of the contamination through numerous publications, which include biannual newsletters, fact sheets and posters, as well as more academic technical publications (SRST website). The SRST also works to ensure the public is aware of the fish consumption advisory in the South River and South Fork Shenandoah River by installing outdoor billboards with the Department of Health fish consumption advisory signs at popular fishing sites, by distributing brochures to physicians and health clinics in the area, as well as by creating wallet-sized advisory cards that fit in fishing tackle boxes and pockets (SRST website). Finally, members of the SRST answer questions about the team's activities and provide take-home information at local community events, such as Riverfest and the Virginia Fly Fishing Festival in a comprehensive outreach program (SRST website).

Study Area

The study area is Augusta County, Virginia, located in the Shenandoah Valley between the Blue Ridge and the Allegheny Mountains in the northwestern portion of the state (see Figure 1). Augusta is the second largest county in Virginia with a median household income of $52,341 in 2008 (US Census Bureau, 2008). Augusta County also contains two independent cities, Staunton and Waynesboro, reporting median household incomes of $42,794 and $41,025, respectively (US Census Bureau, 2008). The distance between the cities is approximately 10 km. The South River and the Middle River are fourth order streams running parallel to each other northwards through Augusta County, where the two tributaries eventually join the North River in neighboring Rockingham County to form the South Fork Shenandoah River.

Property and housing attribute data on single family residences were collected from xxxx. We analyze property data in the northern part of the county where the distance between the two rivers varies from 2 km to 9 km. Our dataset consists of 2,069 and 1,252 Middle River and South River properties respectively. The summary statistics for the data, shown in Table 1, illustrate that Middle and South River properties are similar in size and attributes. The average total assessed property and land value for Middle River properties is $294,049 compared to $273,655 for South River homes. The data also include a number of structural attributes. For Middle River [South River] properties, the average number of bathrooms is 1.74 [1.80], with a lot square footage of 1,657 [1,792], and an average age of property of 37 [30] years. On average, 63 percent [76 percent] of properties have air conditioning and 30 percent [27 percent] are multistory units. Neighborhood variables indicating distances to local amenities were calculated using Geographic Information System software.

Water Quality Hedonic Property Price Methods

The majority of research using hedonic modeling to value environmental goods is based on Rosen's 1974 theoretical framework. Typically, hedonic models use observations on residential property values to estimate the value of non-traded goods, *ceteris paribus*. Assume that each individual's utility function is determined by Z, a composite good representing all goods other than housing with price set equal to one; $\boldsymbol{S}$, a vector of structural attributes (such as square footage, number of bathrooms, lot size and so on); Q, an environmental amenity associated with a specific location (distance to the nearest river); and $\boldsymbol{N}$, a vector of neighborhood characteristics (such as distance to the nearest town or National Park); such that $u(Z, \boldsymbol{S}, Q, \boldsymbol{N})$. Assume that preferences are weakly separable in other goods and housing characteristics so the demand for characteristics is independent from the prices of other goods.

Given these assumptions, the relationship between property value and the property's various attributes can be expressed by the hedonic price function:

$$\boldsymbol{R} = \boldsymbol{R}(\boldsymbol{S}, Q, \boldsymbol{N}) \qquad [1]$$

where $\boldsymbol{R}$ is the property price. Each individual maximizes utility subject to a budget constraint $M - R - Z = 0$, where M is income. Assuming that $\boldsymbol{R}(\bullet)$ is continuously differentiable, taking the first derivative of Equation (1) with respect to each continuous housing attribute variable yields the corresponding implicit price of the characteristic. So, estimating the first derivative of Equation [1] with respect to distance to an adjacent river yields the first-order necessary condition: $\left(\frac{\partial \mathrm{U}}{\partial \mathrm{q}}\right) / \left(\frac{\partial \mathrm{U}}{\partial \mathrm{Z}}\right) = \frac{\partial \mathrm{R}}{\partial \mathrm{q}}$ [2]

The left-hand side of equation [2] represents the marginal rate of substitution between the environmental attribute and the composite good (or the marginal willingness to pay for the environmental attribute). The right-hand side is the implicit marginal price of a characteristic. So market participants choose levels of all characteristics such that the marginal price of each equals the marginal rate of substitution between each characteristic and a composite good. As q is the distance to a river, then the partial derivative represents the additional amount that must be paid (received) to be located one additional unit closer to the river.

