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This dissertation consists of three papers on land use economics and policies. The first two papers focus primarily on local land use policies and urban development. The third paper addresses the question how environmental amenities affect households' residential choices in a metropolitan area.

In the first paper, an option value approach is used to model land development decisions under uncertainty. A land use conversion model is estimated to examine the effect of land use regulations, benefit uncertainty, and other socioeconomic and spatial variables on urbanization and farmland development for counties in five western states (California, Idaho, Nevada, Oregon, and Washington). The empirical results confirm that risks associated with alternative land uses are important variables affecting land allocation. Agricultural zoning, state land use planning, and mandatory review of projects involving farmland conversion are most effective in controlling farmland development among all policies examined in this study.

In the second paper, a theoretical model is developed to analyze the interactions among residential development, land use regulations, and public financial impacts (public expenditure and property tax). A simultaneous equations system with self-selection and discrete dependent variables is estimated to determine the

interactions for counties in the five western states. The results show that county governments are more likely to impose land use regulations when facing rapid land development, high public expenditure and property tax. The land use regulations, in turn, decrease land development, long-run public expenditure, and property tax at the cost of higher housing prices and short-run property tax.

The third paper examines equilibrium properties of local jurisdictions implied by the Tiebout-style model. A set of equilibrium conditions are derived from a general equilibrium model of local jurisdictions. The conditions are parameterized and empirically estimated in a two-stage procedure. The method is applied to communities in a Portland metropolitan area with an extension of public-good provision to include environmental amenities. The results suggest that the model can replicate many of the empirical regularities observed in the data. For example, the predicted income distributions across communities closely matched the observed distribution. The estimated income elasticity of housing demand is consistent with previous findings. One important finding of this paper is that the parameter estimates would be biased if environmental amenities are not considered.

Urbanization under Uncertainty and Land Use Regulations: Theory and Estimation

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Seong-Hoon Cho

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

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Seong-Hoon Cho, Author

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CONTRIBUTION OF AUTHORS

Dr. JunJie Wu was involved in the design, analysis, and writing of each manuscript. He also assisted in data collection for the study. Dr. William G. Boggess was involved in analysis and writing of second manuscript.

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CHAPTER 1

INTRODUCTION

Seong-Hoon Cho

Every society makes choices about how its land is allocated, and it is important to be aware that these choices reflect society's fundamental values. The prevailing values in the United States have been primarily individual initiatives and market determination of land use. By the late 1800s the free market approach was beginning to be challenged by urban reformers who asserted that unregulated urban development had detrimental social and economic consequences. Today, many local communities exercise land use policies. Although land use regulations and policy have been well documented at the federal and state levels, little information is available at the county level. In particular, the role of local land use policies has been a focus of intensive public debate in the western United States and needs to be examined. The first paper in Chapter 2 and the second paper in Chapter 3 examine this issue of land use and the role of local land use policies.

In the first paper, *Urbanization Under Benefit Uncertainty and Government Regulations*, an option value approach is used to model land development decisions under uncertainty. A land use conversion model is estimated to examine the effect of land use regulations, benefit uncertainty, and other socioeconomic and spatial variables on urbanization and farmland development in five western states of the United States. The empirical results confirm that risks associated with alternative land uses are important variables affecting land allocation. Agricultural zoning, state land use planning, and mandatory review of projects involving farmland conversion are most effective in controlling farmland development among all policies examined in this study. Distances to metropolitan centers and national parks are significant spatial attributes affecting farmland development.

In the second paper, *Measuring Interactions among Urban Development, Land Use Regulations, and Public Finance*, a theoretical model is developed to analyze the interactions among residential development, land use regulations, and public financial impacts (public expenditure and property tax). A simultaneous equations system with self-selection and discrete dependent variables is estimated to determine the interactions for counties in the five western states (California, Idaho, Nevada, Oregon, and Washington). The results show that county governments are more likely to impose land use regulations when facing rapid land development, high public expenditures and property taxes. The land use regulations, in turn, decrease land development, long-run public expenditures, and property taxes at the cost of higher housing prices and short-run property taxes. During the period of 1982–1992, land use regulations reduced developed areas by 612,800 acres or 8.8 % of the developed area of these five western states in 1992, but increased housing prices by $5,741 per unit under "stringent" regulations and $1,319 per unit under "low" regulations. The results also show that land use regulations, land development, public expenditures, and property taxes all are significantly affected by population, geographic location, land quality, housing prices, and the risks and costs of development.

Nearly four of five Americans live within 273 metropolitan regions. The Census Bureau estimates that the U.S. will add 34 million people between 1996 and the year 2010. Most of this growth will occur in metropolitan areas. As population and economic growth pressures are vigorously pushing outward from the suburbs, the challenge of managing land use in metropolitan areas becomes more important and complex. Understanding households' residential choices in a system of local jurisdictions is necessary for designing efficient growth management strategies of metropolitan areas. The third paper in Chapter 4 examines the issue of households' residential choices in a metropolitan area.

In the third paper, *Environmental Amenities and Community Characteristics: An Empirical Study of Portland, Oregon*, equilibrium properties of local jurisdictions implied by the Tiebout-style model are examined. A set of equilibrium conditions is derived from a general equilibrium model of local jurisdictions. The conditions are parameterized and empirically estimated in a two-stage procedure. We applied the method to communities in a Portland metropolitan area with an extension of public-good provision to include environmental amenities. It tests the robustness of the framework for estimating spatial equilibrium models by applying it to a different metropolitan area. It also extends the framework by including environmental amenities in the model. The results suggest that the model can replicate many of empirical regularity observed in the data. For example, the predicted income distributions across communities closely matched the observed distribution. The estimated income elasticity of housing demand is consistent with previous findings. One important finding of this paper is that the parameter estimates would be biased if environmental amenities are not considered.

CHAPTER 2

URBANIŻATION UNDER BENEFIT UNCERTAINTY AND GOVERNMENT REGULATIONS

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2.1 Introduction

America's farmland resources have come under increasing pressure since World War II. Total farmland acreage decreased by 17 percent between 1945 and 1990. Americans increased the development of farmland, forests and other open space during the 1990s, from a rate of 1.4 million acres per year between 1982 and 1992 to 2.2 million acres per year between 1992 and 1997 (U.S. Department of Agriculture 2001). At this rate, the amount of land in urban use is projected to double in just over twenty years. The amount of urban land per person is increasing faster than population. One-third more land per person was consumed by urban use in 1990 than in 1970 (Daniels and Bowers 1997).

Highly productive farmland is a strategic resource of national importance (Batie and Healy 1980). However, land markets may fail to allocate land in socially desirable ways for at least two reasons (Daniels 1999b). First, because of government subsidies for development, through, for example, mortgage interest deduction, road construction, and water and sewer lines, the market price of developed land may be distorted below the social price. Second, the market price of farmland is generally lower than the social price because it does not include the public good aspect of farmland. Farmland produces not only agricultural commodities but also environmental services (e.g., open space). Society values these environmental services but do not pay for them.

Given the structure of government in the U.S., there are at least three public policy arenas for agricultural land - national, state, and local. The individual land owner is affected by market incentives for land and the goods and services flowing from land. In addition, the land owner often is influenced by policy incentives imposed by federal, state, or local government. These incentives may be inconsistent among the different levels of government.

At an aggregate, or national level, a primary concern is with the adequacy of agricultural land for food production. There is a considerable literature on this subject which considers such matters as technical change, soil degradation, and international trade in food products. These are issues where national public policy traditionally has played an important role.

State and local land use control and regulation often are intertwined, although there is considerable variation among the various states in this respect. At each level of government, however, a different set of variables and a different array of benefits and costs arise. For example, a state may view open space and population density in a particular locality differently than they are regarded at either the federal or state level.

A local government may wish to preserve farmland in a particular location not only because of its value in agriculture, but also because of its public goods dimension. Yet the state or federal government may not place the same value on the public goods dimension because other sites may be available to provide comparable benefits at a lower cost when viewed from a national or state perspective.

While the federal government monitors trends in land use conversions, most land use controls are in the hands of state and local governments. The federal government has yet to articulate anything close to a clear vision of how urbanization should be managed (Daniels 1999a). However, many federal programs have indirect effects on land use changes. Some of these programs encourage farmland preservation (e.g., the Conservation Reserve Program), while others subsidize land development. Many states attempt to regulate development in some manner. But their role has largely been limited to tax breaks, right-to-farm laws, and purchases of development rights. County and municipal governments have primary control over land use decisions, thus land use regulations are largely a local and regional issue (Daniels 1998).

The overall objective of this study is to examine the effect of state and local land use regulations and uncertainty about the benefits of alternative land uses on urbanization and farmland loss in five western states (California, Idaho, Nevada, Oregon, and Washington). The specific objectives are a) to develop a model of land development decisions under uncertainty and irreversibility, b) to report results obtained from a comprehensive survey on county land use policies in the five western states, and c) to conduct an econometric analysis to evaluate the effects of state and county land use policies and other socioeconomic and geographic factors on land development.

This study makes three contributions to the literature. First, although the importance of uncertainty in land use decisions has been shown in previous theoretical analysis studies (e.g., Freeman 1984 and Titman 1985), it has not been investigated in empirical. Second, because of lack of data, previous studies on local land use regulations tend to focus on a specific program in a specific location. This study uses the first hand data from a comprehensive survey of county land use regulations in five western states to evaluate their effects on land use changes. Finally, we derive our empirical model from a theoretical model, while most previous studies do not.

In the next section, we review the literature on the economics of land use. After that, we present a land use decision model to examine the effect of irreversibility and uncertainty on land development. The last three sections provide an empirical analysis of the effects of uncertainty, land use policies, and spatial and economic variables on land development.

2.2 Literature Review

Much research has focused on the economics of land use, but relatively few studies have focused on local land use policies. Those that do focus on land use policies tend to be case studies of specific programs in specific areas. For example, Bills and Boisvert (1987) examined the effectiveness of farmland protection through agricultural districts and use-value assessments in New York. Henderson (1991) compared the effectiveness of zoning laws, price regulation, and the shifting of fiscal burdens between existing residents and developers. McMillen and McDonald (1993) examined one of the traditional land use policy instruments, zoning ordinances. Pfeffer and Lapping (1994) examined programs based on the exchange of development rights in the northeastern United States. Lang and Hornburg (1997) examined urban growth management in Portland, Oregon. Daniels (1998) examined the purchase of development rights as a tool of farmland protection in Lancaster County, Pennsylvania. Kline and Alig (1999) examined Oregon's land use planning program with regard to how effective it has been in protecting forests and farmland from development.

In recent years, several books on farmland retention have been published. The Proceedings of the 1998 National Conference on the Performance of State Programs for Farmland Retention held in Columbus, Ohio provides an overview of current farmland retention programs in several states. A book by Daniels and Bowers (1997) describes many challenges in farmland protection and explains how to create a package of techniques to meet those challenges. In his most recent book, Daniels (1999a) examines the fringe phenomenon and presents a workable approach to fostering more compact development to protect farmland, forestland, and natural areas.

A number of studies have modeled land use development, but few have considered location and spatial characteristics. Shoup (1970) analyzed urban land development using the option value concept to account for irreversibility. Arrow and Fisher (1974) showed that over-development would occur when irreversibility is ignored. Hanemann (1989) examined the Arrow-Fisher-Henry (AFH) concept of option value and analyzed its relationship to the value of information. Freeman (1984) examined the magnitude of option value under alternative assumptions about income uncertainty, demand uncertainty, and magnitudes of risk-aversion. Titman (1985) examined the relationship between uncertainty and land values and showed that uncertainty about future land values decreases building activities in the current period. Bockstael (1996) emphasized the importance of spatial perspective in modeling economic and ecological effects. Geoghegan et al. (1997) applied hedonic technique to integrate spatial problems in land use analyses. These studies, however, did not examine the effects of alternative land use regulations on land development.

2.3 Theoretical Analysis

Suppose a landowner is considering converting his farmland into development. We model his decision in a two-period framework. The landowner knows the profit from both farming and development in the first period, but is uncertain about the profit from farming and development in the second period. Development in the first period is irreversible.

Let B_i^f be the profit from farming in period i, and let B_i^d be the profit from development in period i. For the time being, we assume that the net gain from development, $(B_2^d - B_2^f)$, can take two possible values. It takes a positive value, ΔB_2^g with probability of P and a negative value, ΔB_2^l with probability of (1-P). The landowner would develop the land in the second period if and only if $(B_2^d - B_2^f)$ turns out to be ΔB_2^g. Later on, we will relax this assumption to examine the degree of uncertainty on development decisions.

Under the traditional net present value approach, the land is developed in the first period if the net present value is positive:

$$\text{NPV} = (B_1^d - B_1^f) + [\text{P}\,\Delta B_2^g + (1\text{-P})\,\Delta B_2^l] > 0, \quad (1)$$

where $(B_1^d - B_1^f)$ is the net gain (loss) from development in the first period and $[\text{P}\,\Delta B_2^g + (1\text{-P})\,\Delta B_2^l]$ is the expected net gain (loss) from development in the second period (discounted). Alternatively, this decision rule can be written as:

$$B_1^d > B_1^f - [(1\text{-P})\,\Delta B_2^l + \text{P}\,\Delta B_2^g]\,. \quad (2)$$

This decision rule works well when both profits from farming and development are relatively certain and when development is reversible. However, when development is irreversible and the profit from development is uncertain in the future, this decision rule would lead to over development because it ignores the "option value" to be gained from obtaining valuable future information and the possibility of not developing if the development benefit turns out to be below the expected level. To derive this result, suppose the landowner waits a period and then makes a decision. If the decision is made in the second period, the expected net gain is

$$\text{NPV} = \text{P}\,\Delta B_2^g\,. \tag{3}$$

This suggests that the expected net gain is given by (3), if the landowner makes the development decisions in the second period, whereas it is given by (1) if he makes the decisions in the first period. Thus, the landowner should develop his land in the first period only if (1) is greater than (3). By setting (1) to be greater than (3), we obtain the optimal decision rule:

$$B_1^d > B_1^f - (1\text{-P})\,\Delta B_2^l\,. \tag{4}$$

This decision rule can also be derived using the standard option value approach (available upon request). The right-hand side of (4) is greater than the right-hand side of (2) because $\text{P}\,\Delta B_2^g > 0$ by assumption. Thus, land is less likely to be developed if the development is irreversible and the landowner can wait. The difference between the right-hand side of (2) and the right-hand side of (4) is called the "flexibility option value", which is what the developer should be willing to pay for the development opportunity in the second period (Dixit and Pindyck 1994).

To examine the effect of the degree of uncertainty on development decisions, we assume that the net gain from development in the second period, $(B_2^d - B_2^f)$, takes a normal distribution, $\text{N}[\Delta B_2^e, \sigma^2]$ instead of only two possible values, ΔB_2^g or ΔB_2^l, and that landowner will develop his land in the second period only if $B_2^d > B_2^f$. The following truncated mean values are obtained based on the theorem of moments of the truncated normal distribution (Greene 1997, pp.949-953).

$$E[B_2^d - B_2^f \mid B_2^d > B_2^f] = \Delta B_2^e + \frac{\sigma\phi(\alpha)}{P}, \tag{5}$$

$$E[B_2^d - B_2^f \mid B_2^d < B_2^f] = \Delta B_2^e - \frac{\sigma\phi(\alpha)}{1-P}, \tag{6}$$

where $\alpha = -B_2^e / \sigma$ and ϕ is the probability distribution function of the standard normal distribution. If the landowner develops his land in the first period, the expected net present value is

$$NPV = (B_1^d - B_1^f) + P[\Delta B_2^e + \frac{\sigma\phi(\alpha)}{P}] + (1-P)[\Delta B_2^e - \frac{\sigma\phi(\alpha)}{1-P}]. \tag{7}$$

On the other hand, if the landowner waits a period and develops only if the net gain from development, $(B_2^d - B_2^f)$, turns out to be positive, the expected net gain is

$$NPV = P[\Delta B_2^e + \frac{\sigma\phi(\alpha)}{P}]. \tag{8}$$

The optimal decision rule for development in the first period is obtained when (7) is set to be greater than (8):

$$B_1^d > B_1^f + \sigma\phi(\alpha) - (1-P)\Delta B_2^e. \tag{9}$$

Note that the $\sigma\phi(\alpha)$ is an increasing function of σ because the derivative of $f(\sigma) = \sigma\phi(\alpha)$ with respect to σ is positive. Thus, the greater the uncertainty about the net gain from development in the second period, the less likely the land will be developed in the first period. This decision rule clearly indicates that expected profits from both farming and development as well as the variance of net gain from development affect land development decisions.

2.4 Empirical Specification

In our emprirical analysis, a county level panel dataset is used to analyze landowners' land conversion decisions. Because it is impossible to observe all variables that affect landowners' land use decisions, we add an error term, ε, to the optimal decision rule in (9) to reflect a) the unobserved variations in landowner characteristics, b) errors in the perception and optimization by landowners, and c) measurement errors that arise when Natural Resource Inventory data is aggregated to the county level (Hardie et al. 2000). Thus, the optimal decision rule can be rewritten as

$$f(x) \equiv B_1^d - B_1^f - \sigma\phi(\alpha) + (1-P)\Delta B_2^e > \varepsilon . \qquad (10)$$

Note that the variance of net profit from the farmland development is a function of the variance of farm profit, σ_f^2, variance of development profit, σ_d^2, and covariance between farm profit and development profit, σ_{fd}^2. Thus, equation (10) implies that

$$f(x) = f(B_1^f, B_1^d, \Delta B_2^e, \sigma_f^2, \sigma_d^2, \sigma_{fd}^2) > \varepsilon . \qquad (11)$$

In previous studies of land allocation decisions, various socioeconomic variables have been included to explain land allocations to urban, residential, and other uses. For example, the distance to metropolitan areas, population and income levels have been used as measures of development pressure in previous studies (e.g., Chicoine 1981, Hushak and Sadr 1979, Wall 1981, Alig and Healy 1987). Hardie and Parks (1989) and Bockstael et al. (1995) found that land quality is an important determinant of land use. Based on these studies, we assume that

$$\Delta B_2^e = g(B_1^f, B_1^d, G, POP, Y, Q, S) \tag{12}$$

where G is a vector of government regulations, POP is population growth, Y is income change, Q is land quality, and S is a vector of spatial attributes such as the distance to the city center. Let P_d be the probability that the farmland will be developed, and let P_f be the probability that the land will remain in farm use. Under the assumption that ε follows the logistic distribution, we derive the following expressions from (11):

$$P_d = \frac{e^{f(x)}}{1+e^{f(x)}},\ P_f = \frac{1}{1+e^{f(x)}}, \tag{13}$$

By taking a log of the ratio of the two equations in (13), we obtain

$$\log(P_d / P_f) = f(x) = f(B_1^f, B_1^d, \sigma_f^2, \sigma_d^2, \sigma_{fd}^2, G, POP, Y, Q, S). \tag{14}$$

In empirical applications, P_d and P_f are often estimated as the shares of land converted and unconverted, respectively. Thus, P_d / P_f equals the ratio of acres converted to acres unconverted. Specifically, in the empirical analysis, we estimated the following two land conversion models:

$$\log(U_{jt}^c / U_{jt}^r) = X_{jt}\gamma + v_{jt} \tag{15}$$

$$\log(A_{jt}^c / A_{jt}^r) = X_{jt}\beta + u_{jt}, \tag{16}$$

where U_{jt}^c = the acres of non-urban land converted to urban land in county j between year t and t + 5, t = 1982, 1987,

U_{jt}^r = the acres of non-urban land remaining in non-urban uses in county j between year t and t + 5,

A_{jt}^c = the acres of land converted from farmland to non-farm land in county j between year t and t + 5,

A_{jt}^r = the acres of farmland remaining in farm uses in county j between year t and
t + 5,

$X_{jt} = (B_{jt}^f, B_{jt}^d, \sigma_{fjt}^2, \sigma_{djt}^2, \sigma_{fdjt}^2, G_{jt}, POP_{jt}, Y_{jt}, Q_{jt}, S_{jt})$.

v_{jt} and u_{jt} = the error terms.

The equation systems in (15) and (16) are estimated using time series and cross-sectional data (see discussion of data in the next section). Because the county size, land use history, and land characteristics are different across counties, heteroscedasticity is likely to be present. The null hypothesis of no heteroscedasticity was tested using the Lagrange multiplier (LM) test suggested by Greene (1997, pp. 653-658). The null hypothesis was rejected at the 1% significance level for each equation. The heteroscedasticity is corrected using the technique suggested by Kmenta (1986, pp. 270-276). The transformed equation system was then estimated using the SUR estimator.

