Negative Externalities on Property Values Resulting from Water Impairment: The Case of the Pigeon River Watershed

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Abstract

The following hypothesis was tested: Willingness to bear a negative water impairment externality differs between those who do and those who do not receive economic benefit from the impairment source, e.g., a paper mill. The hypothesis was tested using a hedonic analysis of ambient water quality in two discrete housing markets in the Pigeon River Watershed, which have been polluted by the operation of a paper mill. The results suggest that North Carolina residents of the subwatersheds with impaired river, who experience economic benefits from the paper mill in addition to harmful effects, do perceive the pollution as a negative externality, whereas they may have a willingness to bear a similar type of negative externality associated with impaired streams. In contrast, the effects of both degraded river and streams on property values is perceived as a negative externality by residents in the Tennessee side, who experience only harmful effects from the pollution. North Carolina residents may hold greater willingness to bear the harmful effects of pollution as a given condition in their decision-making process because they receive economic benefits from the paper mill, while this internalization of the negative externality is weaker for residents in the Tennessee side.

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1. Introduction

1.1. Background

The Pigeon River, which flows from Haywood County in western North Carolina into the western half of Cock County in eastern Tennessee, has been polluted by the operation of a pulp and paper mill owned by Champion International Corporation (now Evergreen Packaging) in Canton, North Carolina, about 40 miles upstream from the Tennessee border (see Fig. 1). Since 1908, when Champion's Canton plant launched its operation, toxic organochlorines in the plant's wastewater have flowed into the Pigeon River and across the border into Tennessee. The mill's National Pollutant Discharge Elimination System (NPDES) permit was controlled by the North Carolina Division of Water Quality (NC DWQ) until 1985, when the U.S. Environmental Protection Agency (EPA) took control of the permit, eventually issuing a new NPDES permit in 1988.

In response to the requirements of the EPA and objections from downstream neighbors in North Carolina and Tennessee, the company began a 3-year, $300 million modernization of the mill in 1990, completing the project in 1994 (Bartlett, 1995). Water quality conditions in the Pigeon River have improved tremendously since completion of the modernization project, with significantly reduced water use, the elimination of molecular chlorine from the bleaching process, and reduced dioxin formation (The Southwest Network for Zero Waste, 2007). According to a report by the Tennessee Department of Environment and Conservation, fish tissue data collected between 1989 and 1995 demonstrated a drop in dioxin contamination, with some species exhibiting safe levels (Denton and Arnwine, 2002). Despite such improvements, water quality in some portions of the Pigeon River Watershed remains impaired. For example, from 2001 to 2004, 9 of 15 and 1 of 3 subwatersheds at the HUC-12 level (hereafter referred to as "subwatersheds") were still impaired in the North Carolina and Tennessee portions of the Pigeon River Watershed, respectively.[1]

Although water impairment is more ubiquitous in North Carolina than in Tennessee, complaints about water pollution from downstream neighbors in Tennessee are more prevalent. For example, residents in Tennessee organized a series of protests against the paper mill's pollution of the Pigeon River. In January 1995, the Dead Pigeon River Council, composed of Cock County residents, organized a memorial service for cancer victims who were allegedly directly affected by effluent discharge into the Pigeon River (Plyler, 1997). Primetime Live filmed this memorial service and televised the story of the Pigeon River (Newport Plain Talk, January 9, 1995; Knoxville News-Sentinel, January 8, 1995). The book *Troubled Waters: Champion International and the Pigeon River Controversy* was also published in August, 1995 (Bartlett, 1995), in which the author chronicles the history of the Pigeon River through the eyes of East Tennesseans. A legal suit for damages caused by water pollution filed in October 2008 by three hundred Tennessee landowners downriver from the Blue Ridge paper mill is still pending (No. 08-6321, 2008). While North Carolina residents have also made a number of protests and launched public campaigns (Bartlett, 1995; Forbes, 2010), the public attention and protests emanating from North Carolina residents, who benefit economically from the paper mill, are fairly mild compared to those by Tennessee residents.

[1] A hydrologic unit describes the area of land upstream from a specific point on the stream that contributes surface water runoff directly to the specified point. Every hydrologic unit is identified by a unique HUC (hydrological unit code) consisting of 2 to 12 digits based on the levels of classification in the hydrologic unit system (STORET 2010). The HUC-12 is the level of the drainage area for a hydrologic unit code with a 12-digit numerical identification and size of 10,000-40,000 acres.

The clear discrepancy between attitudes toward and perceptions of the impairment of the watershed is not surprising given the unique circumstances of the populations involved. In North Carolina, the economy depends on the source of the impairment. For example, in 1914, one-sixth of Canton, North Carolina's 6,000 residents were employed at the plant, and the regional economy in the Canton area has depended heavily on the Champion paper mill since that time (Eller, 1982). Further, in 1997, employees purchased a 45% stake in the company and formed the Blue Ridge Paper Company (Koltzenburg, 2000). In contrast, residents of Tennessee have received no direct economic benefit from the plant because few, if any, Tennessee residents are affiliated with the plant. According to the human resources coordinator of the company, the majority of its employees resides in North Carolina while a few, at most 5-10% of the total number of employees, lives in Tennessee.[2] The mill is one of the oldest paper mills in the country and has been recognized as an integral part of life in Canton, North Carolina in its history because it is a major employer and one of the highest-paying employers in the region. The average annual wage of $50,000 for about 1,600 employees of the mill surpassed the average annual wage of $22,000 for other workers in western North Carolina in 1998 (Ward, 1998). Thus, North Carolina and Tennessee residents may have different perceptions of the water impairment caused by the paper mill, with Tennessee residents viewing the impaired water quality as a more serious negative externality than North Carolinian perceptions of the effluents from the mill.

The contrasting assessment of resident responses to the water quality impairment seems to vary according to the economic benefit derived from the impairment source; hence, whether or not a negative externality is perceived may depend on whether or not an economic benefit is

[2] Telephone interview with human resource coordinator at Evergreen Packaging Inc. was done on April 28, 2011.

received from the impairment source. Specifically, North Carolina residents may have more willingness to bear the negative externality of the water impairment because the negative externality is accompanied by direct and/or indirect economic benefits from the paper mill (Lyons, 2001, p 328). On the other hand, Tennessee residents may not have the same willingness to bear the negative externality because most, if not all, Tennessee residents are third parties who experience harmful effects from the impairment source without being direct or indirect beneficiaries of the economic benefit.

