AN ABSTRACT OF THE DISSERTATION OF

Ivan Hascic for the degree of Doctor of Philosophy in Agricultural and Resource Economics presented on June 21, 2006.
Title: Essays on Land Use Regulation.

Signature redacted for privacy.

Abstract approved: ______________________________
JunJie Wu

This dissertation consists of three papers on land use economics and regulation. The first paper focuses on the environmental impacts of land use and their implications for the design on water quality trading policies. The second and third papers address local land use regulations and their impact on land values and land use patterns.

The first paper provides a national-scale, watershed-level assessment of land use impacts on water quality and aquatic ecosystems in the United States. The results suggest that the level of conventional water pollution in a watershed is significantly affected by the amount of land allocated to intensive agriculture and urban development, while the level of toxic water pollution is significantly affected by the amount of land allocated to transportation and mining. Implications of the results for the design and implementation of water quality trading policies are discussed.

The second paper develops an empirical framework to conduct an exploratory analysis of effects of land use regulations on land values and land use patterns in a GIS-based landscape near Eugene, Oregon. All the land use regulations considered in this study, including exclusive farm use zoning, forest zoning, urban growth boundary designation, residential density zoning, commercial zoning, and industrial zoning, are found to affect land value and use both inside and outside of the designated zones. While there are many issues this framework does not address,

preliminary results indicate that regulations (except commercial zoning) tend to increase the value of land outside the designated zones, but reduce the value of land inside the designated zones. The framework is applied to measure the reduction in value due to regulations vs. the value of individual exemptions at the parcel level to illuminate the controversy surrounding Oregon's Measure 37. The reductions in value due to regulations are found to be considerably smaller than the values of individual exemptions for almost all regulations contested in the Measure 37 claims.

The third paper evaluates the efficiency of the current system of land use regulation, analyzes the possible changes to the regulatory structure, and studies the role of spatial and temporal interaction among neighboring land uses.

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Essays on Land Use Regulation

by
Ivan Hascic

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APPROVED:

Signature redacted for privacy.

Major Professor, representing Agricultural and Resource Economics

Signature redacted for privacy.

Head of the Department of Agricultural and Resource Economics

Signature redacted for privacy.

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Ivan Hascic, Author

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CONTRIBUTION OF AUTHORS

Dr. JunJie Wu was involved in the design, analysis, and writing of each manuscript.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

Acronym	
CBD	Central Business District
EFU	Exclusive Farm Use Zone
HUC	Hydrologic Unit Code
LULC	Land Use and Land Cover
LRR	Land Resource Region
MLRA	Major Land Resource Area
NRCS	Natural Resource Conservation Service
NRI	Natural Resource Inventory
RVR	Reduction in Value due to Regulation
UGB	Urban Growth Boundary
USDA	United States Department of Agriculture
USDA-NRI	United States Department of Agriculture's Natural Resource Inventory
USEPA	United States Environmental Protection Agency
USEPA-IWI	USEPA's Index of Watershed Indicators
USGS	United States Geological Survey
VIE	Value of Individual Exemption

ESSAYS ON LAND USE REGULATION

CHAPTER 1

INTRODUCTION

Ivan Hascic

Land use change is arguably the most pervasive socioeconomic driving force affecting watershed ecosystems. Runoff from agricultural lands is a leading cause of water pollution both in inland and coastal waters. Drainage of wetlands and irrigation water diversions have brought many wildlife species to the verge of extinction. Urban land development has also been linked to many environmental problems, including urban runoff, water pollution, and loss of wildlife habitat. Habitat destruction, fragmentation, and alteration associated with urban development have been identified as the leading causes of biodiversity decline and species extinctions. Although there is a large amount of scientific evidence that land use affects water quality and ecosystems, the relative impacts of alternative land uses on water quality and ecosystems have rarely been quantified. Such information is essential for the design and evaluation of policies aiming at protecting water quality and ecosystems.

The first paper (chapter 2), *Land Use and Watershed Health in the United States*, analyzes the interaction between water quality and aquatic health as affected by land use and other human activities in watersheds covering the lower 48 states of the United States. This study concentrates on water pollution related to agricultural and urban runoff, eutrophication, and toxic pollution. It evaluates how water quality affects the status of wetland and aquatic species and whether land use changes exacerbate the impacts. This study has important implications for water quality trading policies under consideration in many states of the United States.

Unregulated land markets may under-provide certain public goods (such as open space and other environmental amenities) and leave externalities (such as nuisances) uninternalized. These market failures provide the basis for land use regulations. The broad scale of governmental intervention into real estate markets under the justification of growth control or environmental preservation has brought about a concern for the equitable treatment of all property owners. The statewide land use planning regime in Oregon places strict limits on the use of resource lands and confines development within designated urban growth boundaries. In the 2004 election in Oregon, property rights advocates launched Ballot Measure 37 to protect private property rights from land use regulation and to establish the statutory right to demand compensation when a land use regulation reduces the market value of a private property. While zoning and various other land use regulations may indeed cause land prices to change, it is difficult to measure the direction and the magnitude of these changes.

The second paper (chapter 3), *The Reduction in Value due to Land Use Regulation vs. the Value of Individual Exemptions: An Exploratory Analysis of Oregon's Measure 37*, develops an exploratory framework to illustrate the complexity of this issue using data from Eugene, Oregon. We show that the increase in the value of a parcel when it is solely exempted from a regulation does not equal the reduction in value due to regulation to the owner. The reduction in value due to regulation equals the difference between the current value of the property and the value of the property that would have existed if the regulation had not been imposed in the first place. A landowner may benefit from a waiver because the regulation has been applied to other properties. Since the price of a parcel depends on the land use in its surrounding parcels, which in turn depends on their surrounding land use, it is necessary to predict the land use patterns and prices that would have existed on the whole landscape in the absence of the regulation. A GIS-based, spatially explicit model is developed to predict land use and property values for each parcel on a landscape near Eugene, Oregon. The model is applied to predict development patterns and land prices that would have existed if one or more land use regulations had been removed. The value of an individual exemption and the reduction in value due to land use regulation are calculated for all parcels on the landscape under a number of policy scenarios. Our empirical results show that all major zoning regulations in the study region have affected land use and property values both inside and outside the zoned districts. Although the value of a property can never go down when it is exempted from a binding regulation, the reduction in value due to regulation can be positive or negative. Even when the reduction in value due to regulation and the value of an individual exemption have the same sign, their magnitude can be quite different. In most cases, the effects of regulation on land values are considerably smaller than the values of individual exemptions.

The third paper (chapter 4), *Measuring the Regulatory Takings and Givings: Nonlinearity of the Cost Gradient of Land Use Regulations*, evaluates the efficiency of the current system of land use regulation in Oregon and analyzes the possible changes to the regulatory structure. The paper also studies the changes in costs and benefits of land use regulations in response to changes in the composition of the regulatory mix. The results suggest that the cost gradient of land use regulations is a nonlinear function of the composition of the regulatory mix due to interdependencies between land uses and land use regulations. Irregularities may occur where an agglomeration effect or other forms of spatial and temporal interaction among neighboring land uses arise.

CHAPTER 2

LAND USE AND WATERSHED HEALTH IN THE UNITED STATES

Ivan Hascic
and JunJie Wu, Professor

Land Economics
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ABSTRACT

This national-scale, watershed-level analysis provides an empirical assessment of land use impacts on water quality and aquatic ecosystems in the United States. Results suggest that the level of conventional water pollution in a watershed is significantly affected by the amount of land allocated to intensive agriculture and urban development, while the level of toxic water pollution is significantly affected by the amount of land allocated to transportation and mining. The relationship between land use, water quality, and aquatic species extinction is also examined. Implications of the results for the design and implementation of water quality trading policies are discussed.

INTRODUCTION

Land use change is arguably the most pervasive socioeconomic driving force affecting watershed ecosystems (Dale et al. 2000). Runoff from agricultural lands is a leading cause of water pollution both in inland and coastal waters. Drainage of wetlands and irrigation water diversions have brought many wildlife species to the verge of extinction. Urban land development has also been linked to many environmental problems, including urban runoff, water pollution, and loss of wildlife habitat. Habitat destruction, fragmentation, and alteration associated with urban development have been identified as the leading causes of biodiversity decline and species extinctions (McKinney 2002; Rottenborn 1999). Land use in coastal areas and further inland is also a major threat to the health, productivity, and biodiversity of the marine environment in the United States and throughout the world (Intergovernmental Conference 1995).

Although there is a large amount of scientific evidence that land use affects water quality and ecosystems, the relative impacts of alternative land uses on water quality and ecosystems have rarely been quantified. Such information is essential for the design and evaluation of policies aiming at protecting water quality and ecosystems, which typically involve various landscape management options, such as altering management practices on cultivated croplands, retiring land from crop production, or restoring some land to its natural state (e.g., Carpenter et al. 1998, Wu et al. 2004).[1] Recently, several states in the United States have begun to use water quality trading as a policy tool to control water pollution and to mitigate the ecological impacts of land use, and many other states are actively considering the policy (U.S. Environmental Protection Agency 2003a).[2] Water quality trading is an innovative, market-based approach that allows one source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs. As marketable pollution permits, it has the potential to achieve water quality goals at a lower social cost. However, much information is needed to implement the water quality trading policy. At the local watershed level, data are needed on the relative impacts of alternative land uses and conservation practices on water pollution and ecosystems. At the state or national level, the information is needed to develop general guidelines for trading and to target geographic areas or land use changes that are most effective to achieve overall national goals. The objective of this study is to provide such information by evaluating the effect of alternative land uses on selected indicators of water quality and watershed ecosystems.

Numerous studies have examined the structure and functions of various components of ecosystems at the watershed or river-basin scales (see discussion in sections 2 and 3). Although these studies have provided piecemeal evidence that land use affects water quality and ecosystems, no study, to our knowledge, has analyzed multiple aspects of watershed health at the regional or national scales. Watershed ecosystems are complex assemblages of plants, animals, and microbes interacting with each other and their environment. The complexity of ecosystems requires a system approach. This study treats watersheds as ecosystems by analyzing the interaction between water quality and aquatic health as affected by land use and other human activities in watersheds covering the lower 48 states of the United States. It concentrates on water pollution related to agricultural and urban runoff, eutrophication, and toxic pollution. It analyzes how water quality affects the status of wetland and aquatic species[3] and whether land use changes exacerbate the impacts. This watershed-level analysis provides a "big-picture" of the ecological impact of land use at the national scale. Such a "big-picture" analysis is useful because large-scale changes in land use are needed to improve the overall health of the nation's ecosystems.

The remainder of this paper is organized as follows. Section II discusses several selected indicators of watershed health in the United States. Section III reviews the biological and ecological literature to identify the critical relationships among land use, water quality, and wildlife abundance and presents the empirical specification of these relationships. Section IV provides justifications for the empirical specification and describes the estimation methods. Section V discusses the data. Section VI presents the empirical results. Section VII discusses major findings and policy implications. Section VIII concludes the paper.

WATERSHED INDICATORS IN THE UNITED STATES

Freshwater ecosystems, in addition to being valuable in their own right, are indispensable for the functioning of terrestrial ecosystems, and are largely responsible for maintaining and supporting overall environmental health (U.S. Environmental Protection Agency 2004a). In this study, three indicators were selected to describe the health of aquatic resources across the United States. These indicators were retrieved from the U.S. Environmental Protection Agency (USEPA)'s Index of Watershed Indicators, which contains data characterizing the condition and vulnerability of aquatic systems in watersheds across the United States (U.S. Environmental Protection Agency 2004b). Each of the indicators is discussed below.

The *conventional ambient water quality* indicator (CONVWQ) measures the number of surface water samples in a watershed with concentrations of one or more of the four conventional water quality measures (phosphorus, ammonia, dissolved oxygen, pH) exceeding the national reference levels. The indicator is constructed based on water quality monitoring data collected between 1990 and 1998. The data sufficiency threshold requires that each watershed must contain at least 20 observations representing a minimum of five sites over the nine-year period. Figure 2.1 shows the percent of surface water samples in exceedance of the national reference levels for the four conventional ambient water quality measures across the 2,100 watersheds in the contiguous Unites States. Conventional water quality appears to be a nation-wide problem, with more frequent violation of the USEPA standard in the Midwest, the Gulf and Atlantic coasts.

The concentrations of phosphorus and ammonia and the level of dissolved oxygen and pH are important indicators of water quality. It has been well documented that excessive eutrophication associated with high concentrations of phosphorus and ammonia may cause algal blooms, increase water turbidity, generate hypoxic or anoxic conditions, and change aquatic biodiversity (e.g., Carpenter et al. 1998; Smith 1998). The level of dissolved oxygen (DO) is

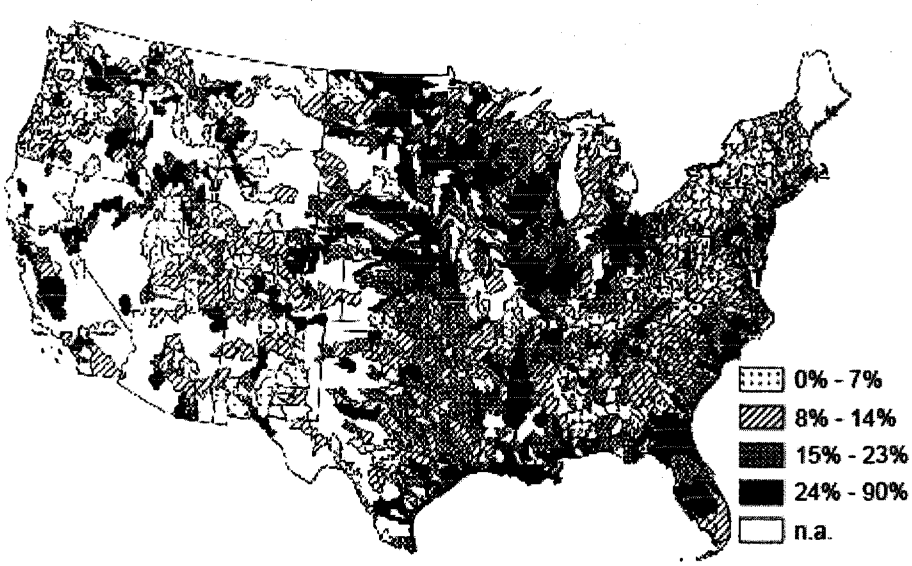

Figure 2.1. Conventional Ambient Water Quality (% samples exceeding criteria)

affected by a number of factors, including eutrophication, photosynthesis of plants and planktonic algae, decomposition of all organic matter, as well as abiotic factors such as temperature and atmospheric pressure (e.g., Deaton and Winebrake 2000; Faurie et al. 2001).[4] Acidification can disrupt the nitrogen cycle in freshwater ecosystems (Vitousek et al. 1997) and has been identified with the occurrence of decreased diversity of animal and plant species (Schindler 1994). The causes and effects of conventional ambient water pollution and the related literature are summarized in table A1 in appendix A.

The *toxic ambient water quality* indicator (TOXICWQ) measures the number of surface water samples in a watershed with concentrations of one or more of the four toxic pollutants (copper, nickel, zinc, chromium) exceeding the national chronic levels. This indicator, however, does not capture pollution by toxic compounds other than the selected four heavy metals. It is constructed based on water quality monitoring data collected between 1990 and 1998. The data sufficiency threshold is the same as for CONVWQ. Figure 2.2 displays the percent of surface

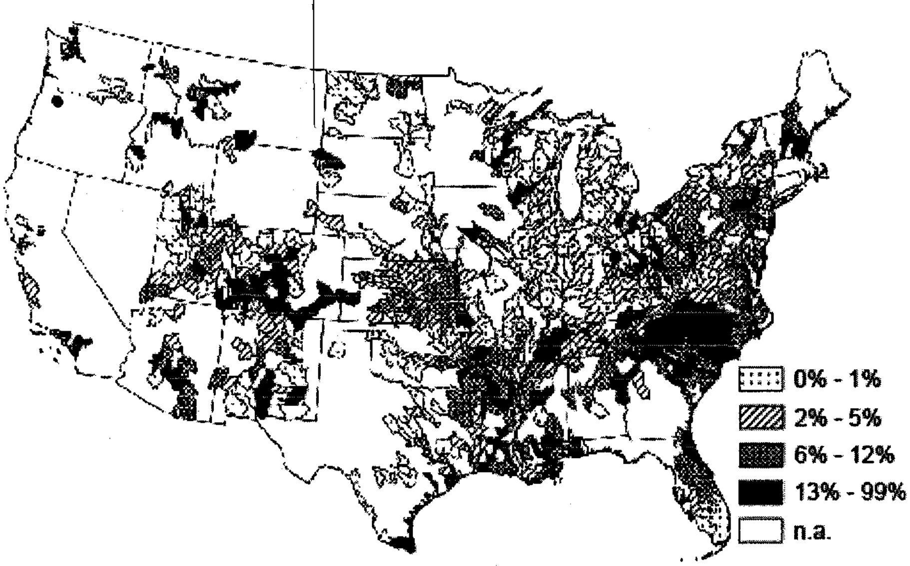

Figure 2.2. Toxic Ambient Water Quality (% samples exceeding criteria)

water samples in exceedance of the national chronic levels for the four toxic pollutants. It shows a clustered pattern of toxic water pollution nationwide, although limited data availability may obscure the overall spatial pattern. Watersheds in the Rocky Mountains and parts of the eastern and southern U.S. have more serious toxic water pollution problems.

Contamination of water bodies by heavy metals is a major concern due to their sedimentation, persistence, and bioaccumulation potential, and their lethal and sublethal effects. Elevated concentrations of toxic substances affect aquatic wildlife in a number of ways. These include changes in morphology, physiology, body biochemistry, behavior, and reproduction (e.g., Skidmore 1964; Handy and Eddy 1990). The causes and effects of toxic ambient water pollution and the related studies are summarized in table A2 in appendix A.

The *species-at-risk* indicator (SPERISK) measures the number of aquatic and wetland species (plants and animals) at risk of extinction in a given watershed in 1996. Figure 2.3 shows the indicator across the contiguous United States. The figure shows that no area in the U.S. is

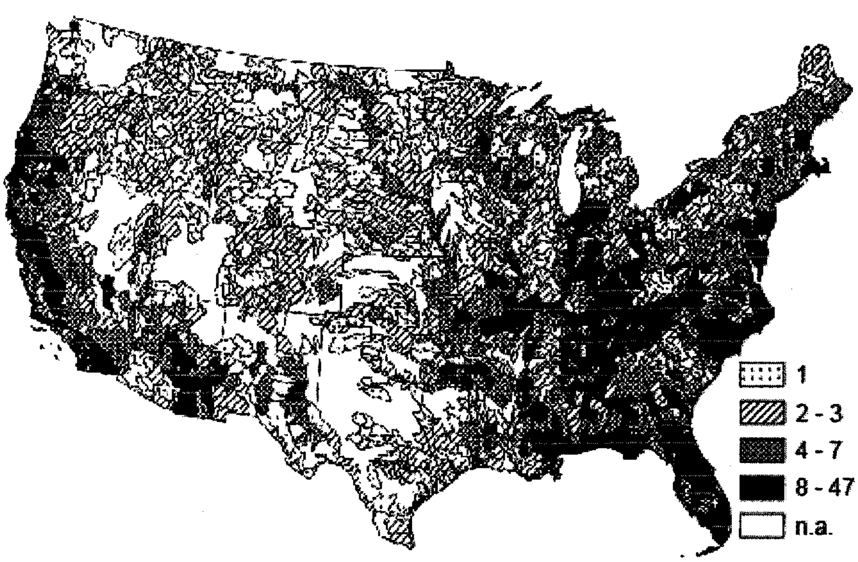

Figure 2.3. Aquatic and Wetland Species at Risk of Extinction (number of species)

spared of the threat to aquatic biodiversity, although southern U.S. and the west coast have more aquatic species at risk of extinction.

Aquatic ecosystems are characterized by a great deal of biodiversity. Several studies have investigated the relationship between the health and abundance of aquatic organisms and their potential as a bioindicator. Amphibians have long been regarded as important indicators of environmental health and aquatic biodiversity due to their extreme susceptibility to perturbations in the environment (e.g., Hartwell and Ollivier 1998; Welsh and Ollivier 1998; Blaustein and Johnson 2003). Fish are considered useful indicators of biological integrity and ecosystem health since they respond predictably to changes in both abiotic factors, such as habitat and water quality, and biotic factors, such as human exploitation and species additions (Davis and Simon 1995). The causes and mechanisms of biodiversity losses with the corresponding literature are summarized in table A3 in appendix A.

EMPIRICAL MODELS

A recursive equation system is estimated to evaluate the impacts of land use on water quality and aquatic ecosystems. The system consists of three equations, representing models of conventional water quality, toxic water quality, and species at risk of extinction, respectively. Land use affects both conventional and toxic water quality, which in turn affect the number of species at risk of extinction. Each model is discussed below.

The Conventional Water Quality Model

The conventional water quality model captures the relationship between different types of land uses and their effect on water quality via the processes of eutrophication and dissolved oxygen depletion. Although eutrophication is a natural process that occurs in virtually all water bodies, its anthropogenic acceleration is a major concern (e.g., Laws 1993; Schnoor 1996). Excessive eutrophication and water pollution have been linked to agricultural land and chemical uses, urban runoff, and topographic and hydrological characteristics (see table A1 for a summary of major causes of conventional water pollution). Based on previous studies, the conventional water quality model is specified as:

$$\ln(CONVWQ_i) = \ln N_i^c + \beta_0 + \boldsymbol{\beta}_1' \boldsymbol{l}_i^c + \boldsymbol{\beta}_2' \boldsymbol{p}_i^c + \boldsymbol{\beta}_3' \boldsymbol{d}_i^c + \varepsilon_i^c \qquad [1]$$

where i is the watershed index, N_i^c is the total number of samples taken to measure conventional water quality, $\boldsymbol{l}_i^c$ is a vector of land- and chemical-use variables affecting conventional water pollution, $\boldsymbol{p}_i^c$ is a vector of physical characteristics measuring the vulnerability of individual watersheds to conventional water pollution, $\boldsymbol{d}_i^c$ is a vector of spatial dummies, and ε_i^c is an error term, with $\exp(\varepsilon_i^c)$ following the gamma distribution. The justification for the empirical specification is given in the next section.

The Toxic Water Quality Model

The toxic water quality model represents the relationship between different types of land uses and the presence of heavy metals in a watershed.[5] The major anthropogenic sources of metallic pollution of water bodies include urban, industrial, and commercial land use and mining (see table A2 for a summary). The whole life cycle of a metallic pollutant, from ore extraction and processing to manufacturing, domestic and industrial use, and disposal, may cause water contamination (e.g., Keyes 1976; Fergusson 1982). Domestic uses, sewage, urban runoff, and traffic also contribute to heavy metal contamination (Alloway 1995). Intensive agriculture is a major non-point source of metals, with the main sources being impurities in fertilizers, sewage sludge, manures from intensive hog and poultry production, and pesticides (Alloway 1995). Based on these previous studies, the toxic water quality function is specified as:

$$\ln(TOXICWQ_i) = \ln N_i^t + \gamma_0 + \gamma_1' \boldsymbol{l}_i^t + \gamma_2' \boldsymbol{p}_i^t + \gamma_3' \boldsymbol{d}_i^t + \varepsilon_i^t \qquad [2]$$

where N_i^t is the total number of samples taken to measure toxic water pollution, $\boldsymbol{l}_i^t$ is a vector of land- and chemical-use variables affecting toxic water pollution, $\boldsymbol{p}_i^t$ is a vector of physical characteristics measuring the vulnerability of individual watersheds to surface water pollution, $\boldsymbol{d}_i^t$ is a vector of spatial dummies, and ε_i^t is an error term, with $\exp(\varepsilon_i^t)$ following the gamma distribution.[6]

The Species-at-Risk Model

The third equation in the system models the effect of water quality on aquatic ecosystems. Previous studies have identified several factors potentially affecting the quality of aquatic environment (see table A3 for a summary).

The decline in biodiversity of both animal and plant species has been linked to a number of conventional water pollution problems, including excessive eutrophication (e.g., Vitousek et al. 1997). The mechanism by which an algal bloom eventually leads to changes in species diversity in eutrophic systems, as well as the effects of eutrophication on species biomass and diversity, are varied (see references in table A3 for details).

Changes in species diversity and abundance have also been attributed to elevated concentrations of toxic substances. The toxicity of a compound varies across different species, individuals, age, life history, DO levels, water hardness, water pH, and the level of pollutant concentration (chronic vs. acute) (e.g., Handy and Eddy 1990; Laws 1993).

Habitat alterations and changes in physical conditions of habitats, such as wetland drainage, wetland fragmentation, river damming and channelization, and other types of hydrologic modification, have been identified as another major factor determining species composition and population abundance in aquatic ecosystems (Faurie et al. 2001).[7]

The literature seems to be conclusive in identifying nutrient loading, toxic pollution, and habitat alterations as the major factors affecting the abundance and diversity of aquatic life. Accordingly, the species-at-risk equation is specified as follows:

$$\ln(SPERISK_i) = \delta_0 + \delta_1 CONVWQ_i + \delta_2 TOXICWQ_i + \delta_3' \boldsymbol{l}_i^s + \delta_4' \boldsymbol{d}_i^s + \varepsilon_i^s \qquad [3]$$

where $\boldsymbol{l}_i^s$ is a vector of land use and habitat variables, $\boldsymbol{d}_i^s$ is a vector of spatial dummies, and ε_i^s is an error term, with $\exp(\varepsilon_i^s)$ following the gamma distribution. Since the total number of aquatic and wetland species in each watershed is unknown a corresponding $\ln N$ component, which appears in the other two equations, is not present in the third equation. However, the differences in species diversity are partially accounted for by the spatial dummies representing the varying ecological conditions across the United States. Equation [3], together with [1] and [2], constitute our equation system. The justifications for the specification of [1]-[3] and the estimation method are discussed in the next section.

ESTIMATION METHOD

The Poisson and negative binomial models have been suggested for estimating the number of occurrences of an event, or event counts (Maddala 1983, p.51; Cameron and Trivedi 1998). In this study, an event count is the number of samples violating the national water quality standard or the number of endangered species in a watershed. Formally, an event count is defined as a realization of a nonnegative integer-valued random variable y. The Poisson model is derived by assuming that y is Poisson-distributed with the conditional density of y equal to $f(y|\mathbf{x}) = (e^{-\theta}\theta^{y})/y!$, where $\theta = E[y|\mathbf{x}]$. The log of the mean θ is assumed to be a linear function of a vector of independent regressors **x**: $\ln\theta = \mathbf{x}'\boldsymbol{\beta}$, where $\boldsymbol{\beta}$ is a parameter vector. This specification ensures nonnegativity of θ (Cameron and Trivedi 1998).

There are two potential problems with the Poisson regression model. One is that it assumes that the sample size is constant (Maddala, p.53). But sample sizes often change in cross-sectional analyses. To address this problem, Maddala suggests an alternative specification. Let N be the total sample corresponding to y so that the rate of occurrence is y/N. With the sample size information, the Poisson model can be re-parameterized as $\ln\theta = \ln N + \mathbf{x}'\boldsymbol{\beta}$. In this study, the sample size is known for conventional and toxic water pollution measures, but unknown for the species-at-risk indicator.

Another problem with the Poisson specification is the restriction imposed by the equidispersion property.[8] Table 2.1 shows that conditional mean and conditional variance are likely to be different for each of the three dependent variables. The standard way to account for overdispersion is the NB2 model suggested by Cameron and Trivedi (1998). They derive this negative binomial model from a Poisson-gamma mixture distribution (Cameron and Trivedi, pp. 100-102). In addition to y being conditionally Poisson-distributed, parameter θ is assumed to be the product of a deterministic term and a random term, $\theta = e^{x'\beta+\varepsilon} = e^{x'\beta}e^{\varepsilon} = \mu\nu$. Cameron and Trivedi show that by assuming a gamma distribution for ν (mean 1, variance α), the marginal distribution of y is the negative binomial with the first two moments $E\left[y|\mu,\alpha\right] = \mu$ and $V\left[y|\mu,\alpha\right] = \mu + \alpha\mu^2$. The model of the form $\ln\theta = \mathbf{x}'\boldsymbol{\beta} + \varepsilon$ is estimated using maximum likelihood methods, along with the dispersion parameter α.

Instrumental variable (IV) techniques are used to estimate the equation system [1]-[3]. First, equations [1] and [2] are estimated as NB2 models using the GENMOD procedure in SAS. These equations are then used to predict CONVWQ and TOXICWQ. Finally, equation [3] is estimated as a NB2 model using the predicted values of CONVWQ and TOXICWQ.

DATA

The data used in this study come from three main sources: The USEPA's Index of Watershed Indicators (IWI), the USDA's National Resources Inventories (NRI), and the NOAA's Coastal Assessment and Data Synthesis System. All datasets have been retrieved by the 8-digit hydrologic units, the nationally consistent set of watersheds in the Hydrologic Unit Classification System developed by the USGS. The dataset includes about 2,100 watersheds.[9] Table 2.1 describes the variables selected for this study and the basic statistics.

Table 2.1. Definitions of Variables and Descriptive Statistics

Variables	Description	Data source
CONVWQ	*Conventional water quality:* Number of samples in exceedance of national reference levels for concentrations of phosphorus, ammonia, dissolved oxygen, and pH in surface waters.	USEPA-IWI
N^C	Total number of samples taken to measure conventional water quality	USEPA-IWI
TOXICWQ	*Toxic water quality*: Number of samples in exceedance of national chronic levels for concentrations of copper, nickel, zinc, and chromium in surface waters.	USEPA-IWI
N^T	Total number of samples taken to measure toxic water quality.	USEPA-IWI
SPERISK	*Species at risk*: Number of aquatic and wetland species at risk of extinction	USEPA-IWI
POPDEN	*Population density*: Based on 1990 U.S. Census (persons/acre)	USEPA-IWI
SOILPERM	*Index of soil permeability*	USEPA-IWI
STORAGE	*Total storage* of dams and reservoirs (1,000 acre-feet)	USEPA-IWI
UR	*Urban land* (% area)	USDA-NRI
TR	*Rural transportation* (% area)	USDA-NRI
CC	*Cultivated cropland* (% area)	USDA-NRI
NONCC	*Noncultivated cropland* (% area)	USDA-NRI
PAST	*Pastureland* (% area)	USDA-NRI
RANG	*Rangeland* (% area)	USDA-NRI
FO	*Forestland* (% area)	USDA-NRI
CRP	*CRP land* (% area)	USDA-NRI
MINOR	*Minor land* (% area)	USDA-NRI
MIN	*Mining land* (% area)	USDA-NRI
OMINOR	*Other minor land* (excl. mining land) (% area)	USDA-NRI
FED	*Land owned by the federal government* (% area)	USDA-NRI
IRRIGacres	*Irrigated land* (1,000 acres)	USDA-NRI
USLE	Soil loss due to *water erosion* (tons/acre/year)	USDA-NRI
EIWIND	Soil loss due to *wind erosion* (tons/acre/year)	USDA-NRI
WETLANDacres	Area of palustrine and estuarine wetlands (1,000 ac)	USDA-NRI
LANDacres	Total land area of watershed (1,000 ac)	USDA-NRI
WATERacres	Area of water bodies in watershed (1,000 ac)	USDA-NRI
FERTUSE	*Fertilizer use*: Average annual nitrogen and phosphorus fertilizer use (lbs/ac of fertilized area)	NOAA
PESTUSE	*Pesticide use*: Average annual pesticide use (lbs/ac of agricultural area)	NOAA

Table 2.1. Definitions of Variables and Descriptive Statistics (Continued)

Variables	Year	Obs.	Mean	Std. Dev.	Min.	Max.
CONVWQ	1990-98	1344	586.94	2593.92	0	56476
N^C	1990-98	1344	3469.10	11889.01	20	204168
TOXICWQ	1990-98	758	70.86	234.16	0	4323
N^T	1990-98	758	731.16	1121.56	20	13059
SPERISK	1996	1595	4.56	4.94	1	47
POPDEN	1990	2062	18.31	65.06	0	1314.74
SOILPERM	1998	2109	4.17	1.21	0	8.96
STORAGE	1995-96	1915	262.03	1277.30	0.001	28255
UR	1982,87,92,97	2109	4.39	8.82	0	87.47
TR	1982,87,92,97	2109	1.18	0.68	0	3.39
CC	1982,87,92,97	2109	18.70	23.99	0	91.73
NONCC	1982,87,92,97	2109	2.46	3.21	0	31.83
PAST	1982,87,92,97	2109	6.95	9.28	0	71.99
RANG	1982,87,92,97	2109	18.97	26.25	0	99.98
FO	1982,87,92,97	2109	24.68	27.43	0	99.55
CRP	1982,87,92,97	2109	1.01	2.06	0	16.72
MINOR	1982,87,92,97	2109	2.75	5.09	0	81.41
MIN	1982,87,92,97	2109	0.27	1.33	0	41.52
OMINOR	1982,87,92,97	2109	2.48	4.82	0	81.41
FED	1982,87,92,97	2109	18.90	27.99	0	100.00
IRRIGacres	1982,87,92,97	2109	31.86	107.14	0	3240.18
USLE	1982,87,92,97	2109	1.86	1.97	0	18.64
EIWIND	1982,87,92,97	2109	2.08	7.16	0	146.50
WETLANDacres	1997	2109	52.65	102.72	0	1524.90
LANDacres	1982,87,92,97	2109	895.30	570.23	0	5510.58
WATERacres	1982,87,92,97	2109	23.43	57.99	0	860.00
FERTUSE	1982-91	2074	359.48	2908.05	0	60814.15
PESTUSE	1992	2071	2.07	5.48	0.0015	129.38

Land Use and Other Human Impacts

The USDA's NRI contain detailed data on land use, land cover, and natural resource conditions on nonfederal lands in the United States. The data are collected every 5 years from the same statistically based sample sites and are classified by state, county, major land resource area, and hydrologic unit. All variables used in this study were retrieved from the 1997 NRI database, which also contains data from previous three NRIs (1982, 1987, 1992). Unless mentioned otherwise, all variables are constructed as percent of total land area of the hydrologic unit and are averaged over the four NRI years (1982, 1987, 1992, 1997). This study uses the following NRI land use categories: *cultivated cropland* (CC), *noncultivated cropland* (NONCC), *pastureland* (PAST), *rangeland* (RANG), *forestland* (FO), *urban land* (UR), *rural transportation land* (TR), *minor land* (MINOR) - with subcategory of *mining land* (MIN), *CRP land* (CRP) (measuring the land enrolled in the Conservation Reserve Program), and *federal land* (FED) measuring the land owned by the federal government.[10] These land use categories completely describe the landscape. Hence, in order to avoid perfect multicollinearity, forestland (FO) was excluded from the regression models and used as the reference land use. *Irrigated land* (IRRIGacres) reflects the area that shows evidence of being irrigated during the year of the inventory or of having been irrigated during two or more of the last four years.