2.5 Data

2.5.1 Land Use

The data on land use were taken from the 1982, 1987, and 1992 Natural Resource Inventories (NRI)[1]. The NRI was conducted by the Natural Resource Conservation Service (NRCS) to determine the status of the trend in the nation's soil, water, and other related resources. The NRI collected land use data at 800,000 randomly selected sites across the continental United States and divided land use into twelve major categories (cultivated cropland, non-cultivated cropland, pastureland and rangeland, forestland, urban and built-up land, and six other categories). The twelve major land categories were grouped into four major categories (agricultural, forestry,

[1] The 1997 NRI has not been released due to technical problems.

urban and build-up, and other uses) for this empirical analysis. The agricultural uses include cultivated cropland, non-cultivated cropland, pastureland, and rangeland, forestry uses include forestland, urban uses include urban and build-up land, and other uses include six other categories. The survey assigned a weight called an expansion factor or "X" factors to each site in the sample to determine the number of acres each sample site represents. The sum of this value for all sites in a county equals the total county acreage. From 1982 to 1992, total farmland acreage was reduced by 4,483,000 acres or 5%, forestry land was reduced by 472,600 acres or 1%, urban land was increased by 1,437,700 acres or 26%, and other land was increased by 3,517,900 acres or 2% in the five western states.

2.5.2 Socioeconomic Variables

The most important socioeconomic variables affecting land use are farm profit and the value of new housing units. The data on the average value of new housing units were obtained from the Census Bureau's 'USA counties 1998'. Average net farm income data were obtained from the Census Bureau's 'Regional Economic Information System: 1969-1997'. Both the farm profit and the average value of new housing units are adjusted by the consumer price index. The other socioeconomic variables included in the models are population and average salary rates. The population density was included to reflect the demand for housing (e.g., Wall 1981, Alig and Healy 1987). The average salary rate was used to reflect the income level and economic growth. These variables were obtained from the Census Bureau.

2.5.3 Risk and Uncertainty

The adaptive expectation method was used to estimate the expected farm profit and the expected value of new housing units (Chavas and Holt 1990). Specifically, the expected values were estimated using the following equation:

$$EB_t = B_{t-1} + \alpha, \tag{17}$$

where EB_t = expected farm profit or the expected value of new housing units in year t,
t = 1982, 1987,
$\alpha = \frac{1}{4}[(B_{t-1} - B_{t-2}) + (B_{t-2} - B_{t-3}) + (B_{t-3} - B_{t-4}) + (B_{t-4} - B_{t-5})]$.

The expected variances of farm profit and new housing value were used to measure the risk associated with farming and development. These variances were estimated using

$$VB_t = \frac{1}{4}\sum_{t=t-4}^{t-1}(B_t - EB_t)^2, \tag{18}$$

where VB_t = the expected variance of farm profit or new housing value in year t, t= 1982, 1987,
B_t = the farm profit or the value of new housing units in year t,

The covariance between farm profit and the value of housing units was used to measure the correlation between the risks associated with farming and development. These covariances were estimated as

$$CV_t = \frac{1}{4}\sum_{t=t-4}^{t-1}(B_t^f - EB_t^f)(B_t^d - EB_t^d) \tag{19}$$

where CV_t = the covariance between farm profit and the value of new housing units in year t,
t = 1982, 1987,

B_t^f, B_t^d = the farm profit and the value of new housing units in year t, respectively,

EB_t^f, EB_t^d = the expected farm profit and the expected value of new housing units in year t, respectively.

2.5.4 Land Use Policy

The degree of government involvement in land use planning varies greatly over the counties in the five western states. The state and local governments in Oregon and Washington are actively involved in land use planning and regulations, while state and local governments in Nevada and Idaho impose few land use regulations. The state and local governments in California are moderately involved in land use planning and regulations. Thus, the study region offers an excellent "laboratory" to study the effect of land use regulations.

A comprehensive land use policy survey was conducted to obtain information on county land use regulations in the five western states (see Appendix 1 for a sample of the survey and see Appendix 2 for the summary of the survey). The survey, conducted between August and October of 1999, was sent to all county land use planners or equivalent positions in the five western states. Overall response rate was 69%. The counties of Washington had the highest response rate (87%), followed by Oregon (78%), Nevada (65 %), California (60%), and Idaho (57%).

The survey results show that the most important land use policy goal of Nevada counties was the promotion of industrial and commercial investment, while the counties in other states were concerned about the conservation of farmland, forestland, and natural areas. All counties had a serious concern about urbanization.

A county comprehensive plan had been enacted in almost all of the counties in the five states when the survey was conducted, however, the timing of the initial enactment is different across counties. Extra territorial planning and zoning were commonly used in Idaho and urban growth boundaries were commonly used in Oregon and Washington. Agricultural, residential, forestry, conservation, open space, and steep slope zonings were commonly used throughout the states, whereas performance zoning was used only in a limited number of counties in the states. Although minimum parcel sizes were commonly used, maximum parcel sizes were not used in many counties. Developer exaction and dedication was the most common land acquisition technique in many counties of these states. Fee simple purchase and agricultural districts were used most commonly in California. Preferential property taxation for farmland and forestland was the most common incentive-based management technique in the five states. Special assessments were commonly used in Oregon, Washington, and California. Environmental impact assessments were commonly used in Washington and California. Regional fair sharing was commonly used in California.

The planners predicted a high possibility of conversion from farmland to residential land, especially in Idaho and Nevada. Counties in California spend the largest amount of money on planning, while counties in Idaho spend the least amount of money on planning. However, the average share of money spent on planning out of general fund for the entire county budget remained fairly close in the five states. As to the questions regarding influential parties over land use decisions, planners in Oregon and Washington felt strong influences from State government, while planners in

California, Idaho, and Nevada felt strong influences from non-government organizations.

It is a challenge to incorporate all of the land use regulations information into the empirical analysis because there are many forms of land use regulations. Some of the regulations, however, have similar effects on land uses. The following procedure was used to screen regulatory variables for use in the empirical analysis. First, the land use regulations that were ineffective according to the county land use planners were eliminated. Second, dummy variables were created for the remaining regulations according to the enactment year. The autocorrelations among the dummy variables were tested and the highly correlated regulatory dummy variables are eliminated based on the effectiveness of the regulations. Third, the remaining variables were included in the empirical models. Those variables insignificant at the 10 % level were dropped. After the three-step procedure, three regulatory variables were left. These are county comprehensive plans, agricultural zoning, and forestry zoning.

A county comprehensive plan is a set of development guidelines, which are developed based on population projections and future land use-needs. It is not legally binding. Agricultural zoning is a widely used technique for farmland protection along city fringes. It is designed to separate farming activities from conflicting nonfarm land uses and to protect a critical mass of farms and farmland. Forestry zoning is also designed to protect a critical mass of commercial timberland and to separate forestry operations from conflicting nonforestry land uses (Daniels 1999a). The geographical distributions of the three policies in the five states are shown in Figures.

In addition to the county land use policies, two state land use policies were also included in the empirical models. These are state land use planning and mandatory review of projects involving farmland conversion. State land use planning programs generally require counties and cities to adopt comprehensive plans that meet state guidelines. California, Oregon, and Washington have a formal state land use planning program. Washington is the only state that has mandatory review of projects involving farmland conversion.

The timing of land use regulations was also considered in the empirical analysis. Specifically, to explain land allocation in county j in year t in the acreage response model, the dummy variable for agricultural zoning takes the value of 1 if agricultural zoning had been imposed by year t in county j. Similarly, to explain land conversion from year t to t + 5 in the land conversion model, the dummy variable for agricultural zoning takes the value of 1 if agricultural zoning had been imposed by year t in county j, and it takes the value of zero otherwise. The dummy variable for other land use regulations were similarly constructed.

One of the largest federal programs that affect land uses is the Conservation Reserve Program (CRP). Established in the 1985 farm bill, this program has retired about 34 million acres of highly erodable cropland from crop production. The program is targeted to address specific state and nationally significant water quality, soil erosion and wildlife habitat issues related to agricultural land use (U.S. Department of Agriculture 2000). The total acreage of land enrolled in the CRP in each county was calculated using NRI data and was included in the empirical models.

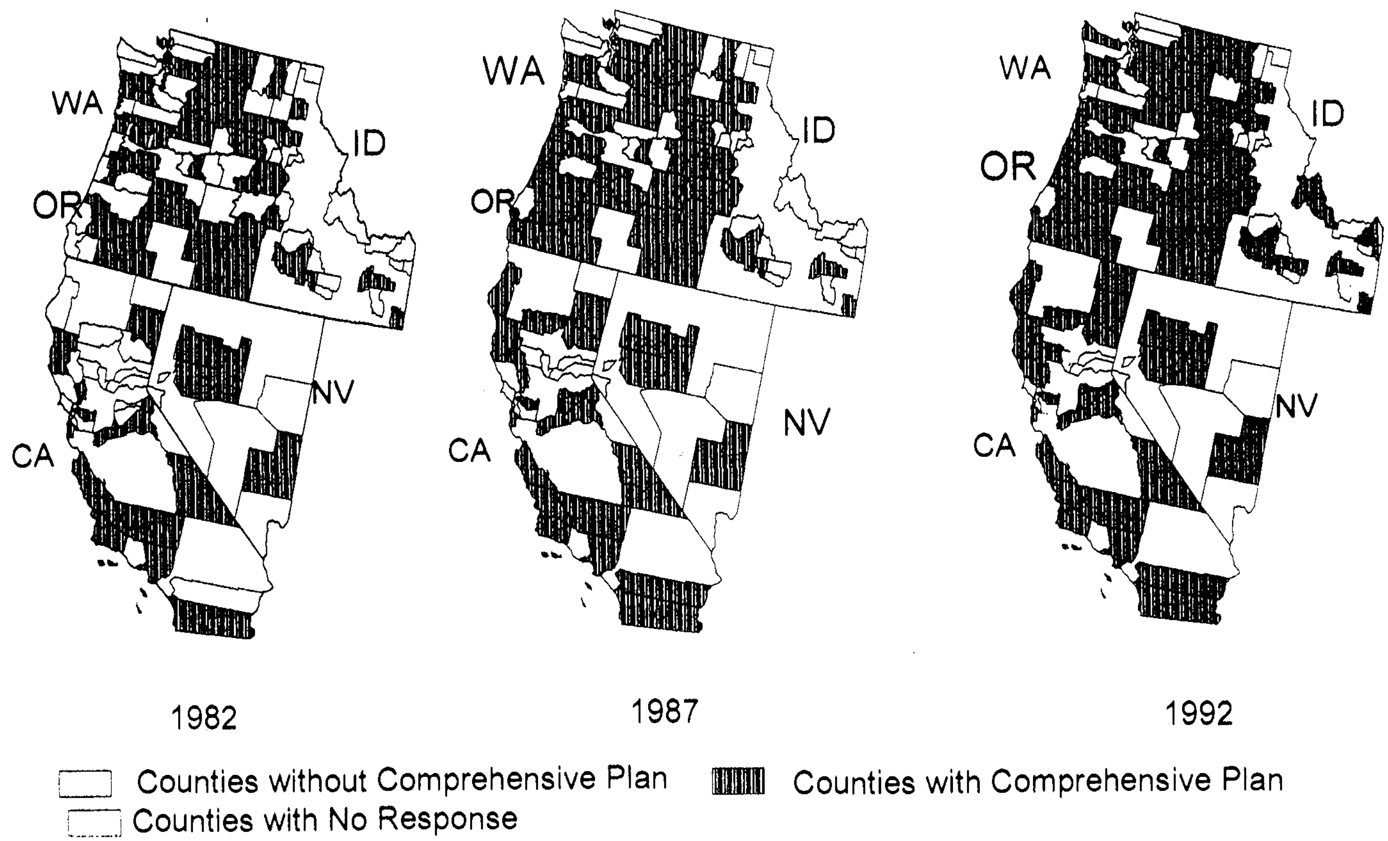

Figure 2.1 Counties with a Comprehensive Plan in Five Western States

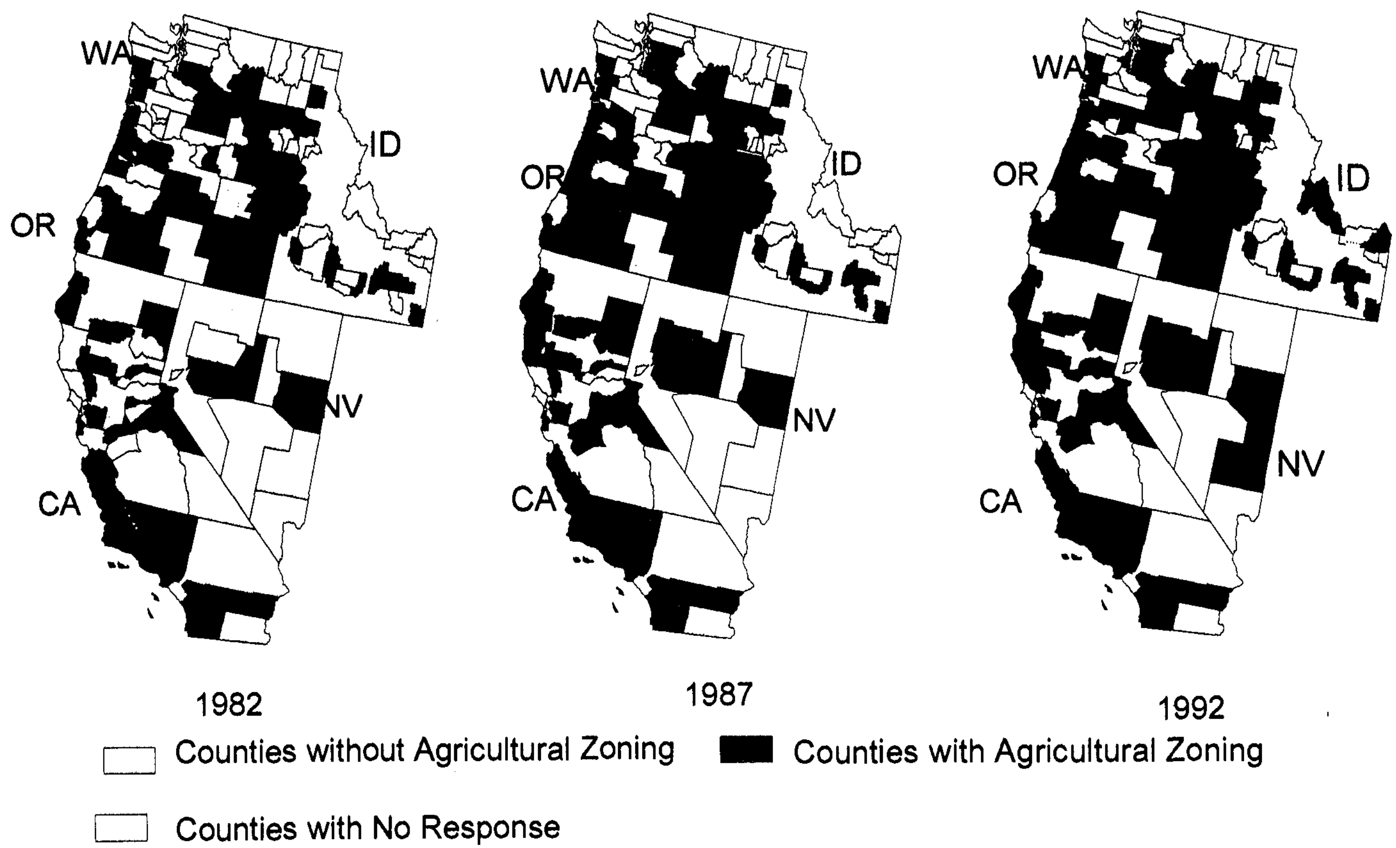

Figure 2.2 Counties with Agricultural Zoning in Five Western States

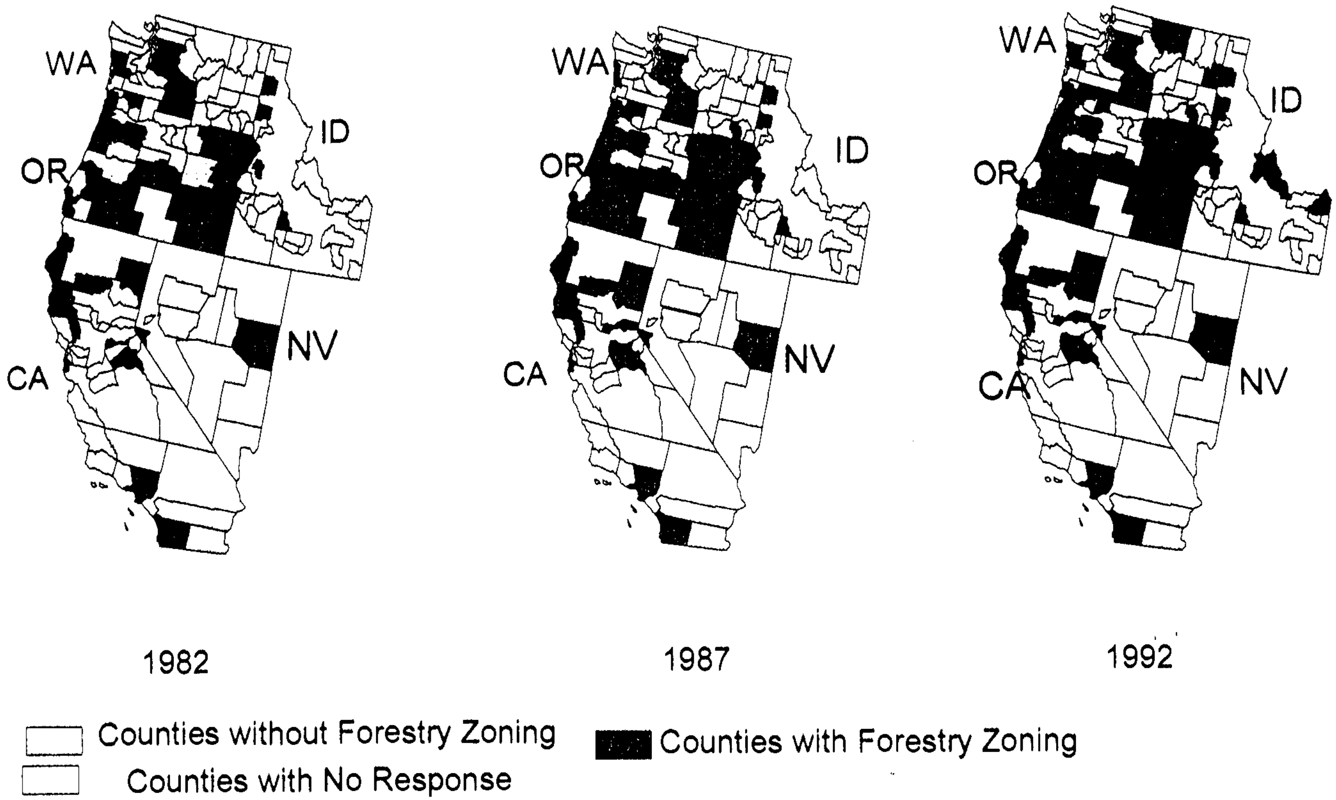

Figure 2.3 Counties with Forestry Zoning in Five Western States

2.5.5 Land Quality and Location Variables

Several land quality and location variables were included in the empirical models, including the average land capability class, distances to the closest metropolitan center (population $\geq$ 100,000) and to the closest national park. The weighted average of land capability classes was calculated for each county using the survey records of the land capability class at each NRI site. The NRCS divided land capability into eight classes, with 1 being the best quality land and 8 being the worst quality land. We estimated the distances from the geographical center of each county (defined as the cross point of the medium latitude and longitude) to the center of the closest metropolitan area (defined as the city with more than 100,000 people), the distance from the geographical center of each county to the center of the closest wilderness national park, and the distance from the geographical center of each county to the center of the closest urban type national park. The data on the latitude and longitude of the geographical center of each county and the closest metropolitan area were collected from the National Association of Counties. The data were used with the website, www.indo.com/distance, to measure the distances. A summary of all variables used in the empirical analysis is shown in Table 2.1.