1.2. Hedonic literature on water quality

The economic benefits of a given water supply's quality are derived from withdrawal benefits (i.e., the benefits of water quality arising from water withdrawn from the stream) and instream benefits (i.e., the benefits of water quality arising from water left in the stream and not withdrawn). Instream benefits include two subcategories: use benefits (e.g., swimming, boating, and fishing) and nonuse benefits (e.g., stewardship value, altruistic value, bequest value, and existence value) (Dumas et al., 2005; Feenberg and Mills, 1980). Instream nonuse benefits are often difficult to estimate because they involve the public-good characteristics of nonrivalry and nonexcludability and they are typically not directly reflected in market prices. In respond to these challenges, a great deal of research has been devoted to the estimation of instream nonuse benefits, based mostly on nonmarket valuation methods (e.g., Agudelo, 2001; Bergstrom et al., 1996; Loomis, 1998; Wilson and Carpenter, 1999). Among these studies, the literature is split as to whether hedonic studies are worthy of attention because the question of whether water quality influences residential property values remains unsettled.

Some researchers claim that the value captured by hedonic price methods might only be a perception (or even a misperception) of water quality to which property owners implicitly apply value rather than actual water quality (Boyle et al., 1998; Poor et al., 2001; Steinnes, 1992). The basis for this claim is that homeowners have difficulty recognizing and interpreting the measures of water quality commonly used by natural scientists (e.g., dissolved oxygen, nitrogen, and phosphorous), and they tend to make purchase decisions based on their own perceptions (Walsh et al., 2008). As a result, homeowners tend to rely on subjective perceptions (or misperceptions) that may not directly relate to objective measures of water quality.

Another research camp shows that significant effects of water quality on property value exist (e.g., Epp and Al-Ani, 1979; Leggett and Bockstael, 2000; Poor et al., 2007). According to these researchers, the question is not whether water quality influences residential property values but whether the estimation has been done correctly. For example, Poor et al. (2007) claim that the finding of no significant water quality effect on property values is related to not including in a hedonic model overall measures of ambient water quality that include both waterfront and non-waterfront property sales across an entire watershed. The reason for this omission involves the physical nature of water bodies and their relationship to housing markets. While the ambient water quality of properties located on a single lake might not vary sufficiently across the lake, expanding the geographic domain of an analysis to capture more variation in water quality could extend a study beyond what can legitimately be considered a single market, thus violating the assumption of a common hedonic equilibrium.

While determining the existence and value of negative water-quality externalities has received attention in previous literature, focusing on how a negative externality is influenced by those who do and those who do not receive economic benefit from the source of impairment has not yet been accomplished. The influence of economic benefit on negative water-quality externalities, however, is a central component in evaluating the cost-benefit performance of water-quality regulations. Because hard choices about water quality are continuously being thrust upon residents of the Pigeon River Watershed and these residents receive different levels of economic benefit from the source of impairment, accurate estimates of the effects of impaired water bodies on the values of residential properties owned by the residents are needed. Subsequently, water-quality regulations to accommodate the perceptions of water quality to which property owners implicitly apply value can be established.

1.3. Objective

The objective of this research is to determine whether willingness to bear the negative externality of the water impairment differs between those who do and those who do not receive economic benefit from the paper mill. Hedonic housing-price models for North Carolina and Tennessee residents, using combined measures of ambient water quality that reflect the impairment status and view of and proximity to impaired portions of the Pigeon River and streams in the Pigeon River Watershed, are used to test the hypotheses that (1) houses located in the subwatersheds with impaired portions of the Pigeon River and contributing streams crossing into Tennessee have lower values than houses located in otherwise comparable subwatersheds with unimpaired river and streams crossing into Tennessee, and these differences in housing values are lower in North Carolina than in Tennessee, (2) houses with views of the impaired river and contributing streams have lower values than houses without views of the impaired river and its streams in Tennessee, while differences in housing values due to the view of impaired river and streams are smaller in North Carolina than in Tennessee, and (3) houses located closer to impaired water bodies in Tennessee have lower values than those located near unimpaired water bodies, while the negative effect of proximity to impaired water bodies on housing value in North Carolina is smaller than in Tennessee. Such negative effects on residential property values of the impairment status and view of and proximity to impaired water bodies would suggest, respectively, differences in North Carolina and Tennessee residents' perceptions of the negative externalities from residing in impaired subwatersheds, with a view of and closer proximity to impaired water bodies.

2. Empirical Model

2.1. Specification of spatial hedonic model

Because the price of a house is strongly influenced by the prices and quality of houses in its immediate neighborhood (Brasington and Hite, 2005; Cho et al., 2009, 2010; Cohen and Coughlin, 2008), there may be a need to control for neighborhood effects in determining the effects of impairment status and view of and proximity to impaired water bodies. Consequently, the spatial hedonic model was specified following a 'general to specific' approach to select the appropriate model (Larch and Walde 2008). The null hypothesis is that a general spatial hedonic model (Anselin, 1988, pp 64-65 and 182-183), that includes spatial lag and spatial error components, represents the "true" data generating process:

$$(1) \qquad \begin{aligned} \mathbf{y} &= \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \\ \boldsymbol{\varepsilon} &= (\mathbf{I} - \lambda\mathbf{W})^{-1}\boldsymbol{\mu} \end{aligned},$$

where **y** is an n × 1 vector representing the dependent variable (natural log of the sale price of a single-family house), **Wy** is an n × 1 vector representing the spatial lag of the dependent variable in which **W** is a spatial weight matrix identifying a neighborhood structure, ρ is the parameter of the spatially lagged dependent variable, $\mathbf{X}$ is an n × (k + 1) matrix representing explanatory variables including measures of ambient water quality (see detailed description in the *Measures of ambient water quality* section below), $\boldsymbol{\beta}$ is a vector of parameters, λ is the parameter of the spatial autoregressive structure of the disturbance $\boldsymbol{\varepsilon}$, and the error term $\boldsymbol{\mu}$ is taken to be normally distributed. Given consistent estimates of the lag and error autoregressive parameters, the null hypothesis that $\lambda = 0$ and $\rho = 0$ is tested for each regression using the Wald statistic. Evidence favors the error model when $\rho = 0$ and $| \lambda | > 0$, and the converse suggests a lag autoregressive model. When $\lambda = 0$ and $\rho = 0$, ordinary least squares (OLS) may be used with an appropriate covariance matrix robust to heteroskedasticity.

