Environmental Amenities and Community Characteristics: An Empirical Study of Portland, Oregon

by

Seong-Hoon Cho and JunJie Wu

Corresponding author:
Seong-Hoon Cho
Warnell School of Forest Resources
University of Georgia
Athens, GA 30602
Phone: 706-542-4298
Fax: 706-542-8356
Email: shc4982@owl.forestry.uga.edu

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Seong-Hoon Cho is post doctoral associate, Warnell School of Forest Resources, University of Georgia and JunJie Wu is associate professor, Department of Agricultural and Resource Economics, Oregon State University.

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Abstract

This 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.

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I. 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 area (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 pressure 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 area.

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 fold. First, robustness of the relatively new method for estimating spatial equilibrium model developed by Epple and Sieg (1999) is tested using data from the Portland Oregon metropolitan area. Second, the framework of spatial equilibrium model is extended by including environmental amenities for the interests from a policy perspective. The robustness of the spatial

equilibrium model is tested by comparing the predicted distribution of household by income across communities. The consequence of disregarding environmental amenities in the estimation of equilibrium models of local jurisdictions, as did in Epple and Sieg (1999), is investigated. Properties of the spatial equilibrium implied by the model are examined. These properties entail strong predictions about the distribution of household by income across communities.

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 amenities in the spatial equilibrium model captures and isolates households' preferences for environmental amenities from public-good provision. 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 from index of structure parameters.

In the next section, a brief review of relevant literature is provided. Equilibrium conditions of distribution of household by income across 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. The environmental 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.

II. Literature Review

Since the publication of the theoretical model of local finance by Tiebout (1956), Tiebout 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 Tiebout hypothesis implies decentralized provision of public services for economic efficiency.

The Tiebout mechanism is used to investigate institutional governing boundary. 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. 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.

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.

III. 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:

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

$$\text{s.t. } ph = y - x$$

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

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

(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 structural parameter B with a function of g. The assumption is maintained since the relaxation of the assumption would complicate the second stage estimation.

IV. 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:

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

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

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

where $K_0 = -\infty$,

$$K_j = \ln(\frac{Q_{j+1} - Q_j}{g_j^\rho - g_{j+1}^\rho}), \quad j = 1, ..., J-1, \qquad (8)$$

$$K_J = \infty,$$

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:

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

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).

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

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

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

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

where $Z_j(y) = \Omega_j + \omega_1 \dfrac{y^{1-v} - 1}{1-v} + \varpi_2 \ln(y)$ \tag{14}

where $\Omega_j = \dfrac{K_j - \mu_{\ln(\alpha)} + [\lambda\sigma_{\ln(\alpha)}\mu_{\ln(y)}/\sigma_{\ln(y)}]}{\sqrt{1-\lambda^2}\,\sigma_{\ln(\alpha)}}$ \tag{15}

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

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

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

To normalize the weighting function, we assume that

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

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

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

then

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

The equation (16) can be rewritten as

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

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.

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 $(\mu_{\ln(y)}, \sigma_{\ln(y)}, v, \lambda)$ 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

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

This completes the identification of all parameters.

V. Data

The empirical study focuses on the metropolitan area of Portland, Oregon. The Portland metropolitan area includes three counties, 44 cities, and 48 townships[1] 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, 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.

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

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. In fact, local public-good provision is multidimensional (school quality, crime, parks, pollution, etc), crime rate and education expenditure per household are to express level of the public good provision because lack of better data. 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 4.4 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.

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 4.6 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 4.7 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 4.8 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.

VI. Empirical Results

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, v (see table 4.2).

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.

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, v,

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.

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.

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.

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.

VI. 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.

References

Bergstrom, T. C. and Goodmand, R. P. "Private Demands for Public Goods." *American Economic Review* 63(1973): 280-296.

Daniels, T., "When City and County Collides," Island Press, Washington, D.C. (1999).

Ellickson, B. "Jurisdictional Fragmentation and Residential Choice," *American Economic Review* 61(1971): 334-339.

Epple, D., Fillimon, R., and Romer, T. "Existence of Voting and Housing Equilibrium in a System of Communities with Property Taxes." *Regional Science and Urban Economics* 23(1993): 585-610.

Epple, D., Fillimon, R., and Romer, T. "Equilibrium among Local Jurisdictions: Toward and Integrated Approach of Voting and Residential Choice." *Journal of Public Economy* 24(1984): 281-308.

Epple, D. and Romer, T. "Mobility and Redistribution." *Journal of Political Economy* 99(1991): 828-858.

Epple, D. and Romer, T. "On the Flexibility of Municipal Boundaries." *Journal of Urban Economics* 26(1989): 307-319.

Epple, D. and Sieg, H. "Estimating Equilibrium Models of Local Jurisdictions," *Journal of Political Economy* 107(1999): 645-681.

Fisch, O. "Spatial Equilibrium with Local Public Goods: Urban Land Rent, Optimal City Size and the Tiebout Hypothesis." *Regional Science and Urban Economics* 7(1977): 197-216.

Goodspeed, T. J. "A Re-examination of the Use of Ability to Pay Taxes by Local Governments." *Journal of Public Economy* 38(1989): 319-342.

Gyourko, J. and Tracey, J. S. "On the Political Economy of Land Value Capitalization and Local Public Sector Rent-Seeking in a Tiebout Model." National Bureau of Economic Research Working Paper 1919(1986).

Mieszkowski, P. Zodrow, G. R. "Taxation and the Tiebout Model: The Differential Effects of Head Taxes, Taxes on Land Rents, and Property Taxes." *Journal of Economic Literature* 27(1989): 1089-1146.

Oates, W. E. "The Effects of Property Taxes and Local Public Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis." *Journal of Political Economy* 77(1969): 957-971.