Table 2.1 A Summary of Variables

Variable	Definition	Mean	Std Dev
Socioeconomic Variables:			
Farm profit ($)	Farm profit per acre at the beginning of the period	8.2	15.9
New housing value ($1,000)	Value of private new housing units at the beginning of the period	159.0	91.5
Population growth (population/acre)	Changes in population per acre between the periods	0.2	0.9
Changes in the average salary ($1,000)	Changes in average salary between the periods	16.8	5.0
Risk Variables:			
Variance of farm profit	Variance of farm profit at the beginning of the period	169.3	1006.1
Variance of new housing value	Variance of housing value at the beginning of the period	353.5	1949.1
Covariance between farm profit and new housing value	Covariance between farm profit and new housing value at beginning period	560.6	5545.1
Land Use Policies:			
County comprehensive plan	A dummy variable for the county comprehensive plan at beginning period	0.7	0.5
Agricultural zoning	A dummy variable for the agricultural zoning at the beginning of the period	0.7	0.5
Forestry zoning	A dummy variable for the forestry zoning at the beginning of the period	0.4	0.5
State planning	A dummy variable for the state land use planning at the beginning of the period	0.7	0.5
Mandatory review	A dummy variable for mandatory review of project involving farmland conversion at the beginning of the period	0.2	0.4

Table 2.1 A Summary of Variables (Continued)

Acreages enrolled in the CRP (1,000)	Acre of land enrolled in the Conservation Reserve Program at beginning period	13.1	32.2
Land Quality and Location Variables:			
Land capability class	Weighted average of land capability class with 1 being the best land and 8 being the worst land	5.2	0.9
Distance to the closest metropolitan center (mile)	Distance from the geographic center of a county to the closest metropolitan center (population ≥ 100,000)	80.0	52.6
Distance to the closest wilderness national park (mile)	Distance from the geographic center of a county to the center of the closest wilderness national park	88.0	50.7
Distance to the closest urban type national park (mile)	Distance from the geographic center of a county to the center of the closest urban type national park	231.4	157.0

2.6 Estimation Results

The estimated coefficients for the system of land conversion equations in (15) and (16) are presented in Table 2.2. Overall, the model fits the data well, with a system weighted R^2 of 0.99. The acreage elasticities of land development and farmland loss with respect to each explanatory variable are estimated using the coefficients and are presented in Table 2.3. The acreage elasticities with respect to the new housing value and farm profit show that an increase in the new housing value increases urbanization and farmland loss, while an increase in farm profit decreases urbanization and farmland loss. Increases in the population density and average salary increase urbanization and farmland loss. All of these results are consistent with economic theory.

The acreage elasticities with respect to the variances of farm profit and new housing value are both significant at the 1 % level. An increase in the variance of new housing value decreases urbanization and farmland loss, while an increase in the variance of farm profit increases urbanization and farmland loss. These results are consistent with the development decision rule derived in the theoretical analysis. The acreage elasticities with respect to the covariance between farm profit and new housing values are also significant at the 1 % level. The elasticities show that an increase in the correlation between farm profit and new housing value decreases the land development and farmland loss. This is explained by the fact that counties with a high correlation between farm profit and new housing value are mainly agricultural counties. These counties experienced less land development and farmland loss than other counties.

Of the three county land use regulations (county comprehensive plan, agricultural zoning, and forestry zoning), only agricultural zoning is significant at the 1 % level in both equations. The elasticities show that agricultural zoning reduces urbanization and farmland loss. However, forestry zoning appears to increase farmland loss and urbanization. The elasticities of county comprehensive plan is less significant than agricultural zoning, although counties with a comprehensive plan are less likely to experience urbanization or farmland loss.

The acreage elasticities with respect to state planning show that state land use planning reduces land development and farmland loss. State land use planning is a process that requires counties and cities to adopt development guidelines. States with state land use planning (California, Oregon, and Washington) are actively involved in land development regulations. The acreage elasticities with respect to the mandatory review show similar effects as that of state planning. These results suggest that state planning and the mandatory review of projects involving farmland conversion are effective in controlling farmland losses. The positive elasticities with respect to the CRP acreages seem counter-intuitive. This result reflects the fact that the CRP acres were not counted as farmland acres in the NRI data.

The acreage elasticities with respect to the land capability class shows that counties with higher land quality (i.e., lower land capability classes) experienced less farmland loss but more land development. This result may reflect that high-quality land is more suitable for farming, but counties with high quality land may also experience large development pressure (due to more economic activities). The elasticities with respect to the location variables show that 1) the closer a parcel is to a metropolitan center, the more likely it is to be developed, 2) the closer a parcel is to a wilderness national park, the less likely it is to be developed, and 3) the closer a parcel is to an urban type national park, the more likely it is to be developed. These results indicate that 1) land at city fringes is more likely to be developed, 2) most wilderness type national parks are located in remote areas where pressure of land development is low, and 3) the urban type national parks draw a signficant level of land development.

Table 2.2
SUR Estimates of the Coefficients for the Land Conversion Model

Variable	Urbanization Model	Farmland Loss Model
Socioeconomic Variables:		
Farm profit	-0.0003^{***}	-0.0003^{*}
New housing value	3.699^{***}	2.797^{*}
Population growth	0.137^{***}	0.054^{***}
Changes in the average salary	0.0002^{*}	0.0003
Risk Variables:		
Variance of net farm profit	$2.94E\text{-}7^{***}$	$3.43E\text{-}7^{***}$
Variance of new housing value	-0.0004^{***}	-0.0004^{***}
Covariance between farm profit and new housing value	$-5.86E\text{-}7^{***}$	$-6.23E\text{-}7^{***}$
Land Use Policies at the Beginning of the Period:		
County comprehensive plan	-0.006^{*}	-0.117^{*}
Agricultural zoning	-0.476^{***}	-0.512^{***}
Forestry zoning	0.285^{*}	0.551^{**}
State planning	-0.499^{***}	-0.277^{*}
Mandatory review	-0.710^{***}	-0.223^{***}
Acreages enrolled in the CRP	0.0008^{***}	0.002^{***}
Land Quality and Location Variables:		
Land capability class	-0.398^{***}	0.044^{*}
Distance to the closest metropolitan center	-0.008^{***}	-0.006^{***}
Distance to the closest wilderness national park	0.0004	0.002^{**}
Distance to the closest urban type national park	-0.002^{***}	0.0003
	System Weighted R-square: 0.99	

* denotes significant at 10%; ** denotes significant at 5 %; *** denotes significant at 1%.

Table 2.3
Estimated Acreage Elasticities from the Land Conversion Model

Variable	Acres of Land Urbanized	Acres of Farmland Loss
Socioeconomic Variables:		
Farm profit	-3.5E-5***	-0.003**
New housing value	0.018***	0.014**
Population growth	0.137***	0.054***
Changes in the average salary	0.0002*	3.0E-5
Risk Variables:		
Variance of net farm profit	0.049***	0.057***
Variance of new housing value	-0.132***	-0.0004***
Covariance between farm profit and new housing value	-3.22E-2***	-0.034***
Land Use Policies at the Beginning of the Period:		
County comprehensive plan	-0.004*	-0.071*
Agricultural zoning	-0.289***	-0.312***
Forestry zoning	0.102*	0.199**
State planning	-0.336***	-0.183*
Mandatory review	-0.140***	-0.042***
Acreages enrolled in the CRP	0.101***	0.268*
Land Quality and Location Variables:		
Land capability class	-2.021***	0.264
Distance to the closest metropolitan center	-0.652	0.226***
Distance to the closest wilderness national park	-0.430***	-0.194***
Distance to the closest urban type national park	-0.466***	0.072

* denotes significant at 10%; ** denotes significant at 5 %; *** denotes significant at 1%.

2.7 Conclusions

In this paper, an option value approach is used to model land development decisions. A land conversion model is estimated to examine the effect of land use regulations, benefit uncertainty, and other socioeconomic and spatial variables on urbanization and farmland development in five western states of the United States.

The empirical analysis substantiates theoretical findings concerning about the effect of risk and uncertainty on land development. It suggests that the greater the risk associated with development and the smaller the risk associated with farming, the less likely farmland is to be developed. Thus, in addition to the relative profits of farming and development, the relative magnitude of risks associated with development and farming also play an important role in land allocations. The results also confirm that increases in population density and household income increase urbanization and farmland development.

Our results suggest that agricultural zoning is an effective farmland preservation policy. State land use planning and the mandatory review of projects involving farmland conversion are effective state land use regulations for controlling land development. Distances to metropolitan centers and to national parks (wilderness and urban type) are significant spatial attributes affecting land development. A parcel is more likely to be developed if it is closer to a metropolitan center or an urban type national park. A parcel is less likely to be developed if it is closer to a wilderness national park.

This study can be extended in at least two directions. First, this study estimates the effect of pre-imposed land use regulations on farm land development, but land development may in turn affect land use regulations. An interesting topic for future research is to estimate the interaction between land development and land use regulations. Second, this study does not account for land quality variations within a county, but such variations may have a significant impact on land development. An analysis of spatial patterns of amenities and their impact on development patterns is needed.

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2.9 Appendices

APPENDIX **PAGE**

Appendix 1.
Land Use Policy Survey

Thank you for taking the time to participate in our survey. We would like to begin by asking you a question concerning the goals of land use policy of your county.

1. How important are the following goals of land use policy to your county? (Please circle either N/A for not available or the level of importance for each with 1 being least important and 5 being most important.)

		Least Important				Most Important
a. To conserve agricultural land	N/A	1	2	3	4	5
b. To conserve forestry land	N/A	1	2	3	4	5
c. To conserve environmentally sensitive natural areas	N/A	1	2	3	4	5
d. To promote residential investment	N/A	1	2	3	4	5
e. To promote industrial/manufacturing investment	N/A	1	2	3	4	5
f. To promote commercial/retail investment	N/A	1	2	3	4	5
g. To promote compact urban development and reduce public infrastructure cost	N/A	1	2	3	4	5

In the next section, we would like to know about the techniques your county uses to pursue the goals of land use policy (Please limit your answers to county government policy).

2. The list below shows some possible land development policies. We would like to know whether any of the following policies have been enacted, and if enacted, when they were enacted and how effective the policies have been? (Please, circle either N/A for not available or the level of effectiveness with 1 being not effective 5 being effective. Please also circle the range of years they were enacted.)

		Not effective				Effective
a. County comprehensive plan (To set policy goals & objectives and provide guidance on development)	N/A	1	2	3	4	5

Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

b.Extraterritorial planning and zoning
(State-granted power to cities to

control the development of county
land at the edge of cities.) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

c. Urban growth boundaries (To set
a geographic limit on the extension of
urban-type services) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

d. Housing caps (To limit the number
of houses built each year) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

e. Other growth caps (To set a limit on
the percentage rate of annual
growth) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

3. The list below shows some of possible land zoning and subdivision ordinances. We would like to know whether any of the following ordinances has been enacted, and if enacted, when they were enacted and how effective the ordinances have been? (Please, circle either N/A for not available or the level of effectiveness with 1 being not effective 5 being effective. Please also circle the range of years they were enacted.)

Not effective Effective

a. Agricultural zoning .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

b. Forestry zoning ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

c. Conservation zoning .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

d. Steep-slope zoning (To Prohibit
construction on steep slopes.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

e. Rural residential zoning
(To provide an area for nonfarm
and nonforest housing in the
countryside.) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

f. Maximum parcel sizes (To set a
maximum limit on the size of
residential lots.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

g.Minimum parcel sizes (To set a
minimum limit on the size of
residential lots) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

h.Open-space zoning or cluster
zoning (To concentrate buildings
on part of a property while
maintaining a significant amount
of open space.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

i. On-site septic ordinances (To ensure
proper installation and maintenance
of on-site septic systems.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

j. Performance zoning (To regulate
the impacts of development through
standards on noise, view, water:
Does not require separation into
zones by land uses.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

4. The list below shows some possible land acquisitions. We would like to know whether any of the following land acquisitions have been enacted, and if enacted, when they were enacted and how effective the acquisitions have been? (Please,

circle either N/A for not available or the level of effectiveness with 1 being not effective 5 being effective. Please also circle the range of years they were enacted.)

	Not effective					Effective
a. Fee-simple purchase (To acquire property for public use, e.g. parkland)	N/A	1	2	3	4	5
Range of years enacted: i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993						
b. Advance acquisitions, land banking (Government purchases land before it is ready to be developed.)	N/A	1	2	3	4	5
Range of years enacted: i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993						
c. Purchase of development rights	N/A	1	2	3	4	5
Range of years enacted: i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993						
d. Transfer of development rights	N/A	1	2	3	4	5
Range of years enacted: i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993						
e. Developer exaction and dedication (To require developers to provide parks, streets, and even school space or cash in lieu of facilities return for development approval.)	N/A	1	2	3	4	5
Range of years enacted: i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993						

5. The list below shows some possible incentives based management techniques. We would like to know whether any of the following incentives have been enacted, and if enacted, when they were enacted and how effective the techniques have been? (Please, circle either N/A for not available or the level of effectiveness with 1 being not effective 5 being effective. Please also circle the range of years they were enacted.)

Not effective Effective

a. Preferential property taxation (To encourage owners of farm and forestlands to keep their

Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

b. Agricultural districts .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

c. Density bonuses for sensitive design (To encourage sensitive site design that maintain significant open space.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

6. The list below shows some possible other development policies. We would like to know whether any of the following policies have been enacted, and if enacted, when they were enacted and how effective the policies have been? (Please, circle either N/A for not available or the level of effectiveness with 1 being not effective 5 being effective. Please also circle the range of years they were enacted.)

Not effective Effective

a. Special assessments (To place the cost of certain public facilities on the landowners in a specific area.).. N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

b. Impact fees (One time payments from a developer to cover the cost of providing new services for new development.) ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

c. Land conservation tax ....N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

d. Environmental impact assessments...........N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

e. Regional tax base sharing (To make all communities in the region share some property tax

revenues based on ability to pay.)............ N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

f. Regional fair share (To set standards to ensure that all communities accept a share of regional growth and affordable housing.) .... N/A 1 2 3 4 5
Range of years enacted:
i) Before 1982 ii)1983 - 1987 iii) 1988 - 1992 iv) After 1993

We would now like to ask you a question regarding the attitudes towards environmental issues in your county.

7. Recently, there have been much debate concerning the health of our land. The list below summarizes some of these environmental concerns. We would like to know how important these issues are to your county? (Please circle either N/A for not available or the level of importance with 1 being not important and 5 being very important.)

		Not important			Very important	
a. Conserving fish habitat	N/A	1	2	3	4	5
b. Conserving riparian area	N/A	1	2	3	4	5
c. Improving water quality	N/A	1	2	3	4	5
d. Managing and conserving wildlife	N/A	1	2	3	4	5
e. Improving/maintaining endangered species habitat	N/A	1	2	3	4	5
f. Providing more/better public recreation opportunities	N/A	1	2	3	4	5

Finally, we would like to ask you a few general questions about land use policy in your county.

8. As a person who has seen the land use changes of the past, please indicate the likelihood of conversion of land use in the near future in your county? (Please, circle the level of likelihood with 1 being very unlikely 5 being very likely.)

	Very unlikely				Very likely
a. Forestry to agricultural land	1	2	3	4	5
b. Agricultural to forestry land	1	2	3	4	5
c. Forestry to residential/industrial/ commercial land	1	2	3	4	5
d. Agricultural to residential/industrial/ commercial land	1	2	3	4	5

9. How many planners (FTE) are involved in land use planning process in your county?

____

10. What is the approximate annual county government expenditure on planning and about what share is this of your county's general fund?

$ _____________________ _____________________ %

11. When land use planning decisions are made, how much influence would you estimate for each of the following parties has in the decision of your county? (Please, circle the level of influence with 1 being little influence 5 being much influence.)

	Little influence			Much influence	
a. Federal government	1	2	3	4	5
b. State government	1	2	3	4	5
c. Municipal government	1	2	3	4	5
d. Private business	1	2	3	4	5
e. Average citizens	1	2	3	4	5
f. Homeowner's association	1	2	3	4	5
g. Professional planner	1	2	3	4	5
h. Developers	1	2	3	4	5

12. Are there other things you would like to tell us about land use policy of your county?

Appendix 2.
Summary of the Survey

Table
Importance of Goals in Land Use Policy

	Conserve Agricultural Land	Conserve Forestry Land	Promote Industrial Investment	Promote Commercial Investment	Promote Compact Development
OR	4.4	4.4	3.3	3.1	3.8
WA	4.7	3.8	3.8	3.6	3.5
CA	4.0	4.0	3.7	3.6	3.5
ID	4.7	4.2	3.2	3.1	3.6
NV	3.6	2.9	4.6	4.4	4.2

1 being least important and 5 being most import.

Table
Effectiveness of Land Development Policies
(% Counties Enacting Policies)

	County Comprehensive Plan	Urban Growth Boundaries	Housing Caps
OR	4.0 (100%)	4.3 (86%)	1.0 (3%)
WA	3.5 (94%)	3.6 (91%)	2.8 (6%)
CA	4.0 (100%)	3.9 (46%)	2.6 (23%)
ID	3.8 (100%)	3.3 (40%)	N/A
NV	3.2 (100%)	3.5 (36%)	4.5 (18%)

1 being least effective and 5 being most effective.

Table
Effectiveness of Land Zoning
(% Counties Enacting Policies)

	Agricultural Zoning	Forestry Zoning	Rural Residential Zoning
OR	4.4 (96%)	4.4 (93%)	4.0 (89%)
WA	4.1 (82%)	3.9 (65%)	3.6 (79%)
CA	4.1 (94%)	4.4 (49%)	3.5 (86%)
ID	4.0 (96%)	4.0 (36%)	3.9 (80%)
NV	3.7 (82%)	3.3 (27%)	3.4 (91%)

1 being least effective and 5 being most effective.

Table
Likelihood of Conversion of Land Use

	Forestry to Agricultural Land	Agricultural to Forestry Land	Forestry to Residential Land	Agricultural to Residential Land
OR	1.7	1.8	1.7	2.3
WA	1.4	1.8	2.8	3.2
CA	1.8	1.2	1.8	3.1
ID	1.1	1.6	2.4	3.8
NV	1.2	1.5	1.9	3.9

1 being least likely and 5 being most likely.

Table
Average Number of Planners in each County, Annual Expenditure on Planning, and Share of General Fund

	Average Number of Planners in each county	Average Annual Expenditure on Planning	Average Share of General Fund
OR	5.3	$ 494,646	2%
WA	11.8	$ 2,013,928	3%
CA	18.8	$ 6,773,814	3%
ID	3.1	$ 199,062	2%
NV	7	$ 1,230,122	2%

Table
Degree of Influence of Parties in Land Use Planning

	State Government	Private Business	Average Citizens	Professional Planners	Developers
OR	4.2	2.9	3.5	3.1	3.0
WA	3.6	3.2	3.6	3.8	3.3
CA	3.3	3.4	3.7	3.4	3.8
ID	3.3	3.2	3.4	3.0	3.1
NV	2.5	3.4	3.2	3.4	3.8

1 being least influence and 5 being most influence.

CHAPTER 3

MEASURING INTERACTIONS AMONG URBAN DEVELOPMENT, LAND USE REGULATIONS, AND PUBLIC FINANCE

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3.1 Introduction

The role of local land use policies has been examined in a number of studies (e.g. Fischel, 1978; Mills, 1979; Henderson, 1980; Shlay and Rossi, 1981; Epple et al., 1988; McDonald and McMillen, 1998; Levine, 1999; Phillips and Goodstein, 2000). However, little evidence is available on which factors motivate land use regulations. Because local political processes determine land use regulations, treating regulations as exogenous causes a selection bias (Pogodzinski and Sass, 1994). The endogenous nature of zoning regulation was first raised by Davis (1963). He pointed out the different preferences for zoning between the existing homeowners and developers or renters. Rolleston (1987) assessed the link between suburban fiscal environments and zoning policies. She examined the interjurisdictional determinants of restrictive zoning and the relationship between residential and nonresidential zoning decisions in suburban communities. Rolleston measured the restrictiveness of residential zoning by an ad hoc weighted average of lots in various residential zoning categories.