Population density (POPDEN) was calculated as the number of persons per acre in the watershed based on the 1990 Census population data. *Total storage* (STORAGE) measures the total storage capacity of dams and reservoirs in a given watershed. The volume of impounded water is an indicator of the degree of hydrologic modification. These variables were retrieved from USEPA's IWI database. The fertilizer and pesticide use variables (FERTUSE, PESTUSE) were obtained from NOAA's dataset, which contains data on the application of nitrogen and phosphorus fertilizers and numerous pesticides in agricultural production.[11]

Watershed Physical and Habitat Characteristics

Watershed ecosystems are affected not only by human activities but also by their own vulnerability. The vulnerability of a watershed to ecosystem damages is determined by a number of physical and habitat characteristics, including the following: total land area of the watershed (LANDacres); area of the watershed covered by permanent open water

(WATERacres) constructed as the sum of NRI census water and small water areas; area of palustrine and estuarine wetlands (WETLANDacres), as defined by the Cowardin classification system; average wind erosion rate in the watershed (EIWIND), based on the NRI wind erosion estimates; average water erosion rate in the watershed (USLE), based on the NRI soil erosion estimates (USDA 2000); and soil permeability index (SOILPERM) based on the IWI data.[12]

Spatial Dummies

Spatial dummies are included in order to capture some of the spatial variability across the large study area. Two sets of spatial dummy variables are used in this analysis – Land Resource Regions (20 regions) and Ecosystem Divisions (21 divisions). Land Resource Regions, defined by the USDA's Soil Conservation Service (Figure 2.4), are characterized by a particular pattern of soils, climate, water resources, and land uses.[13] Ecosystem Divisions (Figure 2.5) are defined by the USDA's Forest Service as areas that share common climatic, precipitation, and temperature characteristics.[14]

ESTIMATION RESULTS

The equation system [1]-[3] is estimated to evaluate the effect of land use on water quality and aquatic species. The goodness-of-fit measures indicate that the NB2 models fit the data much better than the Poisson model for each of the three equations. The likelihood ratio tests and the Pearson/DF and deviance/DF measures also indicate that the Poisson distribution assumption is inappropriate.[15] Thus, only results from the NB2 models are reported in this paper.

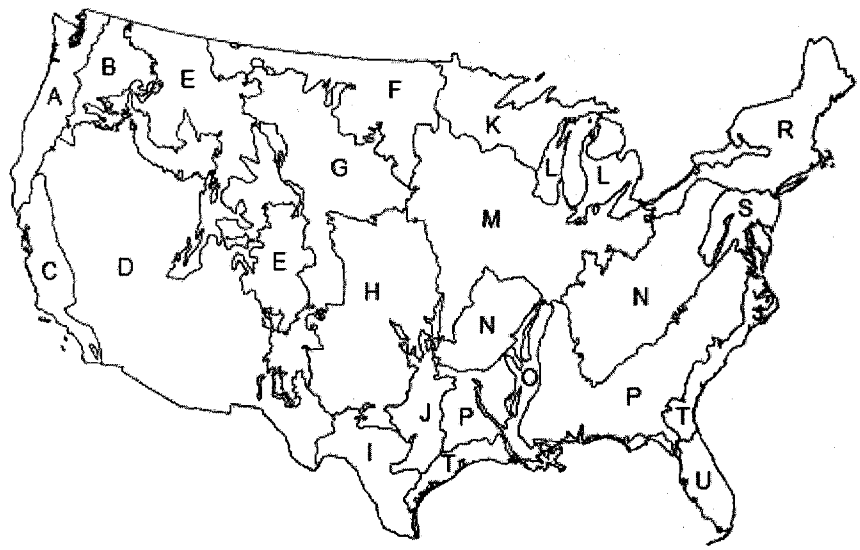

Figure 2.4. Land Resource Regions

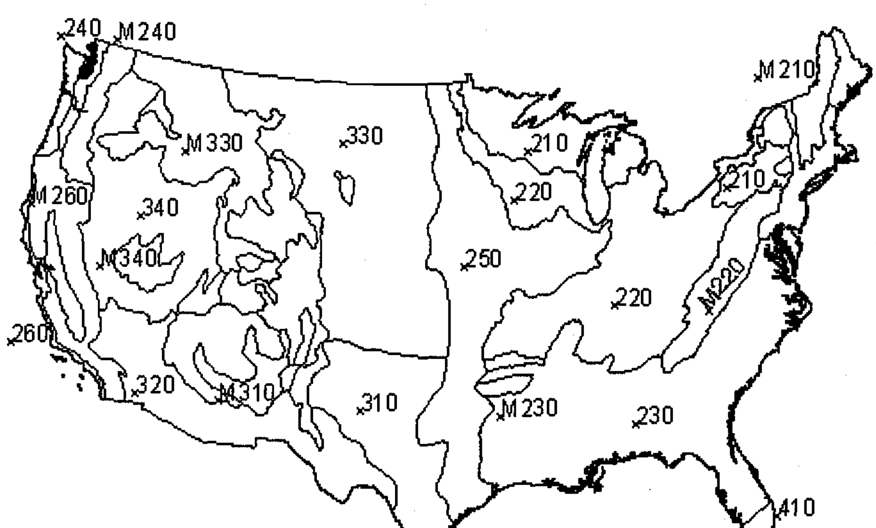

Figure 2.5. Ecosystem Divisions

The Conventional Water Quality Model

Table 2.2 presents parameter estimates for two specifications of the conventional water quality model. The basic specification uses shares of alternative land uses as explanatory variables, and the alternative model uses population density and the average annual fertilizer use per acre as explanatory variables instead of the land use variables. The coefficients on urban land (UR), cultivated cropland (CC), and pastureland (PAST) in the basic model are positive and statically significant at the 1% level or better. Given that forest is used as a reference land use, these results indicate that converting forests to developed land, cultivated cropland, or pastureland increases conventional water pollution. Although the impacts of crop production and urban runoff on water quality have been well documented and the results concerning these land uses are expected, the impact of pastureland on water pollution is less intuitive. A common characteristic of cultivated cropland and pastureland is that they both are treated with fertilizer application. The USDA defines *pastureland* (PAST) as area that is managed primarily for the production of introduced forage plants and where management usually consists of cultural treatments such as fertilization and weed control. This is in contrast to *rangeland* (RANG) which is defined as area covered with native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, with little or no chemicals or fertilizer being applied. As expected, the coefficient on EIWIND is positive, and significant, indicating that wind erosion exacerbates conventional water quality problems.

In the alternative conventional water quality model, the land use variables are replaced with population density and fertilizer use. The coefficient on population density (POPDEN) is positive and statistically significant at the 1% level. This is consistent with the coefficient on urban land use in the basic model. However, the coefficient on fertilizer use (FERTUSE) is statistically insignificant at the 10% level, although it is positive as expected.

Table 2.2. Estimated Coefficients of the Conventional Water Quality Model with the NB2 Specification

	Basic Model		Alternative Model	
Variables	Coefficient	St. Error	Coefficient	St. Error
Intercept	-2.0283***	(0.2343)	-2.8338***	(0.1704)
UR	0.0118***	(0.0026)		
TR	0.0293	(0.0547)	0.1168**	(0.0534)
CC	0.0120***	(0.0018)		
NONCC	-0.0042	(0.0085)		
PAST	0.0105***	(0.0033)		
RANG	0.0030	(0.0022)		
CRP	-0.0074	(0.0164)	0.0067	(0.0165)
MINOR	0.0063	(0.0043)	0.0045	(0.0048)
FED	-0.0010	(0.0020)	-0.0041**	(0.0017)
POPDEN			0.0011***	(0.0003)
FERTUSE			1.87E-05	(1.29E-05)
IRRIGacres	4.55E-05	(0.0002)	0.0004*	(0.0002)
USLE	0.0059	(0.0147)	0.0233	(0.0144)
EIWIND	0.0071*	(0.0039)	0.0102**	(0.0044)
SOILPERM	0.0122	(0.0202)	-0.0232	(0.0200)
Spatial dummies				
Region A	-1.0548***	(0.2092)		
Region B	-0.2282	(0.2071)	0.9348***	(0.1785)
Region C			1.0441***	(0.2108)
Region D	-0.1524	(0.1853)	1.0157***	(0.1441)
Region E	-0.3728**	(0.1862)	0.7692***	(0.1422)
Region F	-0.2089	(0.2241)	1.2792***	(0.1839)
Region G	-0.2588	(0.2207)	0.9947***	(0.1859)
Region H	-0.5266***	(0.1964)	0.8520***	(0.1537)
Region I	-0.7479***	(0.2452)	0.5604***	(0.2157)
Region J	-0.5753**	(0.2269)	0.7808***	(0.1824)
Region K	-0.4070**	(0.2074)	0.7393***	(0.1550)
Region L	-0.5025**	(0.2196)	0.9896***	(0.1697)
Region M	-0.3184	(0.2056)	1.2040***	(0.1471)
Region N	-0.5711***	(0.2023)	0.5746***	(0.1380)
Region O	-0.1898	(0.2586)	1.1123***	(0.2255)
Region P	-0.3155	(0.1997)	0.7999***	(0.1388)
Region R	-0.7252***	(0.2074)	0.3400**	(0.1591)
Region S	-0.7002***	(0.2265)	0.4889***	(0.1859)
Region T	-0.0703	(0.2024)	1.1393***	(0.1519)
Region U	-0.0984	(0.2443)	1.2755***	(0.2107)

Table 2.2. Estimated Coefficients of the Conventional Water Quality Model with the NB2 Specification (Continued)

	Basic Model		Alternative Model	
Variables	Coefficient	St. Error	Coefficient	St. Error
Dispersion	0.4702***	(0.0193)	0.4905***	(0.0201)
Obs.	1,343		1,330	
Deviance/DF	1.1311		1.1288	
Pearson X2/DF	1.0740		1.0761	
Log Likelihood	4,943,982		4,933,349	

Note: The dependent variable is ln(CONVWQ). Forest land serves as the reference land use. One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively. Standard errors are deviance-scaled.

Both models of conventional water quality are estimated using the NB2 assumption, and land use variables are averages over the four NRI years (1982, 1987, 1992, 1997). The qualitative results, however, are robust to alternative specifications of functional forms (linear or log-linear OLS), to error term distribution assumptions (Poisson or NB2), to data selections (based solely on the 1997 NRI data or the four-year average), and to the choice of dummy variables (using the 20 regions or 41 production areas as spatial dummies).[16] Thus, there is strong empirical evidence that intensive agriculture and urban development contribute to conventional water quality problems in the United States.

The sign and magnitude of the coefficients of spatial dummies indicate the degree of water quality concerns in these regions relative to the chosen reference unit. For example, selecting Region C (central and southern California valleys) as the reference dummy yields all coefficients of the spatial dummies negative, approximately a half of them significant. This is not surprising given that Region C has a large agricultural sector and is experiencing rapid urbanization. On the other hand, if Region A (western part of U.S. Pacific Northwest) is selected as a reference region, all spatial dummies have a positive coefficient. This is expected for a region characterized by extensive forests and relatively low levels of urbanization.

Both the continuous land use variables and the spatial dummies tend to identify the same factors affecting water pollution. The reason may be that the dummies capture the vulnerability of a region for water pollution (e.g., high natural background concentrations), with intensive farming and urbanization exacerbating the problem. Furthermore, while the continuous regressors capture only the extent of a particular land use, the dummies are also likely to capture the intensity of land use as well as differences in cropping systems.

The Toxic Water Quality Model

Estimation results for two specifications of the toxic water quality model are also presented in table 2.3. The basic model uses land use shares as explanatory variables, and the alternative one uses population density and the average annual pesticide use per acre as explanatory variables. Results show that toxic water pollution in a watershed is significantly affected by the amount of land allocated to mining (MIN) and transportation (TR) according to both specifications. Surface water samples taken in watersheds with more land allocated to mining and transportation and less to forests are more likely to have toxic pollutant concentrations (copper, nickel, zinc, chromium) above the national chronic level. However, the coefficients on the shares of urban land and cultivated cropland are insignificant in the basic model, nor are the coefficients on population density and pesticide use in the alternative specification. These results are also robust to alternative specification of functional forms, as well as to the choice of data and spatial dummies.[17] From a national perspective, mining and transportation are the two major causes of toxic water pollution.

Table 2.3. Estimated Coefficients for the Toxic Water Quality Model with the NB2 Specification

Variables	Basic Model		Alternative Model	
	Coefficient	St. Error	Coefficient	St. Error
Intercept	-2.2533***	(0.5432)	-4.0067***	(0.3612)
UR	0.0077	(0.0055)		
TR	0.4847***	(0.1338)	0.3084**	(0.1276)
CC	-0.0044	(0.0040)		
NONCC	-0.0297	(0.0189)		
PAST	-0.0192***	(0.0074)		
RANG	0.0060	(0.0054)		
CRP	0.0931**	(0.0428)	0.0490	(0.0404)
MIN	0.0771*	(0.0446)	0.0833*	(0.0451)
OMINOR	0.0031	(0.0100)	0.0068	(0.0105)
FED	0.0075	(0.0046)	0.0080**	(0.0038)
POPDEN			0.0007	(0.0009)
PESTUSE			0.0090	(0.0205)
IRRIGacres	0.0006	(0.0008)	0.0005	(0.0007)
USLE	-0.0215	(0.0298)	-0.0204	(0.0287)
EIWIND	0.0198	(0.0231)	0.0198	(0.0233)
SOILPERM	-0.1107**	(0.0529)	-0.0699	(0.0489)
Spatial dummies				
Region A	-0.1969	(0.8050)	1.4202*	(0.7515)
Region B	-1.7410**	(0.7247)	0.0149	(0.6589)
Region C			1.7400***	(0.5257)
Region D	-0.9701**	(0.4440)	0.8493**	(0.3395)
Region E	0.0548	(0.4326)	1.7217***	(0.3292)
Region F	-1.6023***	(0.5458)	0.1675	(0.4296)
Region G	-1.2550**	(0.5321)	0.7425*	(0.4229)
Region H	-1.6144***	(0.4592)	0.2986	(0.3127)
Region I	-1.8632**	(0.7395)	-0.0697	(0.6809)
Region J	-1.8120***	(0.5402)	-0.1876	(0.4327)
Region K	-0.8486*	(0.4859)	0.6742*	(0.3503)
Region L	-1.4709***	(0.4532)		
Region M	-1.2738***	(0.4398)	0.1721	(0.2759)
Region N	-0.2660	(0.4314)	1.1134***	(0.2527)
Region O	-0.9566*	(0.5520)	0.5320	(0.4422)
Region P	0.0225	(0.4424)	1.6200***	(0.2562)
Region R	-0.0187	(0.4587)	1.5065***	(0.3079)
Region S	-0.3380	(0.4668)	1.1424***	(0.3433)
Region T	-0.2382	(0.4358)	1.4365***	(0.2812)
Region U	-0.0239	(0.5260)	1.2853***	(0.4368)

Table 2.3. Estimated Coefficients for the Toxic Water Quality Model with the NB2 Specification (Continued)

	Basic Model		Alternative Model	
Variables	Coefficient	St. Error	Coefficient	St. Error
Dispersion	1.1707***	(0.0695)	1.2031***	(0.0714)
Obs.	757		751	
Deviance/DF	1.2087		1.2068	
Pearson X2/DF	1.3636		1.3519	
Log Likelihood	211,359		211,129	

Note: The dependent variable is ln(TOXICWQ). Forest land serves as the reference land use. One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively. Standard errors are deviance-scaled.

As for the spatial dummies, Region C (central and southern California valleys) and Region L (parts of Great Lakes states) serve as the reference dummies in the basic and alternative models, respectively. The generally high levels of toxic contamination in the former compared to the relatively low levels in the latter region can explain the different results. It is noteworthy that in the basic model only two regions (Region E and P) have a positive sign, though insignificant. The former is characterized by high concentration of mining, the latter by sprawling urban growth.

The Species-at-Risk Model

Parameter estimates for two specifications of the species-at-risk model are presented in table 2.4. The results show that water pollution, both conventional and toxic, increases the number of aquatic and wetland species at risk of extinction in a watershed, *ceteris paribus*. However, the toxic pollution variable, TOXICWQ, is statistically insignificant. Since the species-at-risk model focuses on aquatic species, land use variables such as shares of developed

Table 2.4. Estimated Coefficients for the Species-at-Risk Model with the NB2 Specification

	Basic Model		Alternative Model	
Variables	Coefficient	St. Error	Coefficient	St. Error
Intercept	1.5207***	(0.0979)	-0.3989	(0.3548)
Endogenous Variables				
CONVWQ	4.52E-05***	(1.54E-05)	4.79E-05***	(1.52E-05)
TOXICWQ	2.17E-04	(2.81E-04)	2.85E-04	(3.24E-04)
Exogenous Variables				
STORAGE	-3.91E-05	(5.54E-05)	-4.22E-05	(5.51E-05)
WATERacres	6.21E-04	(5.39E-04)	7.67E-04	(5.51E-04)
WETLANDacres	1.46E-04	(3.76E-04)	1.06E-04	(3.75E-04)
LANDacres	4.13E-04***	(7.13E-05)	4.03E-04***	(7.13E-05)
Spatial Dummies				
Division 210	-0.7437***	(0.1491)	1.1844***	(0.3661)
Division M210	-0.6372**	(0.2748)	1.2905***	(0.4314)
Division 220	-0.0432	(0.0963)	1.8852***	(0.3440)
Division M220	-0.0085	(0.1340)	1.9031***	(0.3558)
Division 230			1.9158***	(0.3513)
Division M230	-0.0062	(0.4377)	1.9193***	(0.5483)
Division 240	-0.8800	(0.8474)	0.9963	(0.9190)
Division 250	-0.8494***	(0.1310)	1.0763***	(0.3520)
Division 260	0.2135	(0.3728)	2.3407***	(0.5402)
Division M260	0.1480	(0.4190)	2.0709***	(0.5319)
Division 310	-0.6352***	(0.2251)	1.2910***	(0.3947)
Division M310	-0.5105	(0.3527)	1.4242***	(0.4699)
Division 320	-0.4595*	(0.2436)	1.4750***	(0.3988)
Division 330	-1.5923***	(0.1921)	0.3399	(0.3743)
Division M330	-1.3573***	(0.1729)	0.5716	(0.3671)
Division 340	-1.8586***	(0.3323)		
Division 410	-1.7944**	(0.8890)	-0.1689	(1.0075)
Dispersion	0.3820***	(0.0309)	0.3782***	(0.0308)
Observations	614		611	
Deviance/DF	0.9846		0.9844	
Pearson X2/DF	1.1030		1.1011	
Log Likelihood	3527		3534	

Note: The dependent variable is ln(SPERISK). One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively. Standard errors are deviance-scaled.

land and cultivated cropland are not included as independent variables in the final model. When land use variables are also included in the species-at-risk model, they tend to be insignificant. Those significant often have signs consistent with interpretations of representing the size of habitat. Thus, land use variables are not included in the final model except those describing the size and conditions of habitat (WATERacres, WETLANDacres, LANDacres, STORAGE). These results suggest that land use affects aquatic species mainly through its impact on water quality.

One critical issue related to the analysis of interactions between habitat conditions and species richness is that it is not obvious whether the presence of rare or endangered species in a watershed necessarily indicates (a) poor environmental conditions leading to species endangerment, or (b) quite the opposite, high-quality conditions providing habitat for species not found elsewhere. To address this issue, we include several groups of control variables in the regression model. First, a group of acreage variables (WATERacres, WETLANDacres, LANDacres) are included to account for the size of the watershed and its aquatic habitat. Large watersheds with more wetlands and larger areas of water bodies are more likely to have more species including those at risk of extinction. Second, a set of spatial dummies (Ecosystem Divisions) are included to account for the species richness across the watersheds. We assume that an area with low species diversity is likely to have only few rare species (ceteris paribus), while an area with high species diversity is more likely to have many rare species. The third group of variables (CONVWQ, TOXICWQ, STORAGE) are included to control for the human impacts. Hence, this specification will help isolate the partial effects of habitat size, species diversity, and selected habitat quality variables.

The reference dummies chosen in this case include subtropical Division 230 characterized by high levels of aquatic biodiversity, and the temperate desert Division 340 characterized by generally low level of aquatic biodiversity. Results in table 2.4 show that coefficients of the more biologically diverse ecoregions in the eastern U.S. (e.g. Divisions 220, M220, 230, M230) and California (Divisions 260, M260) tend to be greater than those of the steppe and desert ecoregions in the western U.S. (Divisions 310, M310, 320, 330, M330, 340).

In sum, there is evidence that poor water quality is likely to intensify the stress on aquatic ecosystems and contribute to species endangerment. The mutual interdependence of watershed health and water quality implies a need for systemic policies. For this reason, a policy aimed at decreasing the threats to biodiversity has to address the problems of conventional and toxic water quality.

MAJOR FINDINGS AND POLICY IMPLICATIONS

The effect of alternative land uses on water quality and watershed ecosystems is evaluated using the empirical models. Table 2.5 shows the elasticities of the three selected watershed indicators with respect to land use variables that are statistically significant in at least one equation (at the 10% level or better) and are robust to empirical specifications. The elasticities are calculated using the formula shown in appendix B and are evaluated at the sample mean. Because forestland is used as a reference land use in both the conventional and toxic water quality models, the impacts of alternative land uses should be interpreted relative to the impact of forest land use.

The first two columns of table 2.5 show the impact of alternative land uses on conventional water quality. There is strong evidence that converting forests to intensive

Table 2.5. Estimated Elasticities of Watershed Indicators with Respect to Alternative Land Uses

Independent Variables	Dependent Variables: CONVWQ (1a)	CONVWQ (1b)	TOXICWQ (2a)	TOXICWQ (2b)	SPERISK (3a)	SPERISK (3b)
CONVWQ					0.0266***	0.0281***
TOXICWQ					0.0153	0.0202
UR	0.0519***		0.0338		0.0019**	
TR	0.0346	0.1381**	0.5731***	0.3646**	0.0097	0.0113
CC	0.2244***		-0.0823		0.0047	
PAST	0.0730***		-0.1334***		-0.0001	
MIN			0.0209*	0.0226*	0.0003	0.0005
POPDEN		0.0195***		0.0130		0.0008
IRRIGacres	0.0015	0.0128*	0.0176	0.0146	0.0003	0.0007

Note: Elasticities are evaluated at the sample means. One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively. The variables represent conventional water quality (CONVWQ), toxic water quality (TOXICWQ), species at risk of extinction (SPERISK), % urban land (UR), % transportation land (TR), % cultivated cropland (CC), % pastureland (PAST), % mining land (MIN), population density (POPDEN), and irrigated acreage (IRRIGacres).

agriculture and urban development contributes to conventional water pollution in the United States. A 1% increase in cultivated cropland (1,674 acres for an average watershed) increases the number of samples in exceedance of the national reference level for conventional water quality by 0.22% in an average watershed, while a 1% increase in developed land (393 acres for an average watershed) increases the number of samples in exceedance of the national reference level for conventional water quality by 0.05%. Converting forestland to pasture also increases conventional water pollution. A 1% increase in pastureland (622 acres for an average watershed) increases the number of samples in exceedance of the national reference level for conventional water quality by 0.07%.

Columns 3 and 4 of table 2.5 show the impact of alternative land uses on toxic water quality. Converting forestland to transportation or mining will significantly increase the probability of toxic water pollution. A 1% increase in the amount of land allocated to transportation and mining (106 acres and 24 acres, respectively, in an average watershed) is expected to increase the number of samples in exceedance of the national chronic level for toxic water quality by 0.57% and 0.02%, respectively.

The last two columns of table 2.5 show the impact of alternative land use variables on the number of endangered species in an average watershed. The conventional water quality variable is statistically significant at the 1% level. A 1% increase in the percent of samples exceeding the national reference level for conventional water quality is expected to increase the number of endangered aquatic species by about 0.03%. However, the toxic water quality measure is insignificant in the model of endangered species at the 10% level. Although land use variables are not included as independent variables in the species-at-risk model, they affect aquatic species indirectly through their impacts on water quality. These indirect impacts of land uses are also estimated and reported in the last two columns of table 2.5 (see the formula in appendix B). A 1% increase in acreages of developed land and transportation increases the number of endangered aquatic species by 0.002% and 0.01%, respectively.

As shown above, because land is not equally divided among alternative uses, a 1% increase in alternative land uses represents different acres. For example, developed land accounts for only 4.39% of total land area on average, while cultivated cropland accounts for 18.7% of total land area on average. Thus, a 1% increase in developed land translates to 393 acres, while a 1% increase in cultivated cropland translates into 1,674 acres. To compare the impacts of alternative land uses on water quality, the results are converted to the per-acre impacts in table 2.6 using the formula shown in [B5] in appendix B. For an average watershed, converting 1% of forestland (2,210 acres) into urban development increases the percent of samples in exceedance of the national reference level for conventional water quality by 0.29%.[18]

Table 2.6. The Per-Acre Impact of Alternative Land Uses on the Selected Watershed Indicators

One acre of land use category	Estimated impact (%) ($\times 10^{-04}$)					
	CONVWQ		TOXICWQ		SPERISK	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
UR	1.3180***		0.8600		0.0482**	
TR	3.2726	13.0459**	54.1381***	34.4464**	0.9177	1.0633
CC	1.3403***		-0.4915		0.0281	
PAST	1.1728***		-2.1445***		-0.0018	
MIN			8.6116*	9.3041*	0.1321	0.1881

Note: One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively. The variables represent conventional water quality (CONVWQ), toxic water quality (TOXICWQ), species at risk of extinction (SPERISK), % urban land (UR), % transportation land (TR), % cultivated cropland (CC), % pastureland (PAST), and % mining land (MIN).

It has about the same impact as converting the same amount of forests to cultivated cropland, but has a slightly larger impact than converting forests to pastureland on a per-acre basis.

Converting forestland to highways and mining both increases toxic water pollution, but transportation has a much larger impact than mining on a per-acre basis. Converting 1% of forestland to transportation will increase the percent of samples in exceedance of the national chronic level for toxic water quality by 7.61% in an average watershed based on the alternative model, which is about 4 times larger than the impact of converting the same amount of forestland to mining. Transportation also has a larger impact on endangered aquatic species than mining and urban development on a per-acre basis because it has a larger impact on toxic water pollution.

These results have important implications for water quality trading policies under consideration in many states of the United States. Water quality trading is an innovative, market-based approach that allows one source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs. Our results show that trading for reducing conventional water pollution should focus on intensive agriculture and urban development, while trading for reducing toxic water pollution should focus on transportation and mining. In an average watershed, one acre of urban development on forestland can be offset by converting one acre of cultivated cropland to forests in terms of impact on conventional water quality. However, to offset the impact on toxic water quality of one acre of highways built in forests, 3.7 acres of mining must be converted to forests. It is important to note that these results are estimated based on the marginal effects. For large land use changes, the models instead of the elasticities must be used to calculate the approximate trading ratios. In addition, because the marginal effects of land use on water quality are not constant, the amount of land use conversions needed to offset a negative water quality impact will be different for watersheds with different size and mix of land uses. Trading ratios may also be different for inter-watershed trading than intra-watershed trading. For example, equation [B5] shows that one acre of urban development will have a much larger effect on water quality and species in a small watershed than in a large watershed. Thus, in general, the environmental effect of one acre of development cannot be offset by purchasing one acre of development rights in another watershed. The empirical models estimated in this study can be used to calculate trading ratios for both intra- and inter-watershed trading.

The empirical results also have implications for the design and evaluation of conservation programs. Soil erosion, particularly wind erosion, is found to increase both conventional and toxic water pollution. Thus, conservation programs that aim at reducing soil erosion will contribute to improving water quality and aquatic habitat. Given that biodiversity and endangered species are significantly affected by water quality and land uses, it is important to take a ecosystem approach in the design of policies for protecting biodiversity and endangered species (Main, Roka and Noss 1999).

The most important legislative initiative for the species protection in the U.S. is the

Endangered Species Act (ESA). Compared to the previous legislative efforts, ESA expanded the available conservation measures to include all methods and procedures necessary to protect the species rather than emphasizing only habitat protection (Switzer 2004). Although the ESA has been recognized as "a powerful and sensible way to protect biological diversity" (Carroll et al. 1996, p.2), it has been subjected to extensive criticism from both natural scientists (e.g., Carroll et al. 1996; Switzer 2004) and economists (e.g., Brown and Shogren 1998) for ineffective use of scientific information and for sidelining economics. Our empirical results suggest that habitat conditions, particularly water quality, are important factors determining the number of aquatic species at risk of extinction in a watershed.

CONCLUSIONS

Land use issues are a manifestation of the fundamental economic fact of scarcity. The limited land supply implies that more land in one use means less land being left for an alternative use. Although markets play a central role in land allocation, they may fail to allocate land efficiently in the presence of externalities and improper incentives. For example, market prices of developed land may not reflect the environmental damages caused by urban runoff, nor do they account for the loss of wildlife habitat. These externalities may cause developed land being overvalued. However, it is difficult to develop policies to correct market failures in land allocation because of lack of information on the relative impacts of alternative land uses on water quality and ecosystems.

This study has important implications for water quality trading policies under consideration in many states of the United States. Our results show that trading for reducing conventional water pollution should focus on agricultural and urban land use, while trading for reducing toxic water pollution should focus on transportation and mining. In an average watershed, one acre of urban development on forestland can be offset by converting one acre of cultivated cropland to forests in terms of impact on conventional water quality; however, to offset the impact on toxic water quality of one acre of highways built in forests, 3.7 acres of mining must be converted to forests. In general, trading ratios are different for watersheds with different sizes and mixes of land use. The models estimated in this study can be used to calculate such trading ratios.

This study accentuates the "big picture" analysis by examining the relationship between land use, water quality, and aquatic species extinction across the United States. This nation-wide analysis has two major limitations. First, the ecological impact of land use is inherently a spatial issue. Conducting a spatially explicit analysis may yield valuable insights. However, dimensionality and data limitations prevent us from considering locations of economic activities within a watershed. Second, interactions among land use, water quality, and watershed health are intrinsically dynamic. There may also be time lags between land use changes and their ecological impacts. Explicitly modeling these interactions and time lags would be an important topic for future research. Currently, considering these spatial and temporal dimensions is constrained by the lack of spatially explicit, time-series data. In particular, our analysis highlights the need for time-series data on species abundance and habitat characteristics. Despite these limitations, this study provides information for the design and evaluation of land use based policies that aim at improving water quality and ecosystems. Considering spatial and temporal dimensions in future research with improved data will provide additional insights. Given existing information, and current needs to prioritize restoration actions in an effective and efficient manner, this study provides a useful first step.

ENDNOTES

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[1] To increase adoption of these management options, many policies have been implemented at the federal and state levels. These include various conservation programs established under the U.S. Farm Bills, such as the Conservation Reserve Program and the Environmental Quality Incentive Program, and numerous mandatory measures authorized under the Clean Water Act and the Endangered Species Act.

[2] The objectives of the policy are to encourage voluntary trading programs that facilitate implementation of TMDLs, reduce the cost of compliance with the Clean Water Act regulations, establish incentives for voluntary reductions, and promote watershed-based initiatives (U.S. Environmental Protection Agency 2003a). The EPA's 2003 Water Quality Trading Policy supports trading to achieve nutrient (e.g., total phosphorus and nitrogen) and sediment load reductions, as well as cross-pollutant trading for oxygen-related pollutants. Water quality trading is currently being implemented or actively considered in about ten states (U.S. Environmental Protection Agency 2003b).

[3] Aquatic organisms are exceptionally vulnerable to the outside environmental conditions and their health provides an early indicator of the state of the environment (Blaustein et al. 1994; Hartwell and Ollivier 1998). Aquatic ecosystems are also characterized by the highest levels of species endangerment and extinction rates (Stein et al. 2000).

[4] Depletion of DO levels is closely related to biological oxygen demand (BOD). BOD is the indicator of pollution by biodegradable organic matter present in water. It is the amount of oxygen required to completely oxidize a quantity of organic matter by biological processes (Keyes 1976).

[5] The discussion is focused on the sources of metallic pollution since the USEPA's toxic water quality indicator (TOXICWQ) measures pollution by selected heavy metals (Cr, Cu, Ni, Zn).

[6] The conventional and toxic water quality models contain both, the erosion rate variables as well as land use variables. While erosion rates are affected by land use, they also characterize the physical vulnerability of a watershed to water pollution.

[7] For example, Frissell (1993) studied the causes of ichthyofaunal impoverishment in drainage basins of the Pacific Northwest and California, and found that cumulative damage to aquatic habitats caused by logging, grazing, urbanization, and other land uses plays a major role in species diversity losses. Richter et al. (1997) assessed the threats to freshwater fauna in the U.S. through an experts survey and identified three leading threats nationwide: altered sediment loads and nutrients inputs from agricultural nonpoint pollution; interference from exotic species; and altered hydrologic regimes associated with impoundment operations. Czech et al. (2000) found that urbanization endangers more species in the mainland United States than any other human activity. Harding et al. (1998) investigated the influence of past land use on the present-day diversity of stream invertebrates and fish in river basins in North Carolina and found that

past land use activity, in particular agriculture, was the best predictor of present-day aquatic diversity.

