Riparian Buffers and Hedonic Prices: A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin*

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ABSTRACT

Riparian buffers, the strips of vegetation along banks of rivers and streams, have been proposed as a key instrument to protect water quality in the U.S. Riparian buffers impose a restriction on the use of private property limiting harvest and development, but buffers can also provide for aesthetic and recreational benefits that may accrue to property owners. With data from the Neuse River Basin in North Carolina, this study attempts to provide empirical evidence on the effect of a mandatory buffer rule on the value of riparian properties. Spatial autoregressive hedonic models are estimated within a quasi-experimental framework using the imposition of the buffer rule as the treatment and non-riparian properties as a control group. Results indicate that riparian property generally commands a high premium. We find no evidence, however, that the mandatory buffer rule has had a significant impact on riparian property values when compared with the control group.

Keywords: Hedonic prices, riparian buffers, quasi-experimental analysis, spatial econometrics

JEL Classifications: D12, D63, H31, Q26

I. Introduction

A vegetated riparian buffer is a strip of forested or grassy land adjacent to a water body designed to improve water quality by trapping sediment and nutrients that would otherwise wash into the water body during precipitation events. According to the National Research Council (2002), vegetated riparian buffers perform many critical functions, including but not limited to stream bank stabilization, flood abatement, aquatic habitat improvement, nutrient cycling, sediment retention, and pollutant removal. Additionally, functioning riparian buffers are home to an abundance of animal life (mammals, amphibians, reptiles, invertebrates, etc) and often display a unique assemblage of plants species compared to uplands and wetlands. Research has shown that forested riparian buffers remove between 50% and 80% of nitrogen before it reaches the waterway (Jordan, Correll, and Weller 1993). Vegetated riparian buffers have therefore become a popular management tool to address impaired water quality and threatened populations of aquatic species.[1] Typically, a riparian buffer requires at least 30 feet of forest and grassy vegetation adjacent to a river, stream, or lake. Thus, a regulation requiring riparian buffers limits the use of private property adjacent to water bodies. This limitation often mobilizes property-rights advocates in opposition to the riparian buffer rule; they claim that the rule will diminish their property values. In this paper, we use a quasi-experimental design to explore the impact of a vegetated riparian buffer rule on the value of properties adjacent to the Neuse River in North Carolina.

The Neuse River originates in north central North Carolina and flows approximately 200 miles in a southeasterly direction to the Pamlico Sound. The Neuse River Basin is the third largest basin in North Carolina and is home to approximately 1.5 million people (or 1/6 of North

[1] According to a report by the National Association of State Foresters (1996), 47 states implemented programs to promote forestry Best Management Practices (BMPs), which include establishing riparian buffer zones, to minimize adverse impacts of non-point source pollution on riparian systems.

Carolina's population). Poor water quality in the Neuse River has drawn significant attention for many years. Among all rivers that drain into the Albemarle-Pamlico Sound,[2] the Neuse River delivers the highest amount of non-point source pollutants (35% of total nitrogen and 45% of total phosphorus), while it comprises only 20% of the total land area (http://www.neuse.ncsu.edu/focus.html). Widespread fish kills in 1995 spurred the state to prepare the Neuse River Nutrient Sensitive Waters Management Strategy in 1996.

A riparian buffer rule was proposed as an important tool in the overall portfolio of water quality improvement strategies.[3] To prevent preemptive cutting in the riparian zone, the buffer rule was introduced as an immediate rule by the North Carolina Environmental Management Commission in July 1997. The rule was deemed "temporary" to allow fine tuning of the specific language and definitions in the regulation. Subsequent adjustments were made to address concerns regarding a lack of discretion in implementation (Cooke 1998), and the rule became permanent after legislative review in August 2000. The riparian buffer rule requires that the first 50 feet of riparian land be protected and remain vegetated on the banks of waterways in the area. All streams, lakes, and estuaries in the Neuse River Basin are subject to this rule.

The Division of Water Quality (DWQ) at North Carolina Department of Environment and Natural Resources (NCDENR) regularly monitors compliance with the buffer rule.[4] If a rule violation is identified (i.e. a property owner clearing a protected riparian buffer without prior authorization), a notice of violation is issued. The DWQ requires violating property owners to restore the buffer by replanting 320 trees per acre at maturity. If grass is the only vegetation

[2] The Albemarle-Pamlico Sound is the second largest estuary in the United States and supports a variety of habitats including wetlands, rivers, and creeks. Half of the area used as nurseries by fish from Maine to Florida is provided by the Albemarle-Pamlico Estuarine System (Mallin et al. 2000).

[3] Other provisions of the initiative include reduction of nitrogen from wastewater discharges, better management of urban storm water runoff, and implementation of best management practices and education for agricultural operations in the river basin.

[4] Noncompliance can be also identified by civilian and neighborhood reports.

removed during the violation, then the area must be revitalized with grass. If the damaged area cannot be restored, civil penalties up to $25,000 per day per incidence can be levied toward a watershed mitigation fund (http://h2o.enr.state.nc.us/ncwetlands/RiparianBufferRules.htm).

The legal requirement of riparian buffers clearly places restrictions on the use of private property adjacent to waterways, but at the same time the buffer should improve water quality and may enhance aesthetics of the local environment surrounding a property. Proponents of private property rights reject the legal requirement because the individual owner's ability to develop and use their land is limited. It is clear that a restriction on a land parcel's use should not increase its value (by *Le Chatelier's Principle*). Healthy riparian buffers, however, protect stream banks from erosion, protect buildings and other structures from flood waters, and enhance water quality. If a buffer restriction is simultaneously placed on neighboring properties with the result being an improvement (or expected improvement) in water quality and general aesthetics, then it is possible that such a rule may enhance riparian property values. Since these two effects are countervailing, we require empirical evidence to make an assessment of the effects of riparian buffers in practice. We offer quasi-experimental evidence of the effect of the Neuse River riparian buffer rule on the value of property adjacent to the waterway. Using sales data on both riparian and non-riparian land parcels in Craven County, North Carolina, we are able to control for non-policy related market effects, allowing, under plausible assumptions, isolation of the effect of the buffer rule on riparian properties. Our results indicate that a riparian property generally commands a significant premium compared to an otherwise equivalent property. We find no evidence, however, that the imposition of the buffer rule had a significant impact on the riparian property values in the study area.