Erickson and Wollover (1987) estimated the effects of a number of demographic variables on the choice of zoning regulations, but did not account for the simultaneous nature of zoning decisions. Wallace (1988) treated zoning regulations as endogenous when evaluating the impact of land-use zoning. He estimated a logit model to correct for selection bias. McMillen and McDonald (1989, 1991) explored the econometric problems involving the measurement of impact of endogenous zoning decisions. They used a two-step estimation technique to derive unbiased estimates of the zoning regulations, but excluded demographic variables from consideration. Wallace (1988) and McMillen and McDonald (1989, 1991) did not develop a political theory of zoning. Pogodzinski and Sass (1994) model the political procedure of zoning and its implications for measuring the impact of zoning regulations. They assume that zoning regulations are established by maximizing effective political support. In order to measure the effective political support, they consider whether a utility maximizing representative voter would support local land-use zoning.

There are several shortcomings in those previous studies. First, with the exception of Pogodzinski and Sass (1994), land use regulations have not been modeled explicitly. Thus, variables included in land use regulation models were chosen rather arbitrarily. Second, the linkages between land use regulations and land use, public expenditure, and property tax were not considered. These linkages are important factors affecting the choice of land use regulations. Third, previous studies have focused on a specific land use regulation. They have not considered effects of various types and degrees of land use regulations.

In this paper, a theoretical model is developed to analyze the interactions among residential development, land use regulations, and public financial impacts (public expenditure and property tax). Specifically, housing markets and socially optimal land uses are modeled to identify variables affecting land use, land use regulations, housing price, public expenditure, and property tax. The demand function for land development is modeled from a household utility maximization model. The supply function of land development is modeled using an option value approach to accommodate uncertainty and irreversibility of land development. Land use regulations are modeled from a land planner's perspective, which seeks to maximize a social welfare function. A polychotomous-choice model with self-selectivity (Lee,

1983) is used to control self-selection bias in modeling adoption of land use regulations. A simultaneous equations system is estimated to analyze the interactions between land use regulations and land use, public expenditure, and property tax.

3.2 Theoretical Model

3.2.1 Demand for Land Development

Since most land use regulations are imposed at the county level, we consider land use decisions within a region. We assume each region can be divided into sub-regions that are homogenous in physical and demographic characteristics (Epple and Sieg, 1999). The households in each sub-region are assumed to have homogenous preferences and incomes. The utility of a household depends on their consumption choices and the characteristics of the sub-region. The consumption choices include residential lot size (n_i) and consumption of other goods (x_i). The characteristics of the sub-region include public expenditure (g_i), property taxes (τ_i), physical features (Ψ_i), and demographic characteristics (μ_i). The utility function of a household residing in a sub-region i is written as $U_i(n_i, x_i, g_i, \mu_i, \Psi_i)$. The household takes as given the level of public expenditure (g_i), the property tax rate (τ_i), physical features of the sub-region (Ψ_i), and demographic characteristics of the sub-region (μ_i) to maximize its utility function subject to a household budget constraint:

$$\text{Max } U_i(n_i, x_i, g_i, \mu_i, \Psi_i) \quad (1)$$

$$\text{s.t. } p^x \cdot x_i + (1+\tau_i) \cdot R_i \cdot n_i = Y_i. \quad (2)$$

where p^x is price of other goods, R_i is residential rent, and Y_i is household income. The solution of the maximization problem gives the optimal size of residential lot in the sub-region: $n_i^* = n_i(p^x, R_i, \tau_i, g_i, \mu_i, Y_i, \Psi_i)$. Thus, the total demand for land development in year t in the region equals,

$$N_t^d = \sum_{i=1}^{I} N_{it} \cdot n_{it}^* = \sum_{i=1}^{I} N_{it} \cdot n_{it}(p_{it}^x, R_{it}, \tau_{it}, g_{it}, \mu_{it}, Y_{it}, \Psi_i) = N_t^d(p_t^x, R_t, \tau_t, g_t, \mu_t, Y_t, \Psi). \quad (3)$$

where N_i is the number of households in sub-region i, and I is the number of sub-regions in the region. Assuming that individual demand functions are homogenous, $R_t, \tau_t, g_t, \mu_t, Y_t, \Psi$ are the average of residential rent, property tax, government expenditure, demographic characteristics, household income, and land quality.

3.2.2 Supply of Residential Areas

The supply of residential areas is determined by developers. Suppose a developer is considering converting a parcel of undeveloped land (e.g. farmland) into development. The developer develops the land to maximize the expected present value of profit from development. Suppose his decision is made in a two-period framework: a first period followed by future time horizon compressed into a single second period. The developer knows both the rents from farming (F_1) and development (R_1) in the first period, but is uncertain about the rents from farming (F_2) and development (R_2) in the second period. We assume that the net gain from development, $R_2 - F_2$, in the second period, takes a normal distribution, N[$\Delta R_2, \sigma^2$] and that the developer will develop his land in the second period only if $R_2 > F_2$. The following truncated mean values are obtained based on the theorem of moments of the truncated normal distribution (Greene 1997 pp.949-953):

$$E[R_2 - F_2 \mid R_2 > F_2] = \Delta R_2 + \frac{\sigma\phi(\alpha)}{P}, \tag{4}$$

$$E[R_2 - F_2 \mid R_2 < F_2] = \Delta R_2 - \frac{\sigma\phi(\alpha)}{1-P}, \tag{5}$$

where $\alpha = -\mu / \sigma$, ϕ is the probability distribution function of the standard normal, and P is the probability that $R_2 > F_2$. If the land developer develops the land in the first period, the expected net present value is

$$NPV = (R_1 - F_1) + P[\Delta R_2 + \frac{\sigma\phi(\alpha)}{P}] + (1-P)[\Delta R_2 - \frac{\sigma\phi(\alpha)}{1-P}]. \tag{6}$$

On the other hand, if the land developer waits a period and develops only if the net gain from development, ΔR_2, turns out to be positive, the expected net gain is

$$NPV = P[\Delta R_2 + \frac{\sigma\phi(\alpha)}{P}]. \tag{7}$$

The optimal decision rule for development in the first period is obtained when (6) is set to be greater than (7):

$$R_1 > F_1 + \sigma\phi(\alpha) - (1-P)\Delta R_2. \tag{8}$$

Equation (8) implies that the area of land development in time, t, is a function of $R_t, F_t, \Delta R_{t+1}$, and σ_t: $\Delta N_t^s(R_t, F_t, \Delta R_{t+1}, \sigma_t)$, where ΔR_{t+1} is the expected net return from development in the future. In previous studies of land allocation decisions, various socioeconomic and physical variables have been included to explain land allocations to urban, residential, and other uses. For example, land and demographic characteristics and income levels have been used as measures of development pressure in previous studies (e.g., Chicoine (1981), Hushak and Sadr (1979), Wall (1981), Alig and Healy (1987)). Hardie and Parks (1989) and Bockstael et al. (1995) found that land quality is an important determinant of land use. Based on these studies, we assume that

$\Delta R_{t+1} = \Delta R_{t+1}(R_t, F_t, \Psi, \mu_t, \varphi_t, Y_t)$ where φ_t is land use regulation. Thus, the aggregate supply of land for development equals:

$$N_t^s = N_{t-1} + \Delta N_t^s = N_t^s(N_{t-1}, R_t, F_t, \Psi, \mu_t, \varphi_t, Y_t, \sigma_t). \qquad (9)$$

The equilibrium rental rate for housing is obtained when the aggregate supply is set to equal the aggregate demand:

$$R_t = R_t(p_t^x, F_t, \sigma_t, \varphi_t, \Psi, \mu_t, Y_t, \tau_t, g_t, N_{t-1}). \qquad (10)$$

3.2.3 Land Use Regulations and the Social Welfare Function

We assume that the county government (i.e., planning commission) attempts to maximize the net present value from land use by choosing the optimal level of land development in each sub-region:

$$\underset{N_i, q_i, \tau_i}{Max}\ V \equiv \sum_{i=1}^{I}(R_i(N_i)\cdot N_i) + \sum_{i=1}^{I} F_i \cdot (L_i - N_i) - D(\sum_{i=1}^{I} N_i). \qquad (11)$$

$$\text{s.t. } \sum_{i=1}^{I} g_i N_i = \sum_{i=1}^{I} \tau_i R_i N_i .$$

The $\sum_{i=1}^{I} L_i$ represents total area of the county, the $N = \sum_{i=1}^{I} N_i$ represents total urban area of the county. The first term of equation (11) represents the value of urban land, the second term represents the value of farmland, and the last term $D(\sum_{i=1}^{I} N_i)$ represents the social cost of converting farmland to urban land. The first order condition for land development can be written as

$$(1+\lambda\tau_i)\frac{\partial(R_i N_i)}{\partial N_i} - F_i - \lambda g_i = D'(N) \tag{12}$$

i = 1, 2, . . . , I.

where λ, the Lagrange multiplier for the budget balance constraint, can be interpreted as the marginal social cost of public expenditures. Equation (12) indicates that land should be developed where the net rent (development rent minus farmland rent and marginal cost of public goods) equals the marginal social cost of public goods.

The first order condition for optimal land use is illustrated in figure 3.1. The socially optimal level of land development, N^*, obtained from equation (12), is where the marginal benefit of development equals the marginal cost of development. However, the developed area under the market equilibrium can be greater or less than the socially optimal level of land development, resulting in a social welfare loss. If the developed area under the market equilibrium N_l^e is less than the socially optimal level N^*, the welfare loss is the area *abc*. If the developed area under the market equilibrium is N_h^e, the welfare loss is the area *ade*. In both cases, a county government can reduce the welfare loss by shifting the market equilibrium land use toward the socially optimal land use in the form of land use regulations. A county government can encourage development by reducing land use regulations and discourage development by imposing more stringent land use regulations. Thus, the probability that land use regulations will be imposed depends on the difference between the left and right hand sides of (12), which is

$$\Pr_t^* = \varphi_t(p_t^x, F_t, \sigma_t, \tau_t, \Psi, \mu_t, Y_t, g_t, D_t, N_{t-1}). \quad (13)$$

From the first order condition of the county government's maximization problem, we obtain the government expenditure and property tax functions:

$$g_t^* = g_t(p_t^x, F_t, \sigma_t, \varphi_t, \Psi, \mu_t, Y_t, \tau_t, D_t, N_{t-1}), \quad (14)$$

$$\tau_t^* = \tau_t(p_t^x, F_t, \sigma_t, \varphi_t, \Psi, \mu_t, Y_t, g_t, D_t, N_{t-1}), \quad (15)$$

which, together with the public budget constraint, determine the optimal level of public expenditure and property taxes.

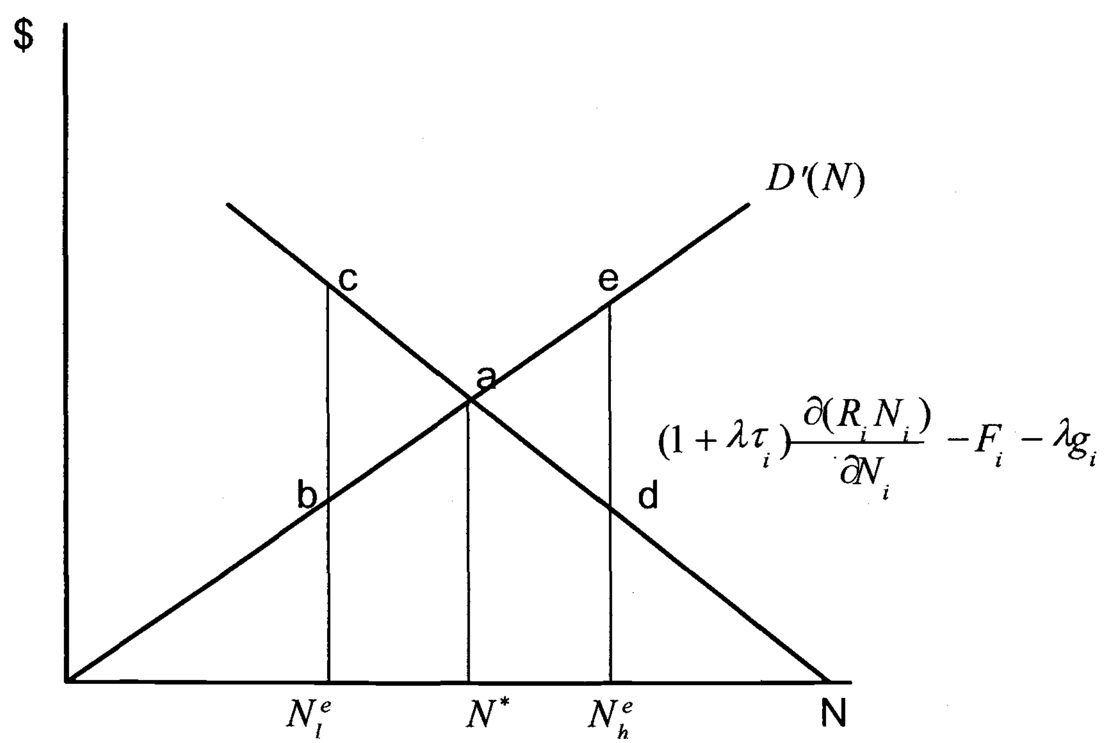

Figure 3.1 Socially Optimal and Market Equilibrium Land Use

3.3 Empirical Model

In the last section, we analyzed the theoretical interrelationships between land use, land use regulations, and their fiscal impacts. In this section, we present an empirical model of these interrelationships. Specifically, the interrelationships are represented by the following simultaneous equations system with self-selection and discrete dependent variables:

$$\Pr_t^j \equiv \Pr(I = j) = \frac{\exp(X_t' \cdot \Pi_j)}{\sum_{i=1}^{M} \exp(X_t' \cdot \Pi_i)}, \; j = 1, 2, 3, 4, \tag{16}$$

$$N_t^{sj} = \beta_0^j + \beta_1^j \cdot R_t + \beta_2^j \cdot Z_t + \varepsilon_t^{sj}, \tag{17}$$

$$R_t^j = \gamma_0^j + \gamma_1^j \cdot \tau_t + \gamma_2^j \cdot g_t + \gamma_3^j \cdot Z_t + \varepsilon_t^{Rj}, \tag{18}$$

$$\tau_t^j = \delta_0^j + \delta_1^j \cdot g_t + \delta_2^j \cdot Z_t + \varepsilon_t^{\tau j}, \tag{19}$$

$$g_t^j = \pi_0^j + \pi_1^j \cdot \tau_t + \pi_2^j \cdot Z_t + \varepsilon_t^{gj}, \tag{20}$$

where $j = 1, 2, 3, 4$ represents the four degrees of land use regulations as defined in table 1, Z_t is a matrix of exogenous variables $(N_{t-1}, F_t, \mu_t, Y_t, \sigma_t, \Psi)$, and $\varepsilon_t^{sj}, \varepsilon_t^{Rj}, \varepsilon_t^{\tau j}, \varepsilon_t^{gj}$ are random error terms.

The degree of land use regulations is defined based on a comprehensive survey of land use regulations in each county in five western states (California, Idaho, Nevada, Oregon, and Washington). From the survey, we identified the 20 most important land use regulations. Survey respondents were asked to evaluate the level of effectiveness of each regulation on a scale of 1, 2, 3, 4, and 5 with 1 being not effective and 5 being most effective. The sum of the level of effectiveness for all regulations in a county is defined as an index of regulatory intensity. For example, a county with 20 land use regulations each with level of effectiveness of 5, would have an index of 100. Counties with indexes greater than 60 are classified as having "stringent land use regulations", counties with indexes greater than 30 and equal to or less than 60 are classified as having "moderate land use regulations", counties with indexes greater than 0 and equal to or less than 30 are classified as having "low land use regulations", and counties without any land use regulations are defined as "no land use regulations" (see table 3.1).

Table 3.1 The Intensity of Land Use Regulation in the Five Western States

Category	Index of intensity of land use regulations (I)	% of Counties
Stringent	$I \geq 60$	31 %
Moderate	$30 \leq I < 60$	33 %
Low	$0 < I < 30$	25 %
No Regulations	0	11 %

The equation system (16-20) is an extension of the polychotomous-choice selectivity model as described in Lee (1983) and applied to agricultural policy analysis in Wu and Babcock (1998). When any two equations of land demand, land supply, and housing price are estimated, the other one would be determined. Here we choose to estimate the land supply and housing price equations.

Maddala (1983, pp. 242-245) describes a two-stage technique for estimating a simultaneous model with discrete dependent variables. In the first stage, we estimate the reduced form equations of (18), (19), and (20), using OLS:

$$R_t^j = \Pi_1^j \cdot Z_t + v_{1t}^j \qquad (21)$$

$$\tau_t^j = \Pi_2^j \cdot Z_t + v_{2t}^j \tag{22}$$

$$g_t^j = \Pi_3^j \cdot Z_t + v_{3t}^j \tag{23}$$

We then use the predicted value of $\hat{R}, \hat{\tau}, \hat{g}$ to estimate the multinomial logit model in (16) and use it to predict $\hat{\Pr}_j$:

$$\hat{\Pr}_t^j = \frac{\exp(\hat{\Pi}_j \cdot X_t)}{\sum_{i=1}^{M} \exp(\hat{\Pi}_i \cdot X_t)}, \; j = 1, 2, 3, 4. \tag{24}$$

which is then used to calculate $\hat{\lambda}_t^j \equiv \phi[\Phi^{-1}(\hat{\Pr}_t^j)] / \hat{\Pr}_t^j$, $j = 1, 2, 3, 4$. The $\hat{\lambda}_t^j$ reflects correction of self-selection bias (Lee, 1983). It is included in the model because counties that adopt land use regulations may behave differently from a randomly selected county with the same characteristics.

In the second stage, the parameters in the structural equations are determined by estimating the following equations using OLS:

$$N_t^j = \beta_0^j + \beta_1^j \cdot \hat{R}_t + \beta_2^j \cdot Z_t - \beta_3^j \cdot \hat{\lambda}_t^j + u_{1t}^j \tag{25}$$

$$R_t^j = \gamma_0^j + \gamma_1^j \cdot \hat{\tau}_t + \gamma_2^j \cdot \hat{g}_t + \gamma_3^j \cdot Z_t - \gamma_4^j \cdot \hat{\lambda}_t^j + u_{2t}^j \tag{26}$$

$$\tau_t^j = \delta_0^j + \delta_1^j \cdot \hat{g}_t + \delta_2^j \cdot Z_t - \delta_3^j \cdot \hat{\lambda}_t^j + u_{3t}^j \tag{27}$$

$$g_t^j = \pi_0^j + \pi_1^j \cdot \hat{\tau}_t + \pi_2^j \cdot Z_t - \pi_3^j \cdot \hat{\lambda}_t^j + u_{4t}^j \tag{28}$$

Since the coefficients of the multinomial logit model are difficult to interpret, the marginal effects of explanatory variables on the degree of regulation are determined using

$$\frac{\partial \Pr^j}{\partial X} = \Pr^j (\Pi_j - \sum_{i=1}^{3} \Pr^i \cdot \Pi_i). \tag{29}$$

This model can be used to estimate the effects of alternative degrees of land use regulations on land development, housing price, public expenditure, and property tax. Consider the public expenditure of a county with and without land use regulations, the expected change in public expenditure due to the adoption of level of land use regulation j is:

$$[E(g^j \mid I = j) - E(g^4 \mid I = 4)]_{short-run} \tag{30}$$

$$= [(\pi_0^j - \pi_0^4) + \hat{R}(\pi_1^j - \pi_1^4) + Z(\pi_2^j - \pi_2^4)] + (\pi_3^4 - \pi_3^j)\hat{\lambda}^j$$

where I = 4 denotes no land use regulations in the county. The first bracket in the right hand side of equation (30) is the expected change in public expenditure resulting from adoption of level of land use regulation j. The remaining term accounts for self-selection.

The expected change in public expenditure resulting from adoption of land regulations on housing prices, public expenditures, and property taxes in a single-period time frame is defined as the short-run effect and is estimated using equation (30). The expected changes in public expenditure from adoption of land use regulations that take into account the effect of changes in developed area is defined as the long-run effect and it is estimated using equation (31):

$$[E(g^j \mid I = j) - E(g^4 \mid I = 4)]_{long-run} \tag{31}$$
$$= [(\pi_0^j - \pi_0^4) + \hat{R}(\pi_1^j - \pi_1^4) + Z^{'}(\pi_2^{j'} - \pi_2^{4'}) + (\pi_{2N_{t-1}}^j N_{t-1} - \pi_{2N_{t-1}}^4 N_{t-1}^*) + (\pi_3^4 - \pi_3^j)\hat{\lambda}^j],$$

where $Z_t^{'}$ is a vector that includes every variable in Z_t except N_{t-1}, $\pi_2^{j'}$ and $\pi_{2N_{t-1}}^j$ are the estimated coefficients on $Z_t^{'}$ and N_{t-1}, and N_{t-1}^* is the acres of land that would be developed without any land use regulation. The expected changes in housing price, land development, and property taxes due to adoption of different degrees of land use regulation can be similarly analyzed.