Previous research suggests that property values in common neighborhoods can be interdependent because they may share similar housing characteristics and location amenities (Paterson and Boyle 2002; Kim et al.2003; Bin et al. 2008; Morgan and Hamilton 2010). Spatial autocorrelation measures the nature, level, and strength of any interdependence, and if present, may be positive or negative. Positive autocorrelation implies that adjacent homes are likely to have similar values (Patterson and Boyle 2002; Bin et al. 2008; Morgan and Hamilton 2010), while negative autocorrelation suggests that one is less likely to observe similar home values for neighboring properties (Irwin and Bockstael 2002). Failure to account for spatial dependence can violate the assumption of uncorrelated error terms and lead to biased and inefficient coefficient estimates (Anselin and Bera 1998). Attention in the hedonic literature for accounting for spatial dependence has focused on two types of spatial processes – spatial lag and spatial error dependence (Anselin and Bera 1998). Results from robust Lagrange Multiplier tests indicated that spatial autocorrelation was present. This occurs when the selling price of one property is a function of the price of neighboring properties.

Our spatial-lag hedonic model takes the form

$$LnR_{it} = \alpha + \beta_i \boldsymbol{s_i} + \delta_i q_i + \gamma_i \boldsymbol{n}_i + \lambda \boldsymbol{WP} + \varepsilon_i \qquad [3]$$

where LnR_{it} is the natural logarithm of the assessed property value, λ is a spatial autoregressive coefficient, $\boldsymbol{WP}$ is a vector of spatially lagged dependent variables for $\boldsymbol{W}$, the weights matrix, and ε is a vector of independent and identically distributed random error terms. The coefficients α, β, δ, γ, and λ are all to be estimated in the model. The spatial-lag model is estimated via maximum likelihood in the GeoDa v.0.9.5-i (2004) environment.

The first step in controlling for potential spatial dependence is to create a spatial weights matrix that reflects the structure of the hypothesized spatial dependence. As suggested by Anselin and Bera (1998), we analyzed the fit of different weights matrices (using different distance measures) in the hedonic. In estimation, we use a spatial weights matrix consisting of binary elements equal to 1 if two properties are within 500 feet of each other, zero otherwise. The diagonal elements of the weights matrix are set to zero and the row elements are standardized so that they sum to one.

Spatial autocorrelation implies that the marginal effects in a spatial-lag hedonic reflect the induced values on neighboring parcels. The marginal effect of distance to the river is given by $\left(\frac{\delta DIST}{1-\lambda}\right).\left(\frac{R}{DIST}\right)$ for the log-transformed continuous variable, while the marginal effect of the flood risk binary variable is $\frac{R.\{\exp(\gamma_{SFHA})-1\}}{1-\lambda}$.

The hedonic literature uses both market assessed values and reported sales prices as proxies for the true sales prices. Reported sales prices may not reflect the true sales price as they may be either internally misreported, or they do not include any price adjustments that occurred during the property sale. This study uses the market assessed value as the dependent variable for three primary reasons. First, as suggested by Steinnes (1992), land value measures may be a more appropriate measure than total sales price when considering water quality effects as water quality may not affect structure values. We want to examine this by estimating two separate models. The first uses the total value (property plus land) as the dependent variable. The second uses land values. To be consistent, as market assessed values are available for both, we use assessed values as the dependent variable in both models. Second, use of market assessed values increases the sample size for econometric analysis. Finally, for those records where sales prices are available, assessed values and sales prices are highly correlated.

For variables accounting for distance, we define the distance variable as the natural log of distance as it seems reasonable to expect that the effect of distance on land and property values declines with distance. We also assume that the effect of the non-dichotomous attributes, such as square footage and age, decline as the level of these attributes increase. We use quadratic specifications to capture the diminishing marginal effect.