II. Effect of Riparian Buffers on Residential Property Values

Existing literature has examined riparian landowner's willingness to accept (WTA) compensation for the restriction on land use implied by a buffer rule. Kline, Alig, and Johnson (2000) and Amigues et al. (2002) each use contingent valuation to value the buffer restriction *ex ante*, producing estimates of the imposed cost under hypothetical conditions and with the status quo property right endowed to the landowner. The data of Kline, Alig, and Johnson, for example, pertain to owners of forested land and suggest that WTA varies by type of landowner, with "recreationists" and "multiple objective" landowners having median WTA close to zero and timber producers having the highest WTA (on the order of hundreds of dollars per acre per year). While the majority of research has been on the owners of agricultural land (e.g., Lynch and Brown 2000; Ryan, Erickson, and De Young 2003), we focus on residential property owners.

Residential property owners differ from agricultural producers in that their use of riparian land is primarily consumptive. As is typical in hedonic models, we assume that attributes of land provide direct utility to homebuyers (Lancaster 1966). The hedonic property price method has been used to estimate the value of water-related amenities—such as proximity, view, and water quality—for residential landowners. Previous studies have shown that proximity to shoreline is highly desirable in residential housing markets (Shabman and Bertelson 1979; Milon, Gressel, and Mulkey 1984; Earnhart 2001; Landry, Keeler, and Kriesel 2003). The literature suggests that residential properties with water views command a price premium (Kulshreshtha and Gillies 1993; Lansford and Jones 1995; Bin et al. 2008), but the premium is influenced by the quality of amenities provided by the water body in addition to the quality of the view (Streiner and Loomis 1995; Benson et al. 1998). Leggett and Bockstael (2000) use hedonic techniques to show that water quality has a significant effect on property values along the Chesapeake Bay.

We are aware of only one published study that attempts to assess the effects of riparian buffers on residential property values. Mooney and Eisgruber (2001) find a negative effect of buffer width on assessed residential property value in Western Oregon. They attribute this result to restricted water view and diminished sunlight penetration (the latter particularly relevant for their generally overcast Western Oregon study site). Their study is motivated by a policy initiative encouraging Oregonians to plant riparian buffers, but their data apply to the period before the policy initiative. As such, their results reflect equilibrium in the residential housing market pre-policy. What their dataset misses, however, are any projected improvements in water quality associated with the policy initiative. If prospective homebuyers perceive that water quality is increasing simultaneously with the policy initiative, they may increase their bid value for riparian property *ceteris paribus*.

Identification of the net effect of a riparian buffer rule requires data both before and after the policy change. In order to control for other temporal factors affecting the residential property market at our study site, we gather data on both riparian and non-riparian property sales and use a difference-in-differences estimator to identify the net effect of the buffer rule on riparian properties. Assuming that macroeconomic, regional, and local factors affecting property values have an equivalent influence on riparian and non-riparian properties, non-riparian properties serve as a control group in isolating the net effect of the buffer rule on riparian properties. The results of our study should provide information for practitioners and policy makers who must deal with decisions regarding riparian buffers.

III. Study Area, Background, and Data

The Neuse River Basin is the third largest river basin in North Carolina, which encompasses approximately 6,192 square miles in 23 counties and supports 1.5 million people. The basin contains 3,293 miles of freshwater streams, about 328,700 acres of salt waters, and thousands of acres of impoundments (North Carolina Department of Environment and Natural Resources (NCDENR) 1993). High nutrient loads have been associated with the Neuse River for a long time. Although the Neuse River Basin comprises only 20% of the total land area that drains into the Pamlico and Albemarle Sounds, the highest nitrogen and phosphorus loads are delivered by the Neuse. The Neuse River contributes 35% of the total nitrogen and 45% of the total phosphorus to the Pamlico and Albemarle Sounds (Spruill and Harned 1997). As a result, portions of the Neuse River were classified as Nutrient Sensitive Waters in 1984, and the entire river received this designation in 1988.

In 1993, the Basinwide Management Plan for the Neuse River Basin was proposed by NCDENR in order to reduce nitrogen discharges from nonpoint sources within the Neuse River Basin. Two years later, in 1995, millions of menhaden, flounder, croaker, and rock fish (indigenous to the estuary) were killed. Record rainfalls during summer 1995 associated with several hurricanes delivered a tremendous load of nitrogen into the Neuse River and lead to algal blooms and subsequently low oxygen levels that then caused fish kills.[5] Collectively, these incidents provided great impetus for NCDENR in 1996 to draft a strategy titled "Neuse River Nutrient Sensitive Waters Management Strategy", often referred to as the Neuse Rules, which set a 30% reduction goal for nitrogen.

Among those, the Riparian Buffer Area Rule plays an important role in the overall nitrogen reduction strategy. The rule was introduced as a temporary rule in July 1997 and after

[5] Pfiesteria piscida were also attributed as an additional cause of the 1995 fish kills.

minor changes became a permanent rule in August 2000.[6] The temporary rule was instituted as an immediate rule in order to prevent preemptive cutting in the riparian zone; those properties without riparian buffers prior to July 22, 1997 were grandfathered as legally non-compliant, while all other riparian properties were subject to the provisions of the Riparian Buffer Area Rule. The rule requires that the first 50 feet of riparian area be protected and maintained on the banks of waterways in the area. The rule applies to all perennial and intermittent streams, lakes, ponds and estuaries in the Neuse River Basin. It protects undisturbed forest vegetation in the first 30 feet of land directly adjacent to any water with few exceptions, while the next 20 feet of land must remain in a dense plant cover with shrubs and other vegetation. A limited amount of harvesting is allowed in the outer 20 feet of the first 30 feet of land while the first 10 feet should remain essentially undisturbed.