3.4 Data

The study area includes five western states, California, Idaho, Nevada, Oregon, and Washington. The data on land use was taken from the 1982, 1987, and 1992 Natural Resource Inventories (NRI)[2]. The NRI collected land use data at 800,000 randomly selected sites across the continental United States and divided land use into twelve major categories (cultivated cropland, non-cultivated cropland, pastureland, rangeland, forestland, urban and built-up land, and six other categories). In this study, cultivated cropland, non-cultivated cropland, pastureland, and rangeland are categorized as farmland and urban and built-up land is categorized as urban land. The NRI survey assigns a weight called an expansion factor or "X" factor to each site in the sample to determine the number of acres each sample site represents. The sum of this value for all sites in a county equals the total county acreage.

The expected variances of farm profit and new housing value were used to measure the risk associated with farming and development. These variances were estimated using

$$VB_t = \frac{1}{4}\sum_{t=t-4}^{t-1}(B_t - EB_t)^2, \qquad (32)$$

where VB_t = the expected variance of farm profit or new housing value in year t, t= 1982, 1987,

B_t= the farm profit or the value of new housing units in year t,

---

[2] The 1997 NRI has not been released due to technical problems.

A comprehensive land use policy survey was conducted to obtain information on county land use regulations in the five western states. The survey, conducted between August and October of 1999, was sent to all county land use planners or equivalent positions in the five states. The overall response rate was 69%. Counties of Washington had the highest response rate (87%), followed by Oregon (78%), Nevada (65 %), California (60%), and Idaho (57%).

The survey results show that the most important land use policy goal of Nevada counties was the promotion of industrial and commercial investment, while the counties in other states were more concerned about the conservation of farmland, forestland, and natural areas. All counties expressed a serious concern about urbanization. A county comprehensive plan had been enacted in almost all of the counties in the five states when the survey was conducted, however, the timing of the initial enactment varied across counties. Extra territorial planning and zoning were popular in Idaho, urban growth boundaries were popular in Oregon and Washington. Agricultural, residential, forestry, conservation, open space, and steep slope zonings were popular throughout the states, whereas performance zoning was used only in a limited number of counties. Specification of minimum parcel sizes was popular in many counties, limits on maximum parcel sizes was not.

Developer exaction and dedication was the most popular land acquisition technique in many counties. Fee simple purchase and agricultural districts were especially popular in California. Preferential property taxation for farmland and forestland were the most popular incentive-based management techniques. Special assessments were popular in Oregon, Washington, and California.

Environmental impact assessments were popular in Washington and California. Regional fair sharing was especially popular in California. The planners predicted a high possibility of conversion from farmland to residential land, especially in Idaho and Nevada. Counties in California spent the largest amount of money on planning, while counties in Idaho spent the least amount. However, the average share of the entire budget spent on planning remained fairly close in the five states. Planners in Oregon and Washington felt that the State governments had strong influence on land use regulations, whereas planners in California, Idaho, and Nevada felt strong influences from non-government organizations such as private business, average citizens, professional planners, and developers.

Land quality and location variables in the empirical models, included the average land capability class and distance to the closest metropolitan center (population $\geq$ 100,000). The weighted average of land capability classes was calculated for each county using the survey records of the land capability class at each NRI site. The Natural Resources Conservation Service divided land capability into eight classes, with 1 being the best quality land and 8 being the worst quality land. Location was calculated as the distance from the geographical center of each county (defined as the cross point of the medium latitude and longitude) to the center of the closest metropolitan area (defined as a city with more than 100,000 people). The data on the latitude and longitude of the geographical center of each county and the closest metropolitan area were collected from the National Association of Counties. The website, 'www.indo.com/distance' was used to measure the distances.

Table 3.2 Definition of Variables

Variables	Mean	Standard Deviation	Definition
Endogenous Variables:			
Percent of total land developed	1.87	0.22	Percent of total land developed (%)
New housing price	159.0	91.5	Value of private new housing units ($1,000)
Property tax	436.0	67.0	Property tax per capita ($)
Public expenditure	1859.0	616.0	Public expenditure per capita ($)
Exogenous Variables:			
Farm profit	8.2	15.9	Farm profit per acre ($)
Population	0.2	0.9	Population per acre
Income	15.6	4.0	Income per capita ($ 1,000)
Land capability class	5.2	0.9	Weighted average of land capability class with 1 being the best land and 8 being the worst land
Distance to the closest metropolitan center	80.0	52.6	Distance from the geographic center of a county to the closest metropolitan center (population ≥ 100,000) (mile)
Construction cost	75.0	28.8	Construction cost as recorded on the building permit ($1,000)
Consumer price index	127.0	13.0	Consumer price index
Variance of farm profit	169.3	1,006.1	Variance of farm profit at the beginning of the period
Variance of new housing value	353.5	1,949.1	Variance of housing value at the beginning of the period

Data on the average value of new housing units, construction cost, income, population, property tax, and public expenditure were obtained from the Census Bureau's 'USA counties 1998'. Average farm profit data were obtained from the Census Bureau's 'Regional Economic Information System: 1969-1997'. Both the farm profit and the average value of new housing units are adjusted by the consumer price index from the Bureau of Labor Statistics. The summary of variables is shown in table 3.2.

3.5 Estimation Results and Discussion

3.5.1 Factors Affecting Adoption of Land Use Regulations

Parameter estimates for the multinomial logit model of land use regulations are presented in table 3.3. The model correctly predicts the level of land use regulation for 67 % of counties. The marginal effects of alternative variables on the intensity of land use regulations are shown in table 3.4. Six of twelve marginal effects are statistically significant at the 5 % level for counties with "stringent" land use regulations. Four of twelve coefficients are statistically significant at the 5 % level for counties with "moderate" and "low" land use regulation indexes. The marginal effects of all twelve variables increase with the index of land use regulations. Although the marginal effects are less significant for counties with a lower land use regulation index, their signs are not affected.

Counties with higher farm profit are more likely to adopt land use regulations more frequently. This reflects the economic incentive of land use regulations against farmland development. Farmers with high farm profit are more willing to support land use regulations preserving their farmland. Population increases the pressure for adopting land use regulations. Stringent and moderate land use regulations are also more frequently adopted by counties with higher household income. These population and income results are consistent with those found by Erickson and Wollover (1987), who estimated the effects of a number of demographic variables on the adoption of zoning regulations.

Counties closer to metropolitan centers are more likely to enact land use regulations. This result is expected because counties closer to metropolitan centers tend to have more land use conflicts. Land use regulations are more likely to be adopted in counties with smaller variances in farm profits and larger variances in new housing prices. This suggests that the greater the risk associated with new housing price compared with the risk associated with farming, the more likely developers are to accept land use regulations. In addition, county governments may use regulations to reduce variations in housing prices.

Adoption rates of land use regulations are higher in counties with high public expenditures and property taxes. This provides empirical evidence that high public expenditures and property taxes encourage county governments to impose land use regulations to control government expenditures. Finally, land use regulations are more frequently adopted in counties with a large proportion of developed areas. This suggests that development pressure promotes county governments to take actions to control land development.

Table 3.3 Parameter Estimates for the Multinomial Logit Model of Land Use Regulation Intensity

Variable	Stringent	Moderate	Low
Constant	-1.554** (0.127)	-1.075** (0.343)	-1.395* (0.631)
Farm profit	0.034* (0.016)	0.026* (0.012)	0.010* (0.004)
Population	0.005* (0.003)	0.005* (0.002)	0.003 (0.002)
Income	0.004* (0.002)	0.002* (0.001)	-0.003 (0.015)
Land capability class	-0.017** (0.003)	-0.126** (0.021)	-0.114* (0.062)
Distance to the closest metropolitan center	-0.007* (0.004)	-0.001 (0.003)	-0.011* (0.005)
Construction cost	0.108** (0.026)	0.149** (0.019)	0.132* (0.066)
Consumer price index	-0.012* (0.005)	-0.010* (0.003)	-0.012 (0.009)
Variance of farm profit	-0.026* (0.017)	-0.043* (0.025)	0.017 (0.034)
Variance of new housing value	0.024** (0.007)	0.047* (0.020)	0.028* (0.013)
Public expenditure	0.207** (0.030)	0.183** (0.018)	0.193* (0.085)
Property tax	1.520** (0.317)	1.952** (0.224)	1.826* (0.639)
Percent of developed area in previous period	1.826** (0.429)	1.524** (0.264)	1.113 (0.653)
Pseudo R^2 0.86			
Likelihood ratio test statistic 231			
Correct predictions of land use regulation 67%			

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Table 3.4 The Marginal Effects of Alternative Variables on the Intensity of Land Use Regulation

Variable	Stringent	Moderate	Low
Farm profit	0.0043*	0.0039*	0.0031*
	(0.0022)	(0.0017)	(0.0012)
Population	0.0013*	0.0010*	0.0006
	(0.0005)	(0.0006)	(0.0005)
Income	0.0007*	0.0005	-0.0003
	(0.0003)	(0.0009)	(0.0024)
Land capability class	0.0053*	0.0045*	0.0038*
	(0.0038)	(0.0021)	(0.0015)
Distance to the closest metropolitan center	-0.0008**	-0.0007*	-0.0001
	(0.0002)	(0.0004)	(0.0018)
Construction cost	0.0275**	0.0175*	0.0098**
	(0.0041)	(0.0084)	(0.0010)
Consumer price index	0.0012	0.0010*	0.0001
	(0.0007)	(0.0004)	(0.0007)
Variance of farm profit	-0.0109*	-0.0088**	-0.0069*
	(0.0061)	(0.0026)	(0.0025)
Variance of new housing value	0.0033**	0.0032*	0.0025
	(0.0008)	(0.0018)	(0.0016)
Public expenditure	0.0142**	0.0135**	0.0105**
	(0.0031)	(0.0027)	(0.0031)
Property tax	0.1126**	0.1105**	0.1021**
	(0.0210)	(0.0184)	(0.0223)
Percent of developed area in previous period	0.1942**	0.1935**	0.1654**
	(0.0031)	(0.0046)	(0.0109)

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

3.5.2 Effects of Land Use Regulations

Tables 3.5-3.8 present the estimated parameters for the land supply equation, the housing price equation, the public expenditure equation, and the property tax equation under alternative levels of land use regulations. There is evidence that self-selection occurred in the adoption of land use regulations. The coefficient of λ^j is statistically significant at the 5 % level in the equations of land supply, housing price, public expenditure, and property tax for stringent level of regulations. It is also statistically significant at the 10 % level in those equations for counties with moderate, low, and no land use regulations. These results indicate that the land use regulations do not have the same effects on non-adopters, should they choose to adopt, as it does on adopters. The parameter estimates for counties with stringent land use regulations are generally greater than for those with less stringent regulations in all four equations. This reflects the fact that under stringent land use regulations, land supply, housing prices, public expenditures, and property taxes are more sensitive to variables affecting them.

The results in table 3.5 indicate that developers are more likely to develop in counties with higher land quality, higher income, and larger population. They also develop more land in counties closer to metropolitan areas. Higher housing prices increase the supply of housing and thus land development; however, housing supply is negatively correlated with farm profit since farm profit is an opportunity cost of land development. The positive coefficients on variance of farm profit and negative coefficients on variance of new housing prices in the land supply equations indicate that developers are more likely to develop when facing high risks and uncertainties of farm profits and less likely to develop when facing high risks and uncertainties of housing prices.

Table 3.5 Parameter Estimates for the Supply Equation of Land Developmentunder Different Levels of Land Use Regulation Intensity

Variable	Stringent	Moderate	Low	None
Constant	0.193** (0.018)	0.156** (0.035)	0.103** (0.029)	0.056* (0.020)
Land quality	-0.013** (0.002)	-0.008* (0.004)	-0.007 (0.009)	-0.002 (0.031)
Farm profit	-0.216** (0.061)	-0.185** (0.043)	-0.029 (0.033)	-0.019** (0.002)
Variance of farm profit	0.014* (0.005)	0.008* (0.004)	0.006** (0.001)	0.001 (0.025)
Variance of new housing value	-0.002* (0.001)	-0.002* (0.001)	-0.001 (0.004)	-0.001* (0.001)
Income	0.012** (0.003)	0.007* (0.004)	0.002* (0.001)	0.001 (0.018)
Population	0.0005** (0.0001)	0.0006** (0.0001)	0.0004 (0.0012)	0.0002* (0.0001)
Distance to the closest metropolitan center	-0.0015* (0.0008)	-0.0011* (0.0004)	-0.0008* (0.0003)	-0.0005* (0.0002)
New housing price	0.0006** (0.0002)	0.0005* (0.0003)	0.0001 (0.0010)	0.0001 (0.0022)
λ^j	-0.128** (0.024)	-0.095** (0.013)	-0.0045** (0.0009)	-0.0029* (0.0016)
R^2	0.89	0.86	0.84	0.77

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Parameter estimates for the housing price equation are shown in table 3.6. Seven of twelve coefficients under stringent regulation are statistically significant at the 5 % level. Only two of twelve coefficients are statistically significant at the 5 % level under the no regulation. The coefficients on the distance to a metropolitan center and property taxes were not statistically significant at the 10% level under no regulation but they were statistically significant at the 5 % level under stringent regulations. This suggests that counties with stringent regulations are likely to be located near a metropolitan center where housing prices are significantly affected by both the distance to the metropolitan center and property taxes.

Housing prices tend to be higher in counties with higher land quality, higher income, larger population, and a larger variance of farm profit but tend to be lower in counties with a large variance of housing prices. Housing prices increase with the consumer price index as the prices of non-housing goods and housing prices tend to move in the same direction. Counties with higher development densities tend to have higher housing prices, but counties with higher property taxes per capita tend to have lower housing prices. Housing prices tend to be higher in counties with a large public expenditure per capita. This may reflect that counties with large public expenditures can provide better public services.

Table 3.6 Parameter Estimates for the Housing Price Equation under Different Levels of Land Use Regulation Intensity

	Stringent	Moderate	Some	None
Constant	14.365** (3.652)	13.362 (9.439)	11.226 (11.669)	14.629* (7.012)
Property tax	-0.011** (0.003)	-0.008* (0.004)	0.002 (0.017)	0.002 (0.029)
Public expenditure	0.055* (0.024)	0.041* (0.028)	0.128 (0.106)	0.194 (0.181)
Percent of developed area in previous period	0.184** (0.031)	0.173** (0.056)	0.123** (0.042)	0.106* (0.071)
Land quality	-1.846** (0.295)	-0.725** (0.078)	-0.652** (0.060)	-0.548** (0.081)
Farm profit	-0.088** (0.023)	-0.053** (0.014)	-0.049** (0.015)	-0.030 (0.051)
Income	0.065 (0.085)	0.123* (0.092)	0.104 (0.063)	0.093* (0.050)
Population	0.296** (0.070)	0.240** (0.051)	0.177* (0.048)	0.295 (0.516)
Variance of farm profit	0.023 (0.051)	0.019 (0.063)	0.022 (0.081)	0.018 (0.049)
Variance of new housing value	-0.057* (0.024)	-0.041* (0.028)	-0.052 (0.057)	-0.037* (0.015)
Distance to the closest metropolitan center	-0.020** (0.005)	-0.015 (0.016)	-0.007* (0.004)	-0.002 (0.004)
Consumer price index	1.224** (0.175)	0.843* (0.481)	0.784* (0.361)	0.448* (0.302)
λ^j	-4.409** (0.468)	-4.882** (1.193)	-2.194* (0.871)	1.944** (0.499)
R^2	0.79	0.71	0.69	0.67

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Parameter estimates for the public expenditure equations are shown in table 3.7. Overall, the model fits the data well, with a high R-square. Most variables are statistically significant at the 10 % level. Public expenditure is positively correlated with income and population. Counties with high construction costs and/or high development densities tend to have higher levels of public expenditures. As expected, the higher the property taxes, the larger the public expenditures.

Table 3.7 Parameter Estimates for the Public Expenditure Equation under Different Levels of Land Use Regulation Intensity

Variable	Stringent	Moderate	Low	None
Constant	14.529* (6.712)	20.133** (3.219)	10.190* (3.971)	8.839** (2.653)
Percent of developed area in previous period	0.0012** (0.0002)	0.0008* (0.0004)	0.0005* (0.0003)	0.0003* (0.0002)
Property tax	1.145** (0.033)	1.165** (0.031)	1.120** (0.026)	0.902** (0.180)
Land quality	-0.389** (0.105)	-0.284** (0.044)	-0.251** (0.045)	-0.106* (0.048)
Farm profit	-0.368** (0.036)	-0.254** (0.059)	-0.094** (0.031)	-0.056* (0.031)
Income	0.569** (0.177)	0.219* (0.131)	0.115* (0.055)	0.093** (0.029)
Population	0.005** (0.001)	0.003 (0.007)	0.012** (0.003)	0.008* (0.005)
Variance of farm profit	-0.309* (0.210)	-0.299* (0.128)	-0.165* (0.092)	0.060* (0.031)
Variance of new housing value	-0.583** (0.199)	-0.395** (0.031)	-0.254** (0.064)	-0.762** (0.041)
Consumer price index	0.017 (0.023)	0.025** (0.007)	0.015 (0.023)	0.011* (0.005)
Construction cost	1.407* (0.781)	1.257** (0.441)	1.109* (0.427)	1.093** (0.270)
λ^j	-0.612** (0.051)	-0.674** (0.017)	-0.324* (0.159)	-0.218* (0.115)
R^2	0.99	0.95	0.93	0.92

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Parameter estimates for the property tax equations are shown in table 3.8. The R-square and the magnitude of coefficients are consistently larger under stringent regulations than under the other degrees of regulations. The coefficients of the variables in the property tax equation have the same signs as their coefficients in the public expenditure equations except variance of farm profit reflecting the balanced budget constraint faced by county governments.

Table 3.8 Parameter Estimates for the Property Tax Equation under Different Levels of Land Use Regulation Intensity

Variable	Stringent	Moderate	Low	None
Constant	-35.921*	12.228**	10.258*	12.259**
	(17.316)	(4.190)	(5.013)	(3.710)
Percent of developed area in previous period	0.165*	0.117	0.097**	0.055
	(0.085)	(0.219)	(0.014)	(0.060)
Public expenditure	0.274**	0.195**	0.164**	0.078*
	(0.069)	(0.037)	(0.024)	(0.033)
Land quality	-1.543*	-0.761*	-0.329**	-0.106
	(0.774)	(0.365)	(0.092)	(0.108)
Farm profit	-0.024**	-0.012**	-0.007*	-0.003*
	(0.006)	(0.004)	(0.003)	(0.001)
Income	0.031	0.029*	0.016	0.007
	(0.062)	(0.014)	(0.032)	(0.036)
Population	0.120**	0.052**	0.030**	0.042**
	(0.028)	(0.014)	(0.009)	(0.010)
Variance of farm profit	0.127	0.073	0.066**	0.032**
	(0.122)	(0.114)	(0.016)	(0.008)
Variance of new housing value	-0.199**	-0.078*	-0.021	-0.010
	(0.038)	(0.042)	(0.013)	(0.024)
Consumer price index	0.082**	0.090**	0.051*	0.025*
	(0.025)	(0.014)	(0.027)	(0.010)
Construction cost	0.259	0.195	0.060**	0.071*
	(0.368)	(0.171)	(0.014)	(0.035)
λ^j	-7.620**	-2.914*	-0.162*	-0.073**
	(0.776)	(1.198)	(0.182)	(0.017)
R^2	0.90	0.81	0.79	0.73

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Equations (30) and (31) can be used to further explore how the intensity of land use regulations affects land development, housing prices, public expenditures, and property taxes. The short-run effects for the period 1982-1987 and long-run effects for period 1982-1992 are shown in Tables 3.9 and 3.10, respectively.