In the general spatial model, the selection of an appropriate spatial weight matrix **W** that reflects the intensity of the geographic relationship between observations in a neighborhood remains a challenge. In general, there is no consensus as to which weights are most appropriate for any econometric study (Anselin, 1988). Florax and Rey (1995) discuss problems that may arise if the spatial weight matrix is poorly selected. Thus, as a sensitivity analysis, several types of weighting matrices and their influence on water-quality values were tested. Four types of spatial weight matrices **W** (i.e., Thiessen polygon, inverse distance, *k*-nearest neighbor, and hybrid spatial weight matrices) were constructed based on Tobler's First Law of Geography—near things are more related than distant things (Tobler, 1970, p. 236). The four types of **W** were considered to test various neighborhood structures.

The Thiessen polygon weight matrix was constructed in two steps.[3] In the first step, Thiessen polygons were constructed so that the centroid of each sales transaction was assigned to

[3] A polygon is a plane figure that is bounded by a closed path. Thiessen polygons are polygons whose boundaries define the area that is closest to each point relative to all other points (GeoDa Center 2010).

an area whose boundaries are defined by the median distance between the centroid of a sales transaction and its nearest centroids of sales transactions. In the second step, the first-order contiguous Thiessen polygons were identified as observations that share a common border or vortex. **W** was structured in such a way that if the sales transactions *i* and *j* were identified as neighbors, the off-diagonal elements of the spatial weight matrix $\mathbf{W}_{ij}$ took the value of 1, and 0 otherwise. The diagonal elements took the value of 0. A Thiessen polygon weight matrix effectively turns the spatial representation of a sample from points into areas (Anselin, 1988).

The inverse distance weight matrix was constructed so that Euclidean distances between any two possible centroids of sales transactions were measured, and their inversed values were taken as the off-diagonal elements of the spatial weight matrix $\mathbf{W}_{ij}$. Again, the diagonal elements took the value of 0. The *k*-nearest neighbor (KNN) weight matrix was constructed so that the number (*k*) of nearest neighbor sales transactions was identified based on the Euclidean distances between any two possible centroids of sales transactions. Given the identified KNN, **W** was structured the same way as the Thiessen polygon weight matrix. The KNN weight matrix is based on the hypothesis that observations outside the KNN of any given observation are assumed to have no influence on the given observation. A series of 2-10 neighbors (i.e., $k = 2, 3, 4, \ldots,$ and 10) was used to construct the KNN weights for use in estimation. Since the choice of *k* for the KNN weight had little effect on the overall measure of fit and did not appear to be a critical factor in terms of model identification among KNN weights, the KNN (k =5) specification was used.

The hybrid spatial weight matrix was constructed by element-wise multiplication between the KNN weight matrix and the inverse distance weight matrix. The hybrid spatial weight matrix interacts the KNN ($k = 5$) weights with the inverse distance weights to allow distance-decay effects among the KNN ($k = 5$). All four matrices were row standardized so that each row sumed to one, which helps to interpret autoregressive parameters (Getis and Aldstadt, 2002).

2.2. Measures of ambient water quality

All states must establish water-quality standards, designate uses for water bodies, and develop a list of impaired water bodies under Section 303(d) of the 1972 Clean Water Act. Additionally, state water-quality standards require EPA approval every three years (U.S. Congress 2002). Because impaired water quality is hazardous to water-based recreation users, water-quality standards must be met for rafting, boating, swimming, and other recreational activities. Furthermore, information about impaired water bodies must be easily transmitted to market participants through signs posted by county officials and notices printed in local newspapers.

Among the parcels that represent sales transactions (hereafter referred to as "parcels") during 2001-2004 in the Pigeon River watershed, the only parcels considered in the model are those in the subwatersheds crossed by the Pigeon River itself: 10 of 18 subwatersheds of the Pigeon River watershed (see Figure 1). The selection was determined given that the parcels in the subwatersheds not crossed by the Pigeon River itself are likely outside the influence of Pigeon River water quality. Variables for measuring ambient water quality were created and included among the explanatory variables **X**. The variables are grouped into three types of water quality measures: impairment dummy variables, water view dummy variables, and proximity variables. All three dimensions of water quality are measured separately for the river and its tributaries because the water quality effects of each source on property values may be different.

The impairment dummy variables were specified to reflect the impairment status of the river and contributing streams that cross 10 subwatersheds of the Pigeon River watershed. The EPA standard for state water-quality was used to establish the two impairment dummy variables: one for the river and one for the streams. The dummy variable for the impairment status of the river was created to reflect whether each parcel in a subwatershed is crossed by an impaired portion of the river. The dummy variable for the impairment status of the streams was created similarly.

The water view dummy variables were specified to reflect visibilities of impaired portions of the river and contributing streams. The dummy variable for the visibility of an impaired portion of the river was established to reflect whether each parcel has a view of an impaired portion of the river. The dummy variable for the visibility of impaired portions of streams was also established to reflect whether each parcel has a view of an impaired portion of any stream. The proximity variables were specified to denote proximity to the impaired portions of the river and streams. These variables represent the distance between parcel centroids and the nearest point on the polylines representing impaired portions of the river and streams.

The dummy variables for the views of un-impaired portions of the river and contributing streams as well as proximity variables to denote proximity to the un-impaired portions of the river and streams were established the same way as the view dummy variables of impaired water bodies and proximity variables of impaired water bodies, respectively. The variables associated with un-impaired water bodies were included in the model to control for potential positive externalities of un-impaired water bodies that may be captured in housing values. There is also a need to control for non-point pollution sources, generally resulting from urban area and agricultural runoff. Because the study area's terrain is mountainous and agricultural land use is relatively small, the majority of potential non-point pollution sources is anticipated to stem from urban land use. Accordingly, the percentage of developed land was included in the model to control the non-point pollution sources.