Results

In total, we ran four separate spatial hedonic models. Model 1 uses the natural log of the market assessed total land and property value as the dependent variable. Here, we estimate separate regressions for Middle River properties and South River properties respectively. Model 2 uses the natural log of the market assessed land values as the dependent variable. Again, we estimate two separate river regressions. The results of the estimations of Model 1 are presented in Table 2. Most structural variables are statistically significant at the 1% level with coefficient signs consistent with the hedonic literature. Larger properties with more bathrooms positively impact total land and property values although the diminishing marginal effects are not statistically significant. As expected, newer properties and properties with air conditioning, a garage, and a fireplace are more valuable, all else equal. The only structural variable with mixed results concerns multistory units. Multistory properties have no effect on property values for residences close to the Middle River but do positively influence residential values for properties proximate to the South River.

Most of the neighborhood variables are statistically significant at the 5% level or better. Of the two local towns, households reveal a preference to be located closer to Staunton than Waynesboro. Proximity to the Shenandoah National Park also increases property values. Interestingly, the coefficients on highway proximity differ. Property values for residences close to the Middle River increase with distance from the nearest highway intersection while they fall with distance for South River properties. One possible explanation lies with the bus stop effect. Homeowners prefer to be close to transportation amenities such as bus stops, train stations, and highways but not so close such that potential noise and congestion is a concern. As Middle River properties are, on average, closer to a major highway intersection than South River properties, they may be within the optimal distance threshold such that locating farther from the highway is preferred. On the other hand, South River properties may be far enough from the highway such that these other negative externalities are not an issue, so property values decline as distance from the highway increases.

The two results of particular interest concern the SFHA designation variable (FLOOD) and the river proximity variables, MID_RIV (non-polluted Middle River) and STH_RIV (polluted South River).

First, in both models, SFHA designation reduces total property and land values, although the effect is only statistically significant for properties close to the South River. For these properties and accounting for the spatial multiplier effect, this result indicates that a SFHA designation reduces property values by approximately 23%, or an average of $61,012 based on mean sample values.

Second, for properties close to both rivers, proximity to the water bodies has a strong effect on values. Coefficient signs for distance to both rivers are negative and statistically significant. In line with a priori expectations, the coefficient on the distance to the Middle River variable is greater in magnitude than for distance to the South River, inferring that land and property values increase more substantially with proximity to the non-polluted water body than the contaminated river. Using these coefficient values, the marginal willingness to pay to locate one foot closer to the non-polluted Middle River is $5.41 compared to $3.77 for an equivalent decrease in proximity to the polluted South River. At the aggregate level, and measured at the mean distance to the river across properties, this implies that the aggregate willingness to pay to locate closer to the Middle River is $23,999,502, compared to $12,151,900 to be closer to the South River. Attributing the difference to water quality effects, this implies that the value of cleaning up the mercury contamination in the South River to the Middle River quality level (i.e., to a level that will lift the fish consumption advisory) is almost $12 million.

As it has been argued that water quality may not affect structure values (Steinnes 1992), Model 2 examines the affect of proximity to the rivers and locational measures on assessed land values only. All location coefficient signs remain the same. For the variables of most interest, locating in a SFHA designated area reduces land values, although again, this is only statistically significant for properties proximate to the South River. Again, proximity to both rivers is negative and statistically significant in both models but the magnitude of the coefficients varies. These results imply a willingness to pay to locate one foot closer to the non-polluted Middle River is $2.67 compared to $1.41 for a one-foot decrease in proximity to the polluted South River. The aggregate willingness to pay for a decrease in distance to the Middle River is $11,282,199, compared to $4,542,088 for an equivalent distance decrease to the South River. These results infer that the benefits of improving the water quality of the South River to a level will would remove the fish consumption advisory is approximately $7.3 million.

Discussion

There is a distinct lack of hedonic studies examining water quality impacts within the economic literature. While the dearth of studies may, at first, appear surprising – especially given the fact that many homeowners may self-select into waterfront property markets due to their preference for water-related activities – the primary reason is due to the inherent problems in analyzing water quality impacts via a hedonic framework. This study uses a natural experiment setting – two rivers with a clearly defined difference in water quality flowing through a small geographic site of interest – to estimate the impact of improved water quality on inland real estate values.

