A Hedonic Analysis of Environmental Zoning: Lake Classification in Vilas County, Wisconsin

Michael M. Papenfus
Bill Provencher
University of Wisconsin-Madison

November 2005

Abstract
In this paper, we use hedonic analysis of the market for lakeshore properties to evaluate the effect of the 1999 Vilas County, Wisconsin Lake Classification, which tightened minimum shoreline frontage restrictions across the county, ostensibly to preserve the environmental goods and services provided by county lakes. The analysis employs Hausman-Taylor (1981) estimation to account for the endogeneity of lakeshore development. We find that on balance the Lake Classification has raised the value of shoreline, even for undeveloped parcels, and that, as measured by its effect on the value of undeveloped parcels, the Lake Classification has not gone "too far".

A Hedonic Analysis of Environmental Zoning: Lake Classification in Vilas County, Wisconsin

I. Introduction

In the forty years prior to 1999, the development of lakeshore property in northern Wisconsin increased steadily, prompting a number of towns to pass minimum shoreline frontage requirements (MSFRs) – ordinances mandating that the shoreline frontage of any newly-created residential shoreline parcel must exceed a specified minimum length –that were stricter than those required by the State of Wisconsin. In 1999, Vilas County adopted a comprehensive lakeshore ordinance, the Vilas County Lake Classification (hereafter called "Lake Classification"), in which lakeshore development restrictions –in particular, MSFRs –vary across lakes, depending in part on a lake's ecological sensitivity to shoreline development. In this paper, we develop a theoretical framework for assessing the price and welfare effects of MSFRs, and then use hedonic analysis to examine the price effects of the Lake Classification. We summarize our findings momentarily. First, though, we set the context by outlining the Lake Classification, and by discussing the relevant literature.

The Lake Classification

Vilas County, Wisconsin lies in the northeast corner of the state. It has over 1300 lakes, of which several hundred are greater than 100 acres, and is the only county in the state with more seasonal than permanent residences (56.2% vs. 40.5%, with 3.3% recorded as "vacant"; data supplied by the University of Wisconsin Applied Population Laboratory, 2005). A 1965 Wisconsin statute (Wisconsin Administrative Code Chapter NR 115) requires that unsewered residential shoreline parcels must have at least 100 feet of frontage, and be at least 20 thousand square feet. Previous to this, some towns of Vilas County were already adopting stricter shoreline development ordinances, beginning with the town of Presque Isle, which in 1959 passed a shoreline development ordinance setting the minimum lake frontage for a residential parcel at 200 feet. By the late 1990's, seven of Vilas County's fourteen towns had passed lakeshore development ordinances stricter than the state law, with all of them setting the minimum frontage at 200 feet.

Alarmed by the rapid rate of lakeshore development, the Wisconsin Department of Natural Resources developed a grant program in the mid 1990s to provide funds to counties for the purpose of developing a lake classification system in which lakeshore development restrictions are customized to the particular features of lakes. Taking advantage of the program, in 1999 Vilas County adopted the VCLC, in which every lake in the county is classified according to its 1999 level of development and its ecological sensitivity. The classification is based on three classes of lakeshore development, and three classes of ecological sensitivity, yielding a nine-cell matrix of lake classes. Development controls are strictest on lakes classified as low-development, high-sensitivity (LD-HS lakes), and most relaxed on lakes classified as high-development, low-sensitivity (HD-LS lakes). The most salient features of the controls are minimum lot size (60,000 square feet for LD-HS lakes, 30,000 feet for HD-LS lakes) and minimum lake frontage (300 feet for LD-HS lakes, 150 feet for HD-LS lakes), and a mitigation feature in which property owners wishing to build an addition or new structure greater than 300 square feet within 300 feet of the shoreline must accumulate "mitigation points" by undertaking mitigation activities, such as moving a principle structure within 75 feet of the shoreline to a location beyond 75 feet (3 points), and creating a 10-foot buffer along the side of the lot (1 point). The required mitigation varies across lake classes, ranging from 6 points for LD-HS lakes to 4 points for HD-LS lakes. Town ordinances that are more strict than the lake classification supersede it; so, for instance, the minimum frontage requirement for a new lot on an HD-LS lake in the town of Presque Isle is not the classification-mandated 150 feet, but rather the

town-mandated 200 feet.

Related Research

Showing empirically that zoning affects land values is a surprisingly elusive enterprise. As noted by Fischel (1990), McMillan and MacDonald (1991a, 10091b, 2002), and others, in general an interzonal price gradient in an urban area reveals potential gains from trade that a community can exploit in the long run by altering the form and geography of its zones. As a consequence, cross-sectional empirical analyses may find no significant effect of zoning on land prices. The empirical analysis presented in this paper circumvents this problem. Like Chicago's 1923 zoning ordinance studied by McMillan and MacDonald (2002), the Lake Classification provides a natural experiment for examining the effect of zoning on property values. Data are available on market sales both before and after the classification took effect, and development restrictions created by the classification vary across lakes. This allows us to isolate the effects of the classification from unobserved serial and cross-sectional covariates.

So-called "Environmental Zoning" –zoning to preserve environmental amenities –manifests a distinctly different issue of endogenous zoning that is also addressed by the natural experiment of our study. Quite simply, protective environmental zones are located where the amenities are. This leads to the problem of separately identifying the effects on land values of both the amenities and the zoning ordinances designed to protect them. In an examination of the price of lakeshore parcels along Lake Michigan, Colwell and Dehring (2005), find that two lakeshore zoning ordinances have no significant effect on lakeshore property prices, though they note this is possibly due to the aforementioned endogeneity problem. Netusil (2005) examines the effect of environmental zoning in Portland, Oregon. Empirical results are mixed; they find that environmental zoning raises property prices in some areas and lowers it in others. Spalatro and Provencher (2001) analyzed market sales of undeveloped lakeshore property in Vilas County over the period 1986-1995. The zoning ordinances examined were town-level minimum frontage ordinances adopted by seven of the fourteen towns of Vilas County as of 1995. In all seven towns, the ordinance raised the minimum frontage requirement for new lots from the state-mandated 100 feet to 200 feet. Because the town ordinances were uniform across lakes, endogeneity bias associated with zoning was deemed to be minimal. The authors concluded that overall the town-level minimum frontage requirement served to increase the price per foot of undeveloped lake frontage. The authors concluded though,

> "Constraining every lakefront property in a town to a minimum 200 feet of frontage has the virtue of simplicity and perhaps political expediency, but it is also capricious. It does not address the clear implication of the study that the net gains from minimum frontage zoning vary from lake to lake. An alternative is to limit development on some lakes, and to allow the market free reign on other lakes, based on lake characteristics and the current state of lakefront development. Defining zoning categories and allocating lakes across categories are matters for which careful economic analysis can provide insights." (p. 481).

The Vilas County Lake Classification imposes just such a lake-by-lake regulatory approach: while the MSFR on no lake is less than pre-1999 levels, some lakes have become *much* more restrictive under the lake classification, and others have become slightly more restrictive.

In this paper we make several contributions to the understanding of environmental zoning. First, we present a theoretical model demonstrating that minimum frontage zoning can improve aggregate welfare, showing too that such zoning can go "too far", causing the value of lakeshore property to fall. Moreover, we demonstrate that the structural approach taken in Vilas County –varying ordinances across lakes, rather than imposing a uniform ordinance on all lakes –has great potential to improve social welfare, especially in the long run, as it allows individuals to sort themselves across lakes according to their preferences over levels of lakeshore development.

Second, in the empirical analysis of the Lake Classification we present estimation results that we believe are relatively free of endogeneity bias. We avoid endogeneity issues associated with zoning by virtue of the natural experiment afforded by the data, and we use Hausman-Taylor estimation to address the endogeneity of lakeshore development, treating the data set as an unbalanced panel of I lakes, each with T_i observed market sales.

Like Spalatro and Provencher (2001), and Netusil (2005), the analysis distinguishes two competing effects from environmental zoning, a negative "development" effect arising because the Lake Classification constrains how shoreline property owners can develop their land, and a positive "amenity" effect arising because such development constraints increase the expected future flow of environmental goods and services from lakeshore living. We conclude that on balance, and at the current margin, the Lake Classification serves to increase shoreline property values compared to the baseline state-level MSFR, with the preferred model indicating that even among undeveloped "vulnerable" parcels for which the Lake Classification is potentially harmful, 70% are estimated to be more valuable under the Lake Classification. A related but distinct issue is whether the Lake Classification has gone "too far", in the sense that the value of these undeveloped parcels would rise still more if the Lake Classification were relaxed somewhat (reduce slightly the MSFR on each lake). The available empirical evidence argues that the answer to this question is "no".