While pooling sales data over a four-year time period increased the sample size, it also increased concerns over the possibility of unaccounted for changes in market conditions and water quality over time. Dummy variables for the time of the year and year in which the transaction occurred (i.e., season and year of sales dummy variables) were included to control for these potential changes in market conditions and water quality.

2.3. Estimation of the spatial hedonic model

The first empirical task was to test whether the model in equation (1) should be estimated with separate regressions for North Carolina and Tennessee or with a single regression with pooled data, because a hedonic model for multiple markets violates the assumption of a common hedonic equilibrium. This task was accomplished with a Tiao-Goldberger test (Tiao and Goldberger, 1962) based on model estimates for North Carolina and Tennessee regressions. The null hypothesis evaluated by this test is that the effects of the variables associated with water quality are equal between the regressions based on an *F*-statistic. If the Tiao-Goldberger test produces a split decision, a Likelihood Ratio (LR) test can be performed based on model estimates for North Carolina, Tennessee, and a pooled regression with a state dummy variable. Rejection of the null hypothesis would indicate that one homogeneous housing market does not exist for North Carolina and Tennessee and that heteroscedasticity exists in the estimation of the pooled data, suggesting that the inclusion of the state dummy variable in the pooled regression does not fully capture state differences (Nelson, 1979). Thus, separate North Carolina and Tennessee regressions should be estimated to allow response coefficients to vary across states.

Goodness-of-fit and spatial autocorrelation were used to evaluate the robustness of the estimates when using different spatial weight matrices. Goodness-of-fit was measured by the Akaike Information Criterion (AIC) (Akaike, 1974). Because the AIC captures the tradeoff between the accuracy and complexity of a model when new variables are added, it can be used to evaluate model performance by comparing how closely estimated values fit true values (Bozdogan, 1987). The residuals from the spatial-hedonic models were tested for spatial error autocorrelation using a spatial Lagrange Multiplier (LM) test (Anselin, 1988). The statistic is distributed as a χ^2 variate with 1 degree of freedom, and the null hypothesis of spatial error independence is tested. The Thiessen polygon, inverse distance, KNN ($k = 5$), and hybrid spatial weight matrices were used to construct a test statistic consistent with the spatial weight matrices used in the spatial-hedonic models (Anselin, 1988). To assess the effects of using different spatial weight matrices, the empirical distributions of the residuals of the four models were compared for each state. Differences between the distributions were gauged using a Kolmogorov–Smirnov (K-S) test (Kolmogorov, 1933; Smirnov, 1933).

3. Study Area and Data

The data for this analysis pertain to 10 of 18 subwatersheds of the Pigeon River Watershed, which cover 317 square miles and houses a population of approximately 51,000 (U.S. Census, 2000). Four GIS data sets were used: individual parcel data, census-block group data, elevation data, and water quality data. The variable names and definitions are presented in Table 1. The individual parcel data (i.e., sales price, lot size, structural information, and season and year of sales) are from the Department of Land Records and GIS and Tax Administrator in Haywood County and the ORI-GIS Services of the Tennessee government. The per capita income from the census-block group data were acquired from the U.S. Census (2000).

The distances from each sales transaction to the nearest physical features were calculated using information from Environmental System Research Institute maps (ESRI, 2001) and the Spatial Join tool in ArcGIS 9.2 (e.g., Cho et al., 2009, 2010; Poudyal et al., 2009). The variables are the distances from a sales transaction to the centroid of the nearest polygon representing a central business district (CBD), local park, or golf course, or the nearest points on each polyline representing a railroad or an interstate highway.[4] The slope was derived from a digital elevation model using U.S. Geological Survey (USGS) data at a 1/3 arc-second (approximately 100 square meters) resolution (USGS, 2004).

The impairment status data were acquired from STORET (2010), the EPA's central data warehouse that serves as a repository for water quality data, including biological and physical data. These data are at the level of the drainage area for a hydrologic unit code (HUC), with a 12-digit numerical identification and size of 10,000-40,000 acres and referred to as HUC-12. The data are collected by state- and federal-level agencies and are accessible to the general public. The water quality data (i.e., list of impaired water bodies under Section 303(d) of the 1972 Clean Water Act) for the Pigeon River and streams in the Pigeon River Watershed were reported in 2002 and 2004 by the Tennessee Department of Environment and Conservation and the North Carolina Department of Environment and Natural Resources and were publicly available through STORET.

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[4] A polyline is a single entity that is made up of a series of connected lines.

The individual parcel data are for detached single-family houses sold between 2001 and 2004. A total of 2,135 sales occurred during the 2001–2004 period: 1,394 sales in North Carolina and 741 sales in Tennessee. Housing prices were adjusted to 2001 dollars using the annual housing price index for each state (Office of Federal Housing Enterprise Oversight, 2010). After eliminating missing data, 595 sales from North Carolina and 497 sales from Tennessee were used in the analysis. Average housing prices are significantly different between states. Specifically, average adjusted housing prices (Office of Federal Housing Enterprise Oversight, 2010) are, respectively, $142,658 and $66,929 (see Table 2 for comparisons of variables between states). The considerably different average housing prices between the two states suggests that the aforementioned testing will likely find evidence for two separate housing markets even though both states have residents in a single watershed.

Because the timing of water quality data (2002 and 2004) and sales records for detached single-family houses (2001–2004) did not match, the 2002 water quality data were assigned to the sales records for 2001 and 2002, and the 2004 water quality data were assigned to the sales records for 2003 and 2004 as proxies for the water quality variables. Although the timing of the census and sales records did not match, given the timing of census taking, the 2000 census data were used as proxies.

4. Empirical Results

4.1 Overall estimates

The null hypothesis that the water quality variables (i.e., impairment dummy variables, water view dummy variables, and proximity variables) are equal for the North Carolina and Tennessee models is rejected by the Tiao-Goldberger test (critical value, F-value = 3.85, 1 and

1031 df, p-value < 0.05). While the individual null hypotheses for the impairment dummy for the river (F-value = 2.22), the impairment dummy for streams (F-value = 3.08), the water view for unimpaired river dummy (F-value = 1.35), and the water view of impaired streams dummy (F-value = 0.016) were not rejected, the null hypotheses for the rest of the water quality variables were rejected at the 5% significance level (F-value = 11.71, 127.20, 1,282.03, 505.79, and 24.82 for the view of unimpaired streams, proximity to the impaired river, proximity to the unimpaired river, proximity to impaired streams, and proximity to unimpaired streams, respectively). Since the effects of all the water quality variables are not consistently different between states according to these test results, the Likelihood Ratio (LR) test was also used. The null hypothesis that all slope parameters (i.e., except the constants) are equal for the North Carolina and Tennessee models is rejected for each of the four spatial weight matrices (LR = 169.76, df = 29, p-value < 0.01), suggesting that the inclusion of the dummy variable for the state in the pooled regression does not fully capture the differences between the states; thus, that separate Tennessee and North Carolina regressions are appropriate.