The unique geographical setting ensures that we avoid the major problems inherent in hedonic modeling of water quality issues. Principally, this means that there is consistent and recognizable variation in water quality that market participants can respond to. This observed consistency in water quality variation implies that we can accurately reflect market participants' perceptions of water quality in the hedonic framework. Further, the discrete difference in water quality in our study area also avoids omitted variable bias that can be prevalent in other studies of water quality impacts.

Controlling for spatial autocorrelation, results show that land and property values increase more substantially with proximity to non-polluted water bodies than polluted. Using a bundle of sticks argument – where land and property values are a function of structural, neighborhood, and environmental components – we attribute differences in willingness to pay for decreased distance to the local river as the value of improved water quality. We estimate the value of improving the environmental quality of the South (polluted) River to a level that would remove the current fish consumption advisory to be between $7.3 and $12 million.

We also provide more evidence to the sparse economic literature regarding the impact of SFHA designation on inland property values with a SFHA designation reducing South River property values by an average of $61,012 (or approximately 23%).

References

Anselin, L. and A. Bera. 1998. "Spatial Dependence in Linear Regression Models with an Introduction to Spatial Econometrics," in A. Ullah and D. Giles, eds., *Handbook of Applied Economic Statistics*.

Anselin, L. and J. Le Gallo. 2006. "Interpolation of Air Quality Measures in Hedonic House Price Models: Spatial Aspects." *Spatial Economic Analysis* 1(1): 31-52.

Beijer, K., and A. Jernelov. 1979. "Methylation of mercury in natural waters." In *Biogeochemistry of Mercury in the Environment*, J. O. Nriagu (Ed.). Elsevier/North-Holland Biomedical Press, New York, pp. 201-210.

Bin, O. and J. Kruse. 2006. Real Estate Market Response to Coastal Flood Hazards. *Natural Hazards Review* 7(4): 137-144.

Carbone, J.C., D.G. Hallstrom, and V.K. Smith. 2006. "Can Natural Experiments Measure Behavioral Responses to Environmental Risks?" *Environmental and Resource Economics* 33: 273-297.

Boyle M.A. and K.A. Kiel. 2001. "A Survey of House Price Hedonic Studies of the Impact of Environmental Externalities." *Journal of Real Estate Literature* 9(2): 117-144.

Carpi, A. and S.E. Lindberg. 1998. "Application of a Teflon Dynamic Flux Chamber For Quantifying Soil Mercury Flux: Tests And Results Over Background Soil." *Atmospheric Environment* 32(5): 873-882.

Carroll, R.W.H. and Warwick, J.J. 2001. "Uncertainty Analysis of The Carson River Mercury Transport Model." *Ecological Modelling* 137: 211-224.

Carter, L. 1977. “Chemical Plants Leave Unexpected Legacy for Two Virginia Rivers.” *Science* 198: 1015-1020.

Celo, V., Lean, D.R.S., and Scott, S.L. 2006. “Abiotic Methylation of Mercury in the Aquatic Environment.” *Science of the Total Environment* 368(1): 126-137.

Eisler, R. 2006. “Mercury Hazards to Living Organisms.” Taylor & Francis Group, LLC, Boca Raton, FL.

Epp, D. and K.S. Al-Ani. 1979. “The Effect of Water Quality on Rural Non-farm Residential Property Values.” *American Journal of Agricultural Economics* 61: 529-534.

Fang, F., Wang, Q., and J. Li. 2001. “Atmospheric Particulate Mercury Concentration and Its Dry Deposition Flux in Changchun City, China.” *The Science of the Total Environment* 281: 229-236.

Flemming, E., E. Mack, P. Green, and D. Nelson. 2006. “Mercury Methylation from Unexpected Sources: Molybdate-Inhibited Freshwater Sediments and an Iron-Reducing Bacterium.” *Applied and Environmental Microbiology*, 72: 457-464.

Graves, P.J., J.C. Murdoch, M.A. Thayer, and D. Waldman. 1988. “The Robustness of Hedonic Price Estimation: Urban Air Quality.” *Land Economics* 64(3): 220-233.

Guentzel, J.L., W.M. Landing, G.A. Gill, and C.D. Pollman. 2001. “Processes Influencing Rainfall Deposition of Mercury in Florida.” *Environmental Science and Technology* 35: 863-873.