Table 3.9 The Estimated Short-Run Effects of Land Use Regulation Intensity on Land Development, Housing Price, Public Expenditure, and Property Tax between 1982 and 1987

Regulation intensity	Percent of total land developed	Housing price ($/unit/year)	Public expenditure ($/capita/year)	Property tax ($/capita/year)
Stringent	-0.23^{**} (0.09)	$5{,}512^{**}$ (124.2)	92^{*} (33.5)	29^{**} (8.9)
Moderate	-0.16^{*} (0.05)	$2{,}391^{**}$ (196.4)	51^{**} (8.4)	12^{*} (3.7)
Low	-0.09 (0.20)	701^{**} (116.3)	26 (41.9)	7 (15.6)

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

Table 3.10 The Estimated Long-Run Effects of Land Use Regulation Intensity on Land Development, Housing Price, Public Expenditure, and Property Tax between 1982 and 1992

Regulation intensity	Percent of total land developed	Housing price ($/unit)	Public expenditure ($/capita/year)	Property tax ($/capita/year)
Stringent	-0.29^{*} (0.11)	$5{,}741^{**}$ (188.9)	-49 (41.0)	-16^{*} (9.5)
Moderate	-0.22 (0.18)	$3{,}013^{**}$ (290.1)	-31^{*} (16.1)	-13^{**} (2.1)
Low	-0.13 (0.14)	1,319 (1,910)	22 (54.1)	2 (10.8)

Note: The numbers in parenthesis are standard errors; * indicates statistical significance at the 10 % level; ** indicates statistical significance at the 5 % level.

The effects of land use regulations increase with the degree of regulation. In counties with "stringent" land use regulations, the percent of developed area is reduced by 0.29 % in the five western states in the long-run. This means that for a county with 100 square miles, stringent regulations reduce the developed area by 0.29 square miles. The total land area in all counties with stringent regulations in the five western states is 85,560,500 acres. By 1992, 2,909,100 acres, or 3.4 % were developed. If land use regulations had not been imposed in those counties, 3.79 % of total land area would have been developed. Thus, regulations in those counties save 248,100 acres of land from development, which is 8.5 % of developed area in 1992.

In counties with "moderate" regulations, the percent of developed area is reduced by 0.22 % in the five western states in the long run. The total land area in all counties with moderate regulations in the five western states is 113,183,300 acres. By 1992, 2,829,600 acres, or 2.5 % were developed. If land use regulations had not been imposed in those counties, 2.72 % of total land area would have been developed. Thus, regulations in those counties saved 249,000 acres of land from development, which is 8.8 % of developed area in 1992. Similarly in counties with "low" regulations, the percent of developed area is reduced by 0.13 %. The total land area in all counties with some regulations in the five western states is 89,026,500 acres. By 1992, 1,826,800 acres, or 1.7 % were developed. If land use regulations had not been imposed in those counties, 1.83 % of total land area would have been developed. Thus, regulations in those counties saved 115,700 acres of land from development, which is 6.3 % of developed area in 1992.

All land use regulations in the five western states saved an estimated total of 458,000 acres (6.6 % of developed area in 1992) in the short-run and 612,800 acres (8.8 % of developed area in 1992) in the long-run. However, in counties with the most stringent land use regulations, the average new housing price increased by $5,741 per unit in the long-run. The average new housing price was $146,000 in 1982, thus the stringent land use regulations increased new housing prices by 3.9 % compared to no land use regulations.

Under stringent regulations, public expenditures increased by the largest amount ($92 per capita) in the short-run. The average public expenditures were $1,320 per capita in 1982, thus the stringent regulations increased public expenditure by 7.0 % in the short-run. However, in the long-run, land use regulations reduced public expenditure by $49 per capita under stringent regulations, a 3.7 % decrease compared to no regulations. Property taxes also increased by the largest amount ($29 per capita) under the stringent regulation in the short-run. However, in the long-run, land use regulations reduced property tax by $16 per capita under stringent regulation.

The different short-run vs. long-run effects on public expenditures and property taxes suggest that in the short-run, county governments raise property taxes to cover the increased public expenditures needed to develop and implement land use regulations, whereas, in the long-run land use regulations reduce public expenditures and property taxes by reducing the extent of developed areas. In summary, in the long-run land use regulation reduced the amount of land developed, long-run public expenditures, and property taxes; however, not without higher long-run housing prices, and short-run increases in public expenditures and property taxes.

3.6 Conclusions

Measuring effects of land use regulations is becoming increasingly important as more communities exercise land use regulations. Previous studies on land use regulations have focused on a single land use regulation, treating all others as given and exogenously determined. They also have neglected interactions among residential development, land use regulations, and public finance (public expenditures and property taxes). In this study a simultaneous equations system with self-selection and discrete dependent variables is used to estimate adoption decisions of land use regulations and their impacts on land use, public expenditures, and property taxes.

The method is applied to land use regulation decisions in five western states using data from a comprehensive survey on land use regulations, the 1982, 1987, and 1992 National Resources Inventories, and other USDA publications. The results indicate that conversion of farmland and open space to development along with high public expenditures and property taxes promote county governments to impose more stringent land use regulations. More stringent land use regulations, in turn, reduce land development, long-run public expenditures, and property taxes; however, not without higher long-run housing prices and short-run increases in public expenditures and property taxes. The results also show that land use regulations, land development, public expenditures, and property taxes all are significantly affected by population, geographic location, land quality, housing rents, and risks and costs of development.

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CHAPTER 4

ENVIRONMENTAL AMENITIES AND COMMUNITY CHARACTERISTICS: AN EMPIRICAL STUDY OF PORTLAND, OREGON

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4.1 Introduction

Nearly four of five Americans live within 273 metropolitan regions. These regions include a central city of at least fifty thousand people, suburbs around the central city, suburbs that have grown into "edge cities," and a fringe of countryside (Daniels 1999). In 1993, the United States Office of Budget and Management classified more than one-quarter of the nation's 3,041 counties as belonging to metropolitan areas (Daniels, 1999). The Census Bureau estimates that America will add 34 million people between 1996 and the year 2010. Most of this growth will occur in metropolitan areas. As population and economic growth pressures push outward from the suburbs, the challenge of managing land use in the metropolitan area becomes more important and complex. Management of land use means striking a balance between economy and population needs on one hand and land development and environmental quality on the other. Understanding households' residential choices in a system of local jurisdictions is necessary for designing efficient growth management strategies for metropolitan areas.

This paper examines households' residential choices and the resulting characteristics of communities using the framework developed by Epple and Sieg (1999). Specifically, the objectives of this paper are two folds. First, the robustness of the relatively new method for estimating spatial equilibrium models developed by Epple and Sieg (1999) is tested using data from the Portland Oregon metropolitan area. Second, the framework is extended by including environmental goods in the estimation. To achieve these two objectives, we first estimate the key part of the spatial equilibrium model and then use the model to predict the distribution of households by income across communities. We test the robustness of the equilibrium model by comparing the predicted distribution with the observed one. We also examine the consequence of ignoring the environmental amenities in the estimation of equilibrium models of local jurisdictions, as did in Epple and Sieg (1999).

A proper empirical analysis of public-good provision in spatial equilibrium requires a complete specification of community choice (Rubinfeld, Shapiro, and Roberts, 1987). This paper provides an integrated approach by drawing inferences from a structural general equilibrium model. The incorporation of environmental goods in the model captures households' preferences for environmental amenities. Although much research has focused on valuing environmental amenities indirectly from property values (e.g., hedonic property price model), few studies have measured the households' preferences for environmental amenities directly.

In the next section, a brief review of relevant literature is provided. Equilibrium conditions of household distribution over local jurisdictions are derived in section 4.3. The equilibrium conditions are parameterized and empirically estimated in two stages in section 4.4. The first stage estimates the parameters that determine the income distribution across local jurisdictions. The second stage estimates parameters characterizing households' preferences for public goods and environmental amenities. The estimated parameters with and without the inclusion of environmental amenities are compared and discussed. Households' preferences for environmental amenities and public goods are measured. Amenity measures include distance to a major river, proportion of open space and parks, proportion of wetland, proportion of rural land, and elevation. Data used in the empirical estimations is discussed in section 4.5. The empirical results are reported and discussed in section 4.6. Conclusions are drawn in section 4.7.

4.2 Literature Review

Since the publication of the theoretical model of local finance by Tiebout (1956), it has served as the point of departure for a now lengthy series of theoretical and empirical investigations into local fiscal behavior, particularly in metropolitan areas. The central idea of the Tiebout hypothesis implies the decentralized provision of public services for economic efficiency.

The Tiebout mechanism is used to develop and to test the theory of zoning. Epple and Romer (1989) argued that even in a system with many jurisdictions, flexibility of boundaries is a key factor determining how land rents get allocated within and across communities by the Tiebout mechanism. Wheaton (1993) examined land capitalization, Tiebout mobility, and the role of zoning regulations. Pogodzinski and Sass (1994) investigated how jurisdictions compete through their choice of tax-expenditure packages and zoning regulations via the Tiebout mechanism.

The Tiebout hypothesis is also used to analyze whether property taxes and public spending affect property values. Oates (1969) estimated the effects of property taxes and local public spending on housing prices. Fisch (1977) used a spatial equilibrium model with local public goods to analyze urban rent, optimal city size, and the Tiebout hypothesis. Gyourko and Tracy (1986) examined the political economy of capitalization in a Tiebout model when there is a rent-seeking public bureaucracy. Mieszkowski and Zodrow (1989) examined the differential effects of head taxes, taxes on land rents, and property taxes on land prices and housing prices or rents in a Tiebout model.

More recently, a number of studies have investigated the existence and properties of equilibrium in a system of local jurisdictions (e.g., Ellickson 1971; Westhoff 1977; Epple, Filimon, and Romer 1984, 1993). Other related research focuses on the estimation of demand functions for local public goods. Bergstrom and Goodman (1973) developed a method for estimating demand functions for municipal public services. This included both traditional price and income variables and demographic characters in the demand functions. However, they ignored the effects of migrations, which are subject to a self-selection bias or Tiebout bias. Rubinfeld, Shapiro, and Roberts (1987) controlled the Tiebout bias by adding a selection function. However, their empirical analysis was done without theoretical specifications.

4.3 A Review of the Framework of Local Jurisdictions

This section describes the general framework of local jurisdictions developed in several previous studies including Epple, Fillimon and Romer (1984), Epple and Romer (1991) and Wu (2001). Suppose there are J communities with fixed boundaries and homogenous land in a metropolitan area. Each community offers a public good, g, which may be thought of as a composite function of locally provided public goods and environmental amenities. Each household maximizes a utility function subject to its budget constraint:

$$\underset{h,b}{Max}\,U(\alpha,g,h,x) \qquad (1)$$

s.t. $ph = y - x$

where α = taste parameter
h = housing good
x = composite private good
y = household income.

The optimization of equation (1) can be solved to derive an indirect utility function, assuming there are no regulatory constraints on housing choices. The indirect utility function of a household is

$$V(\alpha,g,p,y) = U(\alpha,g,h(p,y,\alpha),y - ph(p,y,g,\alpha)). \qquad (2)$$

The tradeoff between the housing price, p and the public good, g for the household is decided by applying the implicit function theorem to equation (2):

$$\left.\frac{dp}{dg}\right|_{v=\bar{v}} = -\frac{\partial V(\alpha,g,p,y)/\partial g}{\partial V(\alpha,g,p,y)/\partial p}. \qquad (3)$$

A key assumption that affects the equation of local jurisdiction concerns how the tradeoff changes as income changes. Epple and Sieg (1999) assume that the tradeoff is monotonically increasing in α and y everywhere. This assumption implies three necessary conditions for intercommunity equilibrium (Epple and Sieg 1999): (1) Boundary indifference: Households are indifferent on the boundary between two neighboring communities. This condition is expressed as

$$I_j = \{(\alpha,y)|V(\alpha,g_j,p_j,y) = V(\alpha,g_{j+1},p_{j+1},y)\}, j = 1,\ldots,J-1. \qquad (4)$$

(2) Stratification: For each α, the households of community j with income y is given by

$$y_{j-1}(\alpha) < y < y_j(\alpha). \qquad (5)$$

(3) Increasing bundles: For two communities i and j with $p_i > p_j$, then $g_i > g_j$ if and only if $y_i(\alpha) > y_j(\alpha)$. Note that the utility function is separable in the public and private goods. This assumption can be relaxed by substituting B with a function of g. The assumption is maintained since the relaxation of the assumption would complicate the second stage estimation.

4.4. Estimation of the Equilibrium Model

The framework is parameterized for empirical estimation. Following Epple and Sieg (1999), the indirect utility function is assumed to take the form:

$$V(\alpha, y, g_j, p_j) = \{\alpha g_j^{\rho} + [e^{\frac{y^{1-\nu}-1}{1-\nu}} e^{-\frac{Bp_j^{\eta+1}-1}{1+\eta}}]^{\rho}\}^{\frac{1}{\rho}}, \tag{6}$$

The boundary indifference condition for community j and $j+1$ can be written as

$$\ln(\alpha) - \rho(\frac{y^{1-\nu}}{1-\nu}) = K_j, \tag{7}$$

where $K_0 = -\infty$,

$$K_j = \ln(\frac{Q_{j+1} - Q_j}{g_j^{\rho} - g_{j+1}^{\rho}}), \; j = 1, \ldots, J-1, \tag{8}$$

$K_J = \infty$,

where $Q_j = e^{[-\frac{\rho}{1+\eta}(Bp_j^{\eta+1}-1)]}$,

The distribution of households across communities are illustrated in figure 4.1. The populations in community j can be obtained by integrating between the lines that go through K_{j-1} and K_j:

$$P(C_j) = \int_{-\infty}^{\infty} \int_{K_{j-1}+\rho[(y^{1-\nu}-1)/(1-\nu)]}^{K_j+\rho[(y^{1-\nu}-1)/(1-\nu)]} f(\ln(\alpha), \ln(y)) d\ln(\alpha) d\ln(y), \tag{9}$$

where $f(\ln(\alpha),\ln(y))$ is the joint distribution form of $\ln(\alpha)$ and $\ln(y)$ and it is assumed to be bivariate normally distributed. The equation above is solved recursively to obtain the community-specific intercepts as a function of $(\mu_y,\mu_\alpha,\lambda,\sigma_y,\sigma_\alpha,\rho,\nu)$ and community sizes. The q th quantile of the income distribution in community j, $\zeta_j(q)$, is implicitly defined by

$$\int_{-\infty}^{\ln[\zeta_j(q)]}\int_{K_{j-1}+\rho[(y^{1-\nu}-1)/(1-\nu)]}^{K_j+\rho[(y^{1-\nu}-1)/(1-\nu)]} f(\ln(\alpha),\ln(y))d\ln(\alpha)d\ln(y) = qP(C_j). \quad (10)$$

The parameters are estimated in a two-stage procedure. The first stage estimation is to match observed income distributions in communities with those predicted by the framework. This step determines parameters of income distribution, $\mu_{\ln(y)}$ and $\sigma_{\ln(y)}$; the correlation between income and tastes, λ; the ratio of $\rho/\sigma_{\ln(\alpha)}$; and the income elasticity of housing, ν. It also verifies the reliability of the framework. The second stage estimates structural parameters, ρ and η; parameters of taste distribution, $\mu_{\ln(\alpha)}$ and $\sigma_{\ln(\alpha)}$; a parameter that characterizes households' preference for different public goods and environmental attributes. The vectors of observed characteristics of community, γ, include parameters of public attributes (education expenditure, γ_1 and crime rate, γ_2) and parameters of environmental amenities (distance to a major river, γ_3, proportion of open space and parks, γ_4, proportion of wetland, γ_5, proportion of rural land, γ_6, and elevation, γ_7).

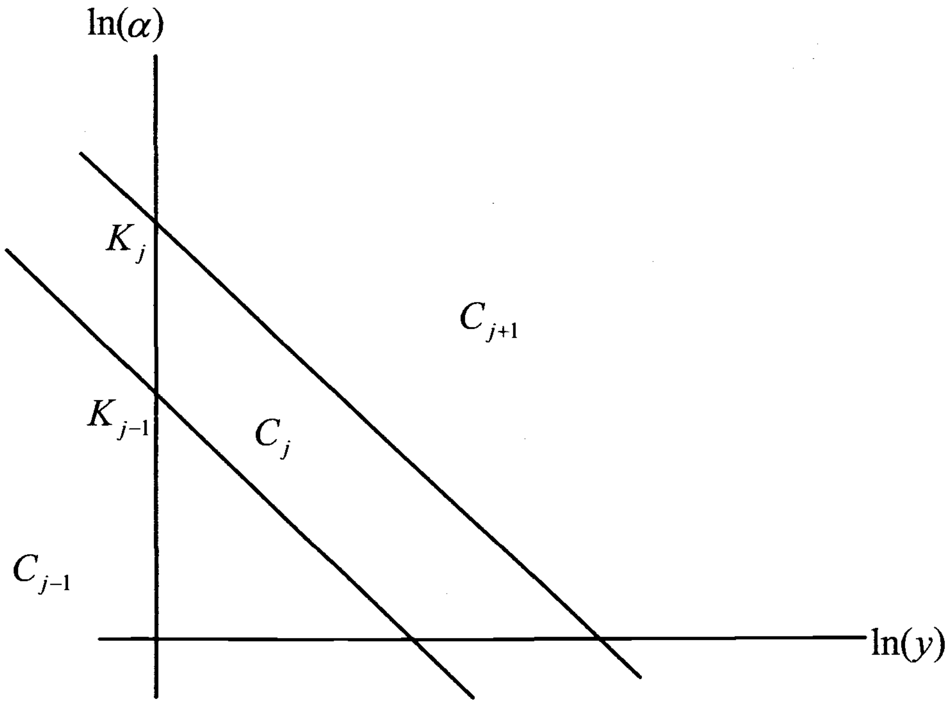

Figure 4.1 Distribution of Households across Communities

4.4.1 The First-Stage Estimation

The parameters of the model characterize the distribution of households across communities and the income distribution within each community. It is known that

$$f(\ln(\alpha),\ln(y)) = f(\ln(y))f(\ln(\alpha)\mid \ln(y)), \tag{11}$$

where $\ln(y) \sim N(\mu_{\ln(y)}, \sigma^2_{\ln(y)})$,

$\ln(\alpha \mid \ln(y) \sim N(\mu_{\ln(\alpha)|\ln(y)}, \sigma^2_{\ln(\alpha)|\ln(y)})$,

where $\mu_{\ln(\alpha)|\ln(y)} = \mu_{\ln(\alpha)} + \lambda\sigma_{\ln(\alpha)} \dfrac{\ln(y) - \mu_{\ln(y)}}{\sigma_{\ln(y)}}$,

$\sigma_{\ln(\alpha)|\ln(y)} = \sqrt{1-\lambda^2}\,\sigma_{\ln(\alpha)}$.

The equation can be rewritten as

$$\int_{-\infty}^{\ln[\zeta_j(\rho)]} f(\ln(y))\{\int_{K_{j-1}+\rho[(y^{1-\nu}-1)/(1-\nu)]}^{K_j+\rho[(y^{1-\nu}-1)/(1-\nu)]} f(\ln(\alpha)\mid \ln(y))d\ln(\alpha)\}d\ln(y) = pP(C_j). \quad (12)$$

Let $\xi = \dfrac{\ln(\alpha)-\mu_{\ln(\alpha)|\ln(y)}}{\sigma_{\ln(\alpha)|\ln(y)}}$, then the following equality holds

$$\int_{-\infty}^{\ln[\zeta_j(\rho)]} f(\ln(y))[\int_{Z_{j-1}(y)}^{Z_j(y)} \phi(\xi)d\xi]d\ln(y) = pP(C_j) \quad (13)$$

$$\text{where } Z_j(y) = \Omega_j + \omega_1 \frac{y^{1-\nu}-1}{1-\nu} + \varpi_2 \ln(y) \quad (14)$$

$$\text{where } \Omega_j = \frac{K_j - \mu_{\ln(\alpha)} + [\lambda\sigma_{\ln(\alpha)}\mu_{\ln(y)} / \sigma_{\ln(y)}}{\sqrt{1-\lambda^2}\sigma_{\ln(\alpha)}} \quad (15)$$

$$\text{where } \varpi_1 = \frac{\rho}{\sqrt{1-\lambda^2}\sigma_{\ln(\alpha)}}, \ \varpi_2 = \frac{-\lambda}{\sqrt{1-\lambda^2}\sigma_{\ln(y)}}.$$

To solve equation (12), a Monte Carlo integration technique is used because integration of the inner integral of equation (12) is not feasible. The Monte Carlo integration is done in the following procedure.