Based on the general to specific approach to select the appropriate model, the Wald statistics suggest that $\lambda = 0$ and $\rho = 0$ for the Tennessee model using the Thiessen polygon, KNN ($k = 5$), and hybrid spatial weight matrices, and thus the OLS was used to estimate the specifications. The general spatial model was estimated for the Tennessee model using the inverse distance weight matrix and for the North Carolina model using the inverse distance and the hybrid weight matrices because the Wald statistics for the North Carolina specifications suggest that $| \rho | > 0$ and $| \lambda | > 0$. The spatial error model with the Thiessen polygon and KNN ($k = 5$) weight matrices was used to estimate for the North Carolina model as the Wald statistics suggest that $\rho = 0$ and $| \lambda | > 0$. Thus, six sets of hedonic estimates are presented in Table 3—an

OLS and a spatial general model with an inverse distance weight matrix for the Tennessee model, two spatial error models with Thiessen polygon and KNN (k = 5) weight matrices, and two general spatial models with the inverse distance and hybrid weight matrices for the North Carolina model. The variables that were statistically significant at the 5% level were denoted with asterisks in the table, and henceforth, those variables are referred to as "significant" in the discussion below.

The spatial LM test results reported in Table 3 using the residuals of each regression suggest that the null hypothesis of no spatial autocorrelation was not rejected at the 5% level for the Tennessee model using each of the four spatial weight matrices, while the same null hypothesis was not rejected at the 5% level for the North Carolina model using only the inverse distance and hybrid spatial weight matrices. The inconsistency in the appropriate models for different spatial weight matrices and their inherent differences in significant spatial lag and error autocorrelation parameters and variants of the spatial LM tests suggest that the difference in neighborhood structures in the housing market between the states causes the differences in spatial variances in the residuals in the regressions.

The results from the spatial-hedonic models using the inverse distance spatial weight matrix consistently had AIC values smaller than those associated with other spatial weight matrices in both states. While smaller AIC values may indicate better goodness-of-fit using the inverse distance weight matrix, differences among the residual distributions among the six models are trivial and statistically insignificant, suggesting that no one spatial weight matrix outperforms the others. For this reason, the discussion below is mostly focused on the consistently significant variables across all spatial weight matrices in each submarket.

4.2. Control variables

The signs of significant parameters associated with the parcel variables are consistent with expectations. A larger finished area, more stories, and fireplace are positively correlated with housing prices in both states. Newer houses and better quality construction are valued more highly in Tennessee than North Carolina whereas houses with brick sidings are valued more highly in North Carolina than Tennessee. The differences in the effects of age, quality of construction, and brick sidings between the states provide clear evidence of separate housing markets in the Tennessee and North Carolina portions of the Pigeon River Watershed.

Houses located in neighborhoods with higher incomes are valued more highly in North Carolina using two of the four spatial weight matrices (Thiessen polygon and KNN (k = 5)). Significant distance variables suggest that North Carolina residents may attach premiums to being closer to a local park and closer to a golf course while these distance variables are not significant for Tennessee residents. The variables measuring the distances to the/a CBD and an interstate highway and slope are consistently not significant for any model.

4.3. Ambient water quality variables

The coefficients for the impairment dummy variables show that houses in the subwatersheds with impaired river in both states have lower values than houses in otherwise comparable subwatersheds with unimpaired river. Conversely, a clear contrast exists in the effects of the variables presenting the impairment status of streams between North Carolina and Tennessee: the effect is consistently not significant in the North Carolina models while it is negative and significant in the Tennessee models. These results suggest that (1) negative externalities from residing in a subwatershed with impaired river exist for the residents of both states and (2) Tennessee residents experience negative externalities from residing in the subwatersheds with impaired streams, while North Carolina residents may have a willingness to bear the same type of negative externalities. The willingness to bear the negative externalities of impaired streams in North Carolina is likely related to those residents who face stream impairment being among those most likely to benefit economically from the plant.

Conversely, the four water view variables are not significant across the states. Out of the four proximity variables, only the distance to the nearest unimpaired river is found to be negative and significant across the states, whereas all other proximity variables are not significant in any model. The consistently significant value of proximity to an unimpaired portion of the river implies that a positive amenity value exists from being closer to the Pigeon River provides as reflected through higher housing price in both states as long as the portion of the river is unimpaired. Thus, residents in both states receive a premium from proximity to an unimpaired portion of the river where no such premium exists for being closer to impaired portions of the river.

5. Conclusion

The following hypothesis was tested: Willingness to bear a negative externality from water impairment differs by those who do and those who do not receive economic benefit from the paper mill. The hypothesis was tested using a hedonic analysis of ambient water quality (i.e., impairment status and view of and proximity to impaired water bodies) in two discrete housing markets in the Pigeon River Watershed that have been polluted by the operation of a paper mill. The pollution occurs in North Carolina and flows downstream into Tennessee. The results suggest that North Carolina residents residing in subwatersheds with impaired portions of the

Pigeon Rive, who experience economic benefits from the paper mill in addition to its harmful effects on water quality, do perceive the pollution as a negative externality, whereas they may have a willingness to bear a similar type of negative externality associated with impaired streams. In contrast, the effects of both degraded river and streams on property values are perceived as a negative externalities by residents in the Tennessee portion of the watershed, who experience only harmful effects from the pollution. That said, the same difference in willingness to bear the negative externality of water impairment by those who do and those who do not receive economic benefit from the source of pollution was not found in the variables of view of and proximity to impaired water bodies.