Pogodzinski, J. M. and Sass, T. R. "The Theory and Estimation of Endogenous Zoning." *Regional Science and Urban Economics* 24(1994): 604-130.

Rubinfeld, D. L., Shapiro, P., and Roberts, J. "Tiebout's Bias and the Demand for Local Public Schooling." *Review of Economics and Statistics* 69(1987): 426-437.

Strazheim, Mahlon. "The Theory of Urban Residential Location." In Handbook of Regional and Urban Economic, vol 2, Urban Economics, edited by Edwin S. Mills. New York: 1987.

Tiebout, C. M. "A Pure Theory of Local Expenditures," *Journal of Political Economy* 64(1956): 416-424.

Westhoff, F. "Existence of Equilibrium in Economies with a Local Public Goods." *Journal of Economic Theory* 14(1977): 84-112.

Wheaton, W. C. "Land Capitalization, Tiebout Mobility, and the Role of Zoning Regulations." *Journal of Urban Economics* 34(1993): 102-117.

Wu, J. "Environmental Amenities and the Spatial Pattern of Urban Sprawl." *American Journal of Agricultural Economics* 84(2001): 691-697.
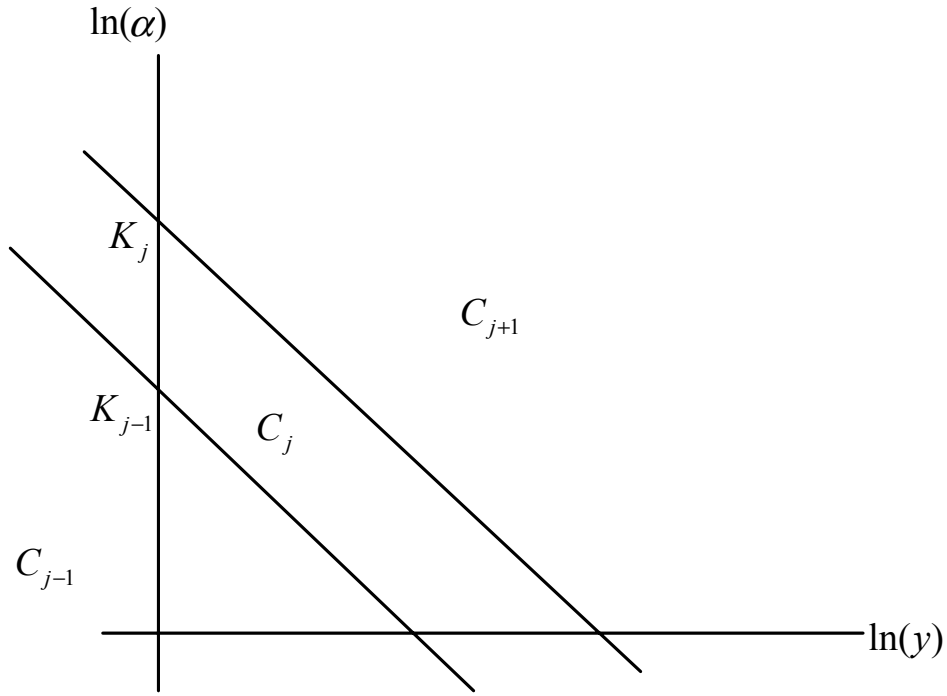
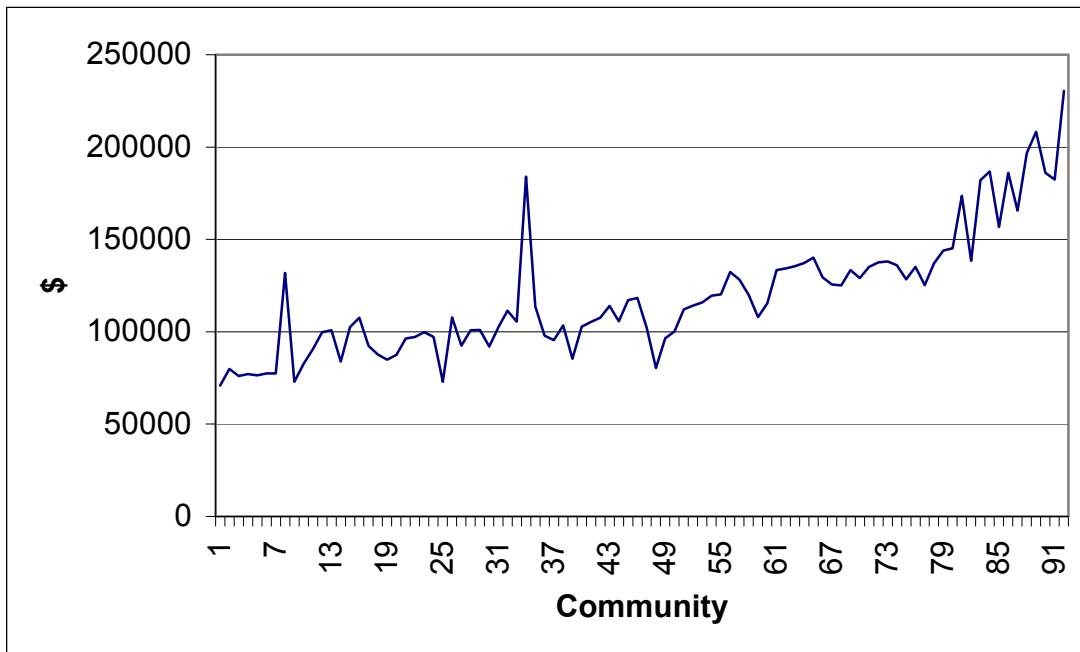Figure 4.1 Distribution of Households across Communities