The riparian buffer rule generated a great deal of debate among landowners, environmental activists, and policy makers. Some property rights advocates in North Carolina opposed imposition of the buffer rule on the basis that such a rule limits the individual property owner's ability to develop and use their land (Schultz 2002). In addition, the buffer rule prevents property owners from culling riparian trees in order to improve their view of the Neuse River. As such, we might expect the Riparian Buffer Area Rule of the State's Nutrient Sensitive Waters Management Strategy could lead to a diminution in riparian property values. Proponents of the buffer rule touted their environmental benefits—better water quality and improved aquatic habitat. Given the highly publicized water quality problems in the Neuse River, the prospective environmental benefits associated with the protected riparian areas could lead to subsequent increases in riparian property values. In addition, riparian buffers protect property owners'

[6] The permanent rule exempted certain activities within the riparian area provided that they are approved by NCDENR Division of Water Quality. These activities include road crossings and bridges, utility crossings, airport facilities, boardwalks and trails, and boat ramps, docks, and bulkheads.

stream banks from eroding and can offer protection from flood waters. If buyers and sellers of riparian property recognize and respond to these environmental services, riparian buffers could further bolster property values. The magnitude of the countervailing effects is an empirical matter, and while we cannot separately identify the two effects, if our modeling assumptions are valid, we can provide an unbiased estimate of the net effect.

Several GIS and spatial data sources are combined for this study. Geo-coded parcel information was obtained from Craven County GIS Department. The dataset has information about property owner, year built, number of bedrooms, lot size, heated area, land use code, sale year, and sale price. This study uses 3,716 "straightforward" single-family residential property transactions between 1992 and 2002.[7] Sales prices were inflation-adjusted using a Consumer Price Index for housing to report figures in December 2002 dollars. The average home sales price in the data set is $126,496. The houses are on average 18 years old and have 3 bedrooms. The mean lot size is about 0.5 acre and the total heated area is about 1,453 square feet. About a third of the total sales occurred in New Bern which is the largest city in the county.

The stream coverage dataset was selected from the Neuse River watershed streams data obtained from the North Carolina Center for Geographic Information Analysis. We use only permanent rivers and streams of Craven County, since these are the ones subject to the Neuse Buffer Rule. Permanent steams in Craven County are mostly classified by the Strahler stream order classification (Gleyzer et al. 2004; Lanfear et al. 1990) as third or higher order streams, which are perennial streams and therefore subject to the riparian rule. About 6.9% (255) of the total properties sold during the study period are in the riparian zone, 155 of which (60.8% of

[7] Other types of transaction include building or land only sales, consolidation of property, and property splits.

riparian) are sold after the buffer rule. Overall, about 55.8% of the sales occurred after the introduction of the buffer rule in July 22, 1997.[8]

Other geo-coded neighborhood amenities/disamenitites include the distances to nearest swine/hog operation, hazardous substance disposal site, and major highway. We use Euclidean distance in feet from the centroid of each property to the nearest feature of interest. Eastern North Carolina has a high concentration of industrial hog farms, and their operations are often associated with odor and wastewater pollution. Palmquist, Roka, and Vukina (1997) have shown that close proximity to large hog operations have adversely affected real estate property values. In our data, the mean distance to nearest hog operation facility is 7,045 feet, with a minimum of 506 feet and a maximum of 19,889 feet. We also measure the distance to uncontrolled and unregulated hazardous waste sites (formerly called superfund sites) in North Carolina, identified by NCDENR. The mean distance to the hazardous substance disposal site is 6,360 feet, with a minimum of 45 feet and a maximum of 28,345 feet. The mean distance to nearest highway is 1,420 feet. Craven County contains 90,504 ha of wetlands which consist of 49.5% of the total land area in the county. Bin and Polasky (2005) have shown that both proximity to and size of nearest wetland lowers residential property values in eastern North Carolina, where no shortage of either open space or wetlands exists. About 21% of the transacted properties in our data are on wetlands. We control for unobserved heterogeneity across cities in the county using a set of dummy variables. Table 1 provides the definition and description of the variables used in this study as well as summary statistics. Figure 1 presents a map of the study area and the properties affected by the buffer rule.

[8] Our dataset includes day of sale, so we are able to pinpoint pre- and post-policy transactions. One may be concerned about the timing of the policy and the length of property purchase transactions. For example, if someone made an offer one week before the rule, their information actually reflects pre-policy. Our data, however, did not include any transactions for riparian properties among the 28 transactions recorded in July 1997.

In order to provide evidence on the efficacy of the riparian buffer rule, we digitized 1993 (the most recent satellite image available before the buffer rule) and 2007 aerial photography for Craven County in order to assess the extent of riparian buffers both before and after the imposition of the rule. We identified three possible scenarios associated with the rule: 1) a riparian forest buffer has been maintained throughout (most common case); 2) forest has been cut with potential buffer violation; and 3) lack of a forested buffer in 1993 and 2007 (grandfathered cases). Figure 2 displays a pair of aerial photos for our riparian areas which illustrates each of the possible cases. Of the 255 riparian properties sold during the study period, 35 residences (13.7%) did not have a buffer in 2007 (Table 2). Among those, 24 parcels did not have a buffer in 1993, indicating grandfathered cases. Thus, only 11 (4.3% of the total riparian properties) are identified as in potential violation of the buffer rule. For these cases, it is possible that the forested buffer could have been cut in the intervening years before the imposition of the riparian rule (i.e. between 1993 and 1997). Therefore, our possible violations represent a conservative measure of efficacy, or an upper bound on the pervasiveness of violation. In addition, 44 of the riparian properties (or 17.25%) were undeveloped in 1993, indicating some expansion of residential development in the intervening years. Given this and other evidence of development pressure in the area,[9] we conclude that the Neuse River Riparian Area Buffer Rule was in all likelihood a binding regulation in the period of our analysis.