With evidence of not rejecting the hypothesis (i.e., difference in significance of the negative effects of impaired streams between the states) and inconclusive evidences for the hypothesis (i.e., insignificant effects of view of and proximity to impaired water bodies in the hedonic models in both states), it is difficult to make an argument for one side or another. Despite of the inconclusive results, the finding of difference in willingness to bear the negative externality of the impaired streams between the states still supports the argument in previous literature that the value captured by hedonic price methods seems to be influenced by a perception of water quality to which property owners implicitly apply value. Specifically, North Carolina residents may hold greater willingness to bear the harmful effects of pollution as a given condition in their decision-making process because they receive economic benefits from the paper mill, while this internalization of the negative externality is weaker for residents in the Tennessee portion of the watershed.

This result suggests that the economic impact of an impairment source has an important relationship with how residents perceive water quality impairment from the impairment source.

This implies that the perception of water quality to which property owners implicitly apply value needs to be considered when establishing water-quality regulations. For example, the control of the mill's NPDES permit by NC DWQ until 1985 should not have been allowed; authorities in Tennessee should have been involved because the loss in Tennessee property values resulting from the negative externality may suggest a legal obligation of the paper mill and the State of North Carolina, which benefits economically from the paper mill, to compensate Tennessee residents for the negative effects of pollution on residential property values.

A challenge remains, however to confirm the relationship between impairment-perception and economic impact. An interaction variable between the level of economic benefit from the plant and the impairment dummy for the river and contributing streams could be included in the hedonic models. This variable would measure the effects on property values of houses located in subwatersheds with impaired portions of the Pigeon River and its streams, conditioned on the individual level of economic benefit received from the paper mill. This interaction variable was not included in the hedonic models because data for the economic benefits from the Canton plant were not available for individual observations. Obtaining economic-benefit data for individuals needs further attention and may require a survey of the residents and property owners in the Pigeon River Watershed of both states.

Another important caveat to this analysis is that it only focuses on the effect of water-quality impairment on housing price. The effects on withdrawal benefits, instream benefits, and direct-use values, such as those for recreation, are not explicitly included. Additionally, non-use values for benefits such as enhanced biodiversity and the existence values of various plant and animal species were not included for this study. Obtaining withdrawal benefits, instream benefits, direct-use values, and the non-use values associated with biodiversity may also require a survey of the residents, property owners, and non-residents in and outside the watershed.

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Table 1

Names and descriptions of variables.

Variable	Description	Unit
Dependent variable		
House price	Housing sale price sold during 2001-2004 (adjusted to dollar of the first quarter of 2001)	$
Parcel variable		
Finished area	Total finished square footage of house	$feet^2$
Lot size	Total square footage of parcel	$feet^2$
Age	Year house was built subtracted from sale year	
Pool	Dummy variable for swimming pool (1 if pool, 0 otherwise)	
Stories	Height of house in number of stories	
Fireplace	Number of fireplaces in house	
Brick	Dummy variable for brick siding (1 if brick, 0 otherwise)	
Quality	Dummy variable for quality of construction (1 if above average, , 0 otherwise)	
Condition	Dummy variable for condition of structure (1 if excellent or good, 0 otherwise)	
Census-block group variable		
Income	Per capita income for census-block group in 2000	$
Distance and slope variable		
Distance to CBD	Euclidean distance from the centroid of a parcel to the centroid of the central business district (court house)	feet
Distance to local park	Euclidean distance from the centroid of a parcel to the centrioid of the nearest local park	feet
Distance to golf course	Euclidean distance from the centroid of a parcel to the centrioid of the nearest golf course	feet
Distance to interstate highway	Euclidean distance from the centroid of a parcel to the nearest interstate	feet
Slope	Slope in percentage at the place of house	
Non-point source water quality variable		
Percentage of developed land	Percentage of developed land at the 10 subwatershed level	%
Impairment dummy variable		
Impairment dummy for the river	Dummy variable for impairment status of Pigeon River at the 10 subwatershed level (1 if a parcel is in subwatershed with impaired river, 0 otherwise)	
Impairment dummy for streams	Dummy variable for impairment status of streams at the 10 subwatershed level (1 if a parcel is in subwatershed with	

	impaired streams, 0 otherwise)	
Water view variable		
Water view dummy for impaired river	Dummy variable for water view for impaired Pigeon River (1 if a parcel has the visibility of the impaired portion of the river, 0 otherwise)	
Water view dummy for unimpaired river	Dummy variable for water view for unimpaired Pigeon River (1 if a parcel has the visibility of the unimpaired portion of the river, 0 otherwise)	
Water view dummy for impaired streams	Dummy variable for water view for impaired streams (1 if a parcel has the visibility of the impaired streams, 0 otherwise)	
Water view dummy for unimpaired streams	Dummy variable for water view for unimpaired streams (1 if a parcel has the visibility of the unimpaired streams, 0 otherwise)	
Water proximity variable		
Proximity variable for the impaired river	Euclidean distance from the centroid of a parcel to the nearest impaired portion of the river	feet
Proximity variable for the unimpaired river	Euclidean distance from the centroid of a parcel to the nearest unimpaired portion of the river	feet
Proximity variable for impaired streams	Euclidean distance from the centroid of a parcel to the nearest portion of impaired streams	feet
Proximity variable for unimpaired streams	Euclidean distance from the centroid of a parcel to the nearest portion of unimpaired streams	feet
Year dummy variable (Reference year 2001)		
Year 2002	Sale occurred in 2002 (1 if yes, 0 otherwise)	
Year 2003	Sale occurred in 2003 (1 if yes, 0 otherwise)	
Year 2004	Sale occurred in 2004 (1 if yes, 0 otherwise)	
Seasonal variable		
Season	Dummy variable for season of sale (1 if April through September, 0 otherwise)	

Table 2
Descriptive Statistics.