Hamaski, T., H. Nagawe, Y. Yoshioka, and T. Sato. 1995. “Formation, Distribution, and Ecotoxicity of Methylmetals of Tin, Mercury, and Arsenic in The Environment.” *Critical Reviews in Environmental Science and Technology,* 25:45-91.

Holmes, J. and D. Lean. 2006. “Factors That Influence Methylmercury Flux Rates From Wetland Sediments.” *Science of the Total Environment*, 368: 306-319.

Huckabee, J. W., J.W. Elwood, and S.G. Hildebrand. 1979. “Accumulation of Mercury in Freshwater Biota.” In *Biogeochemistry of Mercury in the Environment*, J. O. Nriagu (Ed.). Elsevier/North-Holland Biomedical Press, New York, pp. 277-302.

Irwin, E.G. and N.E. Bockstael. 2002. “Interacting Agents, Spatial Externalities and the Evolution of Residential Land Use Patterns.” *Journal of Economic Geography* 2: 31-54.

Kim, C.W., T.T. Phipps, and L. Anselin. 2003. “Measuring the Benefits of Air Quality Improvement: A Spatial Hedonic Approach.” *Journal of Environmental Economics and Management* 45: 24-39.

Landry, C.E. and P. Hindsley. 2010. “Valuing Beach Quality with Hedonic Property Models.” Forthcoming *Land Economics.*

Leggett, C.G. and N.E. Bockstael. 2000. “Evidence of the Effects of Water Quality on Residential Land Prices.” *Journal of Environmental Economics and Management* 39: 121-144.

Lindqvist, O. and H. Rodhe. 1985. “Atmospheric Mercury: A Review.” *Tellus*, 37B: 136-159.

Mason, R. P., W.F. Fitzgerald, and F.M. Morel. 1994. "The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences." *Geochimica et Cosmochimica Acta*, 58(15): 3191-3198.

Mason, R.P., N.M. Lawson, and G.R. Sheu. 2000. "Annual and Seasonal Trends in Mercury Deposition in Maryland." *Atmospheric Environment*, 34: 1691-1701.

Mendelsohn, D., D. Hellerstein, M. Huguenin, R. Unsworth, and R. Brazee. 1992. "Measuring Hazardous Waste Damages with Panel Models. *Journal of Environmental Economics and Management* 22: 259-271.

Morgan, O.A. and S.E. Hamilton. 2010. "Estimating a Payment Vehicle for Financing Nourishment of Residential Beaches using a Spatial Autoregressive Hedonic Property Price Model." *Coastal Management* 38(1): 2010.

Paterson, R. and K. Boyle. 2002. "Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models." *Land Economics* 78: 417-425.

Poor J.K., L. Taylor, and R. Bouchard. 2001. "Objective versus Subjective Measure of Environmental Quality in Hedonic Property-Value Models." *Land Economics* 77(4): 482-493.

Rosen, S., 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy* 82(1): 34-55.

Smith, K.A. and J.-C. Huang. 1993. "Hedonic Models and Air Pollution: Twenty-five Years and Counting." *Environmental and Resource Economics* 3: 381-394.

Smith, K.A. and J.-C. Huang. 1995. "Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models." *Journal of Political Economy* 103: 209-227.

South River Science Team. 2010. "Fish Consumption Advisories." Retrieved from the web < http://www.southriverscienceteam.org/advisories/index.html>

Shultz, S. and P. Fridgen. 2001. Floodplains and Housing Values, Implications for Flood Mitigation Projects. *Journal of the American Water Resources Association* 37(3): 595-603.

Steinnes, D. 1992. "Measuring the Economic Value of Water Quality." *Annals of Regional Science* 26: 171-176.

Taylor, L.O. 2003. "The Hedonic Method." In *The Economics of Non-Market Goods and resources: A Primer on Monmarket Valuation* ed. Patricia A. Champ, Kevin J. Boyle, and Thomas C. Brown. Kluwere Academic Publishers, 331-393.

Young, C.E. 1984. "Perceived Water Quality and the Value of Seasonal Homes." *Water Resources Bulletin* 20(2): 163-168.