Let $\int_{Z_{j-1}(y)}^{Z_{j(y)}} \phi(\xi)d\xi = g(\ln(y))$, then the equation (13) can be rewritten as

$$\int_{-\infty}^{\ln[\zeta_j(p)]} f(\ln(y)g(\ln(y))d\ln(y) = pP(C_j) \quad (16)$$

To normalize the weighting function, we assume that

$$G = \int_{-\infty}^{\ln[\zeta_j(p)]} g(\ln(y))d\ln(y) \quad (17)$$

is a known constant. Then $h(\ln(y)) = g(\ln(y))/G$ is a probability density function in the range of $[-\infty, \ln[\zeta_j(p)]$ because it satisfies the axiom of probability. Let

$$H(\ln(y)) = \int_{-\infty}^{\ln(y))} h(t)dt, \quad (18)$$

then

$$\int_{-\infty}^{\ln[\zeta_j(p)]} f(\ln(y))g(\ln(y))d\ln(y) = G\int_{-\infty}^{\ln[\zeta_j(p)]} f(\ln(y))\frac{g(\ln(y))}{G} = GE_{h(\ln(y))}[f(\ln(y))]. \quad (19)$$

The equation (16) can be rewritten as

$$GE_{h(\ln(y))}[f(\ln(y))] = pP(C_j) \quad (20)$$

where $E_{h(\ln(y))}[f(\ln(y))]$ denotes the expected value of the function, $f(\ln(y))$ when $\ln(y)$ is drawn from the population with probability density function $h(\ln(y))$. A subset of the parameters of the equation (20) can then be estimated using a Minimum Distance Estimator. The optimization procedure to evaluate the model relies on a numerical simulation technique. An advantage of this estimator is that data on housing price and public good provision is not needed and only an income distribution function is necessary to implement the estimation. The rest of the structural parameters are identified at the second stage.

4.4.2 The Second Stage Estimation

The remaining structural parameters are estimated using data on locally provided public goods and environmental amenities. Following the empirical literature on differentiated products in industrial organizations and Epple and Sieg (1999), we assume the level of public good supply can be expressed as an index that consists of locally provided public goods (e.g., school quality and crime rates) and environmental amenities (e.g., elevation, proportion of land in open space):

$$g_j = x_j^{'}\gamma + \varepsilon_j . \tag{21}$$

where x_j = observed characteristics of community j
γ = parameter vectors to be estimated
ε_j = error terms

If we solve the equation (8) for the g_j's, the following recursive representation for g_j is obtained:

$$g_{j+1}^{\rho} = g_j^{\rho} - (Q_{j+1} - Q_j)e^{-K_j} \tag{22}$$

where Q_j is a monotonic function of p_j and K_j can be estimated as shown in the previous section. The equation can be rewritten as

$$g_j = [g_1^{\rho} - \sum_{i=2}^{j}(Q_i - Q_{i-1})e^{-K_i}]^{1/\rho} . \tag{23}$$

If we substitute (23) into equation (21)

$$\varepsilon_j = x_j^{'}\gamma - [g_1^{\rho} - \sum_{i=2}^{j}(Q_i - Q_{i-1})e^{-K_i}]^{1/\rho} \tag{24}$$

where $Q_i = e^{-\rho\frac{Bp_i^{\eta+1}-1}{1+\eta}}$.

Using equation (15), the following equation is derived.

$$K_j = \beta_1 + \beta_2\Omega_j , \tag{25}$$

where $\beta_1 = \mu_{\ln(\alpha)} - \dfrac{\lambda\sigma_{\ln(\alpha)}\mu_{\ln(y)}}{\sigma_{\ln(y)}}$ and $\beta_2 = \sqrt{1-\lambda^2}\sigma_{\ln(\alpha)}$.

If we substitute equation (25) into (24), we can derive the following nonlinear regression model.

$$\varepsilon_j = x_j^{'}\gamma - [g_1^{\rho} - \sum_{i=2}^{j}(Q_i - Q_{i-1})e^{-\beta_1-\beta_2\Omega_{j_i}}]^{1/\rho} \tag{26}$$

Using the data of price, p_j and characteristics, x_j in addition to the parameters estimated in the first stage $(\mu_{\ln(y)}, \sigma_{\ln(y)}, \nu, \lambda)$ and the reduced-form parameter, Ω_j, the parameters $(\rho, \eta, B, \gamma, \beta_1, \beta_2)$ are identified in the above nonlinear regression equation (26). The structural parameters $(\mu_{\ln(\alpha)}, \sigma_{\ln(\alpha)})$ can be estimated by

$$\sigma_{\ln(\alpha)} = \frac{\beta_2}{\sqrt{1-\lambda^2}} \text{ and } \mu_{\ln(\alpha)} = \beta_1 - \frac{\lambda \sigma_{\ln(\alpha)} \mu_{\ln(y)}}{\sigma_{\ln(y)}}. \quad (27)$$

This completes the identification of all parameters.

4.5 Data

The empirical study focuses on the metropolitan area of Portland, Oregon. The Portland metropolitan area includes three counties, 44 cities, and 48 townships[3] within Tri-Met (Tri-County Metropolitan Transportation District of Oregon)'s political boundaries. The 92 communities (44 cities and 48 townships) differ in terms of size and socioeconomic characteristics. The city of Portland is the largest community with 218,700 households and the smallest community is a township with 39 households. The poorest community is a township with a median household income of $18,730 and the richest community is the city of Durham with a median household income of $58,152. Household income and education expenditure per household are taken from the 1997 U.S. Census. A GIS database from Metro Data Resource Center in Portland, Oregon is used to calculate the average housing price in each community. The database is also used to estimate measures of environmental amenities in each community, including distance to a major river, proportion of open space and parks,

[3] There are no official townships in Oregon. The townships are defined by the public land survey.

community, including distance to a major river, proportion of open space and parks, proportion of wetlands, proportion of rural lands, and elevation. All distances are measured from the center of communities using the Geographical Information System (GIS), Arc View. The center of communities is defined as where the city hall is located. The average elevation of each community is calculated as the average of elevations at each residential site in the community. Data on crime rates is obtained from CAP index Inc., one of the crime risk assessment data. A risk is rated by Crime Against Persons and Property (CAP) index, with 1 being the least risk of violent crime and 10 being the most risk of violent crime of each community.

Figure 4.2 shows the housing price of each community. The housing price and median household income is strongly correlated, with a correlation coefficient of 0.89. Public good provision is multidimensional. For lack of better data, we use crime rates and education expenditure per household as indicators of public good provision. The education expenditure per household does not wholly represent the quality of education. A more objective school quality index would include average test scores and other relevant factors. But the data is not available for the Portland metropolitan area at this point. However, a previous study of Boston metropolitan area showed that education expenditure is a fairly good approximate measure of education quality (Epple and Sieg, 1999). Figure 4.3 reports the education expenditures by community (arranged by ascending order of the median household income). There is a strong correlation between median household income and education expenditures (0.80).

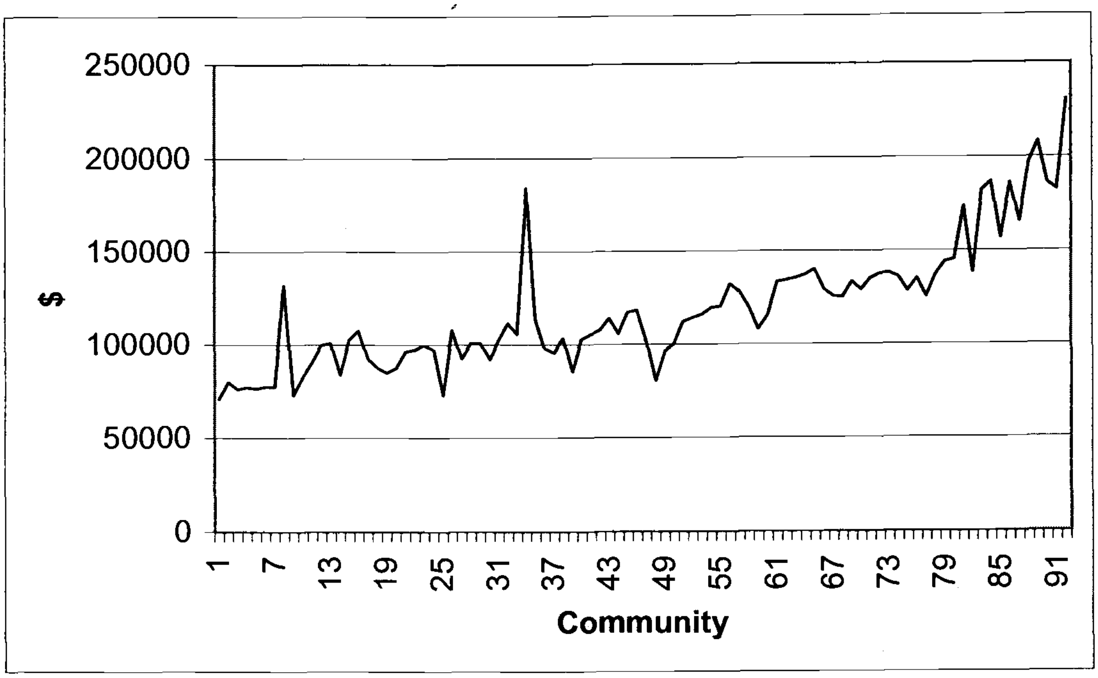

Figure 4.2 Housing Price

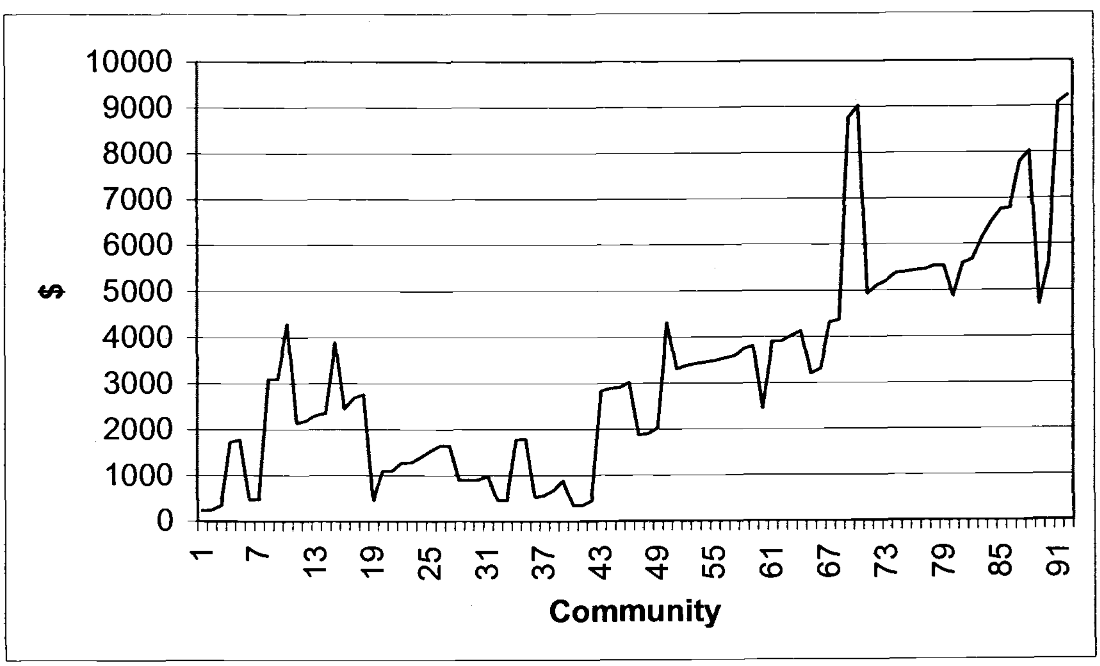

Figure 4.3 Education Expenditure

Figure 4.4 shows the crime rate by community (arranged by ascending order of the median household income). The correlation between median household income and crime rate is –0.62, which is expected because communities with higher income tend to have lower crime rates.

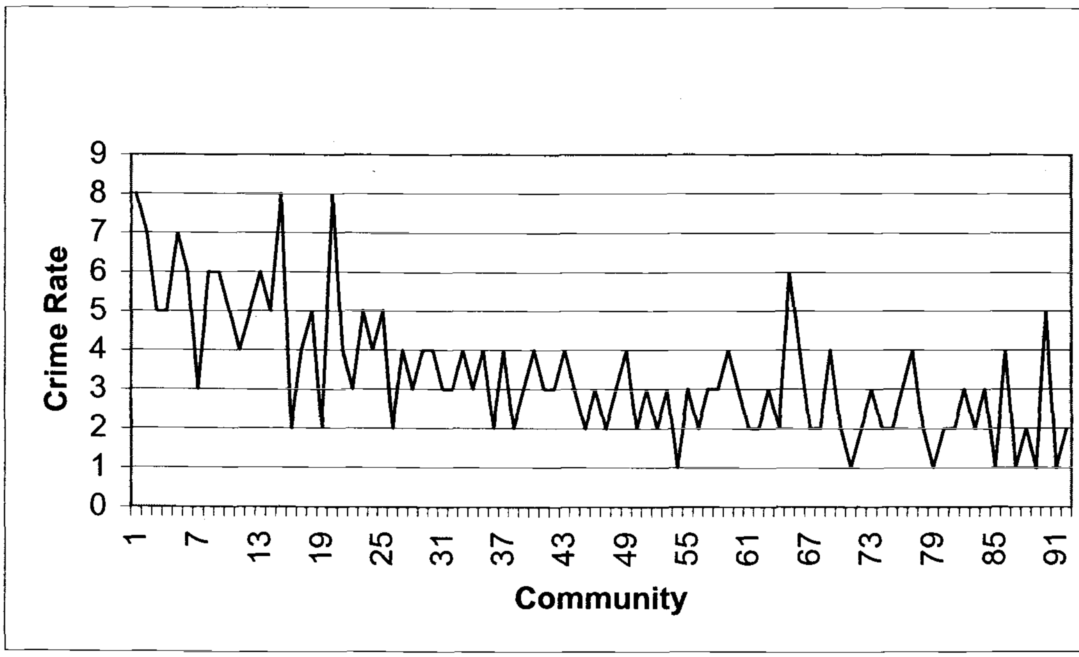

Figure 4.4 Crime Rate

The following variables are used for measuring environmental amenities: the distance between the community center and a major river, proportion of open space and parks, proportion of wetlands, proportion of rural lands, and elevation. The distance from a major river is used to represent possible recreational accessibilities or visual amenities associated with rivers. Figure 4.5 reports the distance from a major river by each community. The correlation between median household income and distance to a major river is –0.38. This reflects the fact that richer households tend to locate closer to a major river.

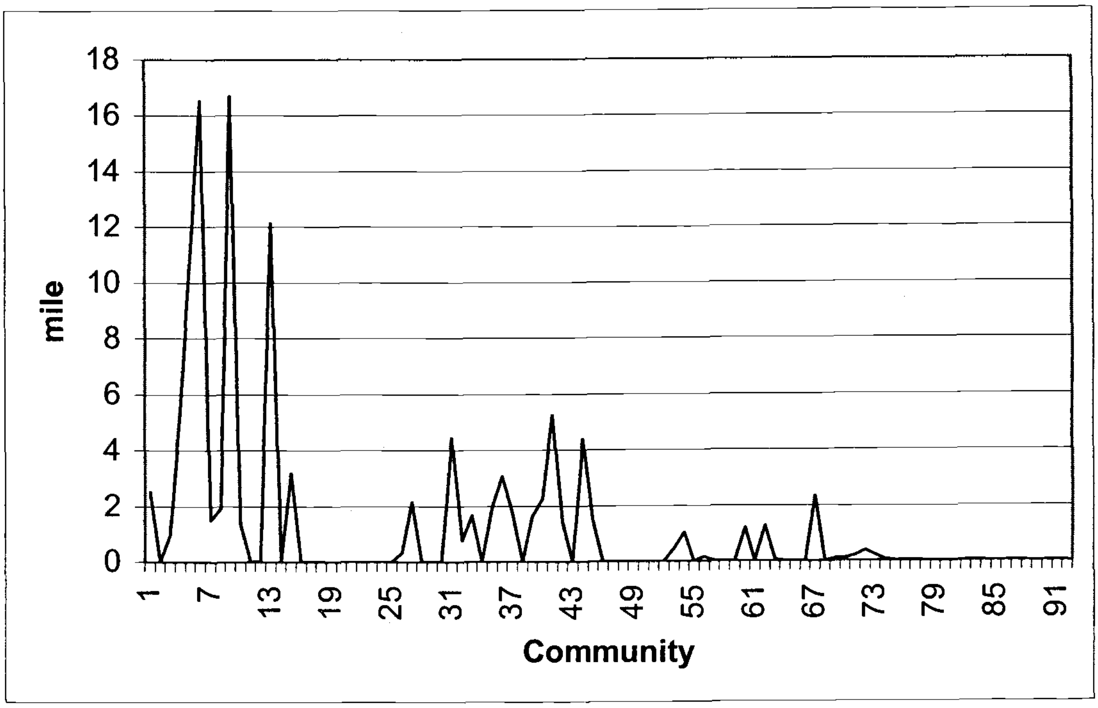

Figure 4.5 Distance to a Major River

Figure 4.6 reports the proportion of land that is on open space and parks in each community. The correlation between median household income and the proportion of open space and parks is 0.37, implying that high-income households tend to locate in communities with more open space and park area.

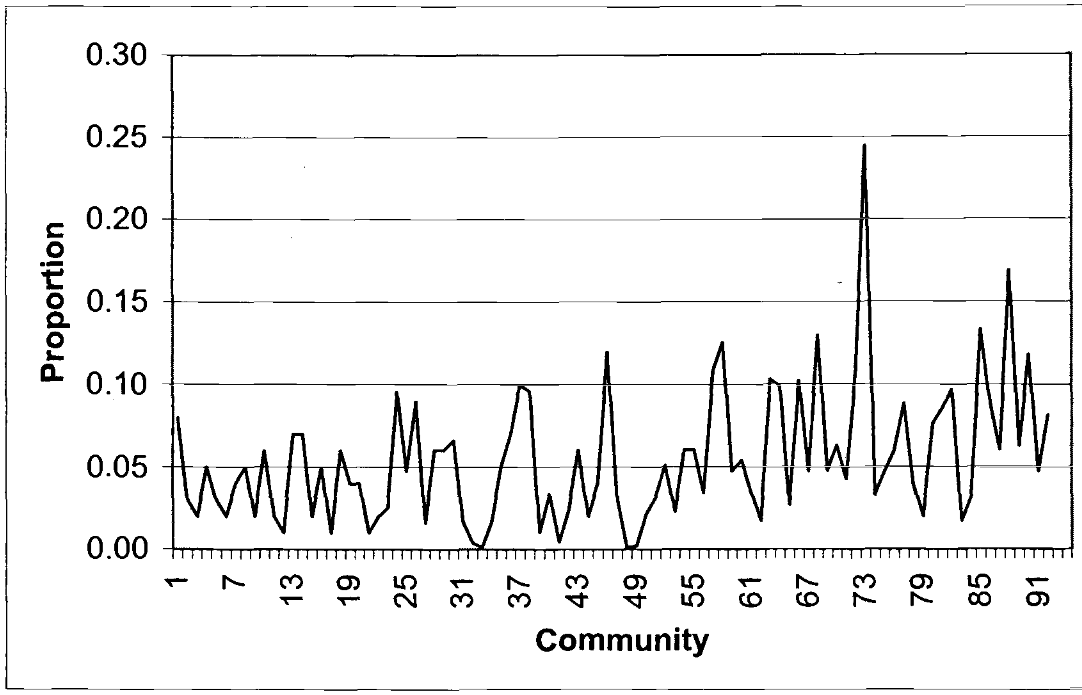

Figure 4.6 Proportion of Open Space and Park

Figure 4.7 reports the proportion of wetlands in each community. The correlation between the proportion of wetland and median household income is 0.13. The correlation shows that high-income households have a positive preference for wetland areas, but the preference is not as strong as the preference for open space and parks.