[8] The property $E\left[y|\mathbf{x}\right]=V\left[y|\mathbf{x}\right]=\theta$ is referred to as the equidispersion property of the Poisson.

[9] Smith, Schwarz, and Alexander (1997) suggest that these watersheds are a logical choice for characterizing national-level water quality because they represent a systematically developed and widely recognized delineation of U.S. watersheds, and provide a spatially representative view of water quality conditions.

[10] Detailed definitions of the land use/cover categories can be found in the *NRI glossary.*

[11] The data come from two sources - The National Center for Food and Agricultural Policy and the Census of Agriculture. The dataset includes statistics on 185 and 208 chemical compounds for the years 1987 and 1992, respectively (NOAA 1999). Only the 1992 data were used in this study, since NOAA expressed some reservations about the reliability of the 1987 vintage.

[12] The USEPA constructed the index based on the State Soil Geographic (STATSGO) database of the USDA's Soil Conservation Service. The soil permeability index reflects the property of the overlying soil and is one of the controlling factors of the transport rate of contaminants through soil. The degree of soil permeability can affect the risk of contamination of ground water resources, and consequently quality of surface waters where ground water feeds rivers and lakes (USEPA 2004b).

[13] For detailed characterization of the Land Resource Regions see Soil Survey Staff (1981) or http://www.soilinfo.psu.edu/soil_lrr/.

[14] For detailed characterization of the Ecosystem Divisions see Bailey (1995) or http://www.soilinfo.psu.edu/soil_eco/.

[15] The deviance and Pearson statistics divided by degrees of freedom with values close to 1 indicate a good fit of the regression model. Values greater (smaller) than 1 indicate over(under)dispersion, i.e. the true variance is greater (smaller) than the mean. Evidence of over(under)dispersion indicates inadequate fit (Cameron and Trivedi 1998).

[16] A third set of spatial dummies, the 41 production areas, was constructed by aggregating the Major Land Resource Areas (MLRA). The USDA defines a MLRA as a geographic area that is characterized by a particular pattern of soils, climate, water resources, land uses, and type of farming. One way of aggregating the MLRAs yields the 20 Land Resource Regions. We clustered the MLRAs into 41 spatial units based on their geographic proximity, climate, land cover, and other characteristics, http://www.nrcs.usda.gov/technical/land/mlra/mlralegend.html.

Results of the conventional water quality model using the 41 production areas as spatial dummies are qualitatively and quantitatively very similar to the results reported in Table 2. No changes in signs of the key variables of interest occur. The significance level of TR improves to 5% and 1% in the basic and alternative models, respectively.

[17] Using the 41 production areas as spatial dummies in the toxic water quality model causes no changes in signs of the key land use variables. In the basic model, significance of CC and NONCC improves to the 1% and 10% levels, respectively. MIN becomes insignificant. In the alternative model, both TR and MIN become insignificant.

[18] 1.3180e-4 per acre × 2,210 acres = 0.29, using results in Table 5.

REFERENCES

Anderson, G. D., Opaluch, J. J., and W. M. Sullivan. 1985. "Nonpoint Agricultural Pollution: Pesticide Contamination of Groundwater Supplies." *American Journal of Agricultural Economics* 67: 1238-43.

Angermeier, P. L. 1995. "Ecological Attributes of Extinction-Prone Species: Loss of Freshwater Species of Virginia." *Conservation Biology* 9(1): 143-158.

Alloway, B. J., ed. 1995. *Heavy Metals in Soils.* 2nd ed. London; New York: Blackie Academic and Professional.

Bailey, R. G. 1995. *Description of the Ecoregions of the United States.* U.S. Department of Agriculture, Forest Service. Misc. Publ. 1391, 2nd ed.

Barbash, J. E., Thelin, G. P., Kolpin, D. W., and R. J. Gilliom. 2001. "Major Herbicides in Ground Water: Results from the National Water-Quality Assessment." *Journal of Environmental Quality* 30: 831-45.

Blaustein, A. R., and P. T. J. Johnson. 2003. "Explaining Frog Deformities." *Scientific American* (Feb. 2003).

Blaustein, A. R., Wake, D. B., and W. P. Sousa. 1994. "Amphibian Declines: Judging Stability, Persistence, and Susceptibility of Populations to Local and Global Extinctions." *Conservation Biology* 8(1): 60-71.

Bockstael, N. 1996. "Modeling Economics and Ecology: The Importance of a Spatial Perspective." *American Journal of Agricultural Economics* 78(5): 1168-81.

Brouwer, F. M., Thomas, A. J., and M. J. Chadwick. 1991. *Land Use Changes in Europe: Processes of Change, Environmental Transformations and Future Patterns: A study initiated and sponsored by the International Institute for Applied Systems Analysis with the support and co-ordination of the Stockholm Environment Institute.* Dordrecht; Boston: Kluwer Academic Publishers.

Brown, H. D. 1987. "Aquatic Macrophytes of Lake Mize, Florida, 1968-1980." *Bulletin of the Torrey Botanical Club* 114(2): 180-82.

Brown, G. M., Jr., and J. F. Shogren. 1998. "Economics of the Endangered Species Act." *Journal of Economic Perspectives* 12(3): 3-20.

Cameron, A. C., and P. K. Trivedi. 1998. *Regression Analysis of Count Data.* Econometric Society Monographs No. 30. Cambridge; New York: Cambridge University Press.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., and

V. H. Smith. 1998. "Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen." *Ecological Applications* 8(3): 559-68.

Carroll, R., Augspurger, C., Dobson, A., Franklin, J., Orians, G., Reid, W., Tracy, R., Wilcove, D., and J. Wilson. 1996. "Strengthening the Use of Science in Achieving the Goals of the Endangered Species Act: An Assessment by the Ecological Society of America." *Ecological Applications* 6(1):1-11.

Czech, B., Krausman, P. R., and P. K. Devers. 2000. "Economic Associations among Causes of Species Endangerment in the United States." *BioScience* 50: 593-601.

Dale, V. H., Brown, S., Haeuber, R. A., Hobbs, N. T., Huntly, N., Naiman, R. J., Riebsame, W. E., Turner, M. G., and T. J. Valone. 2000. "Ecological Principles and Guidelines for Managing the Use of Land." Report of the Ecological Society of America Committee on Land Use. *Ecological Applications* 10(3): 639-70.

Davis, W. S., and T. P. Simon, eds. 1995. *Biological Assessment and Criteria – Tools for Water Resource Planning and Decision Making.* Chapter 16. Boca Raton, FL: Lewis Publishers.

Deaton, M. L., and J. J. Winebrake. 2000. *Dynamic Modeling of Environmental Systems.* New York: Springer-Verlag.

De Roo, H. C. 1980. "Nitrate Fluctuations in Ground Water as Influenced by Use of Fertilizer." Connecticut Agricultural Experiment Station, New Haven, Bulletin 779.

Ehrlich, P. R., and A. H. Ehrlich. 1981. *Extinction: The Causes and Consequences of the Disappearance of Species.* New York: Random House.

Erichsen Jones J. R. 1958. "A Further Study of the Zinc-Polluted River Ystwyth." *Journal of Animal Ecology* 27(1): 1-14.

Faurie, C., Ferra, C., Médori, P., and J. Dévaux. 2001. *Ecology: Science and Practice.* Lisse [Netherlands]; Exton, PA: A.A. Balkema Publ.

Fergusson, J. E. 1982. *Inorganic Chemistry and the Earth: Chemical Resources, their Extraction, Use and Environmental Impact.* New York: Pergamon Press.

Frissell, C. A. 1993. "Topology of Extinction and Endangerment of Native Fish in the Pacific Northwest and California (U.S.A.)." *Conservation Biology* 7(2): 342-54.

Gilliam, J. W., and G. D. Hoyt. 1987. "Effect of Conservation Tillage on Fate and Transport of Nitrogen." In *Effects of Conservation Tillage on Groundwater Quality*, ed. T. J. Logan, J. M. Davidson, J. L. Baker, and M. L. Overcash. Chelsea, MI: Lewis Publ. pp. 217-40.

Handy, R. D., and F. B. Eddy. 1990. "The Interactions between the Surface of Rainbow Trout, Oncorhynchus Mykiss, and Waterborne Metal Toxicants (in

Freshwater)." *Functional Ecology* 4(3) *New Horizons in Ecotoxicology* 385-92.

Harding, J. S., Benfield, E. F., Bolstad, P. V., Helfman, G. S., and E. B. D. Jones. 1998. "Stream Biodiversity: The Ghost of Land Use Past." *Proceedings of the National Academy of Sciences of the United States of America* 95(25) (Dec. 1998).

Hare L., Carignan R., and M. A. Herta-Diaz. 1994. "A Field Study of Metal Toxicity and Accumulation of Benthic Invertebrates; Implications for the Acid-Volatile Sulfide (AVS) Model." *Limnology and Oceanography* 39(7): 1653-68.

Hartwell, H. W., Jr., and L. M. Ollivier. 1998. "Stream Amphibians as Indicators of Ecosystem Stress: A Case Study from California's Redwoods." *Ecol. Applications* 8(4): 1118-32.

Intergovernmental Conference. 1995. *Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities.* As adopted on 3 November 1995 by the Intergovernmental Conference which met for that purpose in Washington, D.C., from 23 October to 3 November 1995.

Kellogg, R. L., Maizel, M. S., and D. W. Goss. 1992. "Agricultural Chemical Use and Ground Water Quality: Where Are the Potential Problem Areas?" USDA Staff Rep., Soil Conservation Service/Economic Research Service, Washington, D.C.

Keyes, D. L. 1976. *Land Development and the Natural Environment: Estimating Impacts.* Washington: Urban Institute.

Lamberson, R. H., McKelvey, R., Noon, B. R., and C. Voss. 1992. "A Dynamic Analysis of Northern Spotted Owl Viability in a Fragmented Forested Landscape." *Conservation Biology* 6 (Dec.): 505-12.

Laws, E. A. 1993. *Aquatic Pollution, An Introductory Text.* 2nd ed. New York: Wiley.

McGowen, S. L., and N. T. Basta. 2001. "Heavy Metal Solubility and Transport in Soil Contaminated by Mining and Smelting." In *Heavy Metals Release in Soils*, eds. H. M. Selim, and D. L. Sparks. Boca Raton, FL: Lewis Publishers; CRC Press.

McKinney, M. L. 2002. "Influence of Settlement Time, Human Population, Park Shape and Age, Visitation and Roads on the Number of Alien Plant Species in Protected Areas in the USA." *Diversity & Distributions* 8(6): 311-18.

Maddala, G. S. 1983. *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge [U.K.]; New York: Cambridge University Press.

Main, M. B., Roka, F. M., and R. F. Noss. 1999. "Evaluating Costs of Conservation." *Conservation Biology* 13(6): 1262-72.

Malmqvist, B., and S. Rundle. 2002. "Threats to the Running Water Ecosystems of the World." *Environmental Conservation* 29(2): 134-53.

Mason, C. F. 1977. "Populations and Productions of Benthic Animals in Two Contrasting Shallow Lakes in Norfolk." *J. of Animal Ecology* 46(1): 147-72.

Montgomery, C. A., Brown, G. M., Jr., and D. M. Adams. 1994. "The Marginal Cost of Species Preservation: The Northern Spotted Owl." *Journal of Environmental Economics and Management* 26(2): 111-28.

National Oceanic and Atmospheric Administration (NOAA). 1999. National Ocean Service, Special Projects Office, National Coastal Assessment Branch, Coastal Assessment and Data Synthesis System, *Pesticides,* Silver Spring, MD.

Novotny V., and H. Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution.* New York: Van Nostrand Reinhold.

Raphael M., and P. Bisson. 2003. "Arise, Amphibians: Stream Buffers Affect More Than Fish." USDA Forest Service, PNW Research Station, *Science Findings* 53 (May 2003).

Richter, B. D., Braun, D. P., Mendelson, M. A., and L. L. Master. 1997. "Threats to Imperiled Freshwater Fauna." *Conservation Biology* 11(5): 1081-93.

Rivard D. H., Poitevin J., Plasse D., Carleton M., and D. J. Currie. 2000. "Changing Species Richness and Composition in Canadian National Parks." *Conservation Biology* 14(4): 1099-109.

Rottenborn, S. C. 1999. "Predicting the Impacts of Urbanization on Riparian Bird Communities." *Biological Conservation.* 88(3): 289-99.

Ryszkowski, L. 2002. *Landscape Ecology in Agroecosystems Management.* Boca Raton, FL: CRC Press.

Sayer, C., Roberts, N., Sadler, J., David, C., and P. M. Wade. 1999. "Biodiversity Changes in a Shallow Lake Ecosystem: A Multi-Proxy Palaeolimnological Analysis." *Journal of Biogeography* 26(1): 97-114.

Schindler, D. W. 1977. "Evolution of Phosphorus Limitation in Lakes." *Science* 195: 260-62.

__ 1988. "Effects of Acid Rain on Freshwater Ecosystems." *Science* 239 (4836): 149-57.

__ 1990. "Experimental Perturbations of Whole Lakes as Tests of Hypotheses Concerning Ecosystems Structure and Function." *Oikos* 57: 25-41.

__ 1994. "Changes Caused by Acidification to the Biodiversity, Productivity and Biochemical Cycles of Lakes." In *Acidification of Freshwater Ecosystems: Implications for the Future: Report of the Dahlem Workshop on Acidification of Freshwater Ecosystems held in Berlin, September 27-October 2, 1992.* eds. Steinberg, C. E. W., and R. W. Wright. Chichester; New York: Wiley.

Schnoor, J. L. 1996. *Environmental Modeling: Fate and Transport of Pollutants in Water, Air, and Soil.* New York: Wiley.

Seehausen, O. J., van Alpen, J. M., and F. Witte. 1997. "Cichlid Fish Diversity Threatened by Eutrophication that Curbs Sexual Selection." *Science* 277: 1808-11.

Sengupta, M. 1993. *Environmental Impacts of Mining: Monitoring, Restoration and Control.* Boca Raton, FL: Lewis Publishers.

Skidmore, J. F. 1964. "Toxicity of Zinc Compounds to Aquatic Animals, with Special Reference to Fish." *Quarterly Review of Biology* 39(3): 227-48.

Smith, V. H. 1998. "Cultural Eutrophication of Inland, Estuarine, and Coastal Waters." In *Successes, Limitations, and Frontiers in Ecosystem Science*, eds. Pace, M. L., and P. M. Groffman. New York: Springer-Verlag.

Smith, R. A., Alexander, R. B., and M. G. Wolman. 1987. "Water-Quality Trends in the Nation's Rivers." *Science* 235 (4796): 1607-15.

Smith, R. A., Schwarz, G. E., and R. B. Alexander. 1997. "Regional Interpretation of Water-Quality Monitoring Data." *Water Resources Research* 33(12): 2781-98.

Soil Survey Staff. 1981. *Land Resource Regions and Major Land Resource Areas of the United States.* Agriculture Handbook 296. Rev. ed. Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service.

Stein, B. A., Kutner, L. S., and J. S. Adams, eds. 2000. *Precious Heritage: The Status of Biodiversity in the United States.* Nature Conservancy. Oxford; New York: Oxford University Press.

Stephenson, T. 1987. "Sources of Heavy Metals in Wastewater." In *Heavy Metals in Wastewater and Sludge Treatment Processes, vol. 1, Sources, Analysis, and Legislation*, ed. J. N. Lester. Boca Raton, FL: CRC Press.

Switzer, J. V. 2004. *Environmental Politics: Domestic and Global Dimensions.* 4th ed. Belmont, CA: Wadsworth / Thomson.

Tessier, A., Couillard, Y., Campbell, P. G. C., and J. C. Auclair. 1993. "Modeling Cd Partitioning in Oxic Lake Sediments and Cd Concentrations in the Freshwater Bivalve Anodonta Grandis." *Limnology and Oceanography* 38(1): 1-17.

U.S. Department of Agriculture. 2000. *Summary Report 1997 National Resources Inventory.*

U.S. Department of Agriculture. *NRI Glossary*, http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/glossary.html.

U.S. Environmental Protection Agency. 2003a. *Introduction to the Clean Water Act.*

http://www.epa.gov/watertrain/cwa. (Accessed on 11/04/2004).

U.S. Environmental Protection Agency. 2003b. *Final Water Quality Trading Policy.* http://www.epa.gov/owow/watershed/trading/finalpolicy2003.pdf.

U.S. Environmental Protection Agency. 2004a. *Aquatic Biodiversity.* http://www.epa.gov/bioindicators. (Accessed in June 2004).

U.S. Environmental Protection Agency. 2004b. *Index of Watershed Indicators.* http://www.epa.gov/iwi (Accessed in May 2004).

Van der Zanden, M. J., and J. B. Rasmussen. 1996. "A Trophic Position Model of Pelagic Food Webs: Impact on Contaminant Bioaccumulation in Lake Trout." *Ecological Monographs* 66(4): 451-77.

Vitousek, P. M., Aber, J. D., Howarth, R. D., Likens, G. E., Matson, P. A., Schindler, D. W., Schlesinger, W. H., and D. G. Tilman. 1997. "Human Alterations of the Global Nitrogen Cycle: Sources and Consequences." *Ecological Applications* 7: 737-50.

Waldichuk, M. 1979. "Review of the Problems." *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* 286 (1015), The Assessment of Sublethal Effects of Pollutants in the Sea (Aug. 1979): 399-422.

Walker, C. H. 1990. "Kinetic Models to Predict Bioaccumulation of Pollutants." *Functional Ecology* 4(3) *New Horizons in Ecotoxicology* 295-301.

Watras, C. J., and N. S. Bloom. 1992. "Mercury and Methylmercury in Individual Zooplankton: Implications for Bioaccumulation." *Limnology and Oceanography* 37(6): 1313-18.

Welsh, R. P. H., and P. Denny. 1980. "The Uptake of Lead and Copper by Submerged Aquatic Macrophytes in Two English Lakes." *Journal of Ecology* 68(2): 443-55.

Welsh, H. H., Jr., and L. M. Ollivier. 1998. "Stream Amphibians as Indicators of Ecosystem Stress: A Case Study from California's Redwoods." *Ecol. Applications* 8(4): 1118-32.

Winston, M. R., Taylor, C. M., and J. Pigg. 1991. "Upstream Extirpation of Four Minnow Species due to Damming of a Prairie Stream." *Transactions of the American Fisheries Society* 120: 98-105.

Wipfli, M. S., Deal, R. L., Hennon, P. E., Johnson, A. C., De Santo, T. L., Hanley, T. A., Schultz, M. E., Bryant, M. D., Edwards, R. T., Orlikowska, E. H., and T. Gomi. 2002. *Managing Young Upland Forests in Southeast Alaska for Wood Products, Wildlife, Aquatic Resources, and Fishes: Problem Analysis and Study Plan.* USDA, Forest Service, PNW-GTR-558. September 2002.

Wu, J. J., Adams, R. M., Kling, C. L., and K. Tanaka. 2004. "From Micro-Level Decisions to Landscape Changes: An Assessment of Agricultural Conservation

Policies." *American Journal of Agricultural Economics* 86: 26-41.

Wu, J. J., and B. A. Babcock. 1999. "Metamodeling Potential Nitrate Water Pollution in the Central United States." *Journal of Environmental Quality* 28(6): 1916-28.

Wu, J. J., Bernardo, D. J., Mapp, H. P., Geleta, S., Teague, M. L., Watkins, K. B., Sabbagh, G. J., Elliott, R. L., and J. F. Stone. 1997. "An Evaluation of Nitrogen Runoff and Leaching in the High Plains." *J. Soil and Water Conservation* 52(1): 73-80.

Zhou, S. 2002. "Estimating Parameters of Derived Random Variables: Comparison of the Delta and Parametric Bootstrap Methods." *Transactions of the American Fisheries Society* 131: 667-75.

APPENDICES

APPENDIX **PAGE**

APPENDIX A

Table A1. The Causes and Effects of Impaired Conventional Water Quality

Causes	Effects
Cultural (excessive) eutrophication:	
• Discharge of organic waste, treated and untreated sewage • Nutrient loading caused by urban and agricultural runoff *(Carpenter et al. 1998; Faurie et al. 2001; Laws 1993; Ryszkowski 2002; Schindler 1977; Schnoor 1996)* • Agricultural practices (e.g., fertilizer and chemical application rates, crop management practices), and topographic and hydrological characteristics *(Anderson, Opaluch and Sullivan 1985; Barbash et al. 2001; De Roo 1980; Gilliam and Hoyt 1987; Kellogg et al. 1992; Malmqvist and Rundle 2002; Smith et al. 1987; Wu et al. 1997 ; Wu and Babcock 1999)*	• Increased growth of algae (algal blooms), aquatic weeds, and other phytoplankton • Increased water turbidity • Wide fluctuations of dissolved oxygen concentration causing hypoxic or anoxic conditions • Changes in species composition and biomass, loss in faunal and floral diversity • Adverse effects on aesthetic and recreational values *(Brouwer et al 1991; Carpenter et al. 1998; Faurie et al. 2001; Laws 1993; Mason 1977; Sayer et al. 1999; Schindler 1990, 1994; Schnoor 1996; Seehausen et al. 1997; Smith 1998; Ryszkowski 2002; Vitousek et al. 1997)*
Dissolved oxygen depletion:	
• Abiotic factors (incl. temperature and atmospheric pressure) • Biotic factors (incl. photosynthesis of plants and planktonic algae) *(Faurie et al. 2001)* • Organic waste (incl. domestic, farm), industrial effluents, or urban runoff *(Alloway 1995; Deaton and Winebrake 2000; Fergusson 1982)*	• Oxygen shortages leading to fish kills and changes in aquatic biodiversity *(Carpenter et al. 1998; Smith 1998)*
Acidification:	
• Atmospheric nitrogen deposition *(Vitousek et al. 1997)*	• Disruption of the nitrogen cycle in freshwater ecosystems *(Vitousek et al. 1997)* • Decreased faunal and floral diversity *(Schindler 1988, 1990, 1994)*

Table A2. The Causes and Effects of Impaired Toxic Water Quality

Causes	Effects
• Metal mining, incl. ore extraction, smelting, and processing *(Fergusson 1982; Keyes 1976; McGowen and Basta 2001; Malmqvist and Rundle 2002)* • Industrial processes, incl. metallurgy, electronics, electrical manufacturing, petroleum refining, or chemical industry Contamination may occur by: - Emission of aerosols and dusts and consequent atmospheric deposition - Discharge of effluents into water ways - Creation of waste dumps in which metals become corroded and leached in the underlying soil (*Alloway 1995; Fergusson 1982; Stephenson 1987*) • Domestic uses, sewage, urban runoff, and traffic *(Alloway 1995; Fergusson 1982; Malmqvist and Rundle 2002)* • Intensive agriculture: e.g., impurities in fertilizers, sewage sludge, manures from intensive hog and poultry production, pesticides *(Alloway 1995)*	• Contamination of sediments in aquatic environments (high persistence of metallic pollution) *(Erichsen Jones 1958 ; Hare et al. 1994; Tessier et al. 1993; Sengupta 1993; Welsh and Denny 1980)* • Bioaccumulation of metallic contaminants in aquatic organisms *(Handy and Eddy 1990; Laws 1993; Novotny and Olem 1994; Skidmore 1964; Van der Zanden and Rasmussen 1996; Walker 1990)*

Table A3. The Causes and Effects of Changes in Aquatic Biodiversity

Causes	Effects
Conventional water pollution: • Excessive eutrophication and its ramifications, e.g. - Algal blooms creating generally uninhabitable environment, with some bloom-forming species being toxic - Oxygen shortages caused by senescence and decomposition of nuisance plants *(Carpenter et al. 1998 ; Ryszkowski 2002; Sayer et al. 1999; Schindler 1990, 1994; Schnoor 1996; Seehausen et al. 1997; Smith 1998; Vitousek et al. 1997)*	• Changes in species composition and biomass of aquatic fauna and flora caused by: - Dominance of a few highly competitive species tolerant of high nutrient concentrations - Reduced habitat heterogeneity - Higher competition and predation *(Brown 1987; Carpenter et al. 1998; Deaton and Winebrake 2000; Laws 1993; Mason 1977; Sayer et al. 1999; Smith 1998)*
• Acidification *(Schindler 1990, 1994)*	
Toxic water pollution: • Toxicity of a compound varies across species, the individuals, their age, life history, and various environmental conditions such as pollutant concentration (chronic vs. acute), dissolved oxygen levels, water hardness and pH. *(Handy and Eddy 1990; Laws 1993; Skidmore 1964; Watras and Bloom 1992)*	• Changes in morphology, physiology, body biochemistry, behavior, and reproduction *(Handy and Eddy 1990; Laws 1993; Skidmore 1964; Waldichuk 1979)* • Fish kills and increased stress *(Skidmore 1964)* • Reduction in photosynthesis *(Laws 1993)* • More complex response (additive, synergistic, or antagonistic effects) may occur due to simultaneous exposure to several metallic contaminants *(Skidmore 1964)*

Table A3. The Causes and Effects of Changes in Aquatic Biodiversity (continued)

Causes	Effects
<u>Habitat alterations:</u> • Changes in physical condition of aquatic habitats, incl. water temperature, water currents, depth of the water column, turbidity, area of open water, sediment type and particle size, organic content of sediments *(Faurie et al. 2001)*	• Changes in species composition and population abundance in aquatic ecosystems *(Faurie et al. 2001; Ehrlich and Ehrlich 1981; Harding et al. 1998)*
• Blockage of migratory routes by dams *(Angermeier 1995)* • Changes in riparian conditions *(Raphael and Bisson 2003; Wipfli et al. 2002)*	• Isolation of populations caused by habitat alterations (e.g., dam construction) can indirectly affect extinction rates of other species (e.g., non-migratory fish) *(Angermeier 1995; Winston et al. 1991)*
• Location versus size of suitable habitat (e.g., fragmentation, connectedness) *(Bockstael 1996 ; Lamberson et al. 1992; Montgomery et al. 1994)*	• Disruption of wildlife interactions, changing wildlife populations and communities *(Rottenborn 1999)*
• Disturbances associated with urban development, incl. noise, human presence, exotic species, habitat fragmentation *(Rottenborn 1999)*	• Decline in species richness along the urban-rural gradient, with the lowest richness usually found in the urban core *(Czech et al. 2000; McKinney 2002)*
• Importance of the land use - ecosystem linkage at the regional or national scales - Land use, incl. logging, grazing, mining, industrial activities, fertilizer use, urban development - Cumulative damage to aquatic habitats caused by human land use - Regional versus local land use pattern *(Czech et al. 2000; Ehrlich and Ehrlich 1981; Frissell 1993; Harding et al. 1998; Malmqvist and Rundle 2002; Richter et al. 1997; Rivard et al. 2000)*	

APPENDIX B

Calculation of elasticities in table 2.5:

For notational simplicity let C=CONVWQ, T=TOXICWQ, S=SPERISK, and X_k denote an exogenous land use variable such as urban land or cultivated cropland. Elasticities in table 2.5 were calculated as follows:

$$\varepsilon_k^C = \frac{X_k}{C}\frac{\partial C}{\partial X_k} = \frac{\partial \ln C}{\partial X_k} X_k = \beta_k X_k \qquad [B1]$$

$$\varepsilon_k^T = \frac{X_k}{T}\frac{\partial T}{\partial X_k} = \frac{\partial \ln T}{\partial X_k} X_k = \gamma_k X_k \qquad [B2]$$

$$\varepsilon_k^S = \frac{X_k}{S}\frac{\partial S}{\partial X_k} = \frac{\partial \ln S}{\partial X_k} X_k = \delta_k X_k \qquad [B3]$$

if X_k affects S directly

$$\varepsilon_k^S = \left(\frac{\partial \ln S}{\partial X_k}\right) X_k = \left(\frac{\partial \ln S}{\partial C}\frac{\partial C}{\partial X_k} + \frac{\partial \ln S}{\partial T}\frac{\partial T}{\partial X_k}\right) X_k = \left(\delta_1 \beta_k C + \delta_2 \gamma_k T\right) X_k \qquad [B4]$$

if X_k affects S through C and T

All elasticities are evaluated at the sample mean. Variances of the elasticity estimates from [B1] – [B3] are calculated by $V(\varepsilon_k^j) = X_k^2 \cdot V(\beta_k \text{ or } \gamma_k \text{ or } \delta_k)$ where j = C, T, S. Variances of the elasticity estimates from [B4] were calculated using the Delta method (Zhou 2002, p.669):

$$V(\varepsilon_k^S) = \left[V(\delta_1)\beta_k^2 + V(\beta_k)\delta_1^{\,2}\right]\bar{C}^2 \bar{X}_k^{\,2} + \left[V(\delta_2)\gamma_k^2 + V(\gamma_k)\delta_2^{\,2}\right]\bar{T}^2 \bar{X}_k^{\,2}.$$

Calculation of factor changes in table 2.6:

Each land use variable in the models, X_k, is constructed as percent of total land area in the watershed. Thus, a 1% change in X_k represents ($1\% \cdot LANDacres \cdot X_k/100$) acres. Because ε_k^j measures changes in indicator *j* (*j* = *C*, *T*, *S*) as a result of a 1% change in X_k, a per-acre impact of variable X_k can be calculated by

$$\varphi_k^j = \frac{\varepsilon_k^j}{1\% \cdot LANDacres \cdot X_k/100} = \frac{\beta_k \text{ or } \gamma_k \text{ or } \delta_k}{LANDacres \cdot 10^{-4}} \qquad [B5]$$

where the denominator is evaluated at the mean of X_k and $LANDacres$. φ_k^j measures the change in indicator *j* as a result of one acre increase in X_k.

CHAPTER 3

THE REDUCTION IN VALUE DUE TO LAND USE REGULATION VERSUS THE VALUE OF INDIVIDUAL EXEMPTION: AN EXPLORATORY ANALYSIS OF OREGON'S MEASURE 37

Ivan Hascic
and JunJie Wu, Professor

ABSTRACT

This paper develops an empirical framework to conduct an exploratory analysis of effects of land use regulations on land values and land use patterns in a GIS-based landscape near Eugene, Oregon. All the land use regulations considered in this study, including exclusive farm use zoning, forest zoning, urban growth boundary designation, residential density zoning, commercial zoning, and industrial zoning, are found to affect land value and use both inside and outside of the designated zones. While there are many issues our framework does not address, preliminary results indicate that regulations (except the commercial zoning) tend to increase the value of land outside of the designated zones, but reduce the value of land inside the designated zones. The framework is applied to measure the reduction in value due to the regulations vs. the value of individual exemptions at the parcel level to illuminate the controversy surrounding Oregon's Measure 37, a property compensation law recently passed to protect private property rights. The reductions in value due to regulations are found to be considerably smaller than the values of individual exemptions for almost all regulations contested in the Measure 37 claims.

INTRODUCTION

For a long time, property rights advocates have maintained that the current level of protection for private property rights, particularly rights associated with real property such as land, is inadequate. They argue that although private property owners can sue the government for regulatory takings and demand compensation under the Fifth Amendment to the U.S. Constitution, the process for getting their claims heard in court is too arduous and, even if a case is heard, the conclusion of no taking that is typically the outcome is unfair because the property owners alone are bearing the burden of regulations that generate benefits for all of society (Congressional Budget Office, 1998). They also contend that governments tend to over regulate – imposing restrictions beyond the point at which the additional benefits of more regulation are at least as large as the additional costs because governments rarely bear the costs of regulation.

Property rights advocates see the State of Oregon as an ideal battle ground for changing the current approach to regulatory takings because the state's land use regulation is among the most stringent in the United States. The statewide land use planning regime in Oregon places strict limits on the use of resource lands (e.g., farmland and forestland) and confines development within designated urban growth boundaries. The planning regime contains specific objectives for protecting resource lands, wildlife habitat, and water resources through a number of zoning ordinances and other regulations. In Oregon, local comprehensive land use planning is mandatory.[1]

In an attempt to protect private property rights from the stringent land use regulations, property rights advocates launched Ballot Measure 37 in Oregon in the 2004 election. Measure 37 provides that state and local governments must compensate the owner of private real property when a land use regulation reduces its "fair market value" or "remove, modify or not apply" the regulation. Reflecting public sentiments against regulatory taking,[2] Measure 37 was passed by 61% to 39% on November 2, 2004. By October 25, 2005, 1255 claims had been filed with the state, requesting at least $2.2 billion in compensation and covering at least 66,000 acres of land (Oregon Department of Land Conservation and Development 2006). However, to the dismay of property rights advocates, Measure 37 was ruled unconstitutional by a lower court on October 14, 2005.[3] The judgment was appealed to the Oregon State Supreme Court, which upheld Measure 37 in a ruling issued on February 21, 2006.

But the ruling upholding Measure 37 does not settle a host of questions about how the law will work. Central among these questions is how to determine the level of compensation under Measure 37. In this paper, we develop an empirical model to illustrate the complexity of this issue using data from Eugene, Oregon. We show that the increase in the value of a parcel when it is solely exempted from a regulation does not equal the reduction in value due to the regulation to the owner. The reduction in value due to the regulation equals the difference between the current value of the property and the value of the property that would have existed if the regulation had not been imposed in the first place. A landowner may benefit from a waiver because the regulation has been applied to other properties. Since the price of a parcel depends on the land use in its surrounding parcels, which in turn depends on their surrounding land use, it is necessary to predict the land use patterns and prices that would have existed on the whole landscape in the absence of the regulation.

Reconstructing the counterfactual in this case – that is, the value of property had regulations never been applied – is extremely difficult due to the complex interactions between land markets and regulations. This paper presents an exploratory analysis that considers some, but by no means all, of these complexities. A GIS-based spatially explicit model is developed to predict land use and property values for each parcel on a landscape near Eugene, Oregon. The model is applied to predict development patterns and land prices that would have existed if one or more land use regulations had been removed. The value of an individual exemption and the reduction in value due to land use regulation are calculated for all parcels on the landscape under a number of policy scenarios. Our empirical results show that all major zoning regulations in the study region have affected land use and property values both inside and outside the zoned districts. Although the value of a property can never go down when it is exempted from a binding regulation, the reduction in value due to regulation can be positive or negative. Even when the reduction in value due to a regulation and the value of an individual exemption have the same sign, their magnitude can be quite different. In cases relevant to Measure 37, the effects of regulation on land values are considerably smaller than the values of individual exemptions.