Table 1. Definitions and Summary Statistics for Variables

Variable	Definition	Middle River Model		South River Model	
		Mean	Std. Dev.	Mean	Std. Dev.
LAND VALUE	Assessed value of land	78,968.69	87,373.18	68,006.92	43,934.97
TOTALVALUE	Assessed value of total land and property	294,049.10	230,013.80	273,655.00	164,395.40
BATH	Number of bathrooms	1.74	0.72	1.80	0.71
AC	Central air conditioning	0.63	0.48	0.76	0.43
GARAGE	Garage (=1)	0.39	0.49	0.49	0.50
SQFT	Total structure square footage	1,657.24	730.72	1,791.92	1,742.40
AGE	Age of property	36.64	31.87	29.58	25.33
FIRE	Fire (=1)	0.35	0.48	0.31	0.46
MULTI	Multistory house (=1)	0.30	0.46	0.27	0.44
MID_RIV	Distance in feet to the Middle River	2,144.20	1,358.03		
STH_RIV	Distance in feet to South River			2,572.56	1,215.87
WAYNE	Distance in feet to Wayne	64,623.11	14,611.17	35,031.75	16,693.47
STAUN	Distance in feet to Staunton	30,334.39	10,605.01	63,197.56	5,447.50
PARK	Distance in feet to Shenandoah National Park	159,150.00	23,105.72	123,944.30	12,504.35
HWY	Distance in feet to nearest highway intersection	17,113.17	14,133.62	33,990.25	7,969.99
FLOOD	Area inundated by 100-year flooding (=1)	0.04	0.19	0.02	0.12

Table 2. Model 1 - Assessed Total Value Estimation Results of the Hedonic Price Models

	Middle River (non-polluted)			South River (polluted)		
Variable	Coefficient	Std. Error	*p*-value	Coefficient	Std. Error	*p*-value
CONSTANT	12.997	0.845	0.000	86.513	8.182	0.000
BATH	0.070	0.031	0.023	0.082	0.032	0.009
$BATH^2$	-0.006	0.007	0.365	0.003	0.007	0.631
AC	0.058	0.013	0.000	0.079	0.018	0.000
GARAGE	0.081	0.013	0.000	0.109	0.014	0.000
SQFT	0.035	0.003	0.000	0.016	0.001	0.000
$SQFT^2$	-0.000	0.000	0.420	-0.000	0.000	0.000
AGE	-0.003	0.000	0.000	-0.004	0.001	0.000
AGE^2	0.000	0.000	0.000	0.000	0.000	0.001
FIRE	0.064	0.012	0.000	0.059	0.015	0.000
MULTI	-0.006	0.015	0.684	0.032	0.016	0.051
ln MID_RIV	-0.040	0.004	0.000			
ln STH_RIV				-0.036	0.006	0.000
ln WAYNE	0.193	0.047	0.000	-0.242	0.096	0.011
ln STAUN	-0.071	0.033	0.031	-2.577	0.175	0.000
ln PARK	-0.233	0.071	0.001	-3.399	0.493	0.000
ln HWY	0.065	0.011	0.000	-0.317	0.048	0.000
SFHA	-0.018	0.032	0.576	-0.204	0.052	0.000
LAMBDA (λ)	-0.014	0.001	0.000	-0.015	0.002	0.000
OBS	2,069			1,252		
AIC	7.134			102.707		
LOG LIK	14.433			69.354		

Table 3. Model 2 - Assessed Land Value Estimation Results of the Hedonic Price Models

	Middle River (non-polluted)			South River (polluted)		
Variable	Coefficient	Std. Error	*p*-value	Coefficient	Std. Error	*p*-value
CONSTANT	12.232	1.169	0.000	99.687	9.681	0.000
ln MID_RIV	-0.075	0.005	0.000			
ln STH_RIV				-0.055	0.007	0.000
ln WAYNE	0.141	0.065	0.030	-0.422	0.115	0.000
ln STAUN	-0.045	0.046	0.326	-2.918	0.202	0.000
ln PARK	-0.217	0.097	0.025	-4.232	0.587	0.000
ln HWY	0.138	0.015	0.000	-0.163	0.057	0.004
FLOOD	-0.053	0.043	0.226	-0.218	0.063	0.000
LAMBDA (λ)	-0.036	0.002	0.000	-0.031	0.002	0.000
OBS	2,069			1,252		
AIC	1,367.150			359.132		
LOG LIK	-675.575			-171.566		