	North Carolina (N=595)		Tennessee (N=497)	
	Mean	Std. Dev.	Mean	Std. Dev.
House price	142,658.220	88,391.061	66,928.507	55,618.051
Parcel variable				
Finished area	1,762.833	714.634	2,018.932	922.520
Lot size	86,272.518	263,171.190	126,979.000	545,250.670
Age	18.101	16.900	27.716	24.129
Pool	0.006	0.078	0.005	0.071
Stories	1.219	0.329	1.103	0.301
Fireplace	0.797	0.623	0.200	0.455
Brick	0.042	0.201	0.163	0.370
Quality	0.247	0.432	0.037	0.189
Condition	0.268	0.443	0.481	0.500
Census-block group variable				
Income	18,494.126	3,232.651	14,706.713	2,966.887
Distance and slope variable				
Distance to CBD	29,178.253	9,448.931	20,112.031	14,880.435
Distance. to local park	17,465.888	10,053.700	18,613.084	14,325.662
Distance to golf course	13,117.373	7,266.229	16,879.293	9,462.237
Distance to interstate highway	20,024.664	13,110.680	10,309.362	8,387.881
Slope	8.290	4.134	4.742	3.382
Non-point source water quality variable				
Percentage of developed land	4.514	0.507	4.461	2.572
Impairment dummy variable				
Impairment dummy for the River	0.141	0.348	0.018	0.135
Impairment dummy for streams	0.111	0.314	0.739	0.439
Water view variable				
Water view dummy for impaired river	0.524	0.500		
Water view dummy for unimpaired river	0.121	0.326	0.565	0.496
Water view dummy for impaired streams	0.086	0.280	0.670	0.471
Water view dummy for unimpaired streams	0.871	0.336	0.928	0.259
Water proximity variable				
Proximity variable for the impaired river	21,484.686	11,317.429	9,217.993	8,608.592
Proximity variable for the unimpaired river	137,618.902	52,148.944	42,378.419	46,637.194

Proximity variable for impaired streams	30,566.791	18,982.377	46,490.731	17,326.704
Proximity variable for unimpaired streams)	5,101.982	5,775.464	6,337.524	8,767.723
Year dummy variable (Reference year 2001)				
Year 2002	0.219	0.414	0.220	0.415
Year 2003	0.266	0.442	0.287	0.453
Year 2004	0.296	0.457	0.309	0.463
Seasonal variable				
Season	0.586	0.493	0.536	0.499

Table 3
Estimation results with four spatial weight matrices.

	North Carolina				Tennessee	
	Thiessen polygon (TP)	Inverse distance (A)	*k*-nearest neighbors (*k* = 5) (B)	Hybrid (A×B)	TP, *k*-nearest (*k*=5), and Hybrid	Inverse distance
Intercept	10.520*	5.898*	10.558*	8.925*	8.328*	6.157*
	(0.357)	(0.201)	(0.389)	(4.347)	(2.093)	(1.835)
Parcel variable						
ln(Finished area)	0.554*	0.543*	0.557*	0.555*	0.504*	0.469*
	(0.083)	(0.083)	(0.083)	(0.078)	(0.071)	(0.066)
ln(Lot size)	0.033	0.019	0.036	0.029	-0.004	-0.015
	(0.036)	(0.035)	(0.036)	(0.036)	(0.026)	(0.023)
Age	0.001	0.001	0.001	0.001	-0.004*	-0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Pool	0.230	0.252	0.248	0.280	0.122	0.152
	(0.443)	(0.441)	(0.445)	(0.449)	(0.284)	(0.268)
Stories	0.262*	0.221*	0.256*	0.225*	0.181*	0.169*
	(0.110)	(0.110)	(0.110)	(0.112)	(0.072)	(0.067)
Fireplace	0.263*	0.272*	0.278*	0.297*	0.204*	0.197*
	(0.084)	(0.083)	(0.084)	(0.084)	(0.043)	(0.040)
Brick	0.326*	0.297*	0.324*	0.316*	0.161	0.155
	(0.098)	(0.093)	(0.097)	(0.096)	(0.117)	(0.106)
Quality	0.100	0.098	0.101	0.100	0.368*	0.334*
	(0.184)	(0.180)	(0.185)	(0.185)	(0.062)	(0.059)
Condition	0.139	0.097	0.134	0.109	0.098	0.094
	(0.088)	(0.084)	(0.087)	(0.086)	(0.053)	(0.048)

Census-block group variable						
ln(Income)	0.343*	0.245	0.338*	0.309	0.100	0.005
	(0.134)	(0.137)	(0.130)	(0.270)	(0.167)	(0.138)
Distance and slope variable						
ln(Distance to CBD)	0.123	0.107	0.119	0.130	-0.164	-0.108
	(0.109)	(0.088)	(0.106)	(0.094)	(0.122)	(0.100)
ln(Distance to local park)	-0.257*	-0.201*	-0.258*	-0.248*	0.001	-0.021
	(0.086)	(0.068)	(0.083)	(0.073)	(0.051)	(0.042)
ln(Distance to golf course)	-0.283*	-0.183*	-0.282*	-0.251*	0.035	0.027
	(0.087)	(0.068)	(0.083)	(0.059)	(0.048)	(0.039)
ln(Distance to interstate highway)	0.015	0.015	0.016	0.013	0.055	0.043
	(0.050)	(0.040)	(0.048)	(0.043)	(0.033)	(0.027)
Slope	0.007	0.006	0.007	0.006	-0.001	-0.004
	(0.012)	(0.011)	(0.011)	(0.011)	(0.006)	(0.006)
Non-point source water quality variable						
Percentage of developed land	-0.047*	-0.035*	-0.046*	-0.041*	0.003	0.003
	(0.015)	(0.014)	(0.015)	(0.014)	(0.046)	(0.040)
Impairment dummy variables						
Impairment dummy for the river	-0.616*	-0.456	-0.626*	-0.614*	-0.257*	-0.238*
	(0.295)	(0.251)	(0.288)	(0.255)	(0.110)	(0.092)
Impairment dummy for streams	-0.152	-0.118	-0.157	-0.161	-0.399*	-0.298*
	(0.124)	(0.102)	(0.120)	(0.095)	(0.139)	(0.121)
Water view variables						
Water view dummy for impaired river	-0.032	-0.044	-0.039	-0.038		
	(0.067)	(0.066)	(0.067)	(0.067)		