Numerous studies have analyzed the impact of land use regulations on property values (e.g., Katz and Rosen 1987; Pollakowski and Wachter 1990; Beaton and Pollock 1992; Malpezzi, Chun and Green 1998; Green 1999; Quigley and Rosenthal, 2004; Wu and Cho, 2006). But relatively few have compared the effects of land use regulations on prices of regulated land versus prices of unregulated land. Henneberry and Barrows (1990) examine the effects of exclusive agricultural zoning in Wisconsin and find that a premium was capitalized in the value of farmland zoned for farm use only compared to farmland with less certain future. Fischel (1990) reviews empirical research on growth controls and concludes that these measures have spillover effects on neighboring municipalities without such restrictions. Parsons (1992) examines the effect of restrictions on residential development on land adjacent to the Chesapeake Bay and finds that the restrictions increased housing prices within the designated area as well as prices near but not in the designated area. Beaton (1991) finds that regulations may affect the price of unregulated lands due to not only the actual imposition of growth controls but also the anticipation of new growth controls on developable land. Schaeffer and Millerick (1991) find that historic district regulations increase land values within the historic district as well as in areas adjacent to the historic districts.

Several studies have evaluated the impact of land use regulations on land prices in Oregon (e.g., Kline and Alig 1999; Cho, Wu and Boggess 2003; Jun 2004; Netusil 2005). For example, Kline and Alig (1999) analyze the efficacy of Oregon's land use program and find that while it has concentrated development within urban growth boundaries, its success at reducing development on resource lands remains uncertain. Cho, Wu and Boggess (2003) analyze the development controls in Portland, Oregon and find that regulations reduce the total developed area but increase housing prices. Netusil (2005) finds that environmental zoning in Portland, Oregon and the related amenities have a positive but small net effect on the value of single-family residential properties. Plantinga (2004) and Jaeger (2006) discuss the distinction between the reduction in value due to regulation and the value of individual exemption. They argue that the reduction in market value resulting from a land use regulation is a fundamentally different concept than the value of an individual exemption to an existing regulation; and that there is no basis for using the value of an individual exemption as a proxy for the reduction in value caused by a land use regulation. To our knowledge, no study has estimated the reduction in value due to regulation vs. the value of individual exemption empirically.[4]

It bears repeating that the empirical framework presented in this study is exploratory in nature. This paper takes a step toward better understanding the effects of land use regulations on land prices and land use patterns. However, the complex nature of land development and regulations makes the reconstruction of the relevant counterfactual extremely difficult. This paper addresses a part of the problem by developing a representation of the real world which is useful in analyzing the interaction between spatial externalities of land use and institutional controls in directing land development. The simulation results presented in this study are thus conditional on the assumptions adopted throughout the analysis. Limitations of this study that might be the subject of future research include: 1) treating marginal values of regulations from a hedonic price equation as constant for non-marginal changes in regulations; 2) failing to account for benefits of regulations of a public goods nature; 3) ignoring differences in infrastructure and the attending public finance effects on property values across regulatory scenarios; and 4) considering only a portion of the real estate market and, thereby, missing price effects from market adjustments occurring outside the study area.

The remainder of this paper is organized as follows. The next section discusses the types of claims that have been filed under Measure 37 and the land use regulations involved. Section 3 presents the structure of the empirical model, describes in detail how each component of the model is developed, and discusses the assumptions and limitations of the adopted approach. Section 4 analyses the aggregate impact of land use regulations. Section 5 presents estimates of the reductions in value due to regulations vs. the values of individual exemptions. Section 6 concludes the paper.

MEASURE 37 CLAIMS AND ZONING REGULATIONS

According to the Oregon Department of Land Conservation and Development (2006), 1255 Measure 37 claims were filed with the state from December 2, 2004 (the day Measure 37 became effective) to October 25, 2005 (the last day a Measure 37 claim was accepted for filing before the Oregon Supreme Court upheld Measure 37). By October 25, 2005, 373 final orders had been issued; approximately 90% of the ruled claims had resulted in waivers of regulations; 10% in denial. No compensation has been awarded on any state claim.

Thirty-one court cases have been filed relating to Measure 37 by October 25, 2005: 23 by claimants, challenging claim decisions; two by neighbors of claimants, challenging claim decisions; four declaratory judgment actions regarding the interpretation or application of the measure; two cases contesting the constitutionality of the measure.

Almost all filed Measure 37 claims required compensation for the reduction in value due to zoning regulations. Exclusive farm use zoning, forest zoning, mixed farm/forest zoning, and rural residential zoning account for 75%, 12%, 2%, and 10% claims, respectively. Eighty-six percent of claims (919 claims) requested land division and dwelling use, and 13% (134 claims) requested dwelling use only.

This study focuses on the effect of zoning ordinances on development patterns and land values given that almost all Measure 37 claims are related to zoning. Specifically, we examine the following zoning ordinances: exclusive farm use zoning, forest zoning, urban growth boundary designation, residential density zoning, commercial zoning, and industrial zoning. We examine their effects on land use patterns and land prices when they are used individually and in combinations. We make preliminary estimates of the reduction in value due to these regulations to individual landowners as well as the values of individual exemptions.

Oregon's land use program is characterized by a clear separation between urban and rural land uses. This is achieved by several instruments, with the urban growth boundaries being perhaps the most prominent one. Urban growth boundaries (UGBs) are lines drawn around urban areas within which all urban development must take place. UGBs thus place an absolute limit on urban development, which is restricted to locations within the boundary. Land outside the boundary is available only for resource uses unless specifically exempted. However, local governments must include sufficient land within UGBs to meet the requirements for urban land uses, including housing, industry, commerce, recreation, and open space. The supply of land contained within a UGB must be sufficient to meet the 20-year requirements for such urban land uses.

The protection of agricultural land for farm use is spelled out in Oregon's statewide planning goal 3 (DLCD 2005). It requires that zoning applied to agricultural land limits uses which can have significant adverse effects on agricultural land, farm uses, or accepted farm practices.[5] All prime farmland, and all other land necessary to farm operations, is placed in exclusive farm use (EFU) zones. In addition to protection of prime farmlands, local governments are required to inventory, designate, and zone forest lands. According to statewide planning goal 4, forest zoning shall limit uses which can have significant adverse effects on forest land, operations, or practices.

Residential zoning in Oregon aims specifically at increasing the population densities in urban areas (statewide planning goal 10) and encourages development of housing units at price ranges and rent levels commensurate with the financial capabilities of Oregon households. Local governments are required to plan for high-density residential development to facilitate construction of affordable housing.[6]

Economic development of urban areas is promoted by targeted designation of land as commercial or industrial zones. Local governments are required to provide adequate opportunities for a variety of economic activities with the aim to stimulate economic growth. Comprehensive plans for urban areas should provide for adequate supply of sites of suitable sizes, types, locations, and service levels for a variety of commercial and industrial uses (statewide planning goal 9).

The study area is located in the southern part of Oregon's Willamette Valley (see figure 3.1). The valley is the state's most heavily urbanized area and is home to about two thirds of the state's population. About two-thirds of Measure 37 claims came from the valley. The study area (27 sq. miles, 70 sq. km) includes urban lands within the Eugene-Springfield metropolitan area as well as rural lands in exurban areas. Table 3.1 provides a summary of land uses and land values in the study area.

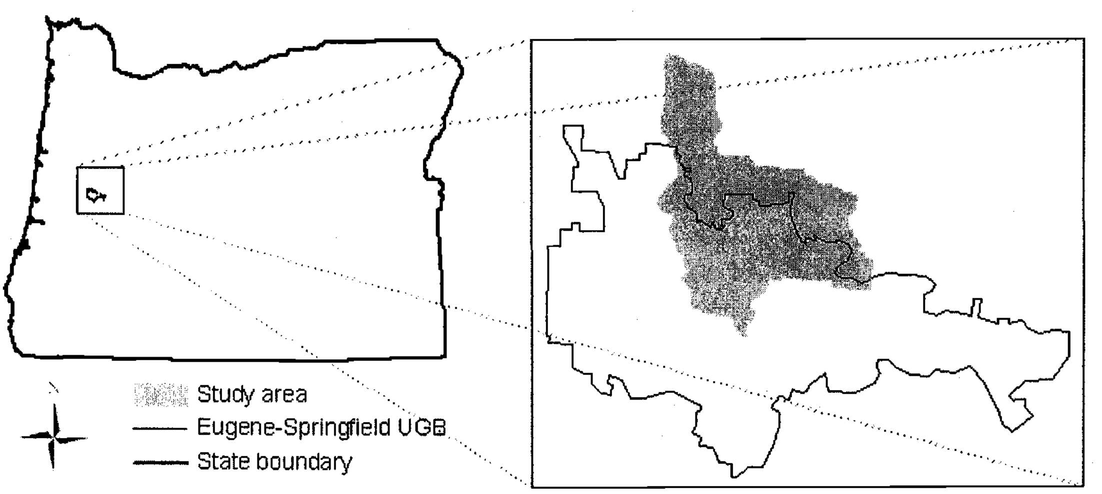


Figure 3.1. Location of the Study Area in Western Oregon

Table 3.1. Land Value and Parcel Area by Land Use Class

Land Use/Cover	Land value ($/acre)		Area (acres/parcel)		
	Mean	Std.Dev.	Mean	Std.Dev.	Sum
Rural lands:	42,181	66,678			5,203
Forest			11.19	19.71	1,766
Agricultural			16.91	30.43	3,003
Rural residential			2.72	2.57	434
Urban residential:					
Low density (0-4 DU/ac)	180,297	89,104	0.41	0.34	1,281
Medium density (4-9 DU/ac)	262,778	103,259	0.20	0.23	1,405
High density (>9 DU/ac)	392,090	235,618	0.39	1.43	531
Commercial	429,056	424,488	0.97	1.81	834
Industrial	253,988	100,584	2.08	4.01	190

Note: Statistics based on privately owned land. DU = dwelling units. The mean statistics for land value refer to a simple arithmetic mean by parcel of per-acre price of land.

THE EMPIRICAL FRAMEWORK

Land development is a complex process characterized by a multitude of relationships across spatial and temporal dimensions (physical, socio-economic, and institutional environment) and at various scales (local, regional, national). Depending on the unit of analysis these processes may work as endogenous and exogenous drivers of land use change. This paper focuses on the economic aspect of land development, with particular attention on the interplay between spatial externalities and institutional controls in directing land development. Land use is assumed to be driven by changes in land values which are influenced by spatial externalities of land use (neighborhood effects). Location and the surrounding landscape play a prominent role in our approach. In particular, a zoning regulation may affect the value of a parcel both directly by restricting its use and indirectly by affecting land use in its surrounding areas.[7]

An exploratory framework is developed to simulate the effects of land use regulations on land values within the study area. The framework has two major components (Figure 3.2). The first component is a set of land price equations estimated to predict land values for eight land use classes in the study area (low, medium, and high-density residential, commercial, industrial, agricultural, forest, and rural residential). The second component is a simulation model, which predicts land use choice and land value at each parcel on the landscape under alternative regulatory scenarios. Each of the two components is described below.

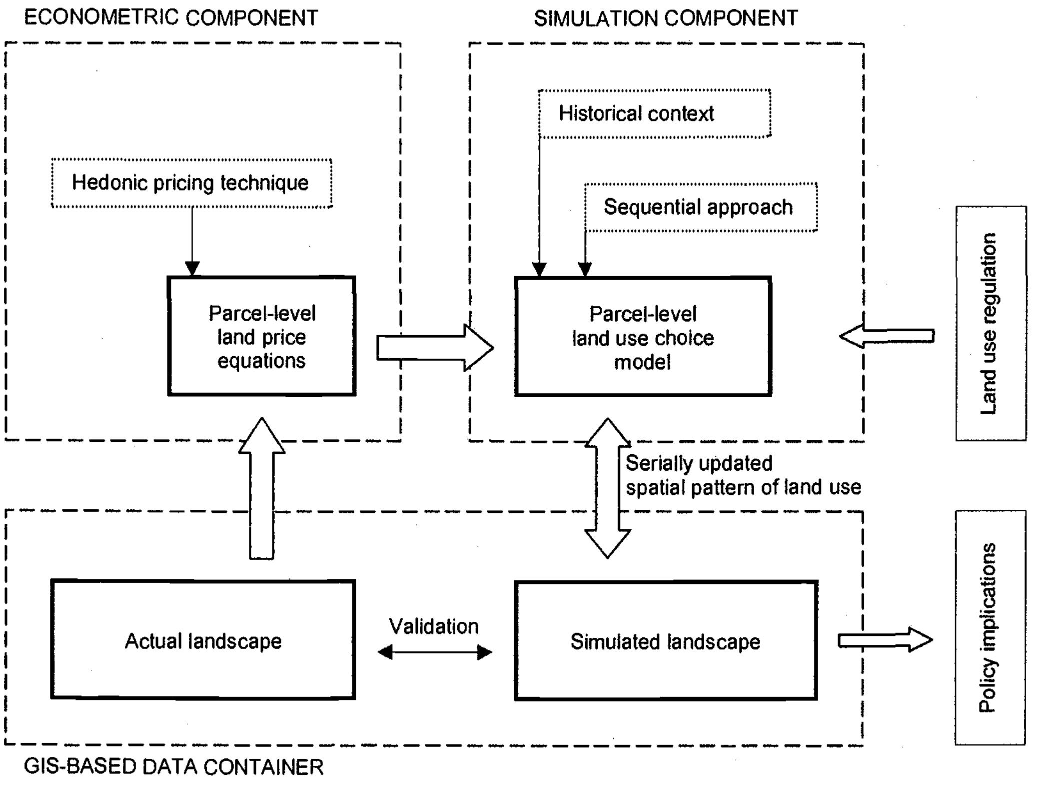


Figure 3.2. The Empirical Framework

A. The Econometric Models

The land price equations serve as the foundation of the empirical framework. They are estimated by regressing parcel-level land prices on a vector of socioeconomic, location, and neighborhood characteristics. Spatial interdependencies between parcels are assumed to take two forms in these land price equations. First, each land price equation is specified as a function of variables summarizing the spatial information. These variables include location characteristics such as the distance of the parcel to certain natural or man-made features (e.g., the city center and highway) and neighborhood characteristics such as the proportion of land in different uses in the neighborhood.[8] Second, the land price equations are specified as spatial error models (Anselin 2002) to explicitly deal with the spatial dependency between unobserved variables affecting various land uses. Formally, each land price equation is specified as

$$y = X\beta + \mu \quad \text{and} \quad \mu = \lambda W \mu + \varepsilon \qquad [1]$$

where y is a vector of the observed land prices, X is a matrix of observations of explanatory variables, β is the parameter vector, and μ is a vector of the autoregressive error terms. Parameter λ represents the spatial autoregressive coefficient which is estimated simultaneously with β, W is the $n \times n$ spatial weights matrix, and ε is a vector of error terms that are independently normally distributed with a mean of zero. Spatial autocorrelation may arise in the land price equations as a consequence of omitted variables. It is quite likely that parcels located near each other are affected by the same omitted variables, leading to spatial autocorrelation (e.g., Bockstael 1996). The spatial error specification has been widely used in previous hedonic studies of land values (e.g., Bell and Bockstael 2000; Irwin and Bockstael 2001; Paterson and Boyle 2002; Plantinga, Lubowski and Stavins 2002; Wu et al. 2004).

To estimate the land price equations, it is necessary to define the "neighborhood" for determining the spatial weight matrix *W* and for calculating the variables characterizing land use in the neighborhood. Specification of neighborhoods has largely been arbitrary in previous studies. One exception is Dale-Johnson and Brzeski (2001) who use semivariograms to determine the size of neighborhood.[9] Here we estimate a semivariogram for each of the eight selected land use classes and determine that a buffer of 100 meters is appropriate for the urban residential parcels. Hence, it is the immediate vicinity that matters most for urban residential lands. In contrast, a wider radius of 500 meters is required to capture the spatial dependence among the parcels of the remaining land use classes.

The explanatory variables in each land price equation are selected based on economic theory and an extensive review of the hedonic pricing literature. A detailed description of the specification, data, and estimation methods of the land price equations is presented in the Appendix. Below we focus on the discussion of estimation results.

Table 3.2 presents the estimated coefficients for the eight land price equations. Although the results are fairly robust to alternative specifications of error structure (spatial error vs. Ordinary Least Squares (OLS)), consideration of the spatial structure of the error terms yields a significant improvement in the goodness of fit. The R-squared increases from an average 0.36 for the OLS models to 0.58 for the spatial error models.

The first three columns of table 3.2 present the estimated coefficients for the low, medium, and high-density urban residential models, respectively. In all three cases, the coefficients of parcel size (AREA) are negative and significant at the 1% level, suggesting that per-acre price of land decreases with parcel size. This is a common finding in the hedonic pricing literature (e.g. Bockstael 1996; Palmquist and Danielson 1989); it is frequently explained by the existence of subdivision costs.[10] The coefficient of median household income

Table 3.2. Estimates of the Land Price Functions with Spatial Error Specification

Variable	LD	MD	HD	CO	IN
INTERCEPT	11.9444***	11.9857***	12.5417***	11.4091***	9.7750***
AREA	-0.5914***	-0.3187***	-0.1421***	-0.0416***	-0.0510*
MHINC	9.31E-06***	6.25E-06***	1.03E-05***		
NPOPDEN	0.0029*	0.0032***	-0.0062***	0.0645***	-0.0179
DIST_HWY	1.08E-04***	7.73E-05***	3.55E-04***	-5.38E-04***	1.85E-04
DIST_RIVER	1.63E-04***	1.90E-04***	1.70E-04***		
DIST_LAKE	-1.94E-04***	-1.57E-04***	-2.48E-04***		
DIST_CBD	-8.40E-05***	-3.37E-05***	-8.30E-05***	-1.26E-04**	-3.80E-06
DIST_UGB					
IN_UGB					
ZONED_RR					
%FO	0.0062***	0.0036**	0.0013	0.0225	-0.0294
%AG	0.0026**	-1.43E-04	-0.0779***	0.0262*	0.0575**
%RR	-0.0067***	-0.0012		0.0744	0.0852
%MD	0.0014**	0.0018***	0.0018	0.0016	0.0203
%HD	-7.67E-04	-0.0059***	0.0014	-0.0534***	0.0302
%CO	-8.88E-04	6.60E-04	-0.0031	0.0389***	0.0404*
%IN	-0.0095	0.0064*	0.0054	0.0207	0.0068
%OTHER	9.15E-04	0.0024***	-0.0024	0.0121	0.0319*
CLNIRR1					
CLNIRR2					
CLNIRR3					
CLNIRR4					
OPEN					
MIXED					
LAMBDA	0.7714***	0.8681***	0.7631***	0.7077***	-0.7562***
R-sq	0.8025	0.7340	0.7106	0.3641	0.2999
Obs.	3,102	6,906	1,083	765	73

Note: The dependent variable is the natural log of market value of land per acre. The radius of neighborhood is 100m for the LD, MD, and HD models. A 500m radius was used for the remaining models. Low-density residential land (%LD) serves as the reference land use category. One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 3.2. Estimates of the Land Price Functions with Spatial Error Specification (Continued)

Variable	RR	AG	FO
INTERCEPT	17.7741**	8.7266**	8.9143**
AREA	-0.2289***	-0.0096***	-0.0321***
MHINC	1.71E-05		
NPOPDEN	-0.3385	-0.0547	-0.0536
DIST_HWY	-1.03E-04	-4.14E-05	-1.11E-04
DIST_RIVER	0.0010		
DIST_LAKE	2.04E-04		
DIST_CBD			
DIST_UGB	4.20E-04	2.25E-04	5.16E-04*
IN_UGB	0.3386	2.0114***	1.7493***
ZONED_RR		0.3278	0.4635
%FO	-0.0909		
%AG	-0.0420		
%RR	0.0059		
%MD	-0.0029		
%HD	-0.2408		
%CO	-0.0361		
%IN	-0.1184		
%OTHER	-0.0839		
CLNIRR1		0.7650	
CLNIRR2		0.6525	
CLNIRR3		0.5455	
CLNIRR4		0.9053	
OPEN			-0.4818
MIXED			-0.0197
LAMBDA	0.6170***	0.6170***	0.6170***
R-sq	0.5441	0.5441	0.5441
Obs.	392	392	392

Note: The dependent variable is the natural log of market value of land per acre. The radius of neighborhood is 500m for the RR, AG, FO models. Low-density residential land (%LD) serves as the reference land use category. One, two, and three asterisks indicate statistical significance at the 10%, 5%, and 1% level, respectively.

(MHINC) is positive and significant at the 1% level, suggesting that land in high-income neighborhoods tends to be more valuable. Evidence that there is a premium associated with high-income location is common (e.g., Geoghegan et al. 1997; Irwin and Bockstael 2001; Irwin 2002;). The effect of predicted neighborhood population density (see the discussion of data in the Appendix) differs by housing density class: increases in population density have a positive effect on the value of low- and medium-density residential land, but have a negative effect on the value of high-density residential land. While population density is commonly found to be negatively related to housing values (e.g., Irwin and Bockstael 2001; Irwin 2002), most studies have focused on single-family residential housing and have not differentiated among residential densities. The prices of residential land, regardless of density, decrease as one moves farther away from the CBD and a lake, but increase as one moves farther away from a highway. There is extensive evidence in the hedonic pricing literature that proximity to downtown and amenities increases land values (e.g., Bockstael 1996; Geoghegan et al. 1997; Wu et al. 2004).

The neighborhood land use pattern variables completely describe the surrounding landscape and they sum to 100%. Low-density residential land is used as the reference category and is excluded from the regression to avoid perfect multicollinearity. The estimated coefficients of the neighborhood measures differ by the housing density class. Overall, the results suggest that higher proportions of medium-density residential land (%MD) and forestland (%FO) in the neighborhood increase the land value, based on the two coefficients being significant at the 10% level. While the presence of forest land in the neighborhood is frequently found to have a positive effect on land values (e.g., Bockstael 1996; Irwin 2002), there is mixed evidence as for the effect of residential land (e.g., Geoghegan et al. 1997; Irwin 2002). Our results show that a large proportion of agricultural land in a neighborhood has a positive effect on the value of low-density residential land, but has a negative effect on the value of high-density residential land. This result may reflect that the demand for high-density housing in areas surrounded by agricultural land is low relative to demand for low-density housing.

The forth and fifth columns in table 3.2 show estimates of the commercial and industrial land price equations. In both cases, per-acre price of land decreases with parcel size (AREA). Population density (NPOPDEN) has different impacts on the value of industrial and commercial lands. Locations in neighborhoods with higher population densities are found to be more valuable as commercial sites. This may be because those locations are surrounded by a larger pool of potential customers. High population density, however, is found to have a negative, although statistically insignificant, effect on the value of industrial land. This may reflect that population centers are less suitable for industrial sites. Proximity to urban centers and highways has a positive and significant effect on the value of commercial property. It also has a positive but statistically insignificant effect on the value of industrial property. These results are generally consistent with previous studies, which found that the location and size of a parcel are the most important explanatory variables determining the value of industrial property (e.g., Kowalski and Colwell 1986; Lockwood and Rutherford 1996). The estimated coefficients for the neighborhood variables suggest that the presence of large acreage of agricultural land in the surrounding area is capitalized into the value of commercial and industrial lands. Agricultural land, as well as other open space, provide worker amenities. At the same time, the presence of undeveloped land in the neighborhood provides opportunities for future expansion. Results for forest land, however, are inconclusive, likely due to the fact that most forestland in the study area is undevelopable either due to its unfavorable location (located in riparian areas or on river islands) or is zoned as protected forestland. Finally, a high concentration of commercial and industrial land (%CO, %IN) in the surrounding landscape has a positive effect on commercial and industrial land values, indicating the presence of an agglomeration effect. Granger and Blomquist (1999) found that while urban agglomeration and scale economies remain paramount in location decisions of manufacturing establishments, amenities also influence manufacturing location in urban areas. The influence varies by type of amenity and by industry.

The last three columns in table 3.2 show estimates of the rural residential, agricultural, and forest land price equations. As expected, location within the urban growth boundary (IN_UGB) significantly increases the value of agricultural and forest parcels. Undeveloped land zoned for rural development (ZONED_RR) also carries a premium, although the effect is statistically insignificant. In all three equations, the coefficients of parcel size, distance to highway, and population density are negative. These results are confirmed by other studies of rural lands (e.g., Bockstael 1996; Hardie and Parks 1997).

The constant terms in the land price equations are large relative to the other coefficients. A decomposition analysis shows that the constant terms account for most of the land price levels. One factor that may be reflected in the constant terms are benefits from regulations that have a public goods nature and, thus, are constant across all parcels in the study area. These benefits are discussed more below.

B. The Simulation Model

The second major component of the empirical framework is a simulation model, which predicts land use and land prices that would have existed at each parcel if some or all land use regulations had been removed. The simulations are conducted in a sequential manner both spatially and temporally. To simulate land use patterns on the landscape at a given time, land parcels are processed sequentially according to their distance to the CBD. Land use choice at the parcel located nearest to the CBD is considered first. The spatially variant measures of surrounding land use are computed. The values of the parcel when put to different uses are then estimated using the land price equations. The land use that yields the highest value is selected for the parcel unless constrained by a land use regulation.[11] This process continues on a parcel-by-parcel basis, outwards from the city center, until the last (most distant) parcel is processed. The most important feature of this approach is that each parcel's optimal land use is chosen while taking into account the surrounding land use.[12]

A temporal dimension (in addition to the spatial dimension) is introduced to take into account the irreversible nature of land development process. Several factors were considered to determine the appropriate time frame for the simulation exercise, including: (a) what assumptions must be made to justify the practice of using the estimated land price equations to predict land values in the past[13]; (b) how can we construct a reasonably accurate reproduction of the land use pattern at the starting point of simulation to initialize the GIS-based landscape given the data limitations[14]; and (c) how to take into account the historical milestones that have shaped the development of Oregon's land use planning system.[15] These factors exhibit conflicting tendencies. For example, the desire to maintain accuracy of model predictions suggests keeping the starting point fairly recent. On the other hand, the objective to trace the development patterns in the absence of zoning regulations requires the starting date to be placed before regulations were imposed. We concluded that an intersection of these tendencies occurs at the post-World War II era. This is the period when significant demographic and institutional changes occurred. The total metropolitan population quadrupled in the study area after World War II. In 1948 Lane County, the location of the study area, began zoning and requiring building permits. A series of land use laws resulted in the establishment of the Oregon's statewide land use planning system in 1973. A comprehensive land use plan for the city of

Eugene was developed in 1977.[16] Thus, the time frame for the simulations is set from 1950 to 2000.[17]

To simulate development patterns and land prices in year 2000 that would have existed on the landscape when a regulation had been removed, it is necessary to trace the evolution of land use patterns over time because land use choice is both spatially and temporally variant. Land use choice is spatially variant because it depends on the land use in the surrounding area; it is also temporally variant because current land use patterns are shaped by previous land use decisions due to land use irreversibility and spatial externalities. This study simulates land use choice in 1960, 1970, 1980, 1990, and 2000 on each parcel in the study region based on historical income and population data and urban boundaries. Simulations are conducted for every ten years because of data and computational constraints.[18] For a given year, land parcels are allocated to different uses subject to a set of irreversibility constraints. The constraints prohibit conversions of land to lower-intensity use, such as conversion of developed land to resource use, or conversion of medium-density to low-density housing. Land in high-density residential, industrial, or commercial use is only convertible within these three uses.

The impacts of a zoning regulation are evaluated by comparing land prices that would have existed when the regulation had been removed (the baseline) with those when the zoning regulation is in place. Two baselines are considered: First, the no-regulation baseline in which land use allocation is not constrained by any land use regulation; Second, the all-but-the-selected-regulation baseline in which all zoning regulations are imposed except the selected land use regulation. Land use regulations are typically designed to work in concert with each other in a complementary fashion.[19] One of many challenges in evaluating the relative impact of land use regulations is to decouple the effect of a given regulation from the impact of the other regulations. The reduction in value due to a selected regulation (*RVR*) to a property is evaluated relative to the two baselines as:[20]

$$RVR_i = V_i^{\text{no regulation}} - V_i^z \qquad [2]$$

$$RVR_i = V_i^{\text{all zoning except } z} - V_i^{\text{all zoning}} \qquad [3]$$

The reduction in value due to regulation for landowner *i* is calculated as the difference between the land value in the no-regulation baseline $V_i^{\text{no regulation}}$ and the land value under a given zoning regulation V_i^z. Alternatively, RVR_i is calculated as the difference between the land value in the all-but-the-selected-regulation baseline $V_i^{\text{all zoning except } z}$ and the land value under the existing land use regulations $V_i^{\text{all zoning}}$. Based on historical records of land use regulations, zoning regulations affecting rural land uses are imposed at the third simulation stage (1980)[21] and onwards. The remaining regulations are imposed from the start of the simulation (1960).[22]

To implement the simulations, a computer program was written in Python programming language and executed in PythonWin (van Rossum and Drake 2001; Hammond 2001). The program integrates ArcGIS geoprocessing tools (ESRI 2004) with the capacity to access and store the generated data in a geodatabase.

C. *Assumptions and Model Limitations*

One limitation of the modeling framework is related to the prediction of land use in the past using the estimated land price equations. These land price equations are best interpreted as the "bid-price" functions, i.e., the largest amount each of the user groups is willing to pay for various land uses. However, interpreting the marginal implicit prices as measures of households' marginal willingnesses to pay requires the assumption that each household is in equilibrium with respect to a given vector of land prices and that the vector of land prices is the one that just clears the market for a given stock of land. For this aspect of equilibrium to be achieved, it is required that the price vector adjusts to changes in either demand or supply (Freeman 2003). Given this assumption, a land price model can only be used to predict price changes in response to marginal changes in its explanatory variables. We simulate non-marginal changes in regulations and surrounding land uses which requires the strong assumption that marginal values are constant.

To gauge the magnitude of changes in the spatially variant explanatory variables, data on the variables measuring the spatial pattern of land use in the neighborhood surrounding a parcel were recorded during the simulations. The data suggest that the variables exhibit the following tendencies: When a zoning regulation is imposed, neighborhood variables for the regulated land use exhibit only marginal changes relative to the sample or the all-zoning scenario. Some variables measuring the unregulated land use may exhibit non-marginal changes. These changes are consistent with those predicted in the no-regulation scenario. On the other hand, when a zoning regulation is removed, neighborhood variables for the unregulated land use may exhibit non-marginal changes. The remaining variables measuring the regulated land use exhibit only marginal changes consistent with the actual sample or the all-zoning scenario. Therefore, the results obtained by imposing a regulation relative to the no-regulation baseline (tables 3.4 and 3.6) are contrasted with those obtained by removing a regulation relative to the all-but-the-selected-regulation baseline (tables 3.5 and 3.7).

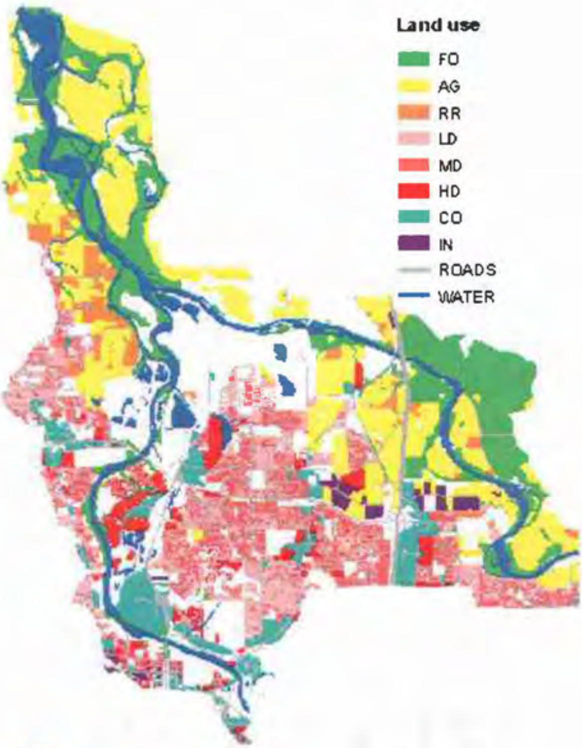
Although the estimated land price equations include household income and population density as explanatory variables, they may not reflect well the demand for land development in the early stages of simulation even after taking into account the income and population density levels in those years because the amount of land development in a region is also influenced by local infrastructure and economic geography. This study, however, does not model population, income, public finances, or infrastructure development. For example, we do not account for additional infrastructure that might be needed to support development in the no-regulation scenario. Were this to be financed by local property tax levies, property values would likely be lower. Another limitation of our approach is that it implicitly assumes that human preferences (e.g. perception of amenities) are static.

The study area forms only a portion of the Eugene/Springfield land market. The size of study area thus limits the ability of the model to capture adjustments of the land market in response to changes in demand and supply. For example, were regulations to be removed from all properties in the larger land market, rather than just those in our study area, property values under the no-regulation scenario would likely be lower. In addition, the landscape-wide effects of land use regulation (e.g., preservation of rural landscapes) remain embedded in the predicted land prices in the counterfactual (see the discussion of the constant terms above). However, availability of geospatial data and computational constraints of parcel-based simulation prevent us from incorporating the city-wide land market in the analysis.

Two constraints are imposed in the simulation process. One constraint limits urban development within the existing urban boundary when simulating land use patterns in a particular year. If this constraint is not imposed, land development would occur outside the city boundary in early stages of simulation (1960). Such a development pattern seems implausible given the absence of regulations during these early years. However, using empirical boundaries existing in time when zoning regulations were in place to simulate land development in the absence of zoning is inappropriate. As a compromise, urban boundaries in 1960, 1970, and 1980 were imposed in the simulation of land use patterns in those years, but such a constraint was not imposed in the simulation of land use patterns in 1990 and 2000. This decision reflects that there were few regulations that limited land use choices before 1978 when a comprehensive land use plan for the city of Eugene was developed. The other constraint imposed in the simulation process places a cap on the cumulative acreages of commercial, industrial, high- and medium-density residential development, and rural residential use. There is empirical evidence that zoning regulations only affect the location of land development, but not the total acreage of land development (Wu and Cho 2006).