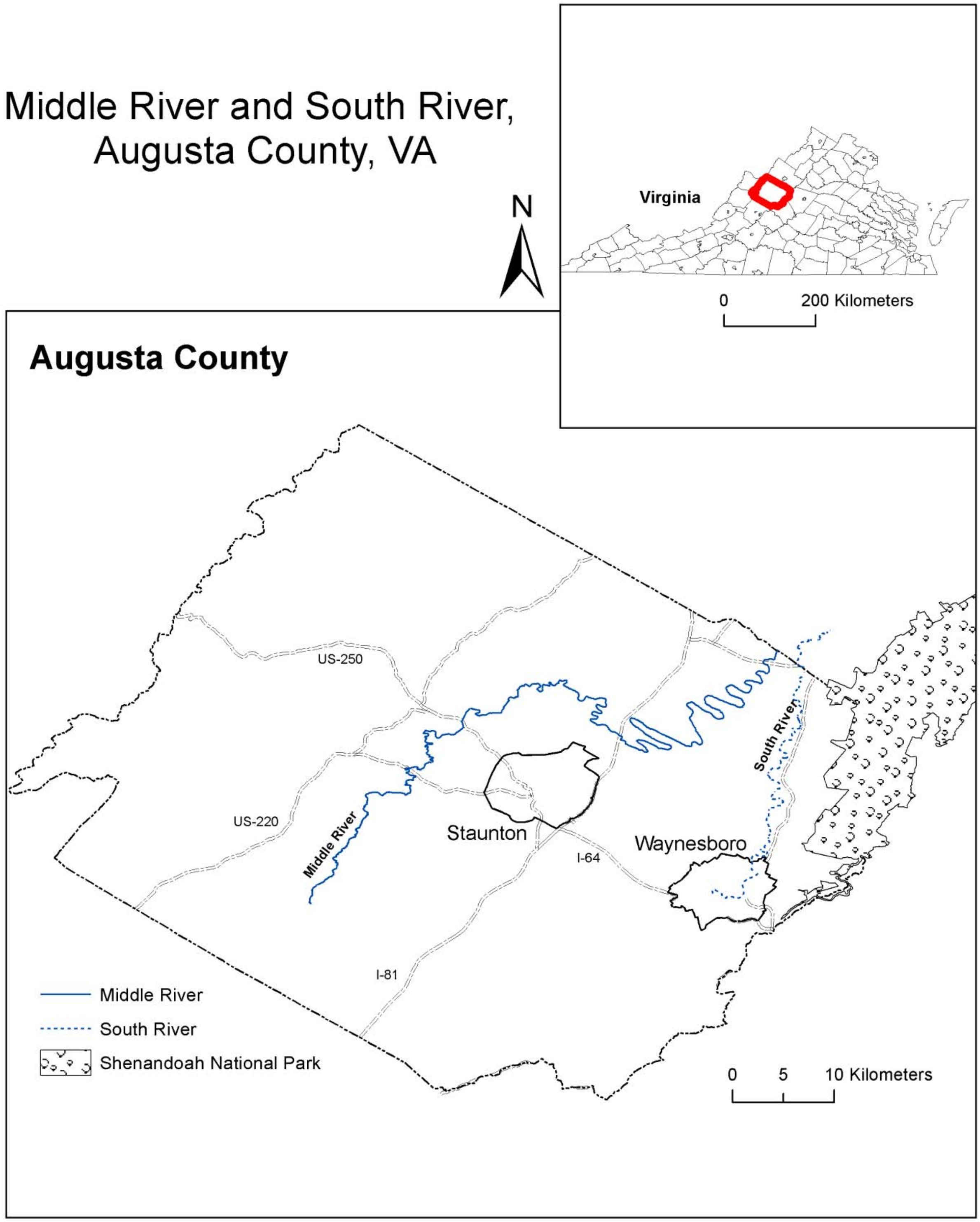

Figure 1. Site of Interest