[9] Comparing Craven County with the 24 other counties in the Neuse River watershed and coastal zone, we find that Craven is 12th in population growth (12% increase) and 15th in employment growth (over 13% increase) between 1990 and 2000. This suggests that development pressure and economic growth in the study area is both considerable and somewhat similar to other counties in the watershed and coastal zone.

IV. Methods

This study uses data before and after imposition of the immediate riparian buffer rule to attempt to measure the average effect of the rule on riparian property values. The immediacy of the rule provides rationale for an unanticipated policy shock to the real estate market along the Neuse River. A common problem in using temporal variation in policy, however, is that it is often difficult to distinguish the effect of the treatment from the effect of other contemporaneous variables. For example, changes in housing market conditions stemming from household migration, changes in the local labor market, and land use alterations may affect riparian property values over time, and it may be difficult to separate their influences from the buffer rule. One way to address this issue is to examine the outcome for a comparison group that did not receive the treatment but was otherwise subject to the same contemporaneous influences—a before and after design with an untreated comparison group (Meyer 1995). In this study, the treatment is the imposition of the buffer rule. The treatment group is composed of riparian properties that are subject to the riparian buffer rule after July 1997, and the untreated comparison group is composed of non-riparian properties that do not receive the treatment but experience some or all the contemporaneous influences that affect the treatment group. This quasi-experimental approach requires data on property transactions for the time period before and after the imposition of the buffer rule and for both riparian and non-riparian properties.

The approach utilizing an untreated comparison group with pretest and posttest is known as difference-in-differences. Controlling for spatial dependence among neighboring properties, our difference-in-differences model can be written as:

$$\begin{aligned} ln\, P_{it}^{j} &= \beta_0 + \sum_{k=1}^{K} \beta_k X_{kit} + \gamma_1 d_t + \gamma_2 d^{j} + \gamma_3 d_t^{j} + \varepsilon_{it}^{j} \\ \varepsilon_{it}^{j} &= \lambda W_i \varepsilon + u_{it}^{j} \end{aligned} \qquad [1]$$

where $ln\,P_{it}^{j}$ is the log of price of i^{th} residence for the *j* group sold in the period *t*, X_{kit} is the k^{th} housing attribute for the i^{th} residence in the period *t*, d_t = 1 if sold after imposition of the buffer rule (July 22, 1997) and 0 otherwise, d^{j} = 1 if riparian property and 0 otherwise, d_t^{j} = 1 if the riparian property sold after the buffer rule and 0 otherwise, λ is the spatial autoregressive coefficient, W_i is the *i*th row of the spatial weights matrix, ε is a vector of error terms, and *u* is a vector of independent and identically distributed random error terms. Spatial dependence in property values can arise because neighboring properties share common location features or because they have similar structural characteristics due to contemporaneous construction. If the relevant spatial dependence is ignored in estimation, then the resulting estimates could be inefficient or even inconsistent, and any inference based the estimates may be misleading (Anselin and Bera 1998).

In equation [1], the coefficient γ_3 represents the true causal effect of the imposition of the buffer rule on the riparian property values. The key identifying assumption is that $E[\varepsilon_{it}^{j} | d_t^{j}] = 0$ – the conditional mean of the random error is zero. Then, the unbiased estimate of γ_3 can be obtained by difference-in-differences as:

$$\tilde{\gamma}_3 = \overline{lnP_1^1} - \overline{lnP_0^1} - (\overline{lnP_1^0} - \overline{lnP_0^0}) \qquad [2]$$

where the bar indicates an average value, the subscript denotes the time period, and the superscript denotes the group (Meyer 1995). The coefficient γ_1 captures a raw time effect for both riparian and non-riparian properties. The coefficient γ_2 represents time-invariant differences between riparian and non-riparian properties.

Considerable attention has been given to examining spatial dependence in estimated hedonic equations (Patterson and Boyle 2002; Kim, Phipps, and Anselin 2003; Bin et. al 2008).

The existence of spatial dependence implies that a sample contains less information than an uncorrelated one, and that the loss of information should be acknowledged in estimation to properly carry out statistical inference. Regression diagnostics based on Ordinary Least Squares (OLS) estimation and the Lagrange Multiplier (LM) test statistics suggest the first-order spatial error hedonic model which is given in equation [1]. For this specification, the OLS estimator remains unbiased but is no longer efficient due to the nonspherical error covariance. Efficient estimators are obtained by utilizing the particular structure of the error covariance implied by the spatial process. Spatial autoregressive error models are estimated via maximum likelihood (MLE). The estimation is implemented within the GeoDa v.0.9.5-i (2004) environment in conjunction with ArcView GIS 3.3 extensions.

We report the estimated marginal willingness to pay (WTP) for location attributes (HOG, HWY, WETLAND, and RIPARIAN). As suggested by Halvorsen and Palmquist (1980), the marginal effect for binary variables is calculated by $P \cdot \{\exp(\beta) - 1\}$, where P is the sales price and β is the coefficient of a binary variable. For distance related variables, which are log-transformed, the marginal effect is price times the distance coefficient divided by the distance. All marginal effects are evaluated at the observed mean values. A bootstrapping procedure is used to generate confidence intervals for the marginal willingness to pay (Krinsky and Robb 1986). The procedure generates 5,000 random variables from the distribution of the estimated parameters and computes 5,000 marginal WTP estimates. The marginal WTP estimates are sorted in ascending order, and the 95% confidence bounds are found by dropping the top and bottom 2.5% of the estimates.

V. Results

The spatial weights matrix determines the spatial extent of properties that may share unobserved characteristics generating spatial dependence. Using the methods suggested by Anselin and Bera (1998), we experimented with different weights matrices, and in this analysis use a spatial weights matrix that identifies properties within 0.1 kilometer (328 feet) as nonzero elements. This specification of the spatial weights matrix is based on a comparison of fit for several alternative models using a range of distances. We use quadratic specifications for non-dichotomous structural variables, such as age of house and square footage. We hypothesize that the effect of these attributes on property values declines as the level of the attributes increases. We also use the log of the distance-related variables. The primary results were robust across several alternative specifications, and the current specification provided the best overall fit.