D. Model Validation and Sensitivity Analysis

As a partial validation of the empirical framework, we determine whether the model can make accurate in-sample predictions. The framework was used to predict land use choices at each parcel in a scenario in which all zoning regulations are imposed. This scenario comes closest to replicating the real-world conditions. Figure 3.3 shows the actual and the simulated land use patterns in 2000. Table 3.3 presents the actual and the simulated land acreages and acreage-weighted average prices for the eight land use classes. The results suggest that the modeling framework performs well in-sample in allocating land among resource and rural uses, urban residential uses, and commercial and industrial uses; the subtotals for these three groups are close to 100% (column 5 in table 3). However, performance of the model by land use class varies; the model performs well in allocating agricultural, rural residential, commercial, and industrial land (95-119% of actual acreage), but it overpredicts low-density residential acreage (195% of actual acreage) and under-predicts forestland, and medium- and high-density residential acreage (39-67% of actual acreage). The mismatch in allocating land among the urban residential classes is not a deficiency of the model but is rather a result of noncompliance with zoning regulations (the grandfather effects).



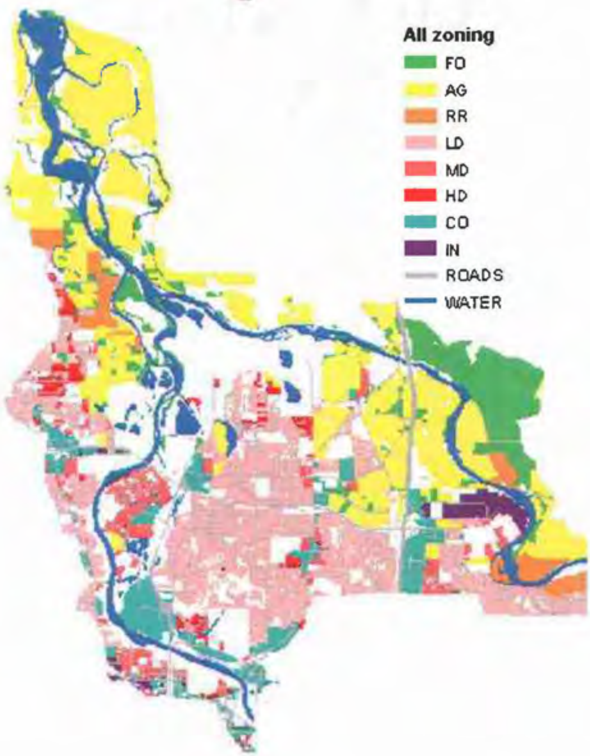


Figure 3.3. Actual vs. Simulated Land Use Patterns in 2000

Table 3.3. Model Validation: Simulated versus Actual Land Values and Acreages

Land use class	Simulated		Actual		Simulated / Actual ratio	
	Acres	Avg. value ($/ac)	Acres	Avg. value ($/ac)	Acres	Avg. value ($/ac)
Forest	1,219	3,915	1,806	-	0.67	
Agricultural	3,642	10,204	3,057	-	1.19	
Rural residential	415	677,688	436	-	0.95	
Subtotal:	5,276	61,254	5,299	14,325	1.00	4.28
Low-density resid.	2,506	151,643	1,282	151,424	1.95	1.00
Medium-density resid.	549	127,639	1,405	245,920	0.39	0.52
High-density resid.	251	279,714	559	148,132	0.45	1.89
Subtotal:	3,306	157,380	3,246	191,759	1.02	0.82
Commercial	816	375,266	862	357,130	0.95	1.05
Industrial	201	161,049	190	253,719	1.06	0.63
Subtotal:	1,017	332,928	1,052	338,453	0.97	0.98

Note: The simulated acreage refers to the scenario when all land use regulations are imposed. The average value is calculated as an area-weighted mean of per-acre price of land.

Sensitivity analysis was conducted to test the robustness of the results. For example, a number of alternative designs have been tested by dropping the constraints or by adjusting the level of control (e.g., by imposing the urban boundary only in early stages of simulations or by imposing acreage caps on fewer land uses). The qualitative results are robust to the alternative designs. For example, in all cases, the estimated values of individual exemptions from resource protection zoning are generally much larger than the estimated reductions in value due to regulation. However, the quantitative results do change under the different designs.[23]

PRELIMINARY RESULTS ON THE AGGREGATE IMPACT OF LAND USE REGULATIONS

Table 3.4 shows estimates of the aggregate impact of selected land use regulations relative to the no-regulation baseline. The results are decomposed by zoned and unzoned lands and by winners and losers. For farmland zoning, landowners who are required to maintain resource use on their land may lose in land value relative to the no-regulation baseline. The combined reduction in land value of the 400 landowners inside the farm use zone represents the direct effect of farmland zoning.[24] At the same, 4339 parcels located outside the farmland zone gain in land value. Hence, while exclusive farm use zoning has a negative direct effect on the value of land within the zone, it has a positive indirect effect on the value of land outside the zone via neighborhood effects. For example, low-density residential development at the urban-rural fringe may benefit from farmland preservation through open-space provision. Protection of farmland also increases commercial and industrial land values, since businesses may view the surrounding undeveloped land as an asset which may enhance their long-term expansion potential. Results for forestland zoning and UGB designation are similar to those of farmland zoning.

Results for residential density zoning suggest that 1,568 parcels gain and 7,903 parcels lose in land value inside the zoned district. Outside the zone, 927 parcels gain and 623 lose, with total gains amounting to 81% of total losses. The negative impact on land values inside the zoned district is mostly caused by reductions in housing density resulting from the regulation. The impact on land outside of the zoned district is caused by relocation of unregulated land uses. The estimated results suggest that residential zoning reduces land value by requiring lower densities inside the zone and by displacing unregulated uses to inferior locations outside the

Table 3.4. Preliminary Estimates of the Impacts of Land Use Regulations in the Study Area, Relative to the No-regulation Baseline

	Number of parcels			Change in land value				
Zoning	Gainers	Losers	Unaff.	Avg gain ($/ac)	Avg loss ($/ac)	Total gain ($)	Total loss ($)	G/L ratio
Farmland zoning								9.13
zoned land	1	400	212	7,180	33,177	84,050	27,453,443	0.00
unzoned land	4,339	1,172	6,674	166,535	9,344	284,588,936	3,742,678	76.04
Forestland zoning								0.23
zoned land	0	43	1	0	4,630	0	3,284,869	0.00
unzoned land	194	43	12,723	1,899	473	760,040	32,482	23.40
UGB designation								6.82
zoned land	1	567	255	7,180	33,832	84,050	38,393,973	0.00
unzoned land	4,219	1,147	6,587	200,336	9,694	286,807,598	3,701,244	77.49
Farm, forest, and UGB together								6.58
zoned land	1	586	241	7,180	22,265	84,050	40,147,630	0.00
unzoned land	4,284	1,135	6,524	199,395	9,750	288,183,508	3,682,272	78.26
Residential density zoning								0.28
zoned land	1,568	7,903	1,215	17,719	232,460	8,927,705	510,926,865	0.02
unzoned land	927	623	426	113,621	444,269	205,429,069	253,381,296	0.81
Commercial zoning								0.20
zoned land	326	446	0	283,740	380,737	110,449,932	153,912,120	0.72
unzoned land	1,326	5,525	5,361	11,476	224,487	6,312,114	417,398,823	0.02
Industrial zoning								0.60
zoned land	1	94	7	174,199	543,957	6,455,413	45,507,679	0.14
unzoned land	2,715	3,702	6,446	301,259	279,768	292,178,353	450,221,087	0.65
All zoning								0.12
zoned land	1,614	9,315	1,361	121,003	172,900	109,999,686	753,052,615	0.15
unzoned land	338	1	0	182,976	20,867	40,223,168	4,986	8067.2

zone. For example, parcels that could have been developed for commercial and industrial uses lose value, while parcels that would otherwise not be developed for commercial and industrial uses gain value. On the balance, the total loss is greater than the total gain.

The results suggest that, in contrast to farm and forest zonings which generally reduce the value of land located inside the zoned areas but increase the value of land outside the zones, the commercial and industrial zonings reduce land values both inside and outside of the zones. This is because commercial and industrial zonings restrict land use both inside and outside the zoned areas. Outside the zoned areas, no commercial and industrial uses are allowed. On the contrary, outside the exclusive farm and forest use zones, both farm and forest uses are allowed, although other land uses are not allowed inside the zoned districts. The estimated values of reduction in value due to commercial zoning suggest that the regulation is relatively more value-improving inside the commercial zones. This is due to the agglomeration effect of commercial land use. Compared to the no-regulation scenario, commercial zoning creates multiple smaller commercial zones in contrast to a more concentrated pattern of commercial development in the no-regulation scenario, leading to a dramatic decrease in the agglomeration effect. Therefore, although total acreage remains largely unchanged, the regulation yields a net loss in land value overall.

Table 3.5 shows preliminary estimates of the aggregate impact of selected land use regulations relative to the all-but-the-selected-regulation baseline. Overall, the results in table 3.5 are qualitatively similar to those in table 3.4. However, compared with the no-regulation scenario, the magnitude of the estimated changes in land values is smaller. This is because, compared with the no-regulation scenario, a regulation is less restrictive when compared with the all-but-the-selected-regulation baseline. Since zoning regulations often work in concert, imposing a regulation on top of others will be less restrictive than imposing the regulation

Table 3.5. Preliminary Estimates of the Impacts of Land Use Regulations in the Study Area, Relative to the All-but-the-selected-regulation Baseline

	Number of parcels			Change in land value				
Zoning	Gainers	Losers	Unaff.	Avg gain ($/ac)	Avg loss ($/ac)	Total gain ($)	Total loss ($)	G/L ratio
Farmland zoning								0.10
zoned land	0	5	623	0	70,145	0	982,382	0.00
unzoned land	79	123	12,185	1,591	4,333	127,991	246,426	0.52
Forestland zoning								0.00
zoned land	0	18	27	0	2,258	0	1,494,111	0.00
unzoned land	0	6	12,964	0	91,317	0	5,441,203	0.00
UGB designation								0.01
zoned land	0	72	674	0	81,211	0	16,545,086	0.00
unzoned land	63	50	12,156	2,152	8,974	98,862	768,764	0.13
Farm, forest, and UGB together								0.60
zoned land	17	566	168	8,474	30,539	499,770	64,858,013	0.01
unzoned land	535	373	11,356	106,132	30,928	42,801,127	7,058,621	6.06
Residential density zoning								0.58
zoned land	1,294	7,662	1,796	22,968	90,623	11,371,266	190,006,304	0.06
unzoned land	741	405	862	178,541	22,618	107,224,643	13,735,785	7.81
Commercial zoning								8.02
zoned land	583	161	40	162,021	57,116	95,459,624	7,166,663	13.32
unzoned land	1,081	2,098	9,052	30,998	10,218	18,397,205	7,034,720	2.62
Industrial zoning								1.47
zoned land	14	109	16	30,410	52,663	3,317,073	13,025,137	0.25
unzoned land	611	134	12,131	36,821	2,815	15,966,229	116,213	137.4

alone.

For commercial zoning, we found a net increase in the value of land located outside as well as inside the zoned district. This is a rather counterintuitive result. Commercial zoning increases the value of land inside the zone because, compared to the all-but-commercial-zoning baseline, it concentrates previously scattered commercial establishments within the designated commercial zones, thus enhancing the agglomeration effect. As the results suggest, the cost advantage due to an agglomeration effect dominates any cost from displacement.

Overall, our results suggest that zoning not only impacts the value of zoned land but also the value of unzoned land. With the exception of commercial zoning, lands inside the zoned areas tend to lose value, while lands outside the zoned areas tend to gain value. Thus, benefits of zoning largely accrue to landowners whose land use choices are not restricted. Of course, we are not accounting for benefits of regulations of a public goods nature that accrue to all landowners, regulated or unregulated.

The simulated gain/loss ratios for all zoning regulations always improve over years. This suggests that there is a premium associated with land use adjustments in response to changes in the surrounding land use over time. For example, zoning to protect farmland not only excludes any development within the zone; it may also have an indirect effect on the land outside the zoned district. Over time, the presence of open-space amenities may alter the structure of residential neighborhoods. Thus, a zoning regulation not only affects land values (as discussed above) it may also affect the spatial pattern of land development both inside and outside of the designated zones.

THE VALUE OF INDIVIDUAL EXEMPTION

Table 3.6 shows estimates of the value of individual exemption (VIE) and the preliminary estimates of the reduction in value due to land use regulation (RVR) relative to the no-regulation baseline.[25] Only those parcels whose values are impacted by a regulation and may ask for an exemption are used in the estimation. Parcels which grandfathered an exemption from a land use regulation were not used in the estimations.

An individual exemption from farmland zoning would yield a gain of $104,855 per acre on average, while the reduction in value due to this regulation to landowners is estimated at only $32,614 per acre on average. Results for forestland zoning and UGB designation suggest a similar pattern. These results suggest that landowners seeking exemption under Measure 37 would overstate the reduction in value due to regulation because an estimate obtained using the standard appraisal methods yields the value of an individual exemption rather than the reduction in value due to regulation. Given that some of the limiting factors in our analysis tend to overstate property values in the no-regulation scenario, it is not clear whether the change in value due to the regulation is positive. The estimates of reduction in value due to regulation are negative for unzoned land located outside the zoned district suggesting that the three resource protection zoning regulations increase the value of unzoned lands by $1,552 to $156,116 per acre on average. Hence, while the resource protection policies may reduce the value of the regulated lands, these policies often increase the value of unregulated lands.

Residential density zoning reduces land value by $185,805/ac on average for the affected parcels inside the zone. However, once residential density zoning is instituted, an exemption is valued at only $165,807/ac. The reduction in value due to this regulation is high because, relative to the no-regulation baseline, it tends to displace commercial and high-density

Table 3.6. The Value of Individual Exemption (VIE) versus the Reduction in Value due to Regulation (RVR), Relative to the No-Regulation Baseline

	Avg. change in land value ($/ac)				Change in total value (million $)			
	Zoned land		Unzoned land		Zoned land		Unzoned land	
Zoning	VIE	RVR	VIE	RVR	VIE	RVR	VIE	RVR
Farmland zoning	104,855	32,614	-	-133,140	89.0	27.4		-280.9
Forestland zoning	4,962	4,630	-	-1,552	3.5	3.3		-0.7
UGB designation	88,717	33,413	-	-156,116	101.7	38.3		-283.1
Farm, forest, and UGB together	58,273	22,075		--156,067	105.8	40.1		-284.5
Residential zoning	165,807	185,805	-	20,161	448.0	502.0		48.0
Commercial zoning	18,153	54,771	109,877	170,621	14.4	43.5	264.7	411.1
Industrial zoning	39,034	323,499	141,856	61,277	4.7	39.1	365.9	158.0
All zoning	219,076	122,149	74,394	-182,754	1,153.3	643.1	3.2	-40.2

The reported values are average changes in land values ($/acre) and changes in total land value of the study area (million $).

residential uses in favor of low-density housing. However, once the regulation is in place, and commercial and high-density development have been forced to other locations, the value of an individual exemption will be reduced because the potential for agglomeration effects in commercial use is reduced.

In contrast to the exclusionary zonings, such as farm and forest zonings, commercial and industrial zonings restrict land use both inside and outside the zoned area: Land inside the zone can only be developed for commercial and industrial uses, while land outside the zone cannot be developed for commercial and industrial uses. The results suggest that, relative to the no-regulation baseline, commercial zoning changes the location of commercial land use by creating several smaller commercial areas. Landowners inside a commercial zone suffer a loss of $54,771/ac on average. However, once commercial zoning is instituted, an exemption is valued at only $18,153/ac since the temptation to be exempt is greatly reduced due to the presence of the agglomeration effect. Outside the commercial zones, commercial land use is not allowed and the potential gains from agglomeration are eliminated. An exemption to use land for commercial purposes commands a premium only when the neighbors do commerce as well.

Compared to the no-regulation baseline, the estimated values of individual exemption are lower than the reductions in value due to regulation for each of the zonings regulating commercial, industrial, and residential development. In a situation when the total acreage of unregulated uses remains largely unchanged, this phenomenon can be attributed to the agglomeration effect and the displacement effect (i.e. a decrease in land value due to relocation to an inferior location). The result is that while the reduction in value due to a regulation in an urban area may be large, once the regulation is in place and changes in the spatial pattern of land use have materialized, the temptation to ask for an exemption is reduced. The value of an individual exemption goes down precisely due to the changes in the surrounding land use that have occurred as a result of the regulation.

Table 3.7 shows estimates of the value of individual exemption and the reduction in value due to regulation relative to the all-but-the-selected-regulation baseline. The findings are consistent with the results in table 3.6, although the magnitude of the effects is lower. This is expected as the potential for land use changes is reduced under the all-but-the-selected-regulation baseline.

For farmland and forestland zonings, the data suggest that when any of these regulations is imposed on top of an enforced UGB, an individual exemption is valued at about the same level as is the reduction in value due to regulation. This is because dropping any one of these regulations would not change the spatial pattern of development. Land use is still

Table 3.7. The Value of Individual Exemption (VIE) versus the Reduction in Value due to Regulation (RVR), Relative to the All-but-the-selected-regulation Baseline

	Avg. change in land value ($/ac)				Change in total value (million $)			
	Zoned land		Unzoned land		Zoned land		Unzoned land	
Zoning	VIE	RVR	VIE	RVR	VIE	RVR	VIE	RVR
Farmland zoning	70,055	70,145	-	862	1.0	1.0		0.1
Forestland zoning	2,258	2,258	-	91,317	1.5	1.5		5.4
UGB designation	86,546	81,211	-	5,090	15.4	16.6		0.7
Farm, forest, and UGB together	46,231	29,485	-	-56,599	96.1	64.4		-35.7
Residential zoning	134,210	68,925	-	-77,401	332.9	178.6		-93.5
Commercial zoning	64,693	-123,546	74,394	-8,863	1.9	-88.3	3.2	-11.4
Industrial zoning	55,327	27,238	0	-33,375	8.5	9.7	0	-15.9

The reported values are average changes in land values ($/acre) and changes in total land value of the study area (million $).

subject to other regulations. For example, an exemption from farmland zoning carries no premium above the reduction in value due to regulation when land is located outside an enforced UGB. It is only when these regulations are taken together that an exemption carries a premium. The farmland and forestland zonings and the UGB together impose a reduction in value due to $29,485/ac to landowners located inside the zoned areas, with an exemption valued at $46,231/ac on average. Outside the zone, the regulations actually increase land values. These findings are consistent with those reported in table 3.6.

When all other regulations are in place, estimates of the reduction in value due to regulation suggest that commercial zoning increases the total value of land located inside the commercial zone. This suggests that when potential for agglomeration effects exists, land use zoning may actually enhance agglomeration advantages. Consequently, most landowners would never want to give up the 'privilege' of being located inside a designated commercial zone, although an exemption may command a premium for some landowners.

The estimated values of individual exemptions from residential, industrial, and commercial zonings are higher than the corresponding reductions in value due to regulation. These results are different from the corresponding results in table 3.6. The difference arises because many regulations are already in place. Imposing a regulation on top of all other regulations does not impose much additional costs compared with the all-but-the-selected-regulation scenario. If regulations cause the misallocation of land among alternative uses, an exemption from residential, commercial, and industrial zoning regulations commands a premium compared to the reduction in value due to the regulations.

In sum, compared with the no-regulation baseline, the zoning ordinances regulating residential, commercial, and industrial development have a much larger impact on land values overall than the zoning regulations for protection of resource lands. However, an individual exemption from residential, commercial, and industrial zoning regulations does not carry a premium beyond the reduction in value due to the regulation. In fact, the average value of an individual exemption is smaller than the average reduction in value due to these regulations because an exemption would result in a loss of the agglomeration effect. In contrast, the value of an individual exemption is much larger than the reduction in value due to regulation for farmland zoning and the UGB restrictions because these regulations increase the value of developed land.

When the all-but-the-selected-regulation scenario is used as a baseline, the values of individual exemptions are about the same as the reductions in value due to these regulations for farmland and forestland zonings and the UGB designation. This is because imposing one of these regulations on top of all other regulations would not significantly change the spatial pattern of land use. Conversely, lifting one of the regulations at a time while keeping all other regulations in place would simply remove the reduction in value due to the regulation. In contrast, an exemption from the residential, commercial, and industrial zoning regulations carries a premium beyond the reduction in value due to regulation.

CONCLUSIONS

Land use regulations have complex effects on property values in both spatial and temporal dimensions. Quantifying these effects requires identification of the relevant counterfactual baseline – the value of the property in the absence of regulations. Particularly for regulations that have been in place for decades, construction of this counterfactual is extremely difficult. This chapter presents an exploratory look at the effects of regulations. Given the challenges this type of analysis presents, we were only able to address some of the important factors. The factors that remain unaddressed represent limitations of the study. These were discussed above.

While the study's limitations prevent any firm conclusions from being drawn, some tentative insights can be offered. In the absence of land use regulation individual landowners typically have little incentives to take into account the spatial externalities of their land use because benefits largely accrue to others in the neighborhood. This is where government intervention in land markets is warranted. Zoning ordinances and other forms of land use regulations aim to correct inefficient land use patterns by promoting provision of positive externalities and by limiting negative externalities of private decisions on others in the community. However, land use regulations are often blamed for causing reductions in property values. While zoning and various other land use regulations may indeed cause land prices to change, it is difficult to measure the direction and the magnitude of these changes because of difficulties of establishing a counterfactual.

This paper develops an exploratory empirical framework to evaluate the effect of land use regulations on land values and land use patterns in a GIS-based landscape near Eugene, Oregon. The results suggest that compared with the no-regulation baseline, zoning ordinances regulating residential, commercial, and industrial development reduce the value of land much more (for landowners as a whole) than the zoning ordinances aimed at protecting resource lands. However, an individual exemption from residential, commercial, and industrial zonings does not carry a premium beyond the reduction in value due to regulation. In fact, the average value of an individual exemption is smaller than the average reduction in value due to these regulations because an exemption would result in a loss of the agglomeration effect. In contrast, the value of an individual exemption is much larger than the reduction in value due to regulation for farmland zoning and the UGB restrictions because these regulations increase the value of developed land.

When the all-but-the-selected-regulation scenario is used as a baseline, the value of an individual exemption from farmland zoning, forest zoning, or the UGB designation is about the same as the reduction in value due to the corresponding regulation. This is because imposing one of these regulations on top of all other regulations would not significantly change the spatial pattern of land use. Conversely, lifting one of the regulations at a time while keeping all other regulations in place would simply remove the reduction in value due to the regulation. In contrast, an individual exemption from the residential, commercial, and industrial zonings carries a premium beyond the reduction in value due to regulation.

The empirical framework developed in this study was used to estimate the difference between the value of individual exemptions and the reduction in value due to land use regulations to illuminate the controversy surrounding Oregon's Measure 37. The measure is likely to have national ramifications because property rights advocates in other states may launch similar measures in future elections. Our empirical results show that all major zoning regulations in the study area have affected land use and property values both inside and outside the zoned districts. Although the value of a property can never go down when it is exempted from a binding regulation, the reduction in value due to regulation can be positive or negative, depending on the location of the land parcel. Even when the reduction in value due to regulation and the value of an individual exemption have the same sign, their magnitude can be quite different. For most of the regulations contested in Oregon's Measure 37 claims, the reduction in value due to regulation is considerably smaller than the value of an individual exemption. However, in the presence of agglomeration effects, the value of an individual exemption could be smaller than the reduction in value due to regulation.

The empirical framework presented in this study is exploratory in nature. The paper takes on a challenging task to analyze the effects of land use regulations on land prices and land use patterns empirically. Given the complexity of the problem, the findings of the study are conditioned on the assumptions of the modeling framework. Future research opportunities may exist in developing better approaches for simulating land use patterns and property values in the absence of land use regulations. For example, developing different representations of land markets, considering other mechanisms of spatial interaction (other than via neighborhood effects), or estimating spatial lag models by modeling land price as a lagged dependent variable may yield additional insights.

ENDNOTES

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[1] For more on Oregon's land use planning see Nelson (1992) and Knaap and Nelson (1992).

[2] Land use regulation is particularly controversial in Oregon. According to a 2005 survey on land use issues, two in three Oregonians said that growth management has made the state a better place to live (Oregon Land Use Statewide Survey 2005). Most respondents were concerned about the environment and they favored public planning over market-based decisions. According to the poll, Oregonians want to protect land for future needs rather than develop it now. Yet, they also recognize a fundamental value in property rights. Two thirds of respondents firmly believe in property rights protection and most value individual rights more than responsibility to the community. The survey illustrates the appeal of land use regulation among Oregon residents. It also demonstrates the controversy surrounding it. Oregon residents want urban sprawl controlled but they also want to use their land as they see fit.

[3] See http://www.oregon.gov/LCD/docs/measure37/macpherson_opinion.pdf for the opinion issued by the Marion County Circuit Court in *MacPherson v. Department of Administrative Services* that holds that Measure 37 is unconstitutional.

[4] The regulatory takings literature has considered the question of whether a regulation infringing upon property rights amounts to a taking for which a just compensation should be paid. Michelman (1967) explored this question in a seminal paper using a utilitarian approach, which was further developed by Epstein (1985). More recent treatments of regulatory takings include Fischel (1985, 1995).

[5] Goal 3 requires each county to adopt exclusive farm use zones by using USDA Soil Conservation Service land capability classes. West of the Cascade Mountains EFU zones include agricultural lands of classes I-IV; east of the Cascades they include classes I-VI (Statewide planning goals 2005).

[6] However, public resistance often results in referenda used to stop affordable housing projects, often on the grounds of concerns about extra crime and drugs that may come with low-income housing.

[7] Several studies have focused on the mechanism of spatial interaction. For example, Irwin and Bockstael (2002) develop a model of land conversion that incorporates local spillover effects among spatially distributed agents. They find that fragmented patterns of land development in the rural-urban fringe could be explained by the negative externalities generated by the surrounding lands. Likewise, open space designation may affect property values both directly and indirectly; it affects property values directly by reducing the total supply of developable land and indirectly by making certain areas more attractive, thereby changing the spatial patterns of demand within a given metropolitan area (Wu et al. 2004).

[8] For example, Wu et al. (2004) use location and amenity variables such as distance to CBD, public park, river, lake, wetland, proximity of the nearest industrial and commercial property, and distance to nearest public transportation. Irwin and Bockstael (2004) use neighborhood land-use variables representing the percentage of low, medium, and high- density residential land, commercial and industrial land, undeveloped land, and open space. Geoghegan et al. (1997) use landscape pattern indices adopted from the ecological literature measuring diversity or fragmentation of the surrounding landscape.

[9] A semivariogram is a plot of semivariance values against the lag distance and is frequently used in geostatistics to describe the spatial correlation of observations. The distance at which the curve levels off is called range. Any two pairs of locations separated by distances closer than the range are spatially autocorrelated, whereas locations farther apart than the range are independent of each other. Consequently, the radius of the neighborhood is set equal to the range of the estimated semivariogram.

[10] One exception is Lin and Evans (2000), who find that land price per unit increases with lot size.

[11] The spatially variant variables include the eight neighborhood measures (%LD, %MD, %HD, %CO, %IN, %AG, %FO) whose values are periodically updated. Variable %OTHER stays invariant throughout the simulations.

[12] Using DIST_CBD as the allocation vehicle representing landowners' decisions may not be the ideal representation of the land development process. However, lack of data prevents us from considering other options. An alternative would be to model developers' decisions represented by a "cherry-on-the-cake" approach. In this case, locations of development would be selected from among all available parcels. This approach would allocate land uses to the highest yielding parcels first and might better reflect the heterogeneous pattern of land development.

[13] The hedonic land price equations were estimated using data from year 2000. The potential of the estimated hedonic coefficients to serve as reasonably accurate representation of people's preferences (e.g. preferences for amenities) decreases with time.

[14] Land-use patterns become increasingly complex over time. The spatial structure of land use within the study area at the end of 1900s might have been relatively simple, with only a fraction of land allocated to development and the rest being in agriculture or forestry. The difficulty of reconstructing a landscape and the margin of error increases as we progress with time, as development becomes the dominant feature of the landscape. Consequently, setting the starting time earlier rather than later increases accuracy. Smaller urbanized area leaves less space for errors and leaves more area to be determined by soil quality, the primary determinant of land use in rural landscapes.

[15] For example, the passing of Senate Bill 100 in 1973 which enacted the nation's first statewide land use planning system in Oregon.

[16] Sources: Helm 1984; Knaap and Nelson 1992; Jackson and Kimerling 2003

[17] The 1950 landscape is initialized in the following way: The delineation of the ca. 1950 city limit is derived from Loy et al. (1976, 2001) and ISE (1999a, 1999b). Medium-density residential use is attributed to areas in the historic downtown south of the Willamette River. The remaining areas within the 1950 city limits are attributed low-density residential use. Land capability index is used to attribute agricultural (CLNIR = 1 to 4) and forest use (CLNIR ≥ 5) in rural areas.

[18] Household income data are collected every ten years by the U.S. Census Bureau.

[19] For example, Oregon's farmland preservation policies work as a package. Exclusive farm use zones preserve farmland for farming; UGBs limit urban sprawl; and exurban districts accommodate the demand for rural residential development. These and other land use policies work towards a common goal of protecting resource lands (Nelson 1992).

[20] Land use regulations may be endogenously determined with land use changes. This paper, however, does not focus on the causes of land use regulations. It simply evaluates what would happen to land use patterns and prices if some of the regulations had been removed.

[21] The comprehensive plan for Lane County was approved in 1977.

[22] Oregon cities were allowed to zone since 1919. Lane County allowed zoning since 1948.

[23] Simulated test runs suggest that, as expected, a higher degree of control slows the progression of urban development and yields a more gradual development pattern. At the same time, more control over urban development lessens the importance and the impact of resource protection zoning. Even in the absence of zoning, more control over urban development materializes in larger acreage of undeveloped land. Consequently, if zoning is imposed, the estimated reduction in value due to such regulation goes up. On the margin, the regulation imposes costs on landowners without providing adequate benefits in return (e.g. undeveloped land). In addition, an individual exemption for a parcel surrounded by open space carries a premium which grows proportionately with the extent of such urban control. If acreage caps are not used, high-intensity uses (HD,CO,IN) dominate the landscape in the no-regulation scenario. Such land use pattern may not correspond to the real-world situation. Absence of acreage caps also impacts the magnitude of the estimated land price changes.

[24] Results show that one landowner benefits from farmland zoning. This seemingly counterintuitive result is a consequence of irreversibility of land development. The parcel's value as residential land (MD) in the no-regulation scenario is lower than its value as agricultural land in the farmland-zoning scenario.

[25] The estimated values of VIE are calculated as $VIE = \max(V^z_{FO}, V^z_{AG}, V^z_{RR}, V^z_{LD}, V^z_{MD}, V^z_{HD}, V^z_{CO}, V^z_{IN}) - V^z$ and $VIE = \max(V^{all}_{FO}, V^{all}_{AG}, V^{all}_{RR}, V^{all}_{LD}, V^{all}_{MD}, V^{all}_{HD}, V^{all}_{CO}, V^{all}_{IN}) - V^{all\ zoning}$ for the two baselines, respectively.

REFERENCES

Alig, R. J., and A. J. Plantinga. 2004. "Future Forestland Area: Impacts from Population Growth and Other Factors that Affect Land Values." *Journal of Forestry* 102(8): 19-24.

Anselin, L. 2002. "Under the Hood. Issues in the Specification and Interpretation of Spatial Regression Models." *Agricultural Economics* 27 (3): 247-67.

Anselin, L. 2003. *GeoDa 0.9 User's Guide.* Spatial Analysis Laboratory, University of Illinois, Urbana-Champaign, IL.

Aronsson, T. and O. Carlen. 2000. "The Determinants of Forest Land Prices: An Empirical Analysis." *Canadian Journal of Forest Research* 30 (4): 589.

Beaton, Patrick W. 1991. "The Impact of Regional Land Use Controls on Property Values: The Case of the New Jersey Pinelands." *Land Economics* 67(2): 172.

Beaton, Patrick W., and Marcus Pollock. 1992. "Economic Impact of Growth Management Policies Surrounding the Chesapeake Bay." *Land Economics* 68: 434.

Bell, K. P., and N. E. Bockstael. 2000. "Applying the Generalized-Moments Estimation Approach to Spatial Problems Involving Microlevel Data." *Review of Economics and Statistics* 82(1): 72-82.

Bockstael, N. E. 1996. "Modeling Economics and Ecology: The Importance of a Spatial Perspective." *American Journal of Agricultural Economics* 78: 1168-80.

Brueckner, J. K., Thisse, J. F., and Y. Zenou. 1999. "Why is Central Paris Rich and Downtown Detroit Poor? An Amenity-Based Theory." *European Economic Review* 43: 91-107.

Cho, S. H., Wu, J. J., and W. G. Boggess. 2003. "Measuring Interactions among Urbanization, Land Use, and Public Finance." *American Journal of Agricultural Economics* 85(4): 988-99.

Colwell, P. F., Munneke, H. J., and J. W. Trefzger. 1998. "Chicago's Office Market: Price Indices, Location and Time." *Real Estate Economics* 26(1): 83-106.

Congressional Budget Office (CBO). "Regulatory Takings and Proposals for Change." 1998.

Dale-Johnson, D., and W. J. Brzeski. 2001. "Spatial Regression Analysis of Commercial Land Price Gradients." *A paper presented at the Asian Real Estate Society Sixth Annual Conference at Keio University, Mita Campus, Tokyo, Japan, July 31 to August 2, 2001.*

Environmental Systems Research Institute (ESRI). *What is ArcGIS.* ESRI, Redlands, CA. 2004.