Water view dummy for unimpaired river	-0.119 (0.104)	-0.118) (0.099)	-0.117 (0.103)	-0.119 (0.102)	-0.029 (0.049)	-0.014 (0.045)
Water view dummy for impaired streams	0.075 (0.119)	0.076 (0.118)	0.098 (0.120)	0.097 (0.120)	0.078 (0.051)	0.063 (0.047)
Water view dummy for unimpaired streams	-0.134 (0.095)	-0.118 (0.094)	-0.132 (0.096)	-0.121 (0.096)	0.031 (0.090)	0.037 (0.085)
Water proximity variable						
ln(Proximity variable for the impaired river)	0.044 (0.038)	0.038 (0.031)	0.045 (0.036)	0.050 (0.028)	0.006 (0.057)	0.005 (0.048)
ln(Proximity variable for the unimpaired river)	-0.408* (0.122)	-0.259* (0.098)	-0.047* (0.118)	-0.348* (0.089)	-0.234* (0.042)	-0.194* (0.037)
ln(Proximity variable for impaired streams)	0.038 (0.050)	0.032 (0.040)	0.038 (0.048)	0.032 (0.042)	0.117 (0.080)	0.051 (0.069)
ln(Proximity variable for unimpaired streams)	-0.034 (0.040)	-0.023 (0.033)	-0.035 (0.039)	-0.027 (0.036)	-0.004 (0.025)	0.009 (0.021)
Year dummy variable						
Year 2002	-0.011 (0.098)	-0.018 (0.097)	-0.015 (0.099)	-0.020 (0.099)	-0.019 (0.066)	-0.036 (0.062)
Year 2003	-0.011 (0.092)	-0.023 (0.091)	-0.013 (0.092)	-0.018 (0.092)	-0.025 (0.064)	-0.025 (0.060)
Year 2004	-0.030 (0.092)	-0.048 (0.091)	-0.031 (0.092)	-0.039 (0.092)	0.075 (0.062)	0.069 (0.059)
Seasonal variable						
Season	0.147* (0.062)	0.154* (0.062)	0.144* (0.062)	0.146* (0.063)	-0.014 (0.045)	-0.011 (0.042)

Spatial lag and error						
Spatial lag		0.269*		0.081*		0.309*
		(0.032)		(0.001)		(0.080)
Spatial error	0.035*	-0.090*	0.183*			-0.251*
	(0.002)	(0.017)	(0.020)			(0.011)
Number of observation	595	595	595	595	497	497
Residual sum of squares	332.863	317.641	332.666	331.350	105.565	104.350
AIC	1,404.943	1,377.091	1,404.591	1,402.232	700.441	697.688
Spatial LM test	11.451*	0.0001	8.897*	3.585	3.424	3.302

The asterisks represent p-values: * $p<0.05$

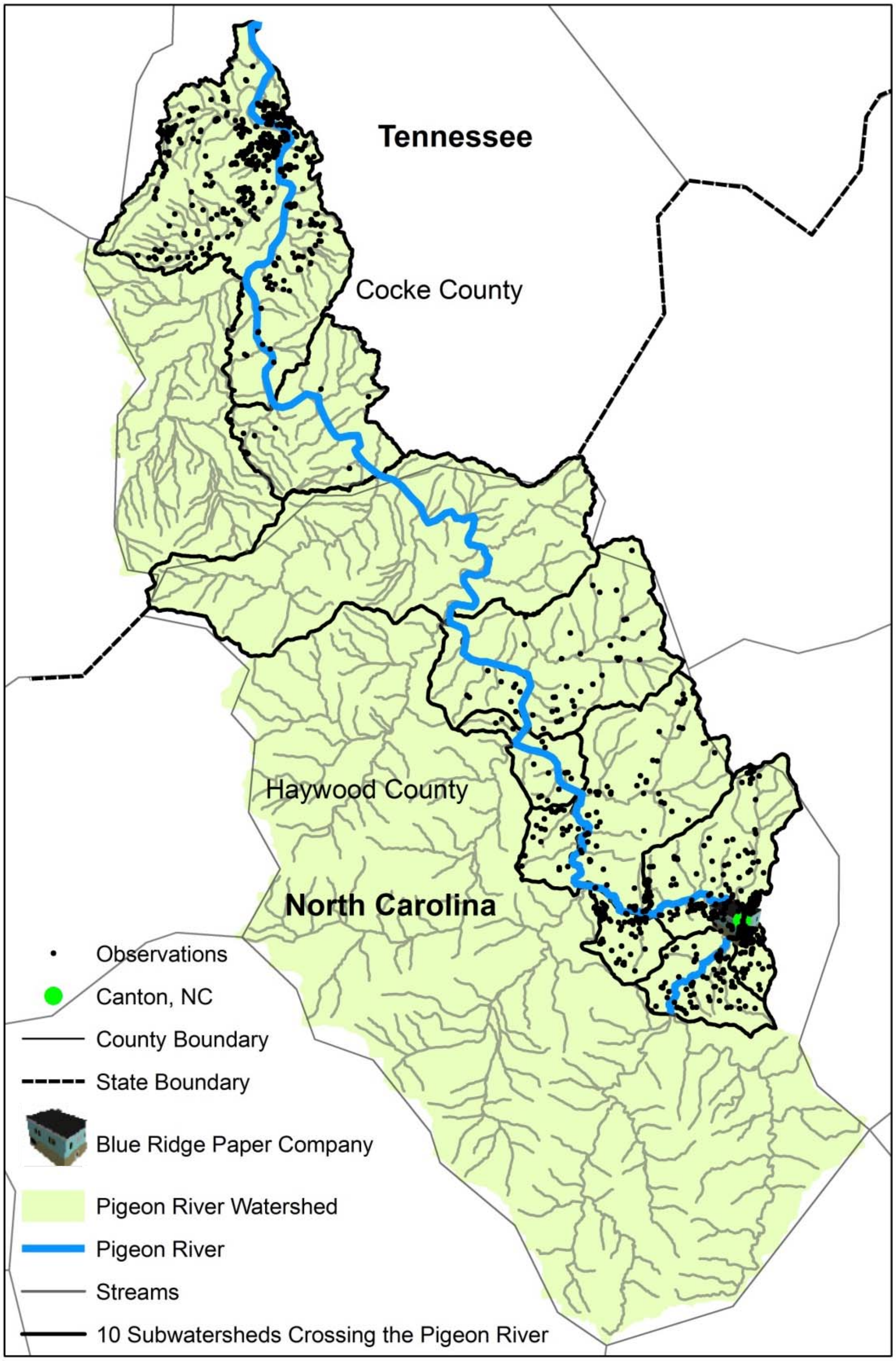

Fig. 1. Pigeon River Watershed in the western half of Cocke County, Tennessee and most of Haywood County, North Carolina.