Table 3 reports the estimation results of both the linear (Model I) and the spatial MLE (Model II) without year fixed effects, as well as the linear (Model III) and the spatial MLE (Model IV) with year fixed effects. We consider first models I and II. All the coefficient signs are stable across Model I and Model II. Most coefficients are significant at the 5% level except for the BRIDGETON, HAVELOCK, and VANCEBORO city dummy variable coefficients, $BEDRM^2$, *ln*(HSDS) and RIPARIAN*RULE. Estimation results indicate a significant spatial autoregressive coefficient ($p\text{-value} < 0.0001$) suggesting that spatial dependence in our primary sample of housing prices indeed exists. The difference in the log-likelihood functions between Model I and Model II is large enough to conclude that controlling spatial dependence is necessary in the hedonic price model. The regression results reported hereafter are based on the spatial MLE (Model II).

The coefficient on RIPARIAN is positive and statistically significant. The average riparian property commands a substantial premium, raising the property value by 25.9%. Table 4 reports the estimated marginal willingness to pay (WTP) for location attributes. Evaluated at the sample mean, location in the riparian zone provides a premium of $37,423 over an otherwise equivalent non-riparian house, with lower and upper 95% confidence interval estimates of $26,299 and $48,999, respectively. In our difference-in-differences framework, this WTP estimate represents the time-invariant difference between riparian and non-riparian properties. This result is consistent with previous studies that have found water frontage or proximity commands a substantial premium and raises property values (Shabman and Bertelson 1979; Milon, Gressel, and Mulkey 1984; Earnhart 2001; Landry, Keeler, and Kriesel 2003). We postulate that non-riparian properties are plausibly subject to the same macroeconomic, regional, and local housing market influences as are riparian properties. Thus, the sale of non-riparian properties provides for a viable control group in that they are exposed to the same contemporaneous influences, but not subject to the buffer rule. The coefficient on RULE captures the temporal effect for both riparian and non-riparian properties. Under the assumptions of our difference-in-differences model, the true causal effect of the imposition of the buffer rule on the riparian property values is reflected in the coefficient for RIPARIAN*RULE. This coefficient estimate is not statistically significant. Results suggest that the mandatory buffer rule had no significant impact on riparian property values; one interpretation of the results is that the negative effects of limiting individual property owners' ability to develop and use their land are offset by environmental benefits accruing to property owners. Although the magnitude of the countervailing effects cannot be identified, our estimate of the net effect on property values is statistically insignificant.[10] Models III and IV in Table 3 report the estimation results with the

[10] We experimented with limited datasets with varying time intervals to test the robustness of our result. The causal

year fixed effects. The year fixed effects are included to better control for unobserved annual shocks, including inflation and other factors. As expected, the dummy for sales after the imposition of the rule loses significance, while overall qualitative results remain unchanged. The estimated marginal willingness to pay (WTP) measures for location attributes with the year fixed effects are reported in Table 4.

The coefficient on WETLAND is negative and statistically significant at 5% level. Property location within a classified wetland lowers the value by 3.6% or $4,416 on average with a lower bound of $8,528 and upper bound of $413 for the 95% confidence interval. Reynolds and Regalado (2002) found mixed results on the impact of wetlands on nearby residential property values; wooded and emergent vegetation wetlands had a negative impact on property values while open water and scrub shrub wetlands had a positive value. Shultz and Taff (2004) found negative values for wetlands on land in production agriculture, where wetlands may restrict production and profitability. Bin and Polasky (2005) found that proximity to wetlands lowers property values regardless of wetland type for rural residential properties in Carteret County, North Carolina where no shortage of either open space or wetlands exists.

The coefficient on the distance to nearest hog operation has a statistically significant and positive sign, implying that proximity to such facilities is undesirable. This result is consistent with Palmquist, Roka, and Vukina (1997) in that close proximity to large hog operations adversely affects real estate property values. Recent interviews with people living near large hog operations revealed that households in these communities are more likely to report headache, runny nose, sore throat, and excessive coughing, and their quality of life, as indicated by the number of times residents could not open their windows or go outside even in nice weather, is

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effect of the imposition of the buffer rule on the riparian property values remained insignificant for the narrow transaction periods of 5 years from1995 to 1999 (1624 obs), 3 years from 1996 to 1998 (1008 obs), and 1 year in 1997 (335 obs). The net effect on property values was consistently insignificant in these narrower time intervals.

greatly reduced (http://www.unc.edu/news/archives/feb00/wing4020800.htm). Our results suggest decreasing distance to nearest hog operation by 1,000 feet decreases property value by $1,227, *ceteris paribus*, with lower and upper 95% confidence interval estimates of $674 and $1,760, respectively. Distance to nearest hazardous waste site has a negative influence to property values, but the negative impact was statistically insignificant. The average property values decrease by $4,503 in moving 1,000 feet closer to nearest highway, *ceteris paribus*, evaluated at the mean price and distance.

All coefficients on the structural characteristics have the expected signs and are statistically significant at one percent level. The quadratic specification seems to capture diminishing marginal effects for age, square footage, and lot size. Evaluated at the average house value, results indicate that house price increases by $96 per additional square foot. An additional year of house age lowers the estimated sales price by $1,879 evaluated at observed mean values. An additional bedroom increases the average property value by $17,535, *ceteris paribus*. Location within the city of New Bern is also highly desirable, raising the property values by 14.9% compared to a property located outside the city limit.

VI. Conclusions

This study offers quasi-experimental evidence of the effect of the mandatory riparian buffer rule on riparian housing values. With property transaction data on both riparian and non-riparian land parcels in Craven County, North Carolina, we attempt to control for non-policy related market effects using a difference-in-differences approach. A spatial autoregressive model is used to account for spatial dependence among neighboring properties. Our results indicate that a riparian property generally commands a high premium compared to an otherwise equivalent non-riparian property. Evaluated at the sample mean, it provides a premium of $37,423 over an otherwise equivalent house. However, we do not find that the imposition of the buffer rule in 1997 lowered the riparian property values in the study area in comparison with a control group of non-riparian properties.

The validity of this result could be compromised or limited in a number of ways. The maintained assumption for the difference-in-differences approach is that the idiosyncratic error term is uncorrelated with the policy-riparian interaction term (γ_3 above). Any omitted variables that could have attenuated the policy-riparian interaction term, such as unobserved shocks in supply or demand of riparian parcels, would possibly lead to erroneous inference regarding the policy. As a robustness check, we estimate auxiliary regressions that focus on a narrower window of property sales, fives years (1995 - 1999), three years (1996 - 1998), and one year (1997) around the policy intervention. The smaller time series help to eliminate concern over omitted time variables that could have affected riparian property values after the policy intervention (e.g. a demand shock in 2000 that lowered bids for riparian properties vis-à-vis non-riparian). While the smaller sample sizes increase standard errors overall, in each of the models the policy-riparian term is insignificant. In addition, the difference-in-differences design does not provide a counterfactual for prospective post-policy effects that would have been unique to the treatment group. For example, potential investments in the riparian zone that could only be realized in the absence of a riparian buffer are not accounted for. Lastly, while we've shown that Craven County is similar to surrounding counties in terms of economic growth, we cannot be certain that our pattern of results would persist for different counties in the watershed, other watersheds, or other states.[11] Unfortunately, we do not have data at hand to run a similar analysis for other counties.

We note that there are two countervailing effects associated with the imposition of the riparian buffer rule. The legal requirement of riparian buffers clearly places restrictions on the use of private property adjacent to waterways, but at the same time improves water quality and may enhance aesthetics of the local environment surrounding a property. Although a restriction on a land parcel's use should not increase its value, a simultaneous restriction on neighboring properties that is expected to improve water quality and general aesthetics may enhance riparian property values. Our results provide an indication that there may indeed exist such a positive effect associated with the imposition of a riparian buffer rule, and that this positive effect may offset the negative effects of the restriction.

It is important to note that our estimates provide only a limited measure of total economic benefits of riparian buffers as perceived by nearby residential property owners. Riparian buffers improve water quality and aquatic habitat by trapping sediment and nutrients that would otherwise wash into the water body during precipitation events. The value of these services is likely not to be fully reflected in property value. In such case, protection of riparian buffers in rural areas such as eastern North Carolina will likely have to be made on grounds other than appeals to increased property value from environmental protection. Evidence that buffer rules may not have significant adverse effects on riparian property values, however, may help resource managers and policy makers make informed policy decisions.

[11] An alternative strategy would utilize riparian properties in a different county, in which no riparian buffer rule was promulgated, as the control group. This approach is complicated by the difficulties inherent in ensuring that the counties are otherwise similar.

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Table 1. Definition and Summary Statistics for Variables

Variable	Definition	Mean	Std. Dev.
PRICE	Sales price adjusted to 2002 dollars	126496.360	74528.840
BRIDGETON	Bridgeton township (= 1)	0.002	0.046
COVER CITY	Cove City township (= 1)	0.002	0.040
DOVER	Dover township (= 1)	0.002	0.049
HAVELOCK	Havelock township(= 1)	0.136	0.343
NEW BERN	New Bern township (= 1)	0.332	0.471
RIVER BEND	River Bend township (= 1)	0.088	0.284
TRENT WOODS	Trent Woods township (= 1)	0.100	0.300
VANCEBORO	Vanceboro township (= 1)	0.009	0.097
AGE	Age of house	18.473	21.238
BEDRM	Number of bedrooms	2.959	0.569
LOTSIZE	Total lot size measured in acres	0.512	0.704
SQFT	Total structure square footage	1452.900	449.430
HOG	Distance in feet to nearest swine/hog operations	7045.350	3305.320
HSDS	Distance in feet to hazardous substance disposal sites	6359.860	4995.070
HWY	Distance in feet to major highways	1419.580	1517.140
WETLAND	On wetland (= 1)	0.207	0.405
RIPARIAN	On riparian zone (= 1)	0.069	0.253
RULE	Sold after the riparian buffer rule (= 1)	0.558	0.497

Note: Number of observations is 3,716.

Table 2. Distribution of Residential Development and Riparian Buffer

Residential Development		Riparian Buffer	
		No	Yes
1993			
	Undeveloped	0 (0.00%)	44 (17.25%)
	Developed	27 (10.59%)	184 (72.16%)
2007			
	Undeveloped	0 (0.00%)	0 (0.00%)
	Developed	35 (13.73%)	220 (86.27%)

Notes: Number of observations is 255 which are sold during the study period in the riparian zone subject to the buffer rule. For those 35 residences that did not have a buffer in 2007, 24 parcels did not have a buffer in 1993 which indicated the grandfathered case. Also, the forested buffer could have been cut in the intervening years before the imposition of the riparian rule (i.e. between 1993 and 1997).

Table 3. Estimation Results of the Hedonic Price Models

	Model I – Linear MLE (without Year Fixed Effects)			Model II - Spatial MLE (without Year Fixed Effects)		
Variable	Coefficient	Std. Err.	P-value	Coefficient	Std. Err.	P-value
Constant	9.525	0.183	0.0000	9.381	0.200	0.0000
BRIDGETON	0.195	0.128	0.1270	0.191	0.141	0.1763
COVER CITY	-0.494	0.146	0.0007	-0.432	0.137	0.0016
DOVER	-0.352	0.121	0.0035	-0.255	0.121	0.0344
HAVELOCK	-0.032	0.023	0.1545	-0.012	0.027	0.6714
NEW BERN	0.109	0.018	0.0000	0.149	0.021	0.0000
RIVER BEND	0.189	0.026	0.0000	0.246	0.032	0.0000
TRENT WOODS	0.341	0.023	0.0000	0.400	0.027	0.0000
VANCEBORO	-0.179	0.067	0.0077	-0.069	0.071	0.3253
AGE	-0.019	0.001	0.0000	-0.019	0.001	0.0000
AGE^2	1.22e-04	5.50e-06	0.0000	1.15e-04	5.80e-06	0.0000
BEDRM	0.129	0.056	0.0204	0.111	0.053	0.0376
$BEDRM^2$	0.005	0.009	0.5474	0.005	0.008	0.5630
LOTSIZE	0.152	0.020	0.0000	0.176	0.019	0.0000
$LOTSIZE^2$	-0.015	0.002	0.0000	-0.017	0.002	0.0000
SQFT	0.001	6.27e-05	0.0000	0.001	6.05e-05	0.0000
$SQFT^2$	-1.09e-05	1.82e-06	0.0000	-9.28e-06	1.73e-06	0.0000
ln(HOG)	0.038	0.014	0.0064	0.068	0.016	0.0000
ln(HSDS)	-0.001	0.010	0.9342	-0.003	0.011	0.7930
ln(HWY)	0.038	0.006	0.0000	0.051	0.007	0.0000
WETLAND	-0.032	0.015	0.0395	-0.036	0.017	0.0336
RIPARIAN	0.216	0.037	0.0000	0.259	0.036	0.0000
RULE	0.094	0.012	0.0000	0.104	0.011	0.0000
RIPARIAN*RULE	0.044	0.047	0.3478	0.003	0.042	0.9497
LAMBDA				0.349	0.016	0.0000
AIC	2807.160			2469.590		
Log Likelihood	-1379.580			-1210.796		

Notes: Dependent variable is the log of adjusted sales price. Number of observations is 3,716.

Table 3. Estimation Results of the Hedonic Price Models - continued

	Model III – Linear MLE (with Year Fixed Effects)			Model IV - Spatial MLE (with Year Fixed Effects)		
Variable	Coefficient	Std. Err.	P-value	Coefficient	Std. Err.	P-value
Constant	9.506	0.185	0.0000	9.356	0.200	0.0000
BRIDGETON	0.181	0.127	0.1549	0.174	0.140	0.2145
COVER CITY	-0.464	0.145	0.0014	-0.397	0.135	0.0034
DOVER	-0.380	0.120	0.0016	-0.279	0.120	0.0198
HAVELOCK	-0.033	0.023	0.1502	-0.010	0.027	0.7087
NEW BERN	0.105	0.018	0.0000	0.144	0.021	0.0000
RIVER BEND	0.191	0.026	0.0000	0.247	0.032	0.0000
TRENT WOODS	0.340	0.023	0.0000	0.401	0.027	0.0000
VANCEBORO	-0.194	0.067	0.0036	-0.084	0.070	0.2323
AGE	-0.019	0.001	0.0000	-0.019	0.001	0.0000
AGE^2	1.23e-04	5.47e-06	0.0000	1.17e-04	5.77e-06	0.0000
BEDRM	0.124	0.055	0.0246	0.109	0.053	0.0392
$BEDRM^2$	0.006	0.009	0.4817	0.005	0.008	0.5266
LOTSIZE	0.152	0.019	0.0000	0.175	0.019	0.0000
$LOTSIZE^2$	-0.015	0.002	0.0000	-0.016	0.002	0.0000
SQFT	0.001	6.24e-05	0.0000	0.001	6.00e-05	0.0000
$SQFT^2$	-1.11e-05	1.81e-06	0.0000	-9.46e-06	1.71e-06	0.0000
ln(HOG)	0.035	0.014	0.0101	0.066	0.015	0.0000
ln(HSDS)	-0.002	0.009	0.8189	-0.005	0.011	0.6492
ln(HWY)	0.037	0.006	0.0000	0.049	0.007	0.0000
WETLAND	-0.037	0.015	0.0148	-0.042	0.017	0.0120
RIPARIAN	0.212	0.037	0.0000	0.256	0.036	0.0000
RULE	-0.032	0.039	0.4186	-0.017	0.035	0.6303
RIPARIAN*RULE	0.050	0.047	0.2868	0.008	0.042	0.8490
LAMBDA				0.354	0.016	0.0000
AIC	2767.110			2421.140		
Log Likelihood	-1349.550			-1176.572		

Notes: Dependent variable is the log of adjusted sales price. Number of observations is 3,716.

Table 4. Marginal Willingness to Pay for Location Attributes

Variable	Marginal Willingness to Pay		
	95% Lower Bound	Mean	95% Upper Bound
Without Year Fixed Effects			
HOG	$673.77	$1,226.65	$1,760.20
HWY	$3,291.08	$4,503.11	$5,701.14
WETLAND	-$8,528.00	-$4,416.15	-$413.30
RIPARIAN	$26,299.25	$37,423.17	$48,998.86
With Year Fixed Effects			
HOG	$659.92	$1,190.14	$1,740.39
HWY	$3,208.71	$4,386.42	$5,587.84
WETLAND	-$9,106.35	-$5,184.98	-$1,227.78
RIPARIAN	$25,915.67	$36,837.63	$48,490.28

Notes: The marginal willingness to pay for HOG and HWY are evaluated at the observed mean values. A marginal change is defined as a 1,000 feet increase in distance. The marginal willingness to pay for WETLAND and RIPARIAN is calculated by following Halvorsen and Palmquist (1980). A bootstrapping procedure is used to generate 95% confidence intervals for the marginal willingness to pay (Krinsky and Robb 1986). The reported confidence intervals are based on 5,000 sets of random parameter vectors from the distribution of the estimated parameters.

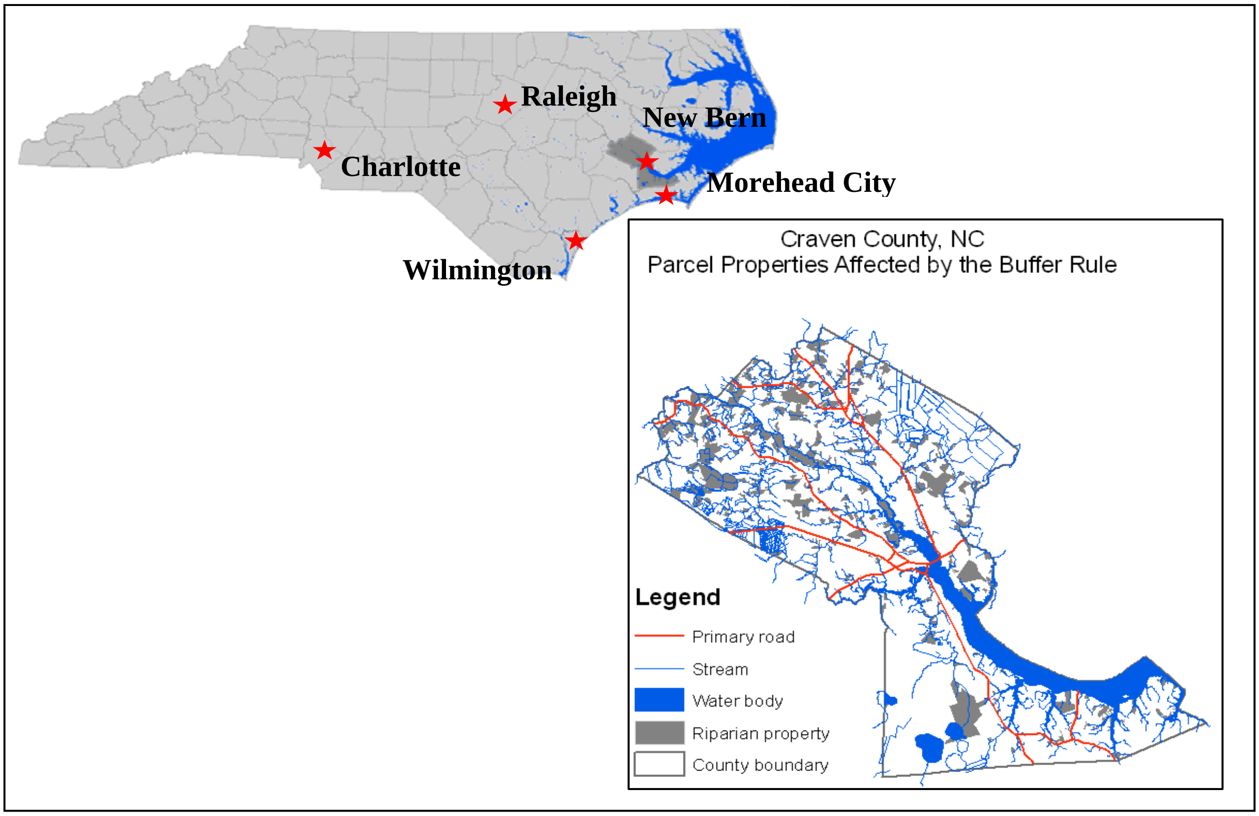
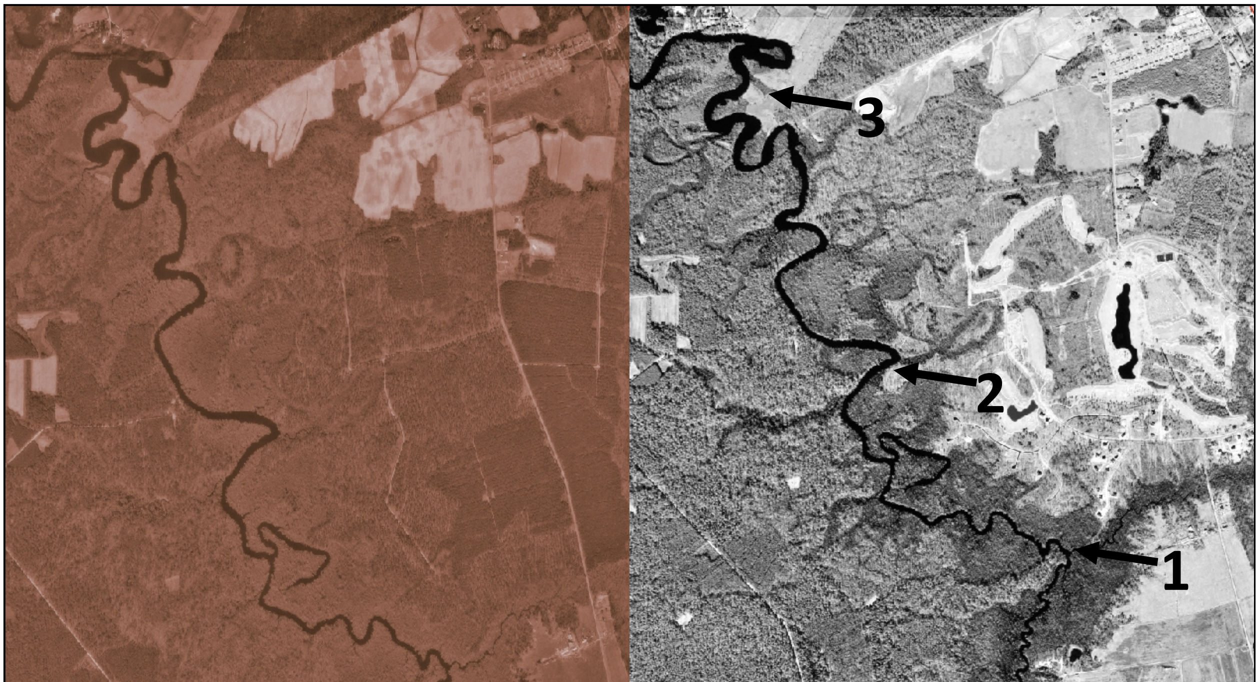


Figure 1. Map of Craven County, North Carolina, and Riparian Properties Affected by the Buffer Rule



1993 2007

Figure 2. Digitized Imagery of the Riparian Buffers in Craven County Before and After the Rule

Notes: Illustrated are three possible scenarios: 1) a riparian forest buffer has been maintained throughout (most common case); 2) forest has been cut with apparent buffer violation; and 3) lack of a forested buffer in 1993 and 2007 (grandfathered case).