Epstein, Richard A. *Takings: Private Property and the Power of Eminent Domain*. Cambridge, MA: Harvard University Press, 1985.

Freeman III, A. Myrick. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*. 2nd edition. Resources for the Future. Washington D.C. 2003.

Fischel, W. A. *The Economics of Zoning Laws: A Property Rights Approach to American Land Use Controls*. Baltimore: The John Hopkins University Press, 1985.

Fischel, W. A. *Do Growth Control Matter? A Review of Empirical Literature on the Effectiveness and Efficiency of Local Government Land Use Regulation*. Cambridge, MA: Lincoln Institute of Land Policy, 1990.

Fischel, W. A. *Regulatory Takings: Law, Economics, and Politics*. Harvard University Press: Cambridge, MA. 1995.

Fujita, Masahisa. 1982. "Spatial Patterns of Residential Development." *Journal of Urban Economics* 12 (1): 22-52.

Geoghegan, J., Wainger L, and N. E. Bockstael. 1997. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS." *Ecological Economics* 23 (3): 251-64.

Granger, M. D., and G. C. Blomquist. 1999. "Evaluating the Influence of Amenities on the Location of Manufacturing Establishments in Urban Areas." *Urban Studies* 36 (11): 1859-73.

Green, Richard K. 1999. "Land Use Regulation and the Price of Housing in a Suburban Wisconsin County." *Journal of Housing Economics* 8(2):144-59.

Hammond, M. *Pythonwin - Python IDE and GUI Framework for Windows*. 2001.

Hardie, I. W., and P. J. Parks. 1997. "Land Use with Heterogeneous Land Quality: An Application of an Area Base Model." *Amer. J. Agr. Econ.* 79(May): 299-310.

Hardie, I., Parks, P., Gottleib, P., and D. Wear. 2000. "Responsiveness of Rural and Urban Land Uses to Land Rent Determinants in the U.S. South." *Land Economics* 76(4): 659-73.

Helm, M. *Eugene, Oregon: A Guide 1984-85 Edition*. Rainy Day Press. 1984.

Henneberry, David M., and Richard L. Barrows. 1990. "Capitalization of Exclusive Agricultural Zoning into Farmland Prices. *Land Economics* 66(3):249-58.

Institute for a Sustainable Environment, University of Oregon (ISE). 1930 Population by Minor Civil Divisions. Spatial dataset. Eugene, OR: March 1999a. Data available at http://oregonstate.edu/Dept/pnw-erc/. Accessed in 10/2005.

Institute for a Sustainable Environment, University of Oregon (ISE). 1970 Population by Census County Divisions. Spatial dataset. Eugene, OR: March 1999b. Data available at http://oregonstate.edu/Dept/pnw-erc/. Accessed in 10/2005.

Irwin, E. G. 2002. "The Effects of Open Space on Residential Property Values." *Land Economics* 78 (4): 465-80.

Irwin, E. G., and N. E. Bockstael. 2001. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." *American Journal of Agricultural Economics* 83(3): 698-704.

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

Irwin, E. G., and N. E. Bockstael. 2004. "Land Use Externalities, Open Space Preservation, and Urban Sprawl." *Regional Science and Urban Economics* 34: 705-25.

Jackson, P. L., and A. J. Kimerling (eds.). *Atlas of the Pacific Northwest.* 9th edition. Oregon State University Press: Corvallis, OR. 2003.

Jaeger, William K. 2006. "The Effects of Land Use Regulations on Property Values." *Environmental Law* 36(1), 2006.

Jun, M. J. 2004. "The Effects of Portland's Urban Growth Boundary on Urban Development Patterns and Commuting." *Urban Studies* 41(7): 1333-48.

Katz, Lawrence and Kenneth T. Rosen. 1987. "The Interjurisdictional Effects of Growth Controls on Housing Prices." *Journal of Law and Economics* 30: 149.

Kline, J. and R. Alig. 1999. "Does Land Use Planning Slow the Conversion of Forest and Agricultural Land?" *Growth and Change* 30(1): 3-22.

Kline, J. D., Moses, A., and R. J. Alig. 2001. "Integrating Urbanization into Landscape-Level Ecological Assessments." *Ecosystems* 4: 3-18.

Kline, J. D., Alig, R. J., and B. Garber-Yonts. 2004. "Forestland Social Values and Open Space Preservation." *Journal of Forestry* 102(8): 39-45.

Knaap, G. and A. C. Nelson. *The Regulated Landscape: Lessons on State Land Use Planning from Oregon.* Lincoln Institute of Land Policy. Cambridge, MA. 1992.

Kowalski, J. G., and P. F. Colwell. 1986. "Market versus Assessed Values of Industrial Land." *Journal of the American Real Estate and Urban Economics Association* 14(2): 361-73.

Lin, Tzu-Chin, and Alan W. Evans. 2000. "The Relationship between the Price of Land and Size of Plot When Plots Are Small." *Land Economics* 76 (3): 386-94.

Lockwood, L. J., and R. C. Rutherford. 1996. "Determinants of Industrial Property Value." *Real Estate Economics* 24(2): 257-72.

Loy, W. G. (ed.), Allan, S., Buckley, A. R., and J. E. Meacham. *Atlas of Oregon.* 2nd ed. University of Oregon Press, Eugene, Oregon. 2001.

Loy, W. G., Allan, S., Patton, C. P., and R. D. Plank. *Atlas of Oregon.* University of Oregon, Eugene, Oregon. 1976.

Malpezzi, Stephen, Gregory H. Chun and Richard K. Green. 1998. "New Place-to-Place Housing Price Indexes for U.S. Metropolitan Areas and their Determinants: An Application of Urban Indicators." *Real Estate Economics* 26(2): 235-74.

Michelman, Frank I. 1967. "Property, Utility, and Fairness: Comments on the Ethical Foundations of 'Just Compensation' Law." *Harvard Law Review* 80: 1165-1258.

Miles, M., Cole, R., and D. Guilkey. 1990. "A Different Look at Commercial Real Estate Returns." *Journal of the American Real Estate and Urban Economics Association* 18(4): 403-30.

Mills, E. S. 1992. "Office Rents Determinants in the Chicago Area." *Journal of the American Real Estate and Urban Economics Association* 20(1): 273-87.

Mills, E. S. 2005. "Why Do We Have Urban Density Controls?" *Real Estate Economics* 33(3): 571-85.

Miranowski, J. A., and B. D. Hammes. 1984. "Implicit Prices of Soil Characteristics for Farmland in Iowa." *American Journal of Agricultural Economics* 66(5): 745-49.

Nelson, A. C. 1992. "Preserving Prime Farmland in the Face of Urbanization: Lessons from Oregon." *Journal of the American Planning Association* 58(4): 467-88.

Netusil, N. R. 2005. "The Effect of Environmental Zoning and Amenities on Property Values: Portland, Oregon." *Land Economics* 81(2): 227-46.

Oregon Department of Land Conservation and Development (DLCD). *Measure 37 Information.* http://www.oregon.gov/LCD/measure37.shtml (accessed February 15, 2006).

Oregon's Department of Land Conservation and Development (DLCD), Statewide Planning Goals and Guidelines. http://www.lcd.state.or.us/LCD/goals.shtml (accessed April 28, 2005).

Oregon Department of Revenue. *Real Property Assessment and Taxation.* Revised 2/2004. http://www.dor.state.or.us/InfoC/303-670.html (accessed June 4, 2004).

Oregon Land Use Statewide Survey. A report for Oregon Business Association and Institute of Portland Metropolitan Studies, Portland State University. CFM Research, Portland, OR. March 2005.

Palmquist, R. B. and L. E. Danielson. 1989. “A Hedonic Study of the Effects of Erosion Control and Drainage on Farmland Values.” *Amer. J. Ag. Econ.* 71(1): 55-62.

Parsons, George R. 1992. “The Effects of Coastal Land Use Restrictions on Housing Prices: A Repeat Sale Analysis.” *Journal of Environmental Economics and Management* 22: 25.

Paterson, R. W., and K. J. Boyle. 2002. “Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models.” *Land Economics* 78(3): 417-25.

Plantinga, A. J. 2004. “Measuring Compensation Under Measure 37: An Economist’s Perspective.” Department of Agricultural and Resource Economics, Oregon State University. Unpublished.

Plantinga, A. J., Lubowski, R. N., and R. N. Stavins. 2002. “The Effects of Potential Land Development on Agricultural Land Prices.” *Journal of Urban Economics* 52: 561-81.

Plantinga, A. J., and D. J. Miller. 2001. “Agricultural Land Values and the Value of Rights to Future Land Development.” *Land Economics* 77(1): 56-67.

Pollakowski, Henry O. and Susan M. Wachter. 1990. “The Effects of Land Use Constraints on Housing Prices.” *Land Economics* 66(3): 315-24.

Quigley, John M. and Larry A. Rosenthal. “The Effects of Land Use Regulation on the Price of Housing: What Do We Know? What Can We Learn?” (April 1, 2004). Berkeley Program on Housing and Urban Policy. Working Papers: Paper W04-002.

Saderion, Z. Smith, B., and C. Smith. 1994. “An Integrated Approach to the Evaluation of Commercial Real Estate.” *Journal of Real Estate Research* 9(2): 151-67.

Schaeffer, Peter V. and Cecily A. Millerick. 1991. “The Impact of Historic District Designation on Property Values: An Empirical Study.” *Economic Development Quarterly* 5: 301.

Shonkwiler, J. S., and J. E. Reynolds. 1986. “Hedonic Price Models in the Analysis of Land Prices at the Urban Fringe.” *Land Economics* 62(1): 58-63.

Sivitanidou, R. 1995. “Urban Spatial Variations in Office – Commercial Rents: The Role of Spatial Amenities and Commercial Zoning.” *Journal of Urban Economics* 38: 23-49.

Tyrväinen, L. and A. Miettinen. 2000. “Property Prices and Urban Forest Amenities.” *Journal of Environmental Economics and Management* 39: 205-23.

Van Rossum, Guido, and Fred L. Drake, Jr. (ed.). *Python Reference Manual.* PythonLabs. 2001.

Wu, J.J., and S. H. Cho. 2006. "The Effect of Local Land Use Regulations on Urban Development in the Western United States." *Regional Science and Urban Economics.*

Forthcoming.

Wu, J.J., R. M. Adams, and A. J. Plantinga. 2004. "Amenities in an Urban Equilibrium Model: Residential Development in Portland, Oregon." *Land Economics* 80 (1): 19-32.

Wu, J.J., and A. J. Plantinga. 2003. "The Influence of Public Open Space on Urban Spatial Structure." *Journal of Environmental Economics and Management* 46(2): 288-309.

Wu, J.J. 2002. "Amenities, Sprawl, and the Economic Landscape." *Paper presented at the Land Markets and Regulation Seminar, Lincoln Institute of Land Policy, Cambridge, MA, July 10-12, 2002.*

Wu, J.J. 2001. "Environmental Amenities and the Spatial Pattern of Urban Sprawl." *American Journal of Agricultural Economics* 83 (3): 691-97.

APPENDIX

APPENDIX : THE LAND PRICE MODELS

In this appendix, we describe how the econometric models of the empirical framework are developed. The models include land price equations for eight alternative land use classes. We first present the empirical specification of these eight land price equations and then discuss the estimation method. The data and estimation methods are presented at the end of this section.

A. Empirical Specification

Urban residential land price equations

A large number of studies have analyzed residential land values using the hedonic pricing approach. These studies typically regress housing or land price on property attributes and location and community characteristics (e.g., distances to the city center, environmental amenities, and neighborhood characteristics). Early attempts to incorporate space into hedonic pricing models used proximity to city centers as a key variable following the Alonso-Muth-Mills tradition (e.g., Fujita 1982). More recently, amenities (Brueckner, Thisse, and Zenou 1999; Wu 2001, 2002), open space (e.g., Tyrväinen and Miettinen 2000; Wu and Plantinga 2003), and agent interactions (e.g., Irwin and Bockstael 2002, 2004) have been recognized as important determinants of property values and development patterns. Spatial interdependencies have been modeled in two forms in the hedonic pricing models. First, techniques from spatial statistics are used to explicitly deal with the issue of spatial dependency (e.g., Bell and Bockstael 2000; Irwin and Bockstael 2001; Paterson and Boyle 2002; Plantinga, Lubowski and Stavins 2002; Wu et al. 2004). Second, the regression equation is specified using variables which summarize the spatial information. This has been done either in the form of location variables measuring the distance of the parcel to certain natural or man-made features (e.g., Lockwood and Rutherford 1996); neighborhood characteristics measuring the share of the surrounding area allocated to a land use of interest (e.g.,; Bockstael 1996; Irwin 2002; Geoghegan et al. 1997), or both (e.g., Irwin and Bockstael 2002; Wu et al. 2004). For example, Irwin and Bockstael (2004) use neighborhood land use variables representing the percentage of low, medium, and high-density residential land, commercial and industrial land, undeveloped land, and open space. Wu et al. (2004) use location and amenity variables such as distance to CBD, public park, river, lake, wetland, proximity of the nearest industrial and commercial property, and distance to nearest public transportation.

We estimate three urban residential land price equations, one for each housing density category (low, medium, and high-density housing). Based on previous studies, the urban residential land price equations are specified as

$$p_i^k = f^k(AREA_i, \mathbf{s}_i, \mathbf{l}_i, \mathbf{a}_i, \mathbf{n}_i) \text{ for } k = LD, MD, HD \qquad \text{[A1]-[A3]}$$

where i is the index of parcels of a particular land use class, p_i^k is the per-acre price of parcel i in class k, $AREA_i$ is parcel acreage, $\mathbf{s}_i$ is a vector of socioeconomic variables, $\mathbf{l}_i$ is a vector location variables, $\mathbf{a}_i$ is a vector amenity variables, and $\mathbf{n}_i$ is a vector of land use characteristics in the neighborhood. The empirical specification and estimation of these residential price equations are discussed in next section.

Parcel acreage serves as a control variable. Price per acre is generally expected to decline with the acreage (Bockstael 1996; Palmquist and Danielson 1989). Two socioeconomic characteristics were used in the regression - median household income by census block group and neighborhood population density which serves as a proxy for congestion. Location variables such as distance to central business district (CBD) and distance to nearest major highway characterize the location of the parcel within the urban area and serve as proxies for travel time to CBD and accessibility, respectively. Amenity variables, such as proximity to riverfront or lakefront, measure the influence of environmental amenities on the price of land. Finally, land use characteristics in the neighborhood are described by the percentage of land in the neighborhood allocated to low-, medium-, and high-density urban residential, rural residential, commercial, industrial, agricultural, and forest uses.

Commercial land price equation

Hedonic estimates of residential land values are typically performed within the framework of consumption theory. However, when applying the hedonic technique to income property (i.e. commercial, industrial, agricultural, forest land), land is typically treated as a factor input into production process (Freeman 2003).

Many studies have analyzed the determinants of commercial property value (e.g., Miles et al. 1990; Mills 1992; Saderion et al. 1993; Colwell et al. 1998; Sivitanidou 1995). For example, Miles et al. (1990) estimate hedonic commercial real estate (retail, office, industrial warehouse, industrial R&D) pricing models based on national location, metropolitan location, lease structure, physical structure, and historical financial performance. Mills (1992) estimates the present value of office asking rent as a function of the building and location characteristics (year, lot size, parking, shops, restaurants, bank, daycare, health care, and district dummies). Colwell et al. (1998) estimate a hedonic office rent function using variables such as lot size, building area, height, footage, age, distance to CBD, airport, density variables such as percentage of land allocated to road, rails, parks and golf, and location dummies. Sivitanidou

(1995) specifies office-commercial rent functions accounting not only for firm amenities but also for worker amenities. Explanatory variables include property-specific variables (age of structure, rentable area), firm amenities (distance to CBD, major airport, accessibility), worker amenities (education expenditure per student by school district, crime rate, distance to ocean, retail employment per resident population), and other spatial advantages (type of industry dummy). The commercial land price equation is specified as

$$p_i^{CO} = f^{CO}(AREA_i, \mathbf{f}_i, \mathbf{w}_i) \qquad [A4]$$

where i is the index of parcels in commercial use, p_i^{CO} is per-acre price of commercial land, $AREA_i$ is parcel acreage, and vectors $\mathbf{f}_i$ and $\mathbf{w}_i$ contain variables measuring the attraction of the property to firms and workers, respectively. Vector $\mathbf{f}_i$ contains variables measuring agglomeration effects and accessibility of output markets (firm amenities). Population density and percent of residential land in the neighborhood characterize the potential pool of customers. Variables such as percent of commercial and industrial land in the neighborhood, distance to CBD and distance to major highway characterize the scope of business activity in the neighborhood and critical agglomeration and accessibility advantages of business location (e.g., Miles et al. 1990; Mills 1992; Colwell et al. 1998). Variables in vector $\mathbf{w}_i$ represent worker amenities (e.g., Colwell et al. 1998; Sivitanidou 1995) and include measures of the surrounding open space such as percent of neighborhood in agricultural and forest land.

Industrial land price equation

Many studies have used the hedonic technique to examine the determinants of industrial property value (e.g., Kowalski and Colwell 1986; Lockwood and Rutherford 1996; Granger and

Blomquist 1999). For example, Kowalski and Colwell (1986) estimate a hedonic model for industrial land as a function of parcel size, macro-location, and micro-location (access, frontage, visibility, neighborhood effects, and amenities). They find that the most important explanatory factors of industrial land value are the size of the parcel and its location. Lockwood and Rutherford (1996) examine the determinants of industrial property value using physical characteristics, national-market and regional-market characteristics, interest rates, and location variables (distance to CBD, airport, major road, access to rail). They find that the value of industrial buildings is primarily related to physical characteristics, regional market influences, and location of the property.

According to Granger and Blomquist (1999) the literature devoted to manufacturers' location has been dominated by studies emphasizing output and input markets, transport cost, raw-material location, energy and water availability, and community/site characteristics. However, factors such as amenities are becoming more important to the location decision (Granger and Blomquist 1999). Granger and Blomquist (1999) investigate the notion that amenities influence manufacturers' location choices in urban areas. They estimate regression models of the location of small and medium-sized manufacturing establishments as a function of two kinds of variables – production shifters and amenities. The production shifter variables account for two types of efficiency gains - local scale economies (proxied by population count) and agglomeration economies (proxied by the number of large manufacturers). Amenities are measured using a composite quality-of-life index. Given that amenities affect production costs, they also affect manufacturers' locations patterns in urban areas. Granger and Blomquist (1999) found that while urban agglomeration and scale economies remain paramount in location decisions of manufacturing establishments, amenities do influence manufacturing location in urban areas and the effect varies by type of amenity and by industry. Labor-intensive industries are more strongly attracted to high-amenity urban locations, while land-intensive manufacturers seek sites where amenities are scarce. The industrial land price equation is specified as

$$p_i^{IN} = f^{IN}(AREA_i, \mathbf{f}_i, \mathbf{w}_i) \qquad \text{[A5]}$$

where i is the index of parcels in commercial use, p_i^{IN} is per-acre price of industrial land, $AREA_i$ is parcel acreage, and vectors $\mathbf{f}_i$ and $\mathbf{w}_i$ contain variables characterizing firm and worker amenities, respectively. Vector $\mathbf{f}_i$ contains variables measuring agglomeration effects and accessibility of output markets (firm amenities). Population density, percent of commercial and industrial land in the neighborhood, distance to CBD and distance to major highway characterize the critical agglomeration and accessibility advantages of industrial location (e.g., Miles et al. 1990; Mills 1992; Colwell et al. 1998). The size of a parcel and its location have been found as the most important explanatory factors of industrial property value (e.g., Kowalski and Colwell 1986; Lockwood and Rutherford 1996). Vector $\mathbf{w}_i$ contains characteristics of worker amenities (e.g., Colwell et al. 1998; Sivitanidou 1995). These include measures of the surrounding open space such as percent of neighborhood in agricultural and forest land. Amenities have been found to influence manufacturing location in urban areas (Granger and Blomquist 1999).

Rural residential land price equation

Rural residential land values are usually estimated in hedonic studies dealing with valuation of residential properties in the urban-rural fringe area (e.g., Geoghegan et al. 1997; Irwin and Bockstael 2002) or in studies investigating the role of nonagricultural demand for rural lands. For example, Plantinga and Miller (2001) found that variables measuring the location of rural lands with respect to urban areas and natural amenities are important determinants of rural land values. Shonkwiler and Reynolds (1986) estimate a hedonic model using parcel-level data to analyze the effect of physical and location characteristics on the sale price of rural land near an urbanizing area and found that access to economic or recreational activities, as well as location with respect to urban areas and natural amenities, are important determinants of rural land values. Based on previous studies, the rural residential land price equation is specified as

$$p_i^{RR} = f^{RR}(AREA_i, \mathbf{s}_i, \mathbf{l}_i, \mathbf{a}_i, \mathbf{n}_i) \qquad [A6]$$

where i is the index of rural residential parcels, p_i^{RR} is per-acre price of rural residential land, $AREA_i$ is parcel acreage, $\mathbf{s}_i$ is a vector of socioeconomic variables, $\mathbf{l}_i$ is a vector location variables, $\mathbf{a}_i$ is a vector of amenity variables, and $\mathbf{n}_i$ is a vector of neighborhood variables. The socioeconomic characteristics include household income and population density. The location (proximity to or location within the UGB, distance to major highway) and amenity variables (distance to lakefront and riverfront) characterize the development premium and option value associated with the site. Variables reflecting the presence of nearby housing or commercial development (percentage of residential land in the surrounding area) serve as additional measures of urban influence.

Agricultural land price equation

Hedonic studies of agricultural land values are usually estimated using either aggregate county-level data (e.g. Plantinga et al. 2002; Hardie et al. 2000; Hardie and Parks 1997; Miranowski and Hammes 1984) or detailed parcel-level data (e.g. Bockstael 1996; Shonkwiler and Reynolds 1986; Palmquist and Danielson 1989). Typically, two groups of explanatory variables are used;

one includes variables affecting net returns to farmland such as farm revenue and production cost or measures of land quality and soil characteristics; the other group include variables that affect growth premium and option values or proxies for future land development potential (Shonkwiler and Reynolds 1986; Plantinga et al. 2002) such as proximity to major metropolitan centers, airport, or highway, location with respect to natural amenities, population density, population change, road density, farm density, personal income, proxies for availability of urban services (presence of community water and sewer system). The land price equation for agricultural land use is specified as

$$p_i^{AG} = f^{AG}(AREA_i, \mathbf{r}_i, \mathbf{d}_i) \qquad \text{[A7]}$$

where i is the index of parcels in agricultural use, p_i^{AG} is per-acre price of agricultural land, $AREA_i$ is parcel acreage, $\mathbf{r}_i$ is a vector of land rent proxies, and $\mathbf{d}_i$ is a vector of variables characterizing the development premium and option value associated with the site. Vector $\mathbf{r}_i$ includes dummy variables describing the agricultural land capability class which serve as proxies for agricultural rents. Variables contained in vector $\mathbf{d}_i$ reflect the development pressure associated with the site such as proximity to UGB, location inside the UGB, distance to major highway, and population density in the neighborhood.

Forest land price equation

Hedonic studies of forest land values typically use variables affecting forestry rents such as timber growth and yield, stumpage prices, age class of stands, tree species, planting and management costs, elevation, slope, soil quality, distance to production facility, and any road building requirements; as well as proxies measuring development pressure such as proximity to major cities, highways, natural amenities, and socioeconomic variables (e.g. Hardie et al. 2000; Aronsson and Carlen 2000; Kline et al. 2001, 2004; Alig and Plantinga 2004). Proxies for future development potential are also found important determinants of forest land values (Alig and Plantinga 2004; Kline, Alig, and Garber-Yonts 2004). The land price equation for forest use is specified as

$$p_i^{FO} = f^{FO}(AREA_i, \mathbf{r}_i, \mathbf{d}_i) \qquad [A8]$$

where i is the index of forest parcels, p_i^{FO} is per-acre price of forest land, $AREA_i$ is parcel acreage, $\mathbf{r}_i$ is a vector of land rent proxies, and $\mathbf{d}_i$ is a vector of variables characterizing the development premium associated with the site. Vector $\mathbf{r}_i$ includes dummies for forest type which serve as proxies for forestry rents. Vector $\mathbf{d}_i$ contains variables characterizing the development premium associated with the site. These include variables such as proximity to UGB, distance to major highway, river, or lake, and population density in the neighborhood reflect the role of non-forestry demand for rural lands.

The log-linear functional form is used to estimate each of the land price equations.[1] Previous studies have shown that land price is a non-linear function of its attributes (e.g., Geoghegan et al. 1997; Plantinga and Miller 2001; Wu et al. 2004). In addition, the log-linear specification assures non-negativity of the predicted land prices.

B. Estimation Method

As discussed in section 3.3, the land price functions are specified as spatial error models (Anselin 2002) to explicitly deal with the spatial dependency between the error terms. GeoData

Analysis software (Anselin 2003) was used to fit the spatial error specification of the econometric models. The distance-based variables tend to be highly correlated. To minimize a potential multicollinearity problem a backward elimination procedure was used to select the distance measures while the key economic variables and the neighborhood variables were kept in the models at all times.

The three rural land price equations (RR, AG, FO) are estimated together. The structure of our geospatial dataset is such that parcels inside the urban growth boundary (UGB) have a unique land use class, while parcels outside the UGB tend to be used for multiple purposes. However, the shares of each parcel allocated to RR, AG, FO are known. With the share information, the price of a parcel can be written as $y = \pi_{RR}^{s_{RR}} \pi_{AG}^{s_{AG}} \pi_{FO}^{s_{FO}}$ or $y = \prod_{\delta} \left(\pi_{\delta}\right)^{s_{\delta}}$, where $\delta = \{\text{RR, AG, FO}\}$, y is the (observed) price of the parcel, π_{δ} denotes the (unobserved) price of a parcel segment in use δ, and s_{δ} represents the share of the parcel segment on the total acreage of the parcel, thus $\sum s_{\delta} = 1$. In this specification the parcel price is expressed as the Cobb-Douglas geometric mean of its unobserved components. Assuming $\ln \pi_{\delta} = X_{\delta} \beta_{\delta} + \mu$, where X_{δ} is the vector of characteristics of the parcel segment, it follows that

$$\ln y = \sum_{\delta} \left(s_{\delta} X_{\delta} \beta_{\delta}\right) + \mu \qquad \text{[A9]}$$

The parameters for the three rural land price equations, β_{δ}'s, are estimated simultaneously using equation [A9].

C. The Data

The 2000 land use/cover map layer was derived from satellite images, aerial orthophoto maps, and taxlot maps. Land use is classified as low-, medium-, and high-density urban residential (0-4, 4-9, >9 dwelling units per acre), commercial (retail and office establishments), industrial (warehouses, assembly plants, R&D), rural residential, agricultural (cropland, pastureland, wood/nurseries), and forestland.

The data sample used for econometric estimation includes privately owned land that is currently in one of the eight land use classes (equations [A1]-[A8]) totaling some 13,000 parcels. The same sample is used for conducting simulations. The remaining land within the study area which is publicly owned or is used for other purposes (e.g. roads, water bodies) stays invariant throughout the simulations.

Table A4 shows the basic statistics for the explanatory variables. Parcel-level land value data were derived from county assessors' records on real market value of land (without improvements). According to Oregon law, assessor must appraise all property at 100 percent of its real market value. Real market value is typically the price the property would sell for in a transaction between a willing buyer and a willing seller. The county assessor initially appraises the property using a physical inspection and a comparison of market data from similar properties. During the ensuing tax years, the county assessor updates the value according to trends of similar properties. Some properties, such as farm or forest property, may be subject to special valuation processes (Oregon Department of Revenue 2004). Median household income (MHINC) was derived from the 2000 U.S. Population Census block group-level data. Population density in the neighborhood (NPOPDEN) represents predicted values from a land use-adjusted population model based on the 2000 U.S. Population Census block-level data.

Table A4. Variables and Descriptive Statistics by Land Use Class

		Urban residential parcels (LD,MD,HD)		Commercial and industrial parcels (CO,IN)		Rural resid., agricultural, and forest parcels (RR,AG,FO)	
Variable	Definition	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
AREA	Parcel area (acres)	0.28	0.52	1.07	2.12	10.63	22.18
MHINC	Median household income (1,000 $)	45.71	11.05	32.77	11.48	49.84	8.59
NPOPDEN	Neighborhood population density (persons/ha)	18.76	9.13	10.48	6.13	1.51	2.81
IN_UGB	UGB dummy (1 if within the UGB; 0 otherwise)	1	0	1	0	0.16	0.36
ZONED_RR	Rural residential zoning (1 if zoned; 0 otherwise)	-	-	-	-	0.09	0.29
CLNIRR1	Agricultural soil capability dummy (1 if CLNIRR = 1)	-	-	-	-	0.11	0.31
CLNIRR2	Agricultural soil capability dummy (1 if CLNIRR = 2)	-	-	-	-	0.65	0.48
CLNIRR3	Agricultural soil capability dummy (1 if CLNIRR = 3)	-	-	-	-	0.09	0.29
CLNIRR4	Agricultural soil capability dummy (1 if CLNIRR = 4)	-	-	-	-	0.11	0.31
CLNIRR5	Agricultural soil capability dummy (1 if CLNIRR $\geq$ 5)	-	-	-	-	0.04	0.20
OPEN	Forest type dummy (1 if open forest)	-	-	-	-	0.03	0.17
MIXED	Forest type dummy (1 if mixed forest)	-	-	-	-	0.25	0.43
CLOSED	Forest type dummy (1 if closed forest)	-	-	-	-	0.72	0.45

Table A4. Variables and Descriptive Statistics by Land Use Class (Continued)

Variable	Definition	Urban residential parcels (LD,MD,HD) Mean	Std. Dev.	Commercial and industrial parcels (CO,IN) Mean	Std. Dev.	Rural resid., agricultural, and forest parcels (RR,AG,FO) Mean	Std. Dev.
Distance measures							
DIST_HWY	Distance to nearest major highway (1,000 m)	0.77	0.68	0.24	0.28	2.26	1.93
DIST_CBD	Distance to central business district (1,000 m)	4.36	1.55	3.06	1.84	-	-
DIST_UGB	Distance to UGB (1,000 m)	-	-	-	-	0.81	0.99
DIST_RIV	Distance to riverfront (1,000 m)	1.30	0.72	0.82	0.65	0.04	0.26
DIST_LAKE	Distance to lake (1,000 m)	1.23	0.82	1.02	0.61	0.22	0.55
Neighborhood measures							
	Percentage of neighboring area that is in:						
%FO	Forest use	0.38	2.79	1.53	2.93	30.48	18.10
%AG	Agricultural use	0.69	4.24	1.84	6.89	14.10	13.71
%RR	Rural residential use	0.25	2.58	0.18	0.86	0.04	0.17
%LD	Low-density resid. use	23.29	20.23	7.42	9.70	2.41	4.56
%MD	Medium-density resid. use	35.47	20.54	8.90	8.54	2.48	5.01
%HD	High-density resid. use	4.96	12.02	7.98	6.07	0.83	2.51
%CO	Commercial use	1.89	6.61	22.01	13.42	1.01	3.61
%IN	Industrial use	0.20	2.05	2.52	4.99	1.25	4.14
%OTHER	Other uses (incl. civic, vacant, non-vegetated, grasslands, shrublands, roads, and water bodies)	32.87	13.61	47.62	16.08	47.40	21.30

Dummy variables were constructed to characterize the parcel with respect to its location within the UGB (IN_UGB), the type of forest (open forest, mostly oak; closed forest, mostly conifer; and mixed forest), and the soil capability classes (CLNIRR). The USDA Soil Conservation Service classifies the suitability of land for agricultural production using the CLNIRR soil capability index. The index rates soil for non-irrigated agricultural use and ranges from 1 to 8 indicating progressively greater limitations and narrower choices for use.[2]

The distance and neighborhood measures were computed using Python programming language (van Rossum and Drake 2001) and Python scripts for the ArcGIS geoprocessing tools (ESRI 2004). The distance measures were calculated as the shortest straight line (Euclidian) distance between the parcel centroid and the nearest edge of a feature of interest, such as the central business district (DIST_CBD), urban growth boundary (DIST_UGB), riverfront (DIST_RIVER), lakefront (DIST_LAKE), or major highway (DIST_HWY).

The neighborhood measures characterize the land use pattern in the surrounding area. They measure the percentage of the surrounding landscape that is in low-, medium, and high-density urban residential, commercial, industrial, rural residential, agricultural, and forest use. The remaining area (%OTHER), not accounted for by the above eight categories, includes land in civic use, vacant land, wetlands, grassland, shrublands, sand and gravel, roads, and permanent water. The neighborhood is defined as the surrounding landscape within a 100-meter or 500-meter buffer around the parcel boundary.[3]

APPENDIX: ENDNOTES

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[1] The linear specification of the spatial error models causes the regression to collapse.

[2] We are grateful to John Bolte, Pat Berger, Frank Miller, and Michael Guzy at Oregon State University for assistance with the land use/cover spatial dataset and the land use-adjusted population estimates.

[3] To ease the computational constraint, the definition of parcel neighborhood is simplified during simulations by drawing a buffer around the parcel and searching for parcels with centroids located within a given buffer distance.

CHAPTER 4

MEASURING THE REGULATORY TAKINGS AND GIVINGS: NONLINEARITY OF THE COST GRADIENT OF LAND USE REGULATIONS

Ivan Hascic
and JunJie Wu, Professor

ABSTRACT

This paper evaluates the efficiency of the current system of land use regulation in Oregon and analyzes the possible changes to the regulatory structure. The results suggest that the cost gradient of land use regulations is a nonlinear function of the composition of the regulatory mix due to interdependencies between land uses and land use regulations. Irregularities may occur where an agglomeration effect or other forms of spatial and temporal interaction among neighboring land uses arise.