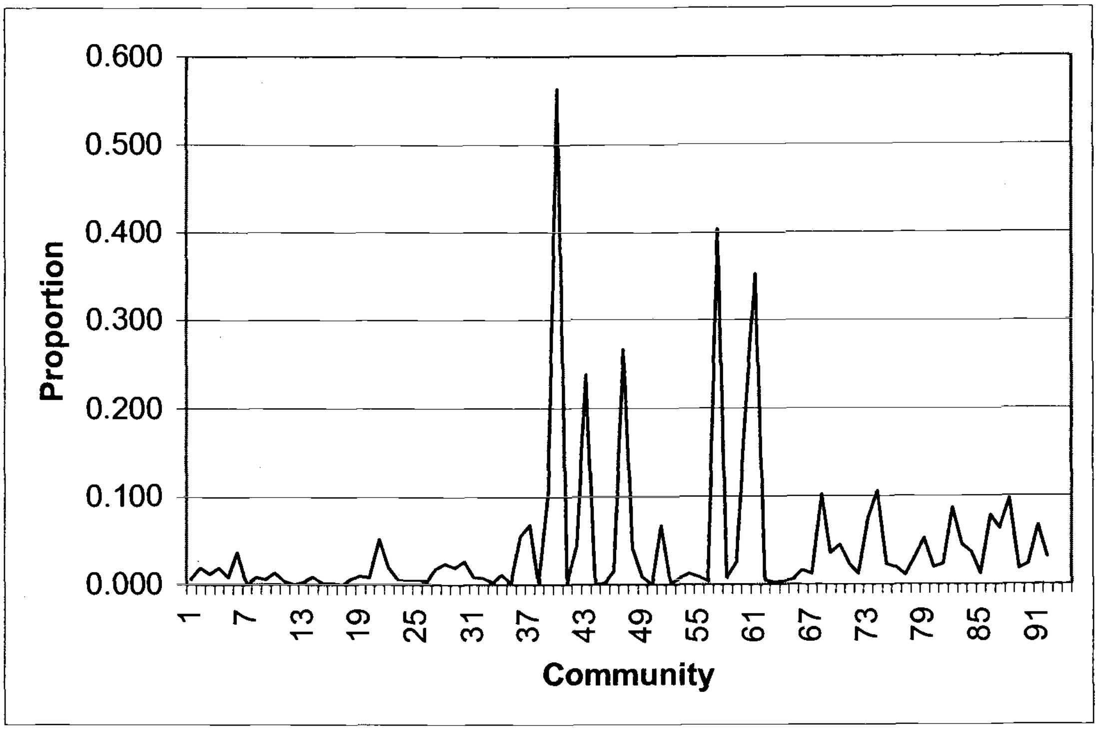

Figure 4.7 Proportion of Wetland

Figure 4.8 reports the proportion of rural land in each community. There is a negative correlation, -0.10, between income and proportion of a community, implying high-income households are more likely to be located in community with less rural land. Figure 4.9 reports the elevation of each community. There is a positive correlation, 0.30, between income and elevation, implying that high-income households are more likely to be located in the hills surrounding Portland. Households prefer housing with good views, and elevation is critical to generate good views in most places. The summary of variables is shown in table 4.1.

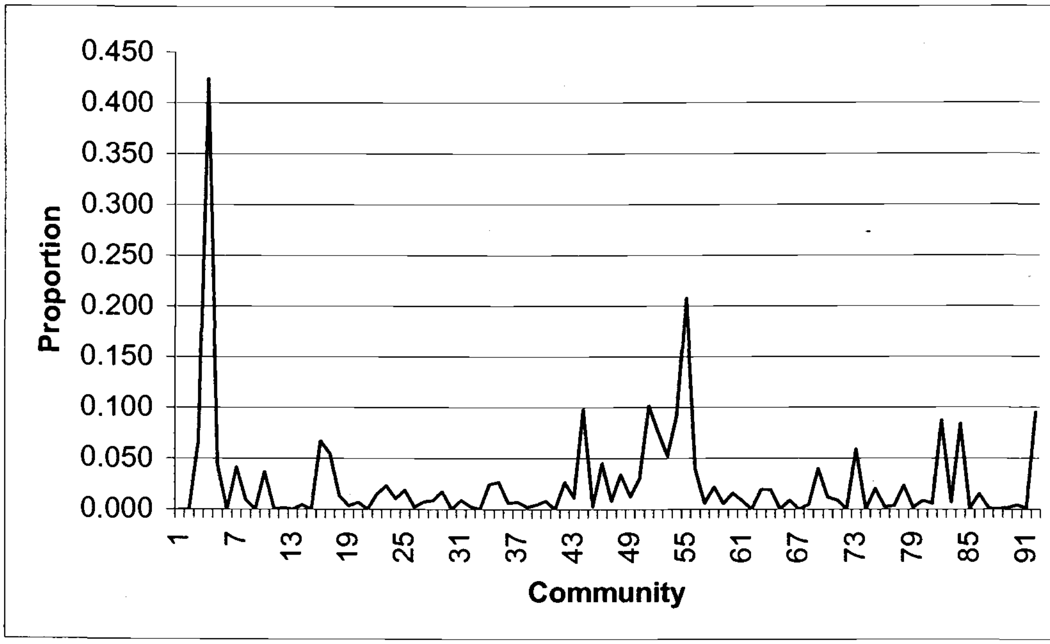

Figure 4.8 Proportion of Rural Land

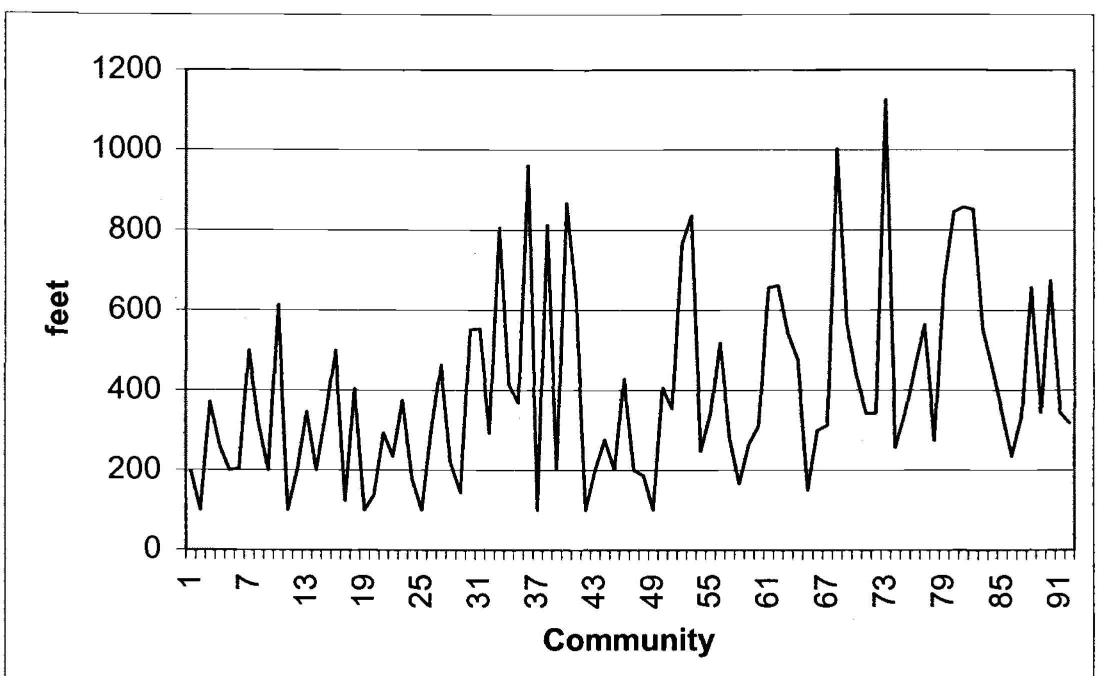

Figure 4.9 Elevation

Table 4.1 Summary of Variables

Variables	Mean (Standard deviation)
Population	9,312 (13033)
Median household income ($)	35,358 (8634)
Housing price ($)	118,820 (33,284)
Education expenditure per household ($)	3,255 (2,289)
Crime rate	3.38 (1.64)
Distance to major river or lake (mile)	1.24 (3.06)
Proportion of open space and park area (%)	5.52 (4.73)
Proportion of wetland (%)	4.68 (8.94)
Proportion of rural area (%)	2.61 (5.31)
Elevation (feet)	399 (237)

4.6 Empirical Results

4.6.1 First Stage Estimates

The structural parameters of the spatial equilibrium model of local jurisdictions are estimated using a two-stage procedure. The first stage estimates the parameters of the income distribution ($\mu_{\ln(y)}$ and $\sigma_{\ln(y)}$), the correlation between income and tastes, λ, the ratio of $\rho / \sigma_{\ln(\alpha)}$, and the income elasticity of housing, ν (see table 4.2).

Table 4.2 Estimated Parameters of Stage 1

Parameters	Estimates
$\mu_{\ln(y)}$	10.125 (0.061)
$\sigma_{\ln(y)}$	0.435 (0.012)
λ	-0.0135 (0.007)
$\rho / \sigma_{\ln(\alpha)}$	-0.170 (0.039)
ν	0.925 (0.039)
Function of value	0.046
Degree of freedom	86

The values in the parentheses are standard errors.

Over all, the five parameters estimated in the first stage have reasonable magnitudes with small standard errors. The reported standard errors include numerical errors caused by Monte Carlo integration and inversion of the function. Specifically, the point estimators of $\mu_{\ln(y)}$ and $\sigma_{\ln(y)}$ are highly significant. The figure 4.10 shows the predicted and observed median income for each community in the Portland metropolitan area.

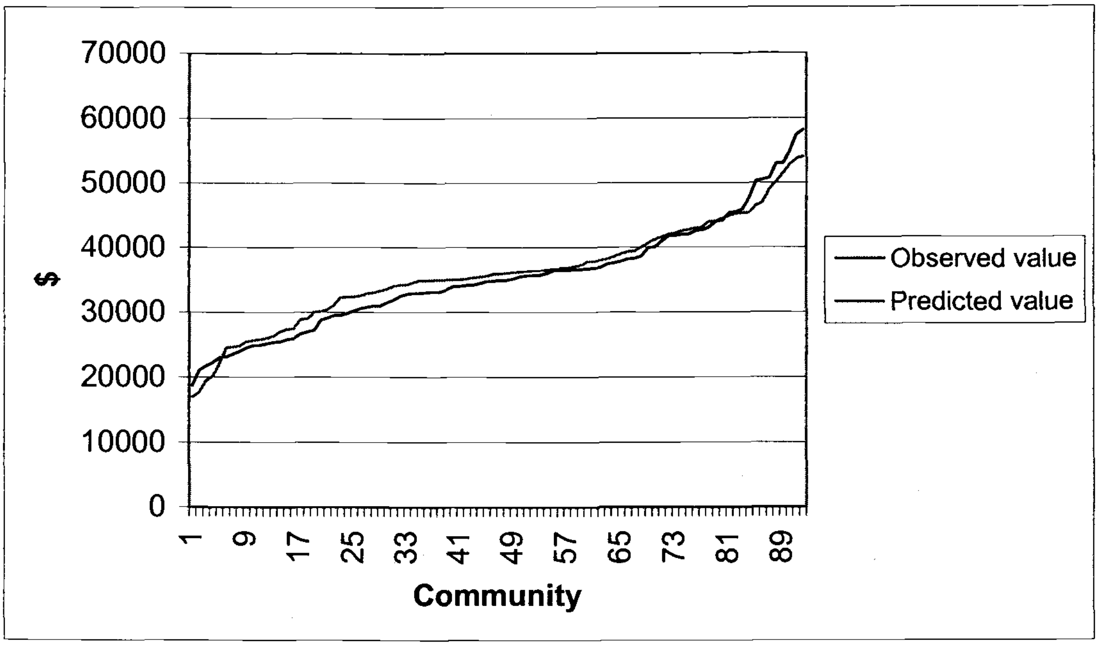

Figure 4.10 Median Income by Communities

The communities are arrayed by ascending order of the median household income. Community 92 has the highest median income and community 1 has the lowest median income. The difference between observed and predicted median income is less than 5 % in average, which shows the model fits the data well. This verifies that the framework used in this study is reasonably reliable. The correlation between income and taste for public goods, λ, is –0.0135 and highly significant. The income elasticity of housing, ν, is 0.925 which indicates income elasticity of housing in Portland metropolitan area is relatively high. The magnitude of the elasticity is consistent with previous findings. For example, Polinsky and Ellwood (1979) estimate that the income elasticity of housing demand is over 0.8. Harman (1988) estimates it as 1, and Haurin and Lee (1989) estimate it as 1.1. Epple and Sieg (1999) estimate it as 0.938. This consistency of the result of income elasticity of housing demand is additional support for the reliability of the framework, especially since there were no constraints of value of the income elasticity in this framework.

4.6.2 The Second Stage Estimates

The second stage estimates structural parameters, ρ and η; parameters of taste distribution, $\mu_{\ln(\alpha)}$ and $\sigma_{\ln(\alpha)}$; and parameters that characterizes households' preference for different public goods and environmental attributes. In this set of specifications, the assessed vale of structure is included as an explanatory variable in linear, log linear, and quadratic specifications. The results are reported in table 4.3.

The estimated coefficients on the environmental amenity variables indicate that distance to major rivers, proportion of open space and park, proportion of wetland, and elevation affect the overall level of environmental amenities. The coefficients of all the three specifications show that households prefer communities with higher education expenditure, lower crime rate, closer to major rivers, higher proportion of open space and parks, higher proportion of wetland, and higher elevation. The significant coefficients of the quadratic specification indicate: 1) the effect of education expenditure on public-good provision decreases as the expenditure increases, 2) the effect of crime rate on public-good provision increases as the CAP index increases, 3) the effect of distance to a major river decreases as the distance increases, 4) the effect of proportion of wetland increases as the proportion increases, and 5) the effect of elevation decreases as the elevation increases.

Table 4.3 Estimated Parameters of Stage 2

	Linear	Inverse semi-log	Quadratic
$\mu_{\ln(\alpha)}$	-1.498 (0.297)	-28.425 (2.29)	-0.820 (0.184)
$\sigma_{\ln(\alpha)}$	0.420 (0.071)	5.625 (0.017)	0.521 (0.052)
ρ	-0.057 (0.033)	-0.763 (26.332)	-0.102 (0.031)
η	-0.331 (0.084)	-2.648 (0.613)	-0.651 (0.075)
γ_1	0.076 (0.003)	34.445 (1.226)	0.085 (0.029)
γ_2	-1.102 (0.028)	-3.001 (0.571)	-1.386 (0.041)
γ_3	-0.216 (0.005)	-1.276 (0.068)	-0.407 (0.004)
γ_4	0.049 (0.025)	0.153 (0.412)	0.035 (0.031)
γ_5	0.032 (0.003)	0.104 (0.024)	0.027 (0.007)
γ_6	-0.354 (0.413)	-0.972 (0.075)	0.083 (0.032)
γ_7	0.167 (0.030)	9.485 (0.125)	0.219 (0.036)
γ_1^2			-2.6E-7 (6.6E-8)
γ_2^2			4.7E-7 (2.7E-8)
γ_3^2			-2.9E-8 (6.0E-9)
γ_4^2			-5.3E-7 (8.4E-7)
γ_5^2			-7.1E-7 (6.2E-8)
γ_6^2			2.1E-7 (1.9E-7)
γ_7^2			-1.4E-8 (1.2E-9)

The values in the parentheses are standard errors.

Epple and Sieg (1999) estimated a spatial equilibrium model of local jurisdiction using data from Boston metropolitan area, but they excluded environmental amenities. In order to demonstrate the importance of environmental amenities in household's local decisions, we also estimate the model by excluding the environmental variables. The results are reported in table 4.4.

Table 4.4 Estimated Parameters of Stage 2 without Environmental Amenities

	Linear	Inverse semi-log	Quadratic
$\mu_{\ln(\alpha)}$	-2.431 (0.441)	-34.271 (7.279)	1.817 (0.904)
$\sigma_{\ln(\alpha)}$	0.681 (0.059)	7.906 (0.328)	0.924 (0.085)
ρ	-0.071 (0.008)	-1.688 (0.184)	-0.057 (0.004)
η	-0.319 (0.063)	-3.263 (0.126)	0.897 (0.041)
γ_1	0.081 (0.004)	41.122 (0.148)	0.095 (0.006)
γ_2	-1.226 (0.025)	-5.103 (0.084)	-2.150 (0.037)
γ_1^2			3.7E-8 (2.0E-9)
γ_2^2			5.8E-7 (5.7E-8)

The point estimates of $\mu_{\ln(\alpha)}$ and $\sigma_{\ln(\alpha)}$ are significant. However, the absolute values of estimates of $\mu_{\ln(\alpha)}$ and $\sigma_{\ln(\alpha)}$ are greater in the estimates without environmental variables than in the estimates with environmental variables. This indicates that parameter estimates not including environmental amenities over estimate both the magnitude and heterogeneity of tastes among households.

The positive and highly significant coefficients on education expenditure in both estimates show that households value quality education associated with high education expenditures and would be willing to pay for it. The negative coefficients on crime rate show that higher crime rates have a negative effect on public-good provision. Both the effects of education expenditures and the crime rate are greater in the estimates without environmental variables than in the estimates with environmental variables. This indicates that households' willingness to pay for quality of education and safety would be over estimated if spatial heterogeneity of environmental amenities is ignored.

4.7 Conclusions

In a recent paper, Epple and Sieg (1999) developed a new method for estimating spatial equilibrium models of local jurisdictions. The method estimates the structural parameters by matching quantiles of household's income distributions and by exploring boundary indifference conditions implied by rational residential choices of households. They applied the method to communities in Boston with two local public goods (school quality and crime rate) but ignored environmental amenities. They point out that further research is needed to address the question how robust the method is to different data sets from different metropolitan areas. They also suggest that extending vectors of public-good provision to include environmental amenities is interesting from a policy perspective. This paper extends Epple and Sieg (1999) in both aspects.

We applied the method to communities in the Portland metropolitan area with an extension of public-good provision to include environmental amenities. The results suggest that the model can replicate many of the empirical regularities observed in the data. For example, the predicted income distributions across communities closely matched the observed distribution. The estimated income elasticity of housing demand is consistent with previous findings.

One important finding of this paper is that the parameter estimates are biased if environmental amenities are not considered. This result is not surprising given that relative importance of alternative environmental amenities and public goods to households. These results can increase the understanding of households' residential choices and contribution to the design of efficient growth management strategies in metropolitan areas.

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CHAPTER 5

CONCLUSION

Seong-Hoon Cho

The first paper examined the effect of land use regulations, benefit uncertainty, other socioeconomic and spatial variables on farmland development and urbanization. This paper contributes to the literature by investigating the importance of uncertainty in land use decisions empirically. The study is also valuable because it uses the first hand data from a comprehensive survey of county land use regulations to conduct the analysis. The study can be extended to estimate the interaction between land development and land use regulations, since it only estimates the effect of pre-imposed land use regulations on farm land development. The paper can also be extended to include land quality variations within a county.

In the second paper, a simultaneous equations system with self-selection and discrete dependent variables is used to estimate adoption decisions of land use regulations and their impacts on land use, public expenditure, and property tax. The model is used to estimate the effects of alternative degrees of land use regulations on land development, housing price, public expenditure, and property tax. The short-run and long-run effects of alternative degree of land use regulations are estimated. This study makes contributions to the literature in several aspects. First, variables included in land use regulation models were chosen based on explicitly developed theoretical model of land use regulations. Second, the interactions among land use regulations, land development, public expenditure, and property tax are estimated. Third, effects of various types and degrees of land use regulations are considered using an index of intensity of land use regulations.

The third paper examines the characteristics of local jurisdictions using the new framework developed by Epple and Sieg (1999). It tests the robustness of the framework for estimating spatial equilibrium models by applying it to a different metropolitan area. It also extends the framework by including environmental amenities in the model. The results suggest that the model can replicate many of empirical regularity observed in the data. For example, the predicted income distributions across communities closely matched the observed distribution. The estimated income elasticity of housing demand is consistent with previous findings. One important finding of this paper is that the parameter estimates would be biased if environmental amenities are not considered.

In summary, the first two papers examine the effect of alternative land uses, regulations on farmland development and urbanization, and the interactions among urban development, land use regulations, and public finance. The results of these papers help policy makers develop more effective local land use policies. The third paper examines equilibrium properties of local jurisdictions implied by the Tiebout-style model. The results of the paper can increase the understanding of households' residential choices and contribution to the design of efficient growth management strategies in metropolitan areas.

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