II. The Economic Rationale for Lakeshore Zoning

The most salient feature of lakeshore zoning ordinances are minimum frontage requirements, and the following analysis reflects this. We begin with a model in which all lakeshore is undeveloped and the same, and all lakeshore owners have identical preferences. The total length of shoreline is T. Development along a lake impacts the amenity flow to each parcel on the lake. We assume that the amenity flow is determined by the density of lakeshore development. This is captured by the amenity function $A(K)$, where K is the total capital along the lakeshore. The amenity function is decreasing in K.

Let f denote the size of a lakeshore parcel, measured in terms of lakeshore frontage, let k denote the capital on the parcel, and let x denote the consumption of a composite good with price normalized to unity. The utility of a parcel owner (no one owns more than one parcel) is denoted by $U\left(f, k(f), A(K), x\right)$.[1] It is not possible to enjoy the amenities of a lake without *both* strictly positive frontage and strictly positive capital. Status quo utility –that is, utility in the absence of lakeshore property –is $U^y \equiv U(0,0,0,y)$, where y is income.

We define $W\left(f, k, A(K), y, U^y\right)$ as the willingness-to-pay (WTP) function for a lakeshore parcel of size f. It is the amount paid by an individual for frontage f and capital k on a lake with amenity flow $A(K)$ that leaves him no worse off than he would be without lakefront property. Formally, it is the solution to

$$U^y = U\left(f, k, A(K), y - W\right) .$$

Assuming that U is nondecreasing in f, k, A, and y, W is also nondecreasing in f, k, A, and y.

[1] Presumably utility depends on *how* capital k is allocated along the property's shoreline. In this case our utility function is the conditional indirect utility function with capital best distributed along the shoreline.

Consider now the problem of a planner choosing *f* to maximize the net benefit of lakeshore development. Given the planner's choice of *f*, lakeshore owners choose the level of capital satisfying,

$$\frac{\partial W}{\partial k} = c\,, \tag{1}$$

where *c* is the exogenous price of capital. Denote by $k(f)$ the lakeshore owner's choice of capital, the planner's problem can be stated as,

$$\max_f \frac{T}{f}\cdot\left[W\left(f, k(f), A\left(\frac{k(f)T}{f}\right), y, U^y\right) - c\cdot k(f)\right], \tag{2}$$

where T/f is the number of lakeshore property owners, and the bracketed expression is the net value of a lakeshore parcel of size *f*. The first-order necessary condition is

$$\frac{(W - c\cdot k)}{f} = \frac{\partial W}{\partial f} + \frac{T}{f}\left[\frac{\partial W}{\partial A}\frac{\partial A}{\partial K}\cdot\left(\frac{\partial k}{\partial f} - \frac{k}{f}\right)\right]. \tag{3}$$

At the solution, the average net benefit of frontage is equal to the private marginal benefit of frontage plus the social marginal amenity benefit of an increase in parcel size, which arises because an overall increase in parcel size reduces capital intensity on the lake (note that T/f is the number of parcel owners) . Critical to the analysis –and to the justification for minimum frontage zoning –is the assumption that the lakefront owner's choice of capital is decreasing or inelastic in frontage. To show this, we multiply the amenity benefit of a marginal increase in frontage by the positive constant $\frac{f}{k}$ to obtain

$$\frac{T}{k}\cdot\frac{\partial W}{\partial A}\cdot\frac{\partial A}{\partial K}\cdot\left(\varepsilon_{kf} - 1\right),$$

where ε_{kf} is the elasticity of capital with respect to frontage. If ε_{kf} <1, then this amenity benefit is positive, as assumed in the analysis below; increasing the frontage of each ownership reduces the density of capital on the lake, thereby increasing the flow of amenities. If ε_{kf} >1 , then increasing frontage serves to *increase* the density of capital on the lake, and thus planners should pursue *maximum* frontage zoning.

Now compare this to the market outcome under zoning. The market generates a solution to a problem similar to that of the planner, except that the amenity level is treated parametrically –the amenity is not a private good chosen by lakefront property owners –and frontage is constrained by the MSFR. Formally this problem is,

$$\max_f \frac{T}{f}\cdot\left[W\left(f, k(f), A, y, U^y\right) - c\cdot k(f)\right] \quad \text{s.t.} \quad f \geq MSFR. \tag{4}$$

Letting λ denote the Lagrange Multiplier for the inequality constraint, the first-order condition for an interior solution is,

$$\frac{W - c \cdot k}{f} - \lambda = \frac{\partial W}{\partial f}. \tag{5}$$

A comparison of (3) and (5) motivates the economic rationale for minimum frontage zoning. When the MSFR equals f^*, the welfare-maximizing frontage length, then

$$\lambda = \frac{T}{f}\left[\frac{\partial W}{\partial A}\frac{\partial A}{\partial K}\cdot\left(\frac{\partial k}{\partial f} - \frac{k}{f}\right)\right].$$

In the absence of zoning, MSFR=0, and so $\lambda = 0$ under the assumption that lake shoreline is desirable, and the market solution is inefficient because the amenity benefit of frontage is external to the market. This is illustrated in Figure 1. In the figure we define the per-parcel social benefit of parcels of size *f* as

$$SNB(f) = W\left(f, k^*(f), A\left(\frac{k(f)T}{f}\right), y, U^y\right) - ck^*(f),$$

and we define the private benefit of parcel size *f*, where all other parcels are size $\tilde{f}$, as

$$PNB\left(f, \tilde{f}\right) = W\left(f, k^*(f), A\left(k\left(\tilde{f}\right)\right), y, U^y\right) - ck^*(f).$$

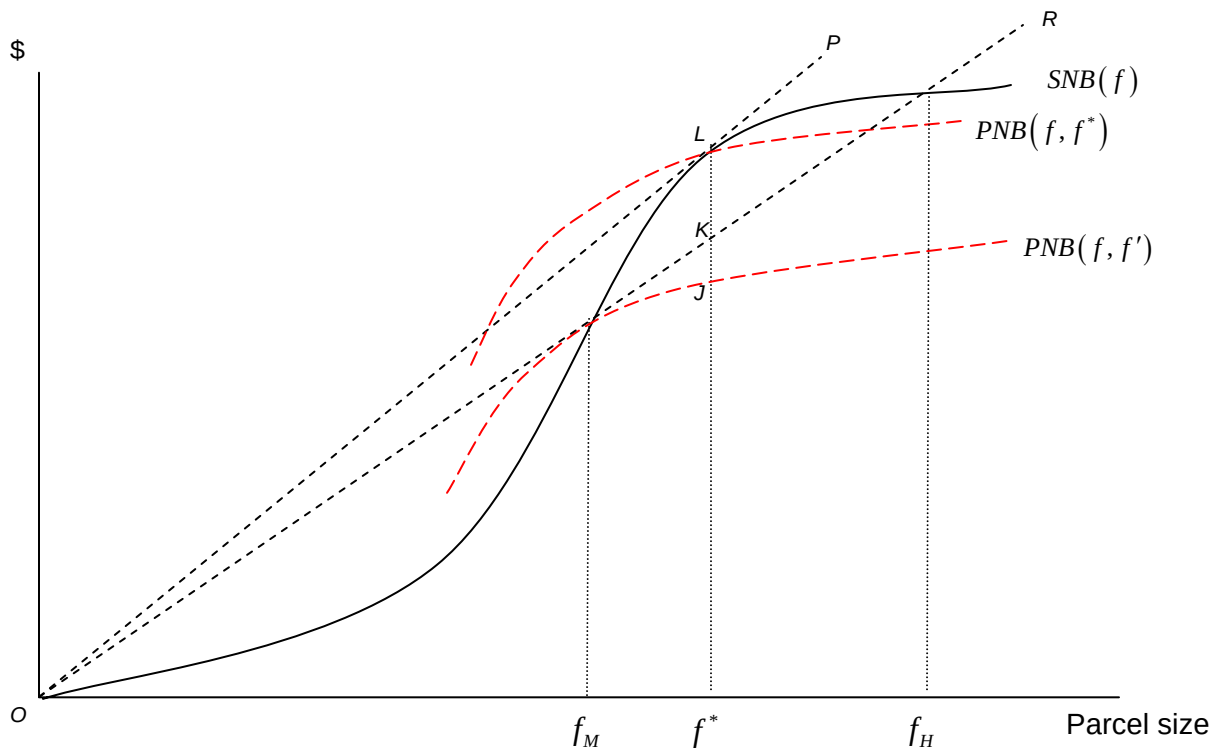
At low levels of *f*, net benefits are convex in frontage.

Aggregate welfare is maximized where the *average* net benefit of frontage is just equal to the *marginal* net benefit per parcel –parcel size f^* in Figure 1, as determined by the tangency between chord OP and $SNB(f)$. Figure 1 indicates that at this amount of frontage per parcel, the *private* net benefit of frontage is too low at the margin to be a viable equilibrium in the marketplace. In particular, letting *p* denote the market price of shoreline, $p = \frac{\partial PNB}{\partial f}$, equation (5) indicates that a market equilibrium requires $p = \frac{\partial PNB}{\partial f} = \frac{PNB}{f}$, where *p* is the market price of frontage, but at f^*, $\frac{PNB}{f} > \frac{\partial PNB}{\partial f}$, in which case all parcel owners would attempt to sell frontage from their parcels. In Figure 1, the market equilibrium parcel size is f_M, and the market price is given by the slope of chord OR.

To understand the amenity and development effects in the context of Figure 1, suppose an individual owns a parcel on a lake where initially all parcels are size f^*. If *only* the individual's parcel were constrained to remain at f^*, and all other parcels in the system were unregulated, the individual would suffer the loss JK –the development effect. This loss arises because under the circumstances the best move by the individual would be to sell frontage $f^* - f_M$ off his parcel at the market equilibrium price given by the slope of chord OR. But if *all* properties on the lake are constrained to remain at f^*, the parcel owner gains JL compared to the unregulated market –the amenity effect –for a net gain of KL.

With reference to Figure 1, setting the MSFR at a value in the range (f_M, f_H) would raise aggregate welfare relative to the unregulated market. In this range, the positive amenity effect of zoning outweighs the negative development effect. Above f_H this is no longer true.

Figure 1. Optimal and market sizes of lake shoreline parcels



The effect of heterogeneity in the model: an example

When not all lakes are the same, or not all people are the same, it is generally no longer optimal to impose a common MSFR along the aggregate lake shoreline. To accommodate the notion that different types of people end up on different lakes, the discussion below recognizes that the total lakeshore T is divided among a number of identical lakes, and that the amenity function $A(\cdot)$ is relevant at the lake level only; what matters to an individual on lake j is not the total amount of capital along the aggregate lakeshore T, but rather the amount of capital along the lakeshore of lake j. The amenity function takes the general form, $A(K_j)$.

Figures 2-3 present two scenarios involving two types of individuals. Type I individuals are not bothered by the accumulation of capital:

$$\frac{\partial W_I}{\partial A_j} \equiv 0,$$

whereas type II individuals *are* bothered:

$$\frac{\partial W_{II}}{\partial A_j} < 0,$$

and so, keeping in mind that the level of capital on a parcel is a positive function of the size of the parcel, we have the result that the number of properties along a lake affects the welfare of type II individuals, but not of type I individuals. In the figures, this is indicated by the identity $PNB_I\left(f, \tilde{f}\right) \equiv SNB_I\left(f\right)$ for type I individuals, whereas for type II individuals, $PNB_{II}\left(f, \tilde{f}\right) \not\equiv SNB_{II}\left(f\right)$.

The figures illustrate a realistic scenario –one consistent with conflicts over shoreline development –in which everyone prefers a larger parcel to a smaller one; some shoreline owners are relatively unconcerned about shoreline development (type I individuals); and the question of who ultimately ends up on a lake depends on both the size of available parcels, and the level of lakeshore development –in the figures, type I individuals are willing to pay more than type II individuals for small parcels along heavily developed shoreline, and type II individuals are willing to pay more than type I individuals for large parcels along lightly developed shoreline.

Assuming unlimited populations of both types of individuals, welfare is maximized where the average net benefit per parcel is maximized. Graphically this is the chord drawn from the origin to the highest point of tangency on the WTP curves. In Figure 2, this point generates frontage level f^*; aggregate welfare is maximized when the entire lake system is colonized by type I individuals, each with parcel size f^*.[2] Due to the lack of an externality effect in this result –remember, type I individuals are not bothered by the accumulated capital on a lake –the market would accomplish this solution with the per unit price of frontage equal to the slope of the chord from the origin, $p = \frac{\partial PNB_I}{\partial f} = \frac{PNB_I}{f}$.

In Figure 3, the optimal frontage level is f^{**}, with the entire lake system settled by type II individuals. Due to the externality effect, this result would not be sustained by a market, and would need to be imposed by the social planner. This is apparent from inspection of $PNB_{II}\left(f, f^{**}\right)$, which shows that a Type II individual's marginal willingness to pay for frontage at f^{**}, *given* that all other properties on the lake are also of size f^{**}, is *lower* than the marginal social benefit of parcels of size f^{**}. As a result, the market cannot sustain lakes with frontage f^{**}.

Figure 3 provides two examples of market solutions. In the first, the price of frontage is given by the slope OQ, the parcel size is f', and the lake system is entirely settled by type II individuals. In the second, the price of frontage is given by the slope of OR, the parcel size is f^*, and the lake system is entirely settled by type I individuals. The actual solution will depend on the specifics of the utility functions of the two types of individuals. The most interesting point illustrated by the figure is that it is possible for the welfare-maximizing solution to involve relatively large parcels occupied by type II individuals, while the market generates a system of relatively small parcels occupied by type I individuals.

[2] The discussion in this section is a bit imprecise, as any given lakeshore may not be exactly divisible by a particular frontage level f^*; but this does not detract from the basic points to be made.

Figure 2. Optimal and market allocations of lake frontage across two types of individuals (Example 1)

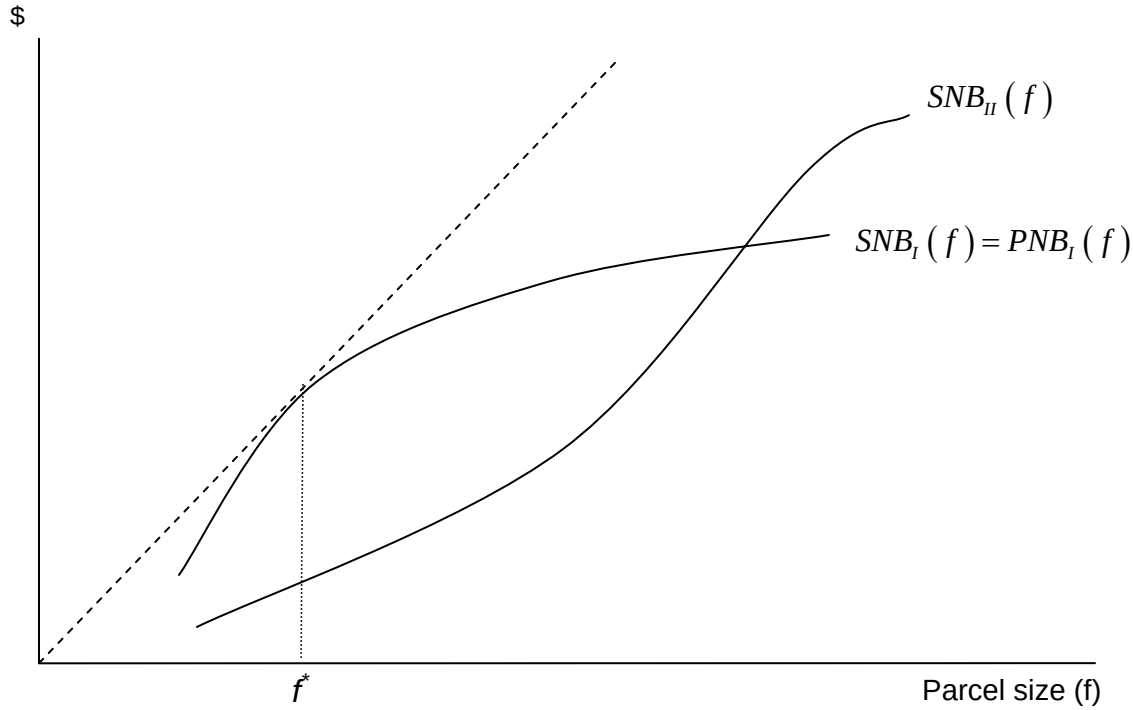
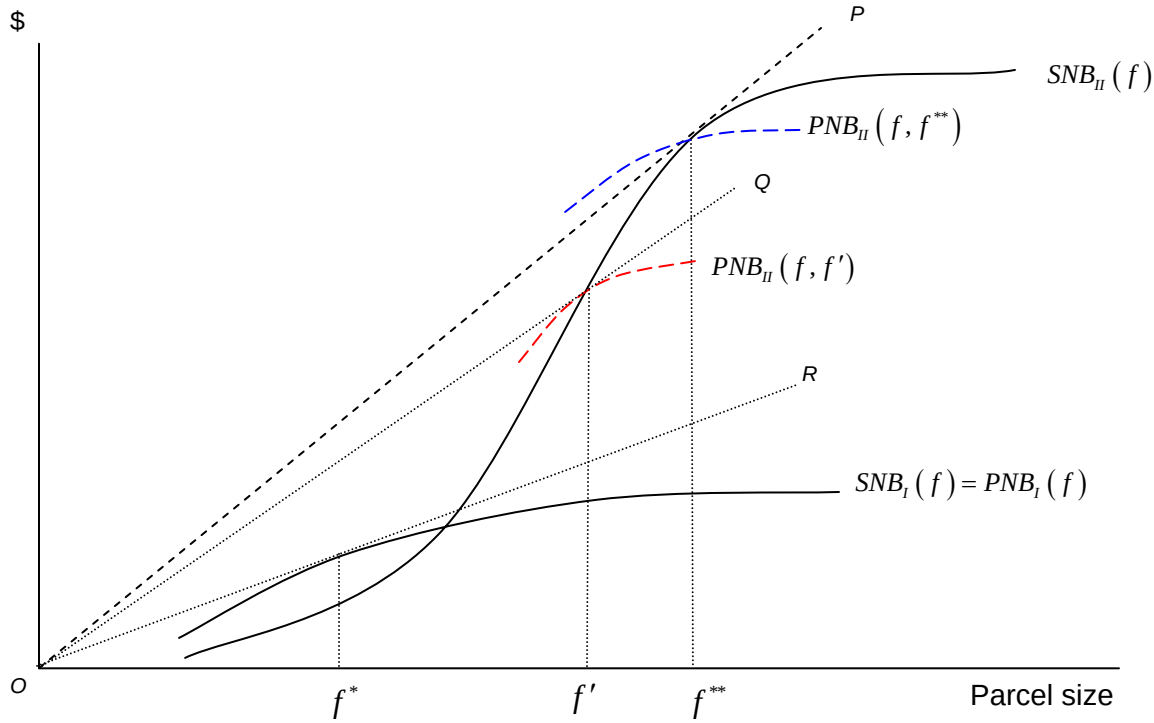


Figure 3. Optimal and market allocations of lake shoreline across two types of individuals (Example 2)



Things get more complicated and interesting as more utility types are added to the mix, and the assumption of an infinite population of each type is dropped. One can imagine a continuous distribution of types defined by their attraction to the amenities disrupted by capital accumulation on a lake. Developing such a model is beyond the scope of this paper, but the direction of such an analysis is apparent upon consideration of the case presented in Figure 4, where we assume that the population of individuals of type I remains unlimited, while the population of individuals of type II is limited. Drawing from the discussion of Figure 3, where the SNB functions are the same as in Figure 4, it might seem logical to conclude that lakeshore frontage is optimally allocated first to type II individuals, in parcels of size f^{**}, and, assuming this does not exhaust the available frontage, to then allocate the remaining shoreline to type I individuals, in parcels of size f^{*}. Note, however, that in this allocation the marginal value of type II parcels would be higher than the marginal value of type I parcels. Welfare gains are thus possible by redistributing lakeshore from type I to type II until the marginal values of all parcels are equal. In figure 4, this gives the result that the size of type I parcels remains f^{*}, while the size of type II parcels is f''. Moreover, this result implies that it would be optimal to keep the two types of individuals on different lakes –type I individuals on "type I lakes", and type II individuals on "type II lakes". The *most* that a type I individual would be willing to pay for a lakeshore parcel on a per-unit basis is no greater than the *marginal* value placed by type II individuals on parcels on type II lakes. In other words, there's no way to "make room" for a type I individual on a type II lake that doesn't lower aggregate welfare. This is not an artifact of the way Figure 4 is drawn. Rather, it is an outcome of the externality effect. Individuals who prefer a relatively undeveloped shoreline are best grouped together.

The unregulated market outcome depends on the PNB functions of type I and type II individuals. The most interesting case is illustrated in Figure 4, where *both* type I and type II individuals coexist on the lake system (albeit on different lakes), with type II individuals on lakes where parcels are size f', and type I individuals occupying the remaining lakes of the system, on parcels of size f^{*}. The price of shoreline on type II lakes is *higher* than the price on type I lakes, as reflected in the differential slopes of chords OQ and OR. Even with all lakes the same, the market may generate a price differential across lakes due to heterogeneity in lakeshore property owners. Importantly, this result only applies in the presence of an externality effect. In the absence of such an effect, the market would equilibrate at a single price of frontage where the marginal value of frontage is the same across all lakes and all parcels.

As in our simplest model with homogenous agents, minimum frontage zoning can have a positive or negative welfare effect compared to the unregulated outcome. Setting the MSFR at any level in the interval $\left(f', \hat{f}\right)$ on "just enough" lakes –that is, enough lakes to accommodate all type II agents, but no more –would raise aggregate welfare compared to the market, because in this range both the total shoreline dedicated to type II agents *and* the average value of shoreline on type II lakes is greater than under the market equilibrium. The amenity effect of MSFR=*f* is the difference between the social net benefit of frontage level *f*, and the private net benefit of frontage level *f*, *given* that all other parcels on the lake revert to the market equilibrium frontage level f'. The development effect is the difference between the private net benefit of holding frontage *f* in the unregulated market, and the income that could be derived in the unregulated market by selling off frontage $f - f'$. In the current context, this "extra"

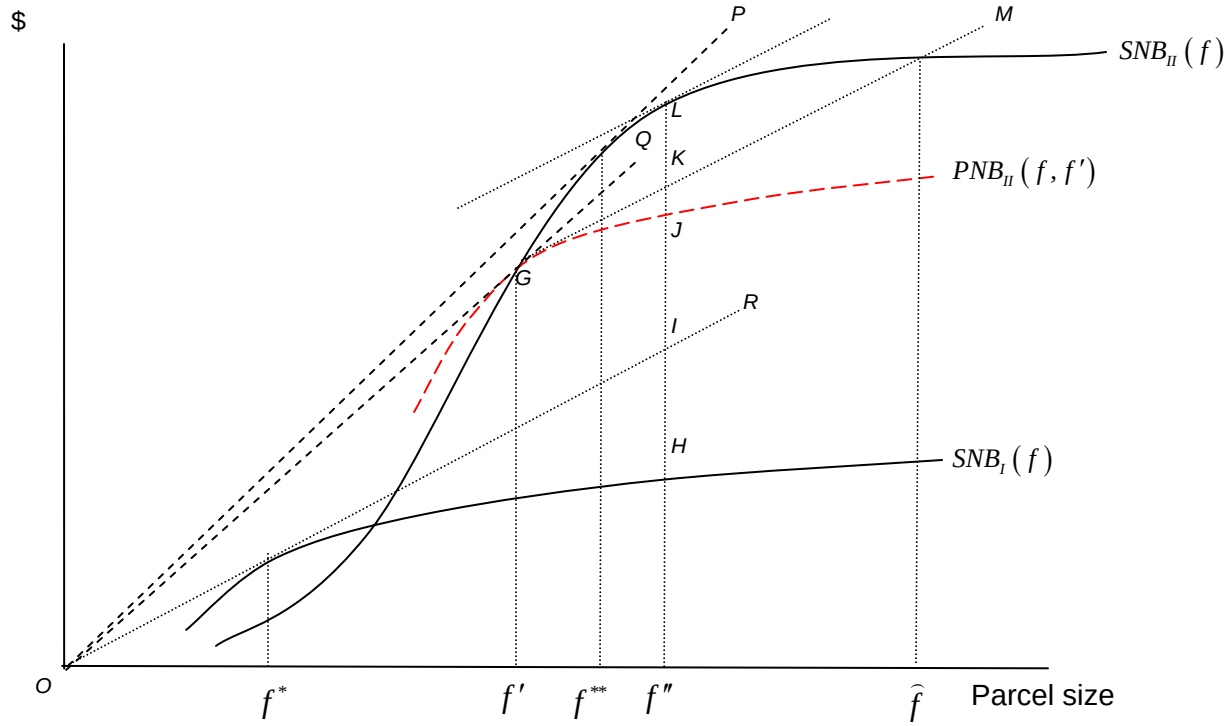
frontage would be sold to type I individuals, as lakes are converted from type I to type II, who would pay the going rate for type I frontage; in Figure 4 this is given by the difference between $PNB_{II}\left(f, f'\right)$ and the chord GM, which has the same slope as the chord OR.

Of course, it's possible for minimum frontage zoning to generate lower welfare than the unregulated market, by either setting the minimum frontage at a level greater than $\hat{f}$, or by applying the minimum level to too many lakes, so that type I individuals are forced to buy larger parcels than they would prefer. This last point deserves emphasis: with heterogeneous agents, getting lakeshore zoning "right", in the sense of generating higher aggregate welfare than obtainable from an unregulated market, involves not only setting the zoning restriction at the correct level, but also setting this level on the correct amount of shoreline (correct number of lakes).

An important point that we emphasize in the empirical analysis in the next section is that finding that the amenity effect is greater than the development effect assures that the MSFR zoning raises welfare compared to the baseline (unregulated market) case, but by itself, it is not sufficient to deduce whether zoning has gone "too far" in terms of aggregate welfare. In Figure 4, setting the MSFR in the range $\left(f'', \hat{f}\right)$ increases welfare compared to the unregulated market –the amenity effect is greater in absolute value than the development effect --but welfare can be increased by reducing the MSFR to f''; and setting welfare in the range $\left(f', f''\right)$ also increases welfare compared the unregulated market, but in this range welfare can be increased by increasing the MSFR to f''.

Finally, the values of the amenity and development effects presented in Figure 4 depend crucially on the claim that type I and type II users sort spontaneously in the absence of zoning, responding to the "Invisible Hand" of the land market. Given that the development of lakes occurs over a long period of time, and that development is quasi-irreversible, so that once a large parcel is divided into many small parcels it tends to remain in this state, it is not too difficult to imagine that in practice such sorting does not arise in the market, or arises unevenly, so that ultimately type I individuals "drive" type II individuals from the lake system. In this event, MSFR zoning has the effect of increasing aggregate welfare by facilitating and in a sense institutionalizing the sorting process. In Figure 4, this is formally understood by observing that the amenity effect of setting $MSFR = f''$ on type II lakes is the vertical distance HL –the difference between the social net benefit of type II shoreline property to type II individuals, and that to type I individuals, who derive no utility from reducing shoreline development; and the development effect is HI, the gain to type I individuals were they allowed to sell shoreline in the unregulated (and unsorted) market; leaving a net welfare effect of IL, which is greater than the net effect when efficient sorting arises in the market (KL).

Figure 4. Optimal and market allocations of lake shoreline across two types of individuals (Example 3)



III. An Application to the Vilas County Lake Classification

We estimate a hedonic price model of shoreline residential parcel values using Vilas County market sales data over the period 1997-2001 to examine the effect of the Lake Classification on shoreline property values. The model applies to the sale of both developed and undeveloped parcels, where as a proxy for the value of improvements we use the assessed value of improvements, indexed by the assessor and the presence of a town-level reassessment during the study period.[3] The underlying perspective of this approach is that assessors accurately judge the value of improvements, up to an assessor/reassessment-specific factor of proportionality. When this factor equals 1, the assessor accurately judges the value of improvements, on average. A value greater than 1 indicates a systematic underassessment, and a value less than 1 indicates a systematic overassessment. Following the explicit assumptions of property assessments, we treat the market value of a lakeshore property as the sum of the value of land and improvements. Letting $f(\mathbf{x})$ denote a parcel's land value, where $\mathbf{x}$ is a vector of parcel characteristics, and letting I denote the assessed value of improvements on the parcel, we have the hedonic form,

$$P = f(\mathbf{x}) + \alpha_{hj} I + \varepsilon \tag{6}$$

where α_{hj} is a factor of proportionality to be estimated, with h indexing the assessor and j indexing the assessment period as pre-reassessment or post-reassessment, for those towns that actually underwent a reassessment during the study period. During the study period the county was assessed by six

[3]Vilas County hires private assessors to assess all county parcels for tax purposes.

assessors, and seven of the fourteen towns underwent a reassessment, and so thirteen parameters α_{hj} were estimated.

In preliminary estimation, we tried several forms for the land value function $f(\cdot)$; all of them gave qualitatively similar results. However, the module in the econometrics package STATA employing the Hausman-Taylor estimation method –a method we considered critical to correct estimation of the model (see the discussion below) –requires a regression equation that is linear in the parameters. Linearity of $f(\mathbf{x})$ is problematic, but quadratic and interaction terms can be added to a linear version of $f(\mathbf{x})$ to capture important nonlinearities.[4] The obvious alternative to this approach is a fully double-log or log-linear form, which contradicts the explicit separation of the values of land and improvements used by assessors –the separation explicit in (6), which we find reasonable. This separation implies, for instance, that the value of a structure does not depend on such variables as distance to town and the availability of public access to the lake. An alternative model is one in which only $f(\mathbf{x})$ is nonlinear. Below we report on two linear models and a model in which $f(\mathbf{x}) = e^{\beta \mathbf{x}}$.

Variables Affecting Property Values

Table 1 provides definitions for the vector **x** used in estimation; Table 2 provides means and standard deviations for a selected set of these variables. Here we discuss several of them.

A lake's state of development is defined by its allocation across four development categories, as determined from Rockford™ plat maps for the year 2001: *TRIBAL*, the share of the lake's shoreline in tribal land; *STATE*, the share of a lake's shoreline in public land, usually county forest, state forest, or national forest; *LARGE*, the proportion of a lake's shoreline in private parcels greater than five acres; and *SMALL*, the share of a lake's shoreline in either private subdivisions or parcels less than five acres. In estimation the variable *SMALL* is dropped from the set of explanatory variables to avoid perfect collinearity, and so the estimated effects of the remaining development categories are measured against this omitted variable.

The amenity effect of a change in minimum frontage zoning depends on both the severity of the new restriction and the current level of development. No matter how strict the new regulation, one would expect it to have no effect on the flow of amenities if the lake is already fully developed. Similarly, a small increase in the severity of a regulation will have a minor impact on the flow of amenities from even an undeveloped lake. Our best index of the amenity effect associated with increasing the severity of the minimum frontage requirement is the difference between the maximum number of parcels that could be developed on shoreline currently classified as *Large* tracts, under two scenarios:

a) the state minimum shoreline frontage requirement (100 feet), and,
b) the actual minimum frontage requirement for the lake at the time of the property's sale.

This index is the variable *AMENITY_EFFECT* used in estimation. By construction, the more shoreline in large tracts, and the greater the difference between the state MSFR and the actual MSFR at the time of

[4]In the estimations presented here, we include three quadratic terms. An obvious set of interactions are those involving the amount of parcel shoreline frontage and the year of sale; including such interactions allows the substantial increase in lakeshore prices over the study period to be larger for larger parcels. However, we found that this was not a significant term in our sample, probably because our sample is concentrated among a narrow range of parcels, and so the models reported below do not include these interactions.

sale, the greater the number of potential "conserved" parcels, and the greater the amenity effect. An important concern is that the effect of a reduction in the number of potential new properties on a lake is different for a large lake than for a small one. In initial estimation we included an interaction term between *AMENITY_EFFECT* and *LAKESIZE*, to capture this differential, but this term was not significant, and so it is omitted from the estimated models presented below.

Possibly the amenity effect, as estimated using our index, changes after the 1999 Lake Classification, because of structural changes in the land market precipitated by the classification, and also because the classification involves a suite of shoreline regulations, of which the MSFR is the most prominent. To address this possibility we include in the analysis *AMENITY_POST*, comprised of an interaction between *AMENITY_EFFECT* and an indicator variable for whether a property was sold after the Lake Classification took effect.

The variable *DEV_EFFECT* is an index capturing the development effect of an increase in the MSFR from the state-mandated level of 100 feet. In estimation it applies *only* to undeveloped (vacant) parcels with more than 200 feet of frontage, and its value depends on the difference between the state MSFR and the actual MSFR in effect at the time the property was sold. Formally,

$$DEV_EFFECT = UNDEVELOPED \cdot 200\,plus \cdot \left(actual\ MSFR - state\ MSFR \right) \qquad (7)$$

where $200\,plus$ is an indicator variable for parcels with more than 200 feet of shoreline frontage. This index recognizes that undeveloped parcels with less than 200 feet of frontage cannot be subdivided under the state MSFR –100 feet –and so the value of such parcels are unlikely to suffer when the MSFR is raised above the state MSFR. The index also implies that the greater the actual MSFR, the greater (in absolute terms) the development effect, and that the development effect for improved properties is zero. By focusing on undeveloped properties with more than 200 feet of shoreline frontage, this measure of the development effect is more likely to identify a negative effect from a tightening of the MSFR than would a more inclusive measure.

Previous studies examining the effects of zoning on land values in urban areas have been concerned about the endogeneity of zoning (see, for instance, McMillen amd McDonald 1991a, 1991b, 2002; Pogodzinski and Sass 1994; and Wallace 1988). The basic argument is that zoning is applied where it is most desired by residents, and so in a hedonic regression, measures of zoning are likely to be correlated with unobservable effects. This is not a concern in our study because town lakeshore zoning ordinances preceding the 1999 Lake Classification were applied uniformly across a large number of diverse lakes, and the 1999 Lake Classification stipulates lake-specific MSFRs according to well-defined criteria concerning the current state of a lake's development and its ecological sensitivity.[5] Consequently, for any given lake in the study the MSFR is effectively uncorrelated with unobservables.

There is, however, an issue of endogeneity that requires attention. The level of development on a lake –in our study defined by the variable *LARGE* –likely depends on a number of unobservable factors that also affect property prices, such as a lake's natural beauty, the shape of its shoreline, the quality of the lake's riparian zone for building and the development of wells, and so on. This issue of the endogeneity of development is apparent in the study presented in Spalatro and Provencher (2001), which finds that

[5] At the time the Lake Classification was adopted, 7 of the 14 towns in Vilas County had MSFR that were 200 feet, with the remaining towns defaulting to the state MSFR.

increasing the share of shoreline in small parcels relative to large parcels *increases* the value of a lakeshore parcel. Possibly this really is the case, either because people prefer more densely developed shoreline, or, more likely in our view, because they are concerned about how undeveloped shoreline eventually will be developed. Another explanation, though, is that this result is the outcome of endogeneity bias: unobservable factors that cause relatively high development on a lake are also a source of high property values.

In this study we are concerned with the effects of zoning on property prices, and so the endogeneity of development is problematical only to the extent that development is correlated with zoning restrictions. For the town-level zoning ordinances preceding the Lake Classification, zoning-related variables are safely assumed to be independent of lake-specific unobserved factors, because these ordinances applied uniformly across lakes. On the other hand, the Lake Classification explicitly uses the level of lakeshore development as a criterion for defining the MSFR, and so it is reasonable to believe that the endogeneity of development biases the estimators of our zoning-related variables.

To address this issue we estimated a hedonic model using the Hausman-Taylor method of instrumental variable estimation of random effects models (Hausman and Taylor 1981; a good brief discussion of the technique is found in Greene 2002, pgs. 303-306).The method is typically applied to panel data in which observations are indexed by *i* –the cross-sectional unit of observation –and *t*. Our sample is equivalent to an unbalanced panel in which *i* indexes the lake and *t* indexes a particular property on the lake (no property in our sample sold twice during the study period). In this context, the estimation method treats the lake-specific effect as a random effect, and requires specification of the variables that are correlated with it. In our analysis these endogenous variables are *LARGE* (invariant across property sales on a lake), and *AMENITY_EFFECT*, *AMENITY_POST*, and *DEV_EFFECT* (all of which vary across property sales on a lake).

Table 1. Variables Used in the function $f(\mathbf{x})$ of the hedonic regression

Variable	Definition
Development Variables	
TRIBAL	Proportion of lakeshore owned by tribal groups
STATE	Proportion of lakeshore owned by local, state, and federal government
LARGE	Proportion of lakeshore in private tracts greater than 5 acres
SMALL	Proportion of lakeshore in subdivisions, or private tracts less than 5 acres; not included in estimation to avoid perfect collinearity
Zoning Variables	
AMENITY_EFFECT	See text
DEV_EFFECT	See text
AMENITY_POST	AMENITY multiplied by an indicator variable taking a value of 1 if the parcel sold after implementation of the county lake classification in June 1999 (see text)
Parcel Characteristics	
FRONTAGE	Shoreline frontage of parcel (feet / 100)
$FRONTAGE^2$	Shoreline frontage squared (feet /1000000)
ACRES	Lot size (acres / 10)
$ACRES^2$	Lot size squared (acres/100)
UNDEVELOPED	Indicator variable for undeveloped lots
Lake Characteristics,	
SENSITIVITY	Lake specific score for sensitivity to development (range 7-16) / 10
DISTANCE	Travel distance to nearest town (miles/10)

DISTANCE^2	Travel distance squared (miles/1000)
WATER CLARITY	Water clarity as measured by seccchi depth (meters)
LAKESIZE	Lakesize (acres/1000)
ACCESS	Indicator variable for public access on lake
Time Variables	
YR98	Indicator variable for sale in 1998
YR99	Indicator variable for sale in 1999
YR00	Indicator variable for sale in 2000
YR01	Indicator variable for sale in 2001
Assessed Value of Improvements	Thirteen indicator variables for the particular assessor and assessment period (before or after a reassessment conducted in the town during the study period). Not reported in the estimation below.

Table 2. Sample Means and Standard Deviations for Parcel Sale Prices and Selected Variables in x

Variable	Mean	Standard Deviation
Dependent Variable		
P (price in thousands of dollars	175.254	123.000
Zoning Variables		
AMENITY_EFFECT	25.279	32.575
Parcel Characteristics		
FRONTAGE	1.789	1.426
ACRES	0.222	0.321
UNDEVELOPED	0.247	0.431
Lake Characteristics		
SENSITIVITY	1.185	0.161
DISTANCE	1.253	0.743
WATER CLARITY	3.258	1.159
LAKESIZE	0.653	0.833
ACCESS	0.834	0.373
Development Variables		
TRIBAL	0.045	0.127
STATE	0.121	0.239
LARGE	0.220	0.204
SMALL	0.614	Xxxx

Estimation results

Estimation results are presented in Table 3. The first model is a simple linear regression, hereafter

referred to as the UCL (uncorrected linear) model, and the second model applies the instrumental variable approach developed by Hausman and Taylor (see above), and is hereafter referred to as the CL (corrected linear) model. To save space, coefficients on the indicator variables for assessed improvements and reassessments during the study period –thirteen variables in all –are not reported here. Concerning those variables, both models indicate that in general assessors underassess improvements –one assessor by more than 60% according to the preferred CL model, and curiously, after four of the seven town-level reassessments, this underassessment became worse.

The linear structure of the models makes interpretation of the coefficients straightforward. According to the CL model, increasing the size of a lake by 100 acres increases the value of a lakeshore property by $2,361. At the median frontage length for the sample (179 feet), the marginal value of frontage is $130.25/foot; this value increases as frontage increases, supposedly reflecting the development value of the parcel, to $166.55/foot for a parcel one standard deviation larger than the mean parcel (321.5 feet). The land value of a lakeshore property increased by more than $36,000 over the 5-year period of the study.

Surprisingly, the effect on shoreline property values of the proportion of a lake in large tracts (LARGE) remains negative in the corrected model, and in fact the point estimate becomes even *more* negative, though the standard error is also much larger. In the UCL model a shift of 10% of the shoreline from the small tract category to the large tract category reduces the value of lakeshore property by $4,838; the CL model predicts that this same shift will reduce the value of lakeshore property by $8,319.

Concerning the effect of lakeshore zoning, the two linear models give fairly similar results. In the CL model, MSFR zoning that reduces the maximum number of potential new lots on a lake by 10% of the mean sample value (2.53 new lots) raises the value of developed lakeshore property by $976 before Lake Classification and $1544 after Lake Classification. These values for the UCL model are $706 and $1248, though in this model the additional value after Lake Classification is not statistically significant at the .10 alpha level.

The negative development effect applies only to undeveloped parcels with at least 200 feet of shoreline. The point estimates for this effect are similar across the two models, though in the CL model this effect is not significant at the .10 level. For an undeveloped parcel with 200 feet of shoreline frontage, and for which the lake's MSFR is 150 feet, point estimates indicate that the development effect is -$5139 for the CL model, and -$5665 for the UCL model.

Extending the estimation to a nonlinear model

Given that, at least with respect to the variables of primary interest, the corrected and uncorrected linear generated fairly similar estimates, indicating that for our purposes endogeneity of development is not a significant issue, we include in Table 3 a third model in which $f(\mathbf{x}) = e^{\beta \mathbf{x}}$, with no correction for endogeneity.[6] At the sample means of the explanatory variables, increasing the size of a lake by 100 acres increases the value of a lakeshore property by $1,136; increasing lake water clarity by 1 meter increases the value of a lakeshore property by about $4860; the marginal value of frontage is $109; and the land value of a parcel increased by about $45,000 over the 5-year period of the study.

As with the previous models, the amenity effect is positive, and like the CL model the development effect is not significant. Using the point estimates of the model, and evaluating the model at sample means, we

[5] As noted previously, the software package we used (STATA) applies the Hauseman-Taylor estimation method only to models that are linear in the parameters.

find that MSFR zoning to reduce the maximum number of potential new lots on a lake by 10% (2.53 new lots) raises the value of developed lakeshore property by $912 after Lake Classification. For an undeveloped parcel with 200 feet of shoreline frontage, and for which the lake's MSFR is 150 feet, the estimated development effect is -$5625, though it bears emphasis that this effect is not statistically significant. [7]

Table 3. Hedonic Price Estimates for Three Models (Standard Errors in Parentheses)

Variable	Uncorrected Linear (UCL) Model	Corrected Linear (CL) Model	Uncorrected Nonlinear (UCNL) Model
Intercept	38.84* (20.22)	78.13 (62.47)	3.561** (0.3029)
TRIBAL	-57.32 (14.81)	-57.94 (37.86)	-0.6335** (0.2091)
STATE	2.154 (10.16)	8.808 (20.56)	-0.07426 (0.1185)
LARGE	-48.38** (9.650)	-83.19* (40.05)	-0.6456** (0.1430)
AMENITY_EFFECT	0.2790* (0.1434)	0.3857* (0.1776)	3.957E-3** (1.683E-3)
AMENITY_POST	0.2144 0.1634)	0.2247* (0.1181)	-3.900E-4 (1.620E-3)
DEV_EFFECT	-0.1133* (0.5898)	-0.1028 (0.07449)	-1.152E-3 (7.464E-4)
FRONTAGE	7.461** (2.598)	8.465** (2.548)	0.1354** (0.01934)
$FRONTAGE^2$	65.83** (11.21)	63.59** (14.93)	-0.2524** (0.07293)
ACRES	38.17** (15.87)	31.67** (12.75)	0.3228** (0.1260)
$ACRES^2$	-3.577 (6.839)	-3.155 (4.389)	-0.02983 (0.03932)
UNDEVELOPED	8.109 (7.897)	10.19 (5.744)	0.07503 (0.09821)
SENSITIVITY	-47.16** (14.18)	-68.21 (44.09)	-0.5823** (0.1752)
DISTANCE	15.46 (10.47)	11.53 (21.30)	0.3649** (0.1391)
$DISTANCE^2$	-40.77 (28.77)	-14.74 (66.88)	-0.8826** (0.3684)
WATER CLARITY	5.196** (1.767)	6.007 (3.706)	0.05824** (0.02311)
LAKESIZE	18.36** (3.513)	23.61** (9.258)	0.1391** (0.02961)
ACCESS	17.24** (4.573)	5.799 (12.79)	0.3728** (0.07571)
YR98	9.754* (5.906)	14.61** (5.967)	0.1684** (0.09261)

[6] These figures apply to 2001. In the linear models the year of sale enters linearly, and so does not affect the calculation.

YR99	29.57** (6.874)	21.69** (6.777)	0.4794** (0.1053)
YR00	32.44** (7.183)	26.99** (7.164)	0.5218** (0.1017)
YR01	39.93** (6.843)	36.14** (7.227)	0.5968** (0.1023)

** Indicates significant at the .01 level; * indicates significance at the .05 level

Net price effects for "vulnerable" undeveloped parcels

The parcels most likely to suffer a loss in value under the Lake Classification are undeveloped parcels with at least 200 feet of shoreline, because these are the parcels that could be subdivided into 100-foot parcels under the state-level MSFR, and are thus potentially degraded by the Lake Classification. Understanding the net price effects of the Lake Classification for these "vulnerable" parcels is complicated because lakes for which the MSFR is greatest –thereby imposing a more severe development effect on undeveloped parcels (see equation (7)) –are, by the design of the Lake Classification, also the lakes for which the amenity effect is greatest, because these lakes tend to be the least developed. Figure 5 presents results for the 109 undeveloped "vulnerable" parcels in the sample. In the figure, these 109 parcels are ordered according to the net price effect under the CL model. Overall, there is good agreement among the models about the effect of the Lake Classification on these "vulnerable" parcels, with the CL model predicting the fewest parcels suffering a negative effect (33), and the NCNL model predicting the most parcels (66). Significantly, in *all* the models the average price effect for these "vulnerable" parcels is positive, ranging from +$12,070 for the CL model to +$3050 for the NCNL model. In other words, among the set of sample properties that could *potentially* suffer a loss under the Lake Classification, the model predicts an overall gain. It deserves emphasis too that although Figure 5 is based on reported point estimates, only in the UCL model is the development effect statistically significant.

As discussed in section two, finding that the amenity effect more than compensates for the development effect is an indication that MSFR zoning provides a welfare improvement compared to the baseline scenario, but it does not answer the question of whether the zoning has gone "too far". In the current context, this question applies in particular to the 109 undeveloped "vulnerable" parcels: how would their values be affected by relaxing the Lake Classification? In Figure 6 we show the predicted effect on each of these parcels of a 25% reduction in the MSFR. In the figure the parcels are ordered as in Figure 5, and so we find, not surprisingly, that the predicted loss from relaxing the Lake Classification is greatest for those parcels that gain the most value under the MSFR. The figure shows that a little more than half of the parcels gain value from relaxing the MSFR, but on average they lose value. Given this result, and the fact that only in the UCL model is the development effect statistically significant, a fair conclusion is that in terms of protecting the value of undeveloped properties, the Lake Classification is not excessively strict.

Figure 5. Effect of the Vilas County Lake Classification's Minimum Shoreline Frontage Requirement on the Value of Undeveloped "Vulnerable" Parcels in the Sample

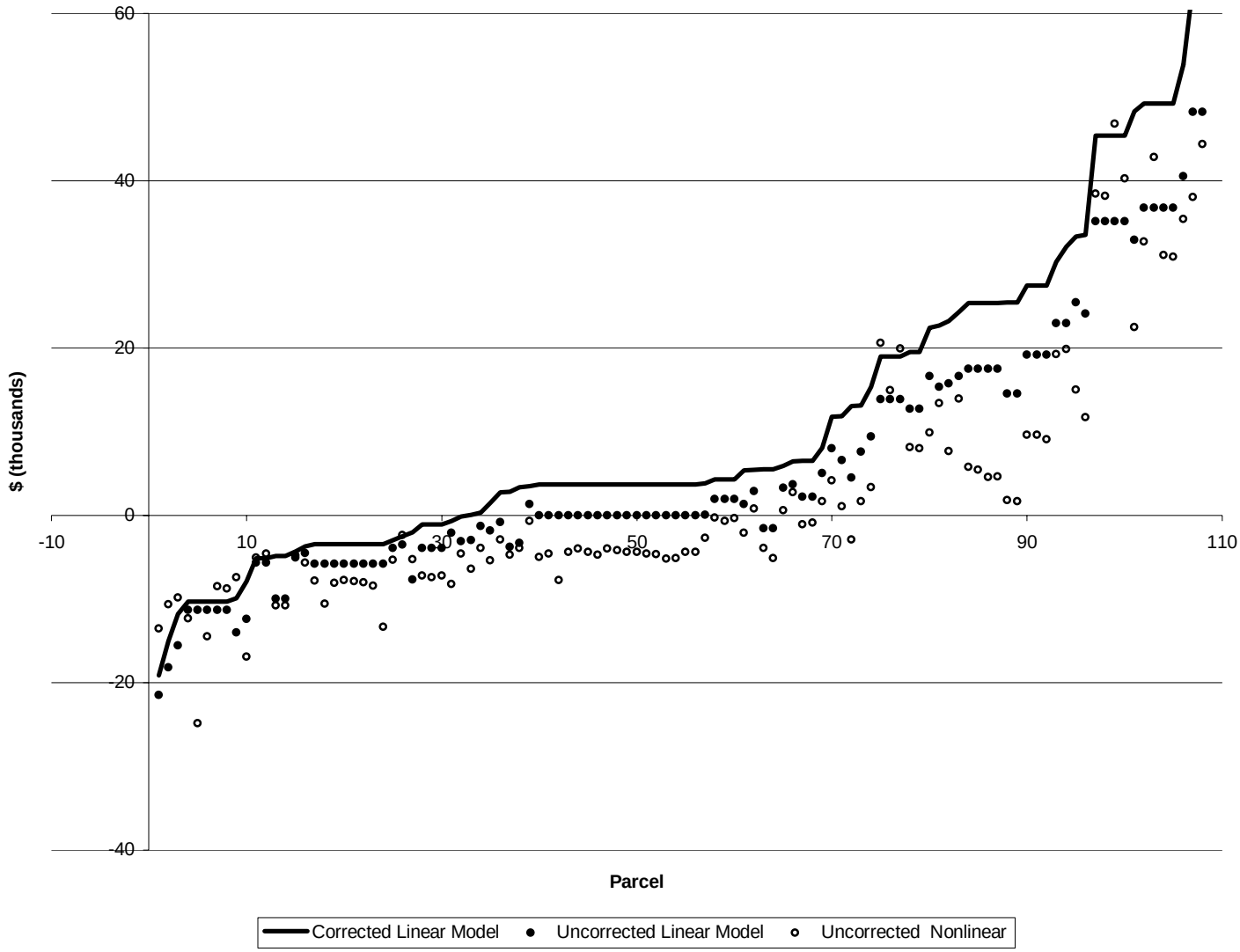
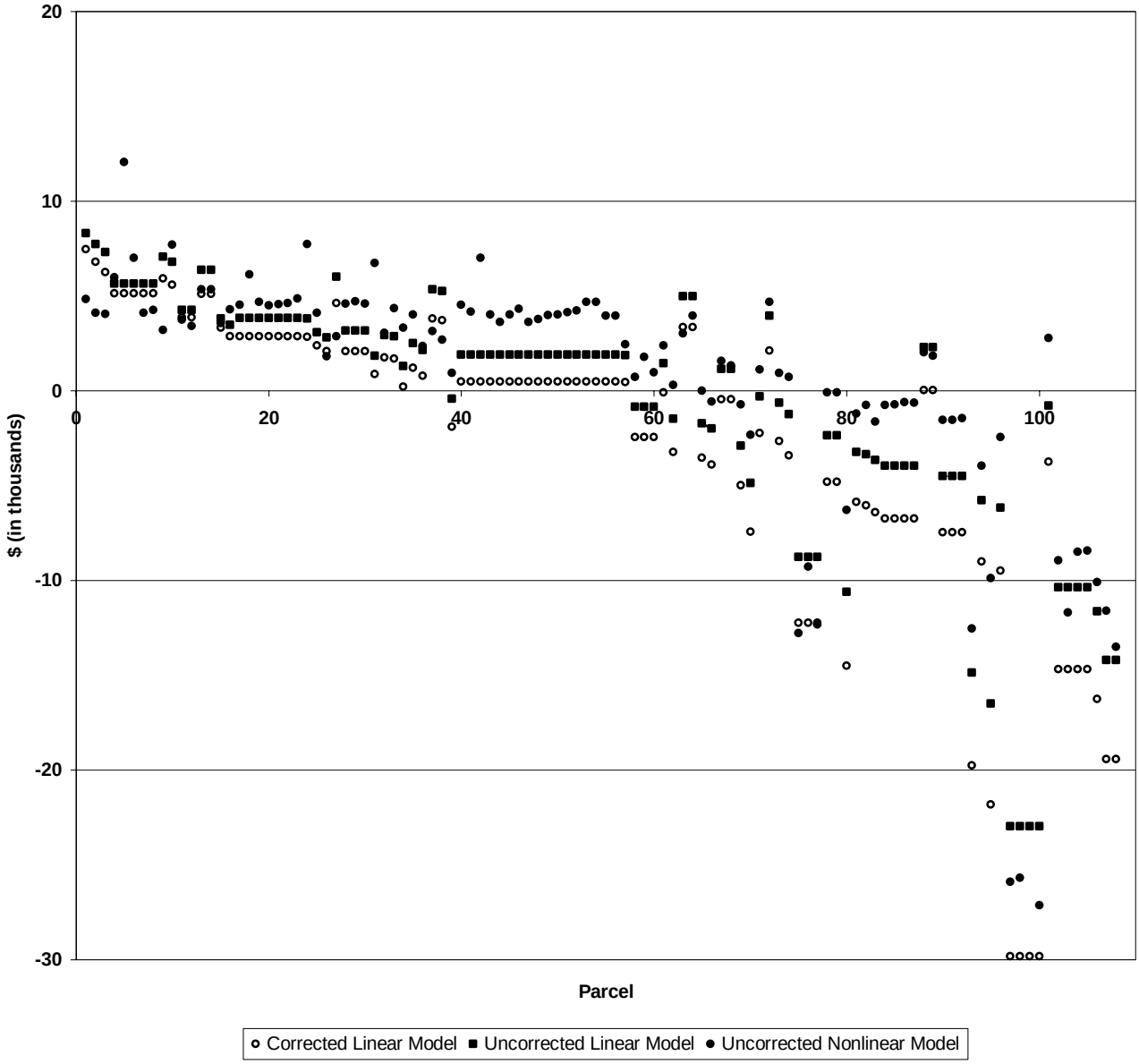


Figure 6. Net effect on "vulnerable" undeveloped parcels of a reduction in the MSFR of 25%



IV. Concluding Remarks

In this analysis we developed the theoretical argument that mimimum shoreline frontage zoning can generate a positive amenity effect and a negative development effect. The analysis indicates that when preferences are heterogeneous there are important welfare implications to the configuration of zoning on a lake system. Creating zones of differing regulatory intensity facilitates the self-sorting of individuals with different intensities of preferences over environmental goods. Individuals with strong preferences for these goods locate on lakes with the strictest zoning. In theory, such sorting would still occur with

uniform zoning (including the absence of zoning), but the heterogeneity of preferences assures that this is not the efficient configuration. Moreover, as a practical matter it is questionable whether individuals really do sort themselves across lakes in the absence of zoning. This is an empirical question that deserves investigation, as it bears on the question of the welfare and distributional effects of heterogeneous zoning.

We found in a hedonic analysis that the Vilas County, Wisconsin Lake Classification has raised shoreline property values compared to a baseline where the statewide minimum shoreline frontage restriction applies. On balance this holds true even for “vulnerable” undeveloped parcels most likely to suffer from the development effect of zoning. Moreover, a brief analysis of whether the Lake Classification has gone “too far”, in the sense that the net gain to undeveloped parcels might be increased by relaxing the Lake Classification somewhat, suggests that as currently configured the Lake Classification is reasonable.

References

Colwell, Peter F., and Carolyn A. Dehring. "The Pricing of Lake Lots", *The Journal of Real Estate Finance and Economics*, **30**:3 (2005), 267–283..

Fischel, W.A. 1990. Introduction: four maxims for research on land-use controls. *Land Economics* **66**, 229-236.

Greene, William H. Econometric Analysis (5th Edition). Prentice-Hall (2003), 1026 p.

Hausman, Jerry A. and William E. Taylor. Panel data and unobserved individual effects. *Econometrica* **49**:6 (1981), 1377-1398.

McMillen, Daniel P., and John F. McDonald, "A Simultaneous Equations Model of Zoning and Land Values," *Regional Science and Urban Economics* **21** (1991a), 55–72.

McMillen, Daniel P., and John F. McDonald, "Urban land value functions with endogenous zoning" *Journal of Urban Economics* **29** (1991b), 14-27.

McMillen, Daniel P., and John F. McDonald, "Land Values in a Newly Zoned City", *The Review of Economics and Statistics* **84**:1 (2002), 62–72.

Netusil, Noelwah R. "The effect of environmental zoning and amenities on property values". Land Economics 81:2 (2005), 227-246.

Pogodzinski, J.M., and T.R. Sass. "The Theory and Estimation of Endogenous Zoning", *Regional Science and Urban Economics* **24** (1994), 601-630.

Spalatro, F., and B. Provencher. "An Analysis of Minimum Frontage Zoning to Preserve Lakefront Amenities", *Land Economics* **77**:4 (2001), 469-481.

Wallace, Nancy E. The market effect of zoning undeveloped land: does zoning follow the market?" *Journal of Urban Economics* **23** (1988), 307-326.