INTRODUCTION

Unregulated land markets may under-provide certain public goods (such as open space and other environmental amenities with characteristics of public goods) and leave externalities uninternalized (negative externalities can arise because of the interdependence of uses of neighboring parcels of land). These market failures provide the basis for land use regulation. The broad scale of government intervention in land markets under the justification of growth control or environmental preservation has brought about a concern for the equitable treatment of all property owners. When regulations are imposed they create winners and losers and redistribute wealth among landowners. Some owners may receive windfalls, others may suffer wipeouts. Where there is a threat of wipeouts, political reaction can threaten the existence of the land use program.

In the 2004 election in Oregon property rights advocates launched Ballot Measure 37 to protect private property rights from strict land use regulation and to establish the statutory right to demand compensation when a land use regulation reduces the market value of a private property. Reflecting public sentiments against regulatory taking, Measure 37 was passed by 61% to 39% on November 2, 2004. By October 25, 2005, 1255 claims had been filed with the state, requesting at least $2.2 billion in compensation and covering at least 66,000 acres of land (Oregon Department of Land Conservation and Development 2006). By October 25, 2005, 373 final orders had been issued; approximately 90% of the ruled claims had resulted in waiving the regulation; 10% in denial.

So far, no compensation has been awarded on any Measure 37 claim in Oregon. However, if Oregonians want to continue to enjoy the achievements of the statewide land use planning program established in 1973, the practice of granting waivers, rather than paying compensations, will need to be discontinued. Recently, the cities of Portland and Eugene, Oregon have been considering to fund the compensation payments out of the increase in property values created by land use planning (The Oregonian 2006; Metro 2006). Specifically, a tax would be levied on the windfall gains created by an expansion of the urban growth boundary. While the recognition of the existence of government-created value is not new, the implementation of this principle in regulatory practice is innovative.[1] The proposition of a cross-financed funding mechanism based on taxing windfall gains of one regulation in order to provide funds necessary to pay compensations for wipeouts of another regulation may sound straightforward; However, it raises a broader question of identifiability. Determining the winners and losers and quantifying the windfalls and wipeouts of a regulation may turn out to be a formidable task in situations where interdependencies between the uses of neighboring parcels exist. In addition, the direction and the magnitude of the change in property values may depend on the composition of the regulatory mix.

This paper draws on the study presented in chapter 3. Specifically, it addresses the following questions: (a) Given the available empirical evidence, what can we conclude about the efficiency of the current system of land use regulation; In particular, do governments over regulate land use? If so, what changes to the current regulatory structure are advisable and what changes should be avoided? (b) What are the direction and the magnitude of marginal costs and benefits of land use regulations in response to changes in the composition of the regulatory mix? And finally, (c) is there a feasible policy alternative to maintaining the status quo and facing the initiatives attempting to undermine the existing land use program?

The cost of land use regulation has been studied extensively within a framework of a theoretical model (e.g., Bento, Franco, and Kaffine 2006; Fischel 2001; Brueckner 2000, 1996, 1995, 1990; Evans 1999; Epple et al. 1988; Sheppard 1988). Less frequent are studies analyzing the cost of land use regulations empirically (e.g., Mills 2005; Cheshire and Sheppard 2002, 1989; Phillips and Goodstein 2000; Evans 1999; Bramley 1993a, 1993b; Fischel 1990). For example, Cheshire and Sheppard (2002) develop an empirical model to quantify the benefits (such as environmental amenities) and costs of land use regulation (such as increased land and housing costs). They find that land use regulation produces considerable benefits but it does so at a high cost. Overall, they find a negative net effect.

Several scholars have addressed the conceptual imbalance in regulatory takings principles. The seminal academic treatment of this subject is in Hagman and Mysczinski (1978). More recent studies on this subject include Elliot (1996) and Meltz, Merriam and Frank (1999). They argue that the regulatory takings law is unfairly skewed because it focuses primarily on the negative economic impacts of government decisions on private property and fails to account for the favorable economic effects created by a wide array of government programs and projects (e.g., appreciation in value of properties located in the vicinity of publicly financed capital improvements) as well as land use regulations (e.g., mitigation of nuisances by regulating incompatible uses).

This paper draws also on the strand of literature which studies the interdependence between neighboring land uses. Several studies have focused on the mechanism of spatial interaction (e.g., Irwin and Bockstael 2002, 2004; Wu et al. 2004). For example, Irwin and Bockstael (2004) find that there are interdependencies between the pattern of current land use and the probability that a neighboring lot will be developed. Using the example of anti-sprawl policies, they illustrate how the indirect or unanticipated effects of land use regulation may run counter to the intention of the policy.

In this paper, the modeling framework from chapter 3 is applied to estimate some of the costs and benefits of land use regulations. The framework is used to analyze the changes in the cost of a particular regulatory mix when a selected regulation, or a combination of regulations, is removed or added to the mix. We conclude that although the current level of land use regulation may be privately suboptimal, the lack of data prevents us from drawing conclusions about the efficiency of land use regulation from the societal point of view. The estimated costs and benefits of various regulatory mixes suggest that the cost gradient of land use regulations is a nonlinear function of the composition of the regulatory mix. Irregularities may occur where an agglomeration effect or other forms of spatial and temporal interaction among neighboring land uses arise. Interdependencies between uses of land of neighboring parcels thus translate into interdependencies among regulations in the regulatory mix. Finally, we found that changes in the location and delineation of the zoned districts may help mitigate the cost of land use regulations to private landowners.

THE MODELING FRAMEWORK

A modeling framework is developed to simulate the effects of land use regulations on land values and land use patterns within a study area located near Eugene, Oregon. The framework focuses on the economic aspect of land development, with particular attention on the interplay between spatial externalities and institutional controls in directing land development. Land use is assumed to be driven by changes in land values which are influenced by spatial externalities of land use (neighborhood effects). Location and the surrounding landscape play a prominent role in this approach. In particular, a zoning regulation may affect the value of a parcel both directly by restricting its use and indirectly by affecting land use in its surrounding area.

The framework has two major components, an econometric and a simulation component. The econometric component consists of land price equations estimated to predict land values for eight land use classes (low, medium, and high-density residential, commercial, industrial, agricultural, forest, and rural residential land). The hedonic pricing technique is applied to construct the land price equations by regressing parcel-level land prices on a vector of socioeconomic, location, and neighborhood characteristics. Spatial interdependencies between parcels are assumed to take two forms in the land price equations. First, each equation is specified as a function of variables summarizing the spatial information (incl. location and neighborhood characteristics). Second, the equations are specified as spatial error models to explicitly deal with the spatial dependency between unobserved variables.

The second major component of the empirical framework is a simulation model which predicts land values and land use choices at each parcel on the landscape under alternative regulation scenarios. The simulations are conducted in a sequential manner both spatially and temporally. To simulate land use patterns on the landscape at a given time, land parcels are processed sequentially according to their distance to the central business district (CBD). Land use choice at the parcel located nearest to the CBD is considered first. The spatially variant measures of surrounding land use are computed. The values of the parcel when put to different uses are then estimated using the land price equations. The land use that yields the highest value is selected for the parcel unless constrained by a land use regulation. This process continues on a parcel-by-parcel basis, outwards from the city center, until the last (most distant) parcel is processed. The most important feature of this approach is that each parcel's optimal land use is chosen while taking into account the surrounding land use.

A temporal dimension (in addition to the spatial dimension) is introduced to take into account the irreversible nature of land development process. To simulate development patterns and land prices in year 2000 that would have existed on the landscape when a regulation had not been imposed, it is necessary to simulate how land use patterns would have evolved over time because land use choice for a parcel is both spatially and temporally variant. Land use choice is spatially variant because it depends on the existing land use in the surrounding area; it is also temporally variant because current land use patterns are shaped by previous land use decisions due to land use irreversibility and spatial exetrnalities. In this study, land use choice is simulated in 1960, 1970, 1980, 1990, and 2000 on each parcel in the study region based on historical income and population data and urban boundaries. For a given year, land parcels are allocated to different uses subject to a set of irreversibility constraints.

The simulation framework is validated against the actual land use pattern in the study area. Further details on the modeling framework are provided in chapter 3.

THE EFFICIENCY OF LAND USE REGULATIONS

From a landowner's perspective, the optimal level of regulation is where the marginal private cost of more regulation equals the marginal benefit, i.e. where the private net benefits are maximized (R* in figure 4.1). The results presented in table 3.4 suggest that when all current zoning regulations are considered relative to the free-market baseline, the total cost of land use regulation is significantly larger than the total benefit. The total gains in land value amount to only 12% of the total losses. For the landowners as a whole, the cost greatly outweighs the benefit of regulation (in figure 4.1, the dark-shaded triangle is greater than the light-shaded triangle). Therefore, the current level of regulation is not anywhere in the neighborhood of the privately optimal level. Rather, this result suggests that the current level of regulation may be

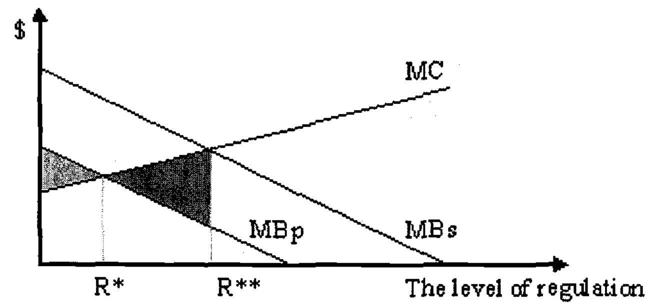


Figure 4.1. The Privately and Socially Optimal Level of Regulation

privately suboptimal because the total costs of regulation are much larger than the total benefits (point R** in figure 4.1).

This brief analytical summary illustrates the main argument made by some property rights advocates who argue that the benefits that private landowners receive from regulations hardly outweigh the costs. While some landowners may indeed be caught in the web of government regulations and the complaint that governments overregulate may be justified in some cases (see Fischel 1995 and Pease 1998 for a selection of regulatory takings cases from the U.S. jurisprudential practice), the general validity of the proposition cannot be established on the basis of such partial evidence. There are several reason why this may not be true.

First, the hedonic pricing approach measures only the private value of land. While some benefits of land use regulations may be external to the affected landowner (such as enjoyment of open space or a nice view), if these benefits accrue to third parties and are capitalized into the land values, they can be captured using the hedonic pricing technique. However, there is a whole range of social benefits (such as preservation of biodiversity, protection of water quality) which are not capitalized into the land value because of their non-market character. It is entirely possible that these social benefits are large enough to balance any costs to private landowners.

However, in the absence of data on the magnitude of these benefits we are unable to draw conclusions about the efficiency of land use regulation from the societal point of view.

Second, private property commands a value precisely because the government enforces the protection of private property rights (e.g. police and fire protection). In addition, large amounts of public resources are spent to serve various public functions and enhance the quality of life of its citizens (e.g., road and infrastructure construction). The ability of the hedonic pricing approach to identify these factors is limited because of the lack of data for a control group.

Third, the protection of private property rights must be viewed in the socioeconomic context. The meaning of property right is not absolute but is subject to change (Bromley 2000). Throughout history, private property rights have been balanced with community values. Rebuilding of old neighborhoods is commonly balanced with historic preservation rules (e.g., the ruling on Grand Central Station in New York City); the public is often granted the right to access ocean or lakeside beaches; and the prevention of nuisance spillovers is grounded in common law. These are just a few examples of how societies deal with the private-public conflict in order to promote land stewardship and social responsibility.

In sum, results in table 3.4 are estimated using the hedonic land price functions which are capable to capture only the marketable benefits. The non-market benefits, which are not capitalized in land prices, remain unaccounted for. In addition, results in table 3.4 suggest that the three resource protection policies (forest zoning, farmland zoning, UGB) yield a net loss relative to the free-market baseline. This may be a consequence of the fact that benefits provided by these regulations are often of non-market nature. The benefits of these regulations may thus be underestimated. On the other hand, results for commercial zoning (table 3.5) suggest that the regulation yields a net gain for landowners overall. Unlike in the former case, the benefits of commercial zoning are overwhelmingly marketable, and thus largely capitalized in land prices. Since the share of benefits which have non-market character is likely to be higher for regulations prohibiting development, the benefit side of these regulations is more likely to be underestimated.

ESTIMATION OF PRIVATE COSTS AND BENEFITS

Although the lack of data prevents us from determining the socially optimal level of regulation, the simulation model developed in chapter 3 allows to analyze the changes in the private cost of a particular regulatory mix when a selected regulation, or a combination of regulations, is removed or added to the mix. In this section, the impact of a given regulatory mix is evaluated by comparing land prices that would have existed in the absence of the regulations (the baseline) with those when the regulations are in place. The costs and benefits of a regulatory mix are calculated by changing the composition of the regulatory mix. We estimate the cost and benefit curves by imposing more and more regulations on land use. The order in which regulations are imposed on top of the free-market baseline is determined using several alternative criteria, including the gain/loss ratio of a regulation, the net benefit of a regulation, and the area constrained by a regulation. The estimated costs and benefits (i.e. the losses and gains in land value) of these regulatory mixes are presented in table 4.1.

Table 4.1a shows the results obtained by imposing regulations based on their gain/loss ratios (see table 3.4). The most beneficial regulations are imposed first. Starting with the free-market baseline, the regulation with the highest gain/loss ratio is imposed. In the following step, the regulation next in the order is imposed on top of the existing regulatory mix, and so on until

Table 4.1. Estimated Costs and Benefits of Land Use Regulations Using Alternative Ordering Criteria

Regulation	Value of the criterion	Order	Total benefit (million $)	Total cost (million $)
a. Regulations ordered based on the gain/loss ratio				
Free market				
+AG	9.125	1	284.67	31.20
+UGB	6.815	2	288.27	42.34
+IN	0.602	3	444.91	502.64
+RES	0.280	4	124.83	839.81
+FO	0.229	5	123.82	841.30
+CO	0.204	6	143.19	758.27
b. Regulations ordered based on the net benefits				
Free market				
+AG	253.5	1	284.67	31.20
+UGB	244.8	2	288.27	42.34
+FO	-2.6	3	288.27	43.83
+IN	-197.1	4	443.55	504.14
+CO	-454.6	5	128.94	692.79
+RES	-550.0	6	143.19	758.27
c. Regulations ordered based on the size of constrained area				
Free market				
+FO		1	0.76	3.32
+AG		2	284.81	34.49
+UGB		3	288.27	43.83
+RES		4	139.73	797.87
+IN		5	123.82	841.30
+CO		6	143.19	758.27

the least beneficial regulation is imposed. Table 4.1b presents the results obtained by imposing regulations based on the net benefit of the regulation. The regulations that generate the largest net benefit are imposed first. Finally, table 4.1c shows results simulated when regulations are imposed based on the area effectively constrained by the regulation. Areas constrained by land use regulations often overlap. For example, designating an urban growth boundary (UGB) typically places a constraint also on land zoned as forest or farmland. Most regulations are exclusive in the sense that they exclude certain land uses from the area inside the zoned district, while they leave land use choices outside the district unconstrained. However, commercial and industrial zonings place an effective constraint both on land inside as well as outside a zoned district. Therefore, these regulations may directly affect the entire study area. Table 4.1c shows an ordering of regulations in which a regulation is imposed only when all other regulations which also constrain the same area are already in place (e.g., UGB is imposed only after forest zoning, because the area constrained by forest zoning is a subset of the area constrained by a UGB). Such ordering exercises a progressively increasing constraint on land use in the study area.

Economic theory suggests that the typical case of costs and benefits of regulation can be depicted by an upward-sloping marginal cost curve and a downward-sloping marginal benefit curve (Figure 4.1). Formally, $C = C(R)$ with $C_R > 0$, and $B = B(R)$ with $B_R < 0$, where $R \in \{FO, AG, UGB, RES, CO, IN\}$ represents the set of land use regulations in place, the regulatory mix. These include three "rural" policies - forest zoning (FO), exclusive farm use zoning (AG), and designation of an urban growth boundary (UGB), and three "urban" policies – residential density zoning (RES), commercial zoning (CO), and industrial zoning (IN).

Results in table 4.1 suggest that none of the three criteria yields a downward-sloping marginal benefit curve, nor an upward-sloping marginal cost curve. This suggests that the direction and magnitude of marginal costs and benefits of a regulation depend on the composition of the regulatory mix. The next section presents a more exhaustive analysis of the relationship between the private costs and benefits of regulation and the composition of the regulatory mix.

NONLINEARITY OF THE COST GRADIENT OF LAND USE REGULATIONS

Table 4.2 presents the results of a series of systematic simulations of alternative regulatory mixes. To reduce the number of regulatory mixes to be simulated, the regulations are grouped in two subsets – rural (FO,AG,UGB) and urban (RES,CO,IN) policies – and only combinations of the regulations within a subset are simulated. First, alternative combinations of the rural policies are imposed on the free-market scenario. When all rural regulations are in place, combinations of the urban policies are imposed on top of the rural policies (table 4.2a). Alternatively, urban policies are imposed first, followed with the rural policies (table 4.2b).

In both cases, the results suggest that the marginal costs of rural land use regulations (FO,AG,UGB) are always positive. For urban regulations, while the marginal costs are positive in most cases, the marginal cost is negative if commercial zoning (CO) is imposed on a regulatory mix which includes residential zoning (RES). This is because residential zoning creates large costs by displacing commercial establishments to inferior locations and reducing the agglomeration effect of commercial clusters. When commercial zoning is imposed, it tends to correct for this fact by creating distinct commercial zones and thus enhancing the agglomeration advantages.

The results also suggest that marginal benefits of more regulation are generally negative. Marginal benefits are positive if commercial (CO) or industrial (IN) zonings are applied on top of a regulatory mix containing residential zoning (RES). The intuition for this result is the same as above. In addition, marginal benefits may also be positive if forest (FO) or farmland (AG) zonings alone are imposed on top of zonings regulating urban land uses (RES,CO,IN). However, imposing forest or farmland zonings in combination with a UGB yields negative marginal benefits. This is because both forest and farmland zonings protect

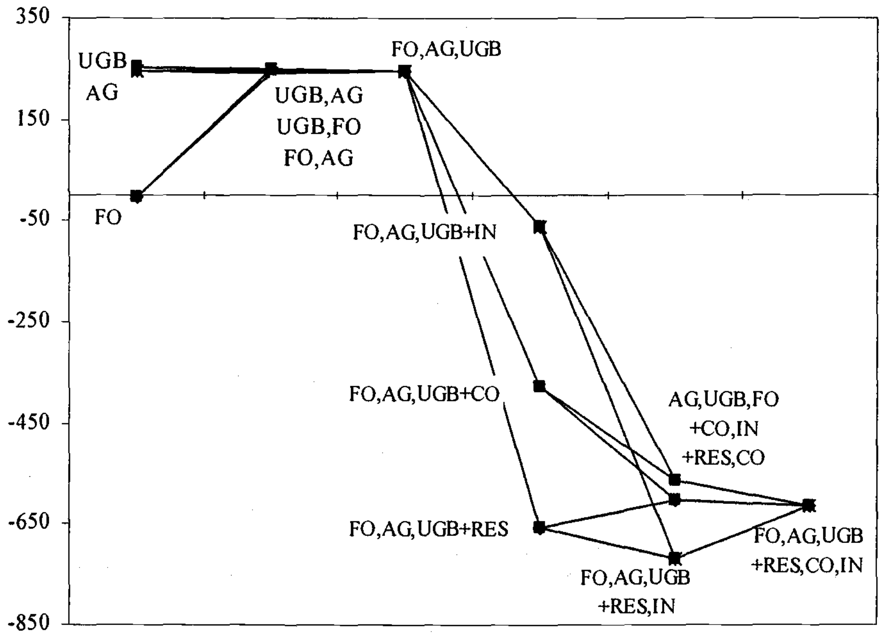
Table 4.2. Estimated Costs and Benefits of Various Regulatory Mixes

Regulation	Value of the criterion	Order	Total benefit (million $)	Total cost (million $)
a.				
FO	Rural	1	0.76	3.32
AG	Rural	1	284.67	31.20
UGB	Rural	1	286.89	42.10
FO,AG	Rural	2	284.81	34.49
FO,UGB	Rural	2	286.89	43.59
AG,UGB	Rural	2	288.27	42.34
FO,AG,UGB	Rural	3	288.27	43.83
FO,AG,UGB + RES	Rural + Urban	4	139.73	797.87
FO,AG,UGB + CO	Rural + Urban	4	198.72	577.30
FO,AG,UGB + IN	Rural + Urban	4	443.55	504.14
FO,AG,UGB + RES,CO	Rural + Urban	5	158.00	760.25
FO,AG,UGB + RES,IN	Rural + Urban	5	123.82	841.30
FO,AG,UGB + CO,IN	Rural + Urban	5	128.94	692.79
FO,AG,UGB + RES,CO,IN	Rural + Urban	6	143.19	758.27
b.				
RES	Urban	1	214.36	764.31
CO	Urban	1	116.76	571.31
IN	Urban	1	298.63	495.73
RES,CO	Urban	2	216.04	731.44
RES,IN	Urban	2	268.21	808.15
CO,IN	Urban	2	116.99	684.46
RES,CO,IN	Urban	3	157.52	742.98
RES,CO,IN + FO	Urban + Rural	4	172.97	744.65
RES,CO,IN + AG	Urban + Rural	4	162.37	745.81
RES,CO,IN + UGB	Urban + Rural	4	144.79	756.54
RES,CO,IN + FO,AG	Urban + Rural	5	161.47	749.11
RES,CO,IN + FO,UGB	Urban + Rural	5	143.79	758.03
RES,CO,IN + AG,UGB	Urban + Rural	5	144.19	756.77
RES,CO,IN + FO,AG,UGB	Urban + Rural	6	143.19	758.27

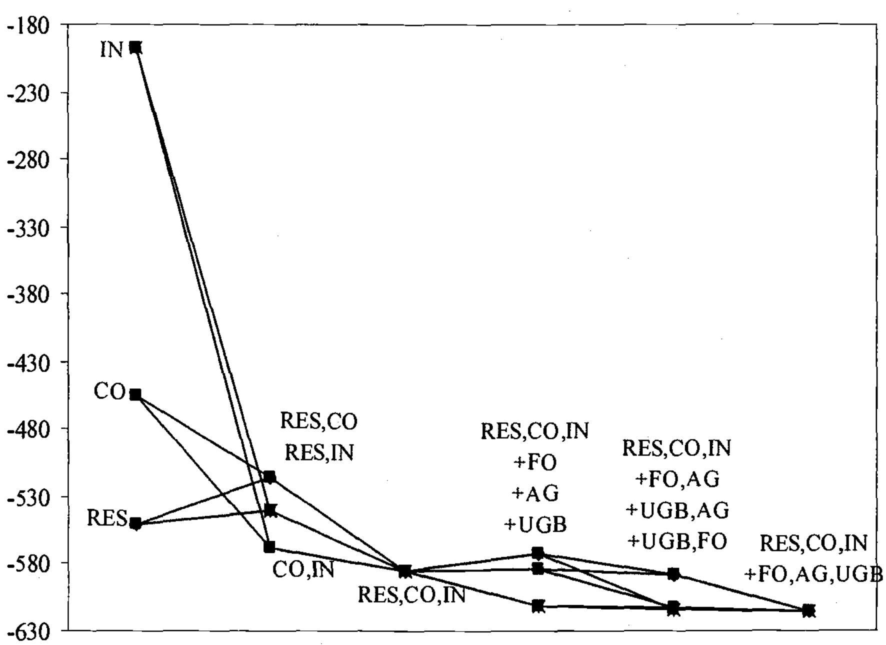
resource lands in such manner that large numbers of residential developments are located in sufficient proximity to open space. However, in the case of a UGB, fewer residential parcels are located in proximity of open space because UGBs tend to be delineated as straight lines in contrast to a more spatially heterogeneous pattern of farm use zones.

Figures 4.2a-b show the net benefit of the simulated regulatory mixes. The results suggest that improvements in net benefits of the current regulatory structure can be achieved by removing one or more of the existing zoning regulations. In particular, removing residential zoning alone yields an increase in net benefits. Removing residential zoning in combination with other zonings regulating urban land use (CO, IN) yields further significant increases in net benefits. Overall, positive net benefit can only be achieved if all urban policies (RES,CO,IN) are removed from the current regulatory mix. On the other hand, removing commercial zoning, alone or in combination with industrial zoning, is not advisable as such move would yield a drop in net benefits.

Overall, the results presented in this section suggest that interdependencies among regulations in the regulatory mix exist. The analysis shows that interdependencies between neighboring land uses translate into interdependencies among land use regulations in the regulatory mix (e.g., between commercial and residential zonings, or between farmland and residential zonings). In addition, the way a zoned district is delineated may affect the impact of the regulation on land values. For example, the location of residential zones affects the way this regulation interacts with commercial zoning. Similarly, the spatial design of a UGB affects its impact on land values when residential zoning is in place. A more heterogeneous delineation of the UGB would provide open-space amenities to more households while mitigating some of the negative impacts on land values.[2]



a.



b.

Figure 4.2. Simulated Net Benefits of Regulation

CONCLUSIONS

This paper examines the efficiency properties of the current system of land use regulation in Oregon and analyzes the possible changes to the regulatory structure. The paper also studies the changes in costs and benefits of land use regulations in response to changes in the composition of the regulatory mix. The normative implications of the findings are discussed.

The estimated net benefit of the current regulatory structure indicates that the current level of land use regulation may be privately suboptimal. From the viewpoint of private landowners, efficiency gains may be achieved. In particular, removing residential zoning, alone or in combination with other zonings regulating urban land use, would yield a significant increase in net benefits. On the other hand, removing commercial zoning, alone or in combination with industrial zoning, is not advisable as such move would yield a drop in net benefits. However, the lack of data on the magnitude of social benefits prevents us from drawing conclusions about the efficiency of land use regulation from the societal point of view.

In addition, we found that the direction and magnitude of marginal costs and benefits of a regulation depend on the composition of the regulatory mix, indicating that the gradients of the costs and benefits of land use regulations exhibit nonlinearities. This phenomenon is due to interdependencies among land uses. Irregularities occur where an agglomeration effect or other forms of spatial and temporal interaction among neighboring land uses arise.

These results have implications for the efforts to alter the current regulatory structure of land use policies. The manner in which spatial interdependencies impact the performance of land use regulations is complex. Therefore, it may be difficult to measure the magnitude of the regulatory takings and givings because land use regulations are difficult to evaluate in abstraction from the entire regulatory mix.

Finally, our results suggest that efficiency gains may be achieved by altering the spatial design of land use regulations. Specifically, changes in the location and delineation of the zoned districts may help mitigate the cost of land use regulations to private landowners, without compromising the level of environmental protection. In situations of difficult trade-offs between granting waivers or paying compensations, incorporating economic principles into the spatial design of land use regulations may prove to be a vital tool in the hands of land use planners.

ENDNOTES

[1] According to Meltz, Merriam, and Frank (1999), no court has explicitly embraced the reciprocal theory of regulatory takings and givings due to the challenges in translating these economic concepts into jurisprudential reality. Problems of valuation, causation, and general feasibility of the monetary transfers from regulatory "winners" to regulatory "losers" have been cited as making such a system impractical to administer. Nevertheless, proponents of the regulatory givings principle suggest that, at least in the case where land owners claim government regulations have devalued their property, such "givings" of public resources for private use should be offset against the fiscal damage attributable to the regulatory taking.

[2] The city of Curitiba, Brazil is an excellent example demonstrating this principle in the real-world regulatory practice. As a result of ingenious urban planning, the city has been designed with residential and commercial districts located along major transportation axes while greenspaces occupy the areas inbetween the axes. Easy access to public transportation, business-friendly attitude, and proximity of urban as well as open-space amenities for all dwellers are among its major successes. For more on Curitiba, see e.g. Hawken et al. (1999).

REFERENCES

Bento, A.M., Franco, S.F., and Kaffine, D. 2006. "The Efficiency and Distributional Impacts of Alternative Anti-Sprawl Policies." *Journal of Urban Economics* 59: 121-41.

Bramley, G. 1993a. "The Impact of Land Use Planning and Tax Subsidies on the Supply and Price of Housing in Britain." *Urban Studies* 30: 5-30.

Bramley, G. 1993b. "Land Use Planning and the Housing Market in Britain: The Impact on House Building and House Prices." *Environment and Planning* A 25:1021-51.

Bromley, D. W. "Regulatory Takings and Land Use Conflicts." In Kaplowitz, M. D. (ed.). *Property rights, economics, and the environment.* 2000.

Brueckner, J.K. 2000. Urban Sprawl: Diagnosis and Remedies." *International Regional Science Review* 23: 160-171.

Brueckner, J.K. 1996. "Welfare Gains from Removing Land Use Distortions: An Analysis of Urban Change in Post-Apartheid South Africa." *J. of Regional Science* 36: 91-109.

Brueckner, J.K. 1995. "Strategic Control of Growth in a System of Cities." *Journal of Public Economics* 57:393-416.

Brueckner, J.K. 1990. "Growth Controls and Land Values in an Open City." *Land Economics* 66:237-48.

Cheshire, P., and Sheppard, S. 1989. "British Planning Policy and Access to Housing: Some Empirical Estimates." *Urban Studies* 26: 469-85.

Cheshire, P., and Sheppard, S. 2002. "The Welfare Economics of Land Use Planning." *Journal of Urban Economics* 52: 242-69.

Elliot, Donald L. *Givings and Takings.* 48 Land Use Law & Zoning Digest, No. 1 at 3 (1996).

Epple, D, Romer, T. Filimon, R. 1988. "Community Development with Endogenous Land Use Controls." *Journal of Public Economics* 35:133-62.

Evans, A. 1999. "The Land Market and Government Intervention." In: P. Cheshire, E. Mills (eds.), *Handbook of Regional and Urban Economics: Vol. 3, Applied Urban Economics.* Elsevier, North Holland, Amsterdam, 1999.

Fischel, W.A. 2001. *The Homevoter Hypothesis*. Harvard University Press, Cambridge, MA.

Fischel, William A. *Regulatory Takings: Law, Economics, and Politics*. Harvard University Press: Cambridge, MA. 1995.

Fischel, W.A. *Do Growth Controls Matter? A Review of Empirical Evidence on the Effectiveness and Efficiency of Local Government Land Use Regulation.* Lincoln Institute of Land Policy, Cambridge, MA. 1990.

Hagman, D. and D. Mysczinski (eds.). *Windfalls for Wipeouts: Land Value Capture and Compensation.* American Society of Planning Officials, Chicago, IL. 1978.

Hawken, P., Lovins, A., and L. H. Lovins. *Natural Capitalism: Creating the Next Industrial Revolution.* Boston : Little, Brown and Co. 1999.

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

Irwin, E. G., and N. E. Bockstael. 2004. "Land Use Externalities, Open Space Preservation, and Urban Sprawl." *Regional Science and Urban Economics* 34: 705-25.

Meltz, R., Merriam, D. H., and R. M. Frank. *The Takings Issue: Constitutional Limits on Land Use Control and Environmental Regulation.* Washington, D.C.: Island Press. 1999.

Metro. "Fair Growth and Farmlands Project." Portland, OR. 2006. Accessed on April 28, 2006 at http://www.metro-region.org/article.cfm?articleid=18904.

Mills, E. S. 2005. "Why Do We Have Urban Density Controls?" *Real Estate Economics* 33(3): 571-85.

Oregon Department of Land Conservation and Development (DLCD). *Measure 37 Information.* http://www.oregon.gov/LCD/measure37.shtml (accessed February 15, 2006).

Oregon Land Use Statewide Survey. A report for Oregon Business Association and Institute of Portland Metropolitan Studies, Portland State University. CFM Research, Portland, OR. March 2005.

Phillips, J., and Goodstein, E. 2000. "Growth Management and Housing Prices: The Case of Portland, Oregon." *Contemporary Economic Policy* 18: 334-44.

Pease, James R. 1998. "Property Rights, Land Stewardship, and the Takings Issue." Oregon State University Extension Service.

Sheppard, S. 1988. "The Qualitative Economics of Development Control." *Journal of Urban Economics* 24: 310-20.

The Oregonian. "Metro panel suggests tax when growth ups land value." April 25, 2006.

Wu, J.J., R. M. Adams, and A. J. Plantinga. 2004. "Amenities in an Urban Equilibrium Model: Residential Development in Portland, Oregon." *Land Economics* 80 (1): 19-32.

CHAPTER 5

CONCLUSION

Ivan Hascic

The first paper has important implications for water quality trading policies under consideration in many states of the United States. Our results show that trading for reducing conventional water pollution should focus on agricultural and urban land use, while trading for reducing toxic water pollution should focus on transportation and mining. In an average watershed, one acre of urban development on forestland can be offset by converting one acre of cultivated cropland to forests in terms of impact on conventional water quality; however, to offset the impact on toxic water quality of one acre of highways built in forests, 3.7 acres of mining must be converted to forests. In general, trading ratios are different for watersheds with different sizes and mixes of land use. The models estimated in this study can be used to calculate such trading ratios.

The second paper estimates the difference between the value of individual exemptions and the effect of land use regulations empirically to illuminate the controversy surrounding Oregon's Measure 37. Using data from Eugene, Oregon, a simulation framework is developed to predict development patterns and land prices that would have existed if one or more land use regulations had not been imposed. The reduction in value due to land use regulation and the value of an individual exemption are estimated for all parcels on the landscape under a number of regulatory scenarios. Our empirical results show that all major zoning regulations in the study area have affected land use and property values both inside and outside the zoned districts. Although the value of a property can never go down when it is exempted from a binding regulation, the reduction in value due to regulation can be positive or negative, depending on the location of the landowner. Even when the reduction in value due to regulation and the value of an individual exemption have the same sign, their magnitude can be quite different. For all the regulations contested in Oregon's Measure 37 claims, the reduction in value due to regulation to a landowner is considerably smaller than the value of an individual exemption. However, in the presence of agglomeration effects, the value of an individual exemption could be smaller than the reduction in value due to regulation.

The third paper examines the efficiency properties of the current system of land use regulation in Oregon and analyzes the possible changes to the regulatory structure. The paper also studies the changes in costs and benefits of land use regulations in response to changes in the composition of the regulatory mix. We conclude that although the current level of land use regulation may be privately suboptimal, the lack of data prevents us from drawing conclusions about the efficiency of land use regulation from the societal point of view. The estimated costs and benefits of various regulatory mixes suggest that the cost gradient of land use regulations is a nonlinear function of the composition of the regulatory mix. Irregularities may occur where an agglomeration effect or other forms of spatial and temporal interaction among neighboring land uses arise. Interdependencies between uses of land of neighboring parcels thus translate into interdependencies among regulations in the regulatory mix. Finally, we found that changes in the location and delineation of the zoned districts may help mitigate the cost of land use regulations to private landowners.

BIBLIOGRAPHY

Alig, R. J., and A. J. Plantinga. 2004. "Future Forestland Area: Impacts from Population Growth and Other Factors that Affect Land Values." *Journal of Forestry* 102(8): 19-24.

Alloway, B. J., ed. 1995. *Heavy Metals in Soils.* 2nd ed. London; New York: Blackie Academic and Professional.

Anderson, G. D., Opaluch, J. J., and W. M. Sullivan. 1985. "Nonpoint Agricultural Pollution: Pesticide Contamination of Groundwater Supplies." *American Journal of Agricultural Economics* 67: 1238-43.

Angermeier, P. L. 1995. "Ecological Attributes of Extinction-Prone Species: Loss of Freshwater Species of Virginia." *Conservation Biology* 9(1): 143-158.

Anselin, L. 2002. "Under the Hood. Issues in the Specification and Interpretation of Spatial Regression Models." *Agricultural Economics* 27 (3): 247-67.

Anselin, L. 2003. *GeoDa 0.9 User's Guide.* Spatial Analysis Laboratory, University of Illinois, Urbana-Champaign, IL.

Aronsson, T. and O. Carlen. 2000. "The Determinants of Forest Land Prices: An Empirical Analysis." *Canadian Journal of Forest Research* 30 (4): 589.

Bailey, R. G. 1995. *Description of the Ecoregions of the United States.* U.S. Department of Agriculture, Forest Service. Misc. Publ. 1391, 2nd ed.

Barbash, J. E., Thelin, G. P., Kolpin, D. W., and R. J. Gilliom. 2001. "Major Herbicides in Ground Water: Results from the National Water-Quality Assessment." *Journal of Environmental Quality* 30: 831-45.

Beaton, Patrick W. 1991. "The Impact of Regional Land Use Controls on Property Values: The Case of the New Jersey Pinelands." *Land Economics* 67(2): 172.

Beaton, Patrick W., and Marcus Pollock. 1992. "Economic Impact of Growth Management Policies Surrounding the Chesapeake Bay." *Land Economics* 68: 434.

Bell, K. P., and N. E. Bockstael. 2000. "Applying the Generalized-Moments Estimation Approach to Spatial Problems Involving Microlevel Data." *Review of Economics and Statistics* 82(1): 72-82.

Bento, A.M., Franco, S.F., and Kaffine, D. 2006. "The Efficiency and Distributional Impacts of Alternative Anti-Sprawl Policies." *Journal of Urban Economics* 59: 121-41.

Blaustein, A. R., and P. T. J. Johnson. 2003. "Explaining Frog Deformities." *Scientific American* (Feb. 2003).

Blaustein, A. R., Wake, D. B., and W. P. Sousa. 1994. "Amphibian Declines: Judging Stability, Persistence, and Susceptibility of Populations to Local and Global Extinctions." *Conservation Biology* 8(1): 60-71.

Bockstael, N. 1996. "Modeling Economics and Ecology: The Importance of a Spatial Perspective." *American Journal of Agricultural Economics* 78(5): 1168-81.

Bramley, G. 1993a. "The Impact of Land Use Planning and Tax Subsidies on the Supply and Price of Housing in Britain." *Urban Studies* 30: 5-30.

Bramley, G. 1993b. "Land Use Planning and the Housing Market in Britain: The Impact on House Building and House Prices." *Environment and Planning* A 25:1021-51.

Bromley, D. W. "Regulatory Takings and Land Use Conflicts." In Kaplowitz, M. D. (ed.). *Property rights, economics, and the environment.* 2000.

Brown, H. D. 1987. "Aquatic Macrophytes of Lake Mize, Florida, 1968-1980." *Bulletin of the Torrey Botanical Club* 114(2): 180-82.

Brown, G. M., Jr., and J. F. Shogren. 1998. "Economics of the Endangered Species Act." *Journal of Economic Perspectives* 12(3): 3-20.

Brueckner, J.K. 2000. Urban Sprawl: Diagnosis and Remedies." *International Regional Science Review* 23: 160-171.

Brueckner, J. K., Thisse, J. F., and Y. Zenou. 1999. "Why is Central Paris Rich and Downtown Detroit Poor? An Amenity-Based Theory." *European Economic Review* 43: 91-107.

Brueckner, J.K. 1996. "Welfare Gains from Removing Land Use Distortions: An Analysis of Urban Change in Post-Apartheid South Africa." *J. of Regional Science* 36: 91-109.

Brueckner, J.K. 1995. "Strategic Control of Growth in a System of Cities." *Journal of Public Economics* 57:393-416.

Brueckner, J.K. 1990. "Growth Controls and Land Values in an Open City." *Land Economics* 66:237-48.

Brouwer, F. M., Thomas, A. J., and M. J. Chadwick. 1991. *Land Use Changes in Europe: Processes of Change, Environmental Transformations and Future Patterns: A study initiated and sponsored by the International Institute for Applied Systems Analysis with the support and co-ordination of the Stockholm Environment Institute*. Dordrecht; Boston: Kluwer Academic Publishers.

Cameron, A. C., and P. K. Trivedi. 1998. *Regression Analysis of Count Data.* Econometric Society Monographs No. 30. Cambridge; New York: Cambridge University Press.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., and V. H. Smith. 1998. "Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen." *Ecological Applications* 8(3): 559-68.

Carroll, R., Augspurger, C., Dobson, A., Franklin, J., Orians, G., Reid, W., Tracy, R., Wilcove, D., and J. Wilson. 1996. "Strengthening the Use of Science in Achieving the Goals of the Endangered Species Act: An Assessment by the Ecological Society of America." *Ecological Applications* 6(1):1-11.

Cheshire, P., and Sheppard, S. 1989. "British Planning Policy and Access to Housing: Some Empirical Estimates." *Urban Studies* 26: 469-85.

Cheshire, P., and Sheppard, S. 2002. "The Welfare Economics of Land Use Planning." *Journal of Urban Economics* 52: 242-69.

Cho, S. H., Wu, J. J., and W. G. Boggess. 2003. "Measuring Interactions among Urbanization, Land Use, and Public Finance." *American Journal of Agricultural Economics* 85(4): 988-99.

Colwell, P. F., Munneke, H. J., and J. W. Trefzger. 1998. "Chicago's Office Market: Price Indices, Location and Time." *Real Estate Economics* 26(1): 83-106.

Congressional Budget Office (CBO). "Regulatory Takings and Proposals for Change." 1998.

Czech, B., Krausman, P. R., and P. K. Devers. 2000. "Economic Associations among Causes of Species Endangerment in the United States." *BioScience* 50: 593-601.

Dale, V. H., Brown, S., Haeuber, R. A., Hobbs, N. T., Huntly, N., Naiman, R. J., Riebsame, W. E., Turner, M. G., and T. J. Valone. 2000. "Ecological Principles and Guidelines for Managing the Use of Land." Report of the Ecological Society of America Committee on Land Use. *Ecological Applications* 10(3): 639-70.

Dale-Johnson, D., and W. J. Brzeski. 2001. "Spatial Regression Analysis of Commercial Land Price Gradients." *A paper presented at the Asian Real Estate Society Sixth Annual Conference at Keio University, Mita Campus, Tokyo, Japan, July 31 to August 2, 2001.*

Davis, W. S., and T. P. Simon, eds. 1995. *Biological Assessment and Criteria – Tools for Water Resource Planning and Decision Making.* Chapter 16. Boca Raton, FL: Lewis Publishers.

Deaton, M. L., and J. J. Winebrake. 2000. *Dynamic Modeling of Environmental Systems.* New York: Springer-Verlag.

De Roo, H. C. 1980. "Nitrate Fluctuations in Ground Water as Influenced by Use of Fertilizer." Connecticut Agricultural Experiment Station, New Haven, Bulletin 779.

Ehrlich, P. R., and A. H. Ehrlich. 1981. *Extinction: The Causes and Consequences of the Disappearance of Species*. New York: Random House.

Elliot, Donald L. *Givings and Takings*. 48 Land Use Law & Zoning Digest, No. 1 at 3 (1996).

Environmental Systems Research Institute (ESRI). *What is ArcGIS*. ESRI, Redlands, CA. 2004.

Epple, D, Romer, T. Filimon, R. 1988. "Community Development with Endogenous Land Use Controls." *Journal of Public Economics* 35:133-62.

Epstein, Richard A. *Takings: Private Property and the Power of Eminent Domain*. Cambridge, MA: Harvard University Press, 1985.

Erichsen Jones J. R. 1958. "A Further Study of the Zinc-Polluted River Ystwyth." *Journal of Animal Ecology* 27(1): 1-14.

Evans, A. 1999. "The Land Market and Government Intervention." In: P. Cheshire, E. Mills (eds.), *Handbook of Regional and Urban Economics: Vol. 3, Applied Urban Economics*. Elsevier, North Holland, Amsterdam, 1999.

Faurie, C., Ferra, C., Médori, P., and J. Dévaux. 2001. *Ecology: Science and Practice*. Lisse [Netherlands]; Exton, PA: A.A. Balkema Publ.

Fergusson, J. E. 1982. *Inorganic Chemistry and the Earth: Chemical Resources, their Extraction, Use and Environmental Impact*. New York: Pergamon Press.

Fischel, W. A. *The Economics of Zoning Laws: A Property Rights Approach to American Land Use Controls*. Baltimore: The John Hopkins University Press, 1985.

Fischel, W. A. *Do Growth Control Matter? A Review of Empirical Literature on the Effectiveness and Efficiency of Local Government Land Use Regulation*. Cambridge, MA: Lincoln Institute of Land Policy, 1990.

Fischel, W. A. *Regulatory Takings: Law, Economics, and Politics*. Harvard University Press: Cambridge, MA. 1995.

Fischel, W.A. 2001. *The Homevoter Hypothesis*. Harvard University Press, Cambridge, MA.

Freeman III, A. Myrick. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*. 2nd edition. Resources for the Future. Washington D.C. 2003.

Frissell, C. A. 1993. "Topology of Extinction and Endangerment of Native Fish in the Pacific Northwest and California (U.S.A.)." *Conservation Biology* 7(2): 342-54.

Fujita, Masahisa. 1982. "Spatial Patterns of Residential Development." *Journal of Urban Economics* 12 (1): 22-52.

Geoghegan, J., Wainger L, and N. E. Bockstael. 1997. "Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS." *Ecological Economics* 23 (3): 251-64.

Gilliam, J. W., and G. D. Hoyt. 1987. "Effect of Conservation Tillage on Fate and Transport of Nitrogen." In *Effects of Conservation Tillage on Groundwater Quality*, ed. T. J. Logan, J. M. Davidson, J. L. Baker, and M. L. Overcash. Chelsea, MI: Lewis Publ. pp. 217-40.

Granger, M. D., and G. C. Blomquist. 1999. "Evaluating the Influence of Amenities on the Location of Manufacturing Establishments in Urban Areas." *Urban Studies* 36 (11): 1859-73.

Green, Richard K. 1999. "Land Use Regulation and the Price of Housing in a Suburban Wisconsin County." *Journal of Housing Economics* 8(2):144-59.

Hagman, D. and D. Mysczinski (eds.). *Windfalls for Wipeouts: Land Value Capture and Compensation.* American Society of Planning Officials, Chicago, IL. 1978.

Hammond, M. *Pythonwin - Python IDE and GUI Framework for Windows.* 2001.

Handy, R. D., and F. B. Eddy. 1990. "The Interactions between the Surface of Rainbow Trout, Oncorhynchus Mykiss, and Waterborne Metal Toxicants (in Freshwater)." *Functional Ecology* 4(3) *New Horizons in Ecotoxicology* 385-92.

Hardie, I. W., and P. J. Parks. 1997. "Land Use with Heterogeneous Land Quality: An Application of an Area Base Model." *Amer. J. Agr. Econ.* 79(May): 299-310.

Hardie, I., Parks, P., Gottleib, P., and D. Wear. 2000. "Responsiveness of Rural and Urban Land Uses to Land Rent Determinants in the U.S. South." *Land Economics* 76(4): 659-73.

Harding, J. S., Benfield, E. F., Bolstad, P. V., Helfman, G. S., and E. B. D. Jones. 1998. "Stream Biodiversity: The Ghost of Land Use Past." *Proceedings of the National Academy of Sciences of the United States of America* 95(25) (Dec. 1998).

Hare L., Carignan R., and M. A. Herta-Diaz. 1994. "A Field Study of Metal Toxicity and Accumulation of Benthic Invertebrates; Implications for the Acid-Volatile Sulfide (AVS) Model." *Limnology and Oceanography* 39(7): 1653-68.

Hartwell, H. W., Jr., and L. M. Ollivier. 1998. "Stream Amphibians as Indicators of Ecosystem Stress: A Case Study from California's Redwoods." *Ecol. Applications* 8(4): 1118-32.

Hawken, P., Lovins, A., and L. H. Lovins. *Natural Capitalism: Creating the Next Industrial Revolution.* Boston : Little, Brown and Co. 1999.

Helm, M. *Eugene, Oregon: A Guide 1984-85 Edition.* Rainy Day Press. 1984.

Henneberry, David M., and Richard L. Barrows. 1990. "Capitalization of Exclusive

Agricultural Zoning into Farmland Prices. *Land Economics* 66(3):249-58.

Intergovernmental Conference. 1995. *Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities.* As adopted on 3 November 1995 by the Intergovernmental Conference which met for that purpose in Washington, D.C., from 23 October to 3 November 1995.

Institute for a Sustainable Environment, University of Oregon (ISE). 1930 Population by Minor Civil Divisions. Spatial dataset. Eugene, OR: March 1999a. Data available at http://oregonstate.edu/Dept/pnw-erc/. Accessed in 10/2005.

Institute for a Sustainable Environment, University of Oregon (ISE). 1970 Population by Census County Divisions. Spatial dataset. Eugene, OR: March 1999b. Data available at http://oregonstate.edu/Dept/pnw-erc/. Accessed in 10/2005.

Irwin, E. G. 2002. "The Effects of Open Space on Residential Property Values." *Land Economics* 78 (4): 465-80.

Irwin, E. G., and N. E. Bockstael. 2001. "The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space on Residential Property Values." *American Journal of Agricultural Economics* 83(3): 698-704.

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

Irwin, E. G., and N. E. Bockstael. 2004. "Land Use Externalities, Open Space Preservation, and Urban Sprawl." *Regional Science and Urban Economics* 34: 705-25.

Jackson, P. L., and A. J. Kimerling (eds.). *Atlas of the Pacific Northwest.* 9th edition. Oregon State University Press: Corvallis, OR. 2003.

Jaeger, William K. 2006. "The Effects of Land Use Regulations on Property Values." *Environmental Law* 36(1), 2006.

Jun, M. J. 2004. "The Effects of Portland's Urban Growth Boundary on Urban Development Patterns and Commuting." *Urban Studies* 41(7): 1333-48.

Katz, Lawrence and Kenneth T. Rosen. 1987. "The Interjurisdictional Effects of Growth Controls on Housing Prices." *Journal of Law and Economics* 30: 149.

Kellogg, R. L., Maizel, M. S., and D. W. Goss. 1992. "Agricultural Chemical Use and Ground Water Quality: Where Are the Potential Problem Areas?" USDA Staff Rep., Soil Conservation Service/Economic Research Service, Washington, D.C.

Keyes, D. L. 1976. *Land Development and the Natural Environment: Estimating Impacts.* Washington: Urban Institute.

Kline, J. and R. Alig. 1999. "Does Land Use Planning Slow the Conversion of Forest and Agricultural Land?" *Growth and Change* 30(1): 3-22.

Kline, J. D., Moses, A., and R. J. Alig. 2001. "Integrating Urbanization into Landscape-Level Ecological Assessments." *Ecosystems* 4: 3-18.

Kline, J. D., Alig, R. J., and B. Garber-Yonts. 2004. "Forestland Social Values and Open Space Preservation." *Journal of Forestry* 102(8): 39-45.

Knaap, G. and A. C. Nelson. *The Regulated Landscape: Lessons on State Land Use Planning from Oregon.* Lincoln Institute of Land Policy. Cambridge, MA. 1992.

Kowalski, J. G., and P. F. Colwell. 1986. "Market versus Assessed Values of Industrial Land." *Journal of the American Real Estate and Urban Economics Association* 14(2): 361-73.

Lamberson, R. H., McKelvey, R., Noon, B. R., and C. Voss. 1992. "A Dynamic Analysis of Northern Spotted Owl Viability in a Fragmented Forested Landscape." *Conservation Biology* 6 (Dec.): 505-12.

Laws, E. A. 1993. *Aquatic Pollution, An Introductory Text.* 2nd ed. New York: Wiley.

Lin, Tzu-Chin, and Alan W. Evans. 2000. "The Relationship between the Price of Land and Size of Plot When Plots Are Small." *Land Economics* 76 (3): 386-94.

Lockwood, L. J., and R. C. Rutherford. 1996. "Determinants of Industrial Property Value." *Real Estate Economics* 24(2): 257-72.

Loy, W. G. (ed.), Allan, S., Buckley, A. R., and J. E. Meacham. *Atlas of Oregon.* 2nd ed. University of Oregon Press, Eugene, Oregon. 2001.

Loy, W. G., Allan, S., Patton, C. P., and R. D. Plank. *Atlas of Oregon.* University of Oregon, Eugene, Oregon. 1976.

McGowen, S. L., and N. T. Basta. 2001. "Heavy Metal Solubility and Transport in Soil Contaminated by Mining and Smelting." In *Heavy Metals Release in Soils*, eds. H. M. Selim, and D. L. Sparks. Boca Raton, FL: Lewis Publishers; CRC Press.

McKinney, M. L. 2002. "Influence of Settlement Time, Human Population, Park Shape and Age, Visitation and Roads on the Number of Alien Plant Species in Protected Areas in the USA." *Diversity & Distributions* 8(6): 311-18.

Maddala, G. S. 1983. *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge [U.K.]; New York: Cambridge University Press.

Main, M. B., Roka, F. M., and R. F. Noss. 1999. "Evaluating Costs of Conservation." *Conservation Biology* 13(6): 1262-72.

Malmqvist, B., and S. Rundle. 2002. "Threats to the Running Water Ecosystems of the World." *Environmental Conservation* 29(2): 134-53.

Malpezzi, Stephen, Gregory H. Chun and Richard K. Green. 1998. "New Place-to-Place Housing Price Indexes for U.S. Metropolitan Areas and their Determinants: An Application of Urban Indicators." *Real Estate Economics* 26(2): 235-74.

Mason, C. F. 1977. "Populations and Productions of Benthic Animals in Two Contrasting Shallow Lakes in Norfolk." *J. of Animal Ecology* 46(1): 147-72.

Meltz, R., Merriam, D. H., and R. M. Frank. *The Takings Issue: Constitutional Limits on Land Use Control and Environmental Regulation.* Washington, D.C.: Island Press. 1999.

Metro. "Fair Growth and Farmlands Project." Portland, OR. 2006. Accessed on April 28, 2006 at http://www.metro-region.org/article.cfm?articleid=18904.

Michelman, Frank I. 1967. "Property, Utility, and Fairness: Comments on the Ethical Foundations of 'Just Compensation' Law." *Harvard Law Review* 80: 1165-1258.

Miles, M., Cole, R., and D. Guilkey. 1990. "A Different Look at Commercial Real Estate Returns." *Journal of the American Real Estate and Urban Economics Association* 18(4): 403-30.

Mills, E. S. 1992. "Office Rents Determinants in the Chicago Area." *Journal of the American Real Estate and Urban Economics Association* 20(1): 273-87.

Mills, E. S. 2005. "Why Do We Have Urban Density Controls?" *Real Estate Economics* 33(3): 571-85.

Miranowski, J. A., and B. D. Hammes. 1984. "Implicit Prices of Soil Characteristics for Farmland in Iowa." *American Journal of Agricultural Economics* 66(5): 745-49.

Montgomery, C. A., Brown, G. M., Jr., and D. M. Adams. 1994. "The Marginal Cost of Species Preservation: The Northern Spotted Owl." *Journal of Environmental Economics and Management* 26(2): 111-28.

National Oceanic and Atmospheric Administration (NOAA). 1999. National Ocean Service, Special Projects Office, National Coastal Assessment Branch, Coastal Assessment and Data Synthesis System, *Pesticides,* Silver Spring, MD.

Nelson, A. C. 1992. "Preserving Prime Farmland in the Face of Urbanization: Lessons from Oregon." *Journal of the American Planning Association* 58(4): 467-88.

Netusil, N. R. 2005. "The Effect of Environmental Zoning and Amenities on Property Values: Portland, Oregon." *Land Economics* 81(2): 227-46.

Novotny V., and H. Olem. 1994. *Water Quality: Prevention, Identification, and*

Management of Diffuse Pollution. New York: Van Nostrand Reinhold.

Oregon Department of Land Conservation and Development (DLCD). *Measure 37 Information.* http://www.oregon.gov/LCD/measure37.shtml (accessed February 15, 2006).

Oregon's Department of Land Conservation and Development (DLCD), Statewide Planning Goals and Guidelines. http://www.lcd.state.or.us/LCD/goals.shtml (accessed April 28, 2005).

Oregon Department of Revenue. *Real Property Assessment and Taxation.* Revised 2/2004. http://www.dor.state.or.us/InfoC/303-670.html (accessed June 4, 2004).

Oregon Land Use Statewide Survey. A report for Oregon Business Association and Institute of Portland Metropolitan Studies, Portland State University. CFM Research, Portland, OR. March 2005.

Palmquist, R. B. and L. E. Danielson. 1989. "A Hedonic Study of the Effects of Erosion Control and Drainage on Farmland Values." *Amer. J. Ag. Econ.* 71(1): 55-62.

Parsons, George R. 1992. "The Effects of Coastal Land Use Restrictions on Housing Prices: A Repeat Sale Analysis." *Journal of Environmental Economics and Management* 22: 25.

Paterson, R. W., and K. J. Boyle. 2002. "Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models." *Land Economics* 78(3): 417-25.

Phillips, J., and Goodstein, E. 2000. "Growth Management and Housing Prices: The Case of Portland, Oregon." *Contemporary Economic Policy* 18: 334-44.

Pease, James R. 1998. "Property Rights, Land Stewardship, and the Takings Issue." Oregon State University Extension Service.

Plantinga, A. J. 2004. "Measuring Compensation Under Measure 37: An Economist's Perspective." Department of Agricultural and Resource Economics, Oregon State University. Unpublished.

Plantinga, A. J., Lubowski, R. N., and R. N. Stavins. 2002. "The Effects of Potential Land Development on Agricultural Land Prices." *Journal of Urban Economics* 52: 561-81.

Plantinga, A. J., and D. J. Miller. 2001. "Agricultural Land Values and the Value of Rights to Future Land Development." *Land Economics* 77(1): 56-67.

Pollakowski, Henry O. and Susan M. Wachter. 1990. "The Effects of Land Use Constraints on Housing Prices." *Land Economics* 66(3): 315-24.

Quigley, John M. and Larry A. Rosenthal. "The Effects of Land Use Regulation on the Price of Housing: What Do We Know? What Can We Learn?" (April 1, 2004). Berkeley Program on Housing and Urban Policy. Working Papers: Paper W04-002.

Raphael M., and P. Bisson. 2003. "Arise, Amphibians: Stream Buffers Affect More Than Fish." USDA Forest Service, PNW Research Station, *Science Findings* 53 (May 2003).

Richter, B. D., Braun, D. P., Mendelson, M. A., and L. L. Master. 1997. "Threats to Imperiled Freshwater Fauna." *Conservation Biology* 11(5): 1081-93.

Rivard D. H., Poitevin J., Plasse D., Carleton M., and D. J. Currie. 2000. "Changing Species Richness and Composition in Canadian National Parks." *Conservation Biology* 14(4): 1099-109.

Rottenborn, S. C. 1999. "Predicting the Impacts of Urbanization on Riparian Bird Communities." *Biological Conservation.* 88(3): 289-99.

Ryszkowski, L. 2002. *Landscape Ecology in Agroecosystems Management.* Boca Raton, FL: CRC Press.

Saderion, Z. Smith, B., and C. Smith. 1994. "An Integrated Approach to the Evaluation of Commercial Real Estate." *Journal of Real Estate Research* 9(2): 151-67.

Sayer, C., Roberts, N., Sadler, J., David, C., and P. M. Wade. 1999. "Biodiversity Changes in a Shallow Lake Ecosystem: A Multi-Proxy Palaeolimnological Analysis." *Journal of Biogeography* 26(1): 97-114.

Schaeffer, Peter V. and Cecily A. Millerick. 1991. "The Impact of Historic District Designation on Property Values: An Empirical Study." *Economic Development Quarterly* 5: 301.

Schindler, D. W. 1977. "Evolution of Phosphorus Limitation in Lakes." *Science* 195: 260-62.

__ 1988. "Effects of Acid Rain on Freshwater Ecosystems." *Science* 239 (4836): 149-57.

__ 1990. "Experimental Perturbations of Whole Lakes as Tests of Hypotheses Concerning Ecosystems Structure and Function." *Oikos* 57: 25-41.

__ 1994. "Changes Caused by Acidification to the Biodiversity, Productivity and Biochemical Cycles of Lakes." In *Acidification of Freshwater Ecosystems: Implications for the Future: Report of the Dahlem Workshop on Acidification of Freshwater Ecosystems held in Berlin, September 27-October 2, 1992.* eds. Steinberg, C. E. W., and R. W. Wright. Chichester; New York: Wiley.

Schnoor, J. L. 1996. *Environmental Modeling: Fate and Transport of Pollutants in Water, Air, and Soil.* New York: Wiley.

Seehausen, O. J., van Alpen, J. M., and F. Witte. 1997. "Cichlid Fish Diversity Threatened by Eutrophication that Curbs Sexual Selection." *Science* 277: 1808-11.

Sengupta, M. 1993. *Environmental Impacts of Mining: Monitoring, Restoration and*

Control. Boca Raton, FL: Lewis Publishers.

Sheppard, S. 1988. "The Qualitative Economics of Development Control." *Journal of Urban Economics* 24: 310-20.

Shonkwiler, J. S., and J. E. Reynolds. 1986. "Hedonic Price Models in the Analysis of Land Prices at the Urban Fringe." *Land Economics* 62(1): 58-63.

Sivitanidou, R. 1995. "Urban Spatial Variations in Office – Commercial Rents: The Role of Spatial Amenities and Commercial Zoning." *Journal of Urban Economics* 38: 23-49.

Skidmore, J. F. 1964. "Toxicity of Zinc Compounds to Aquatic Animals, with Special Reference to Fish." *Quarterly Review of Biology* 39(3): 227-48.

Smith, V. H. 1998. "Cultural Eutrophication of Inland, Estuarine, and Coastal Waters." In *Successes, Limitations, and Frontiers in Ecosystem Science*, eds. Pace, M. L., and P. M. Groffman. New York: Springer-Verlag.

Smith, R. A., Alexander, R. B., and M. G. Wolman. 1987. "Water-Quality Trends in the Nation's Rivers." *Science* 235 (4796): 1607-15.

Smith, R. A., Schwarz, G. E., and R. B. Alexander. 1997. "Regional Interpretation of Water-Quality Monitoring Data." *Water Resources Research* 33(12): 2781-98.

Soil Survey Staff. 1981. *Land Resource Regions and Major Land Resource Areas of the United States.* Agriculture Handbook 296. Rev. ed. Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service.

Stein, B. A., Kutner, L. S., and J. S. Adams, eds. 2000. *Precious Heritage: The Status of Biodiversity in the United States.* Nature Conservancy. Oxford; New York: Oxford University Press.

Stephenson, T. 1987. "Sources of Heavy Metals in Wastewater." In *Heavy Metals in Wastewater and Sludge Treatment Processes, vol. 1, Sources, Analysis, and Legislation*, ed. J. N. Lester. Boca Raton, FL: CRC Press.

Switzer, J. V. 2004. *Environmental Politics: Domestic and Global Dimensions.* 4th ed. Belmont, CA: Wadsworth / Thomson.

Tessier, A., Couillard, Y., Campbell, P. G. C., and J. C. Auclair. 1993. "Modeling Cd Partitioning in Oxic Lake Sediments and Cd Concentrations in the Freshwater Bivalve Anodonta Grandis." *Limnology and Oceanography* 38(1): 1-17.

The Oregonian. "Metro panel suggests tax when growth ups land value." April 25, 2006.

Tyrväinen, L. and A. Miettinen. 2000. "Property Prices and Urban Forest Amenities." *Journal of Environmental Economics and Management* 39: 205-23.

U.S. Department of Agriculture. 2000. *Summary Report 1997 National Resources Inventory.*

U.S. Department of Agriculture. *NRI Glossary*, http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/glossary.html.

U.S. Environmental Protection Agency. 2003a. *Introduction to the Clean Water Act.* http://www.epa.gov/watertrain/cwa. (Accessed on 11/04/2004).

U.S. Environmental Protection Agency. 2003b. *Final Water Quality Trading Policy.* http://www.epa.gov/owow/watershed/trading/finalpolicy2003.pdf.

U.S. Environmental Protection Agency. 2004a. *Aquatic Biodiversity.* http://www.epa.gov/bioindicators. (Accessed in June 2004).

U.S. Environmental Protection Agency. 2004b. *Index of Watershed Indicators.* http://www.epa.gov/iwi (Accessed in May 2004).

Van der Zanden, M. J., and J. B. Rasmussen. 1996. "A Trophic Position Model of Pelagic Food Webs: Impact on Contaminant Bioaccumulation in Lake Trout." *Ecological Monographs* 66(4): 451-77.

Van Rossum, Guido, and Fred L. Drake, Jr. (ed.). *Python Reference Manual.* PythonLabs. 2001.

Vitousek, P. M., Aber, J. D., Howarth, R. D., Likens, G. E., Matson, P. A., Schindler, D. W., Schlesinger, W. H., and D. G. Tilman. 1997. "Human Alterations of the Global Nitrogen Cycle: Sources and Consequences." *Ecological Applications* 7: 737-50.

Waldichuk, M. 1979. "Review of the Problems." *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* 286 (1015), The Assessment of Sublethal Effects of Pollutants in the Sea (Aug. 1979): 399-422.

Walker, C. H. 1990. "Kinetic Models to Predict Bioaccumulation of Pollutants." *Functional Ecology* 4(3) *New Horizons in Ecotoxicology* 295-301.

Watras, C. J., and N. S. Bloom. 1992. "Mercury and Methylmercury in Individual Zooplankton: Implications for Bioaccumulation." *Limnology and Oceanography* 37(6): 1313-18.

Welsh, R. P. H., and P. Denny. 1980. "The Uptake of Lead and Copper by Submerged Aquatic Macrophytes in Two English Lakes." *Journal of Ecology* 68(2): 443-55.

Welsh, H. H., Jr., and L. M. Ollivier. 1998. "Stream Amphibians as Indicators of Ecosystem Stress: A Case Study from California's Redwoods." *Ecol. Applications* 8(4): 1118-32.

Winston, M. R., Taylor, C. M., and J. Pigg. 1991. "Upstream Extirpation of Four Minnow Species due to Damming of a Prairie Stream." *Transactions of the American Fisheries Society* 120: 98-105.

Wipfli, M. S., Deal, R. L., Hennon, P. E., Johnson, A. C., De Santo, T. L., Hanley, T. A., Schultz, M. E., Bryant, M. D., Edwards, R. T., Orlikowska, E. H., and T. Gomi. 2002. *Managing Young Upland Forests in Southeast Alaska for Wood Products, Wildlife, Aquatic Resources, and Fishes: Problem Analysis and Study Plan.* USDA, Forest Service, PNW-GTR-558. September 2002.

Wu, J.J., and S. H. Cho. 2006. "The Effect of Local Land Use Regulations on Urban Development in the Western United States." *Regional Science and Urban Economics.* Forthcoming.

Wu, J. J., Adams, R. M., Kling, C. L., and K. Tanaka. 2004. "From Micro-Level Decisions to Landscape Changes: An Assessment of Agricultural Conservation Policies." *American Journal of Agricultural Economics* 86: 26-41.

Wu, J.J., R. M. Adams, and A. J. Plantinga. 2004. "Amenities in an Urban Equilibrium Model: Residential Development in Portland, Oregon." *Land Economics* 80 (1): 19-32.

Wu, J.J., and A. J. Plantinga. 2003. "The Influence of Public Open Space on Urban Spatial Structure." *Journal of Environmental Economics and Management* 46(2): 288-309.

Wu, J.J. 2002. "Amenities, Sprawl, and the Economic Landscape." *Paper presented at the Land Markets and Regulation Seminar, Lincoln Institute of Land Policy, Cambridge, MA, July 10-12, 2002.*

Wu, J.J. 2001. "Environmental Amenities and the Spatial Pattern of Urban Sprawl." *American Journal of Agricultural Economics* 83 (3): 691-97.

Wu, J. J., and B. A. Babcock. 1999. "Metamodeling Potential Nitrate Water Pollution in the Central United States." *Journal of Environmental Quality* 28(6): 1916-28.

Wu, J. J., Bernardo, D. J., Mapp, H. P., Geleta, S., Teague, M. L., Watkins, K. B., Sabbagh, G. J., Elliott, R. L., and J. F. Stone. 1997. "An Evaluation of Nitrogen Runoff and Leaching in the High Plains." *J. Soil and Water Conservation* 52(1): 73-80.

Zhou, S. 2002. "Estimating Parameters of Derived Random Variables: Comparison of the Delta and Parametric Bootstrap Methods." *Transactions of the American Fisheries Society* 131: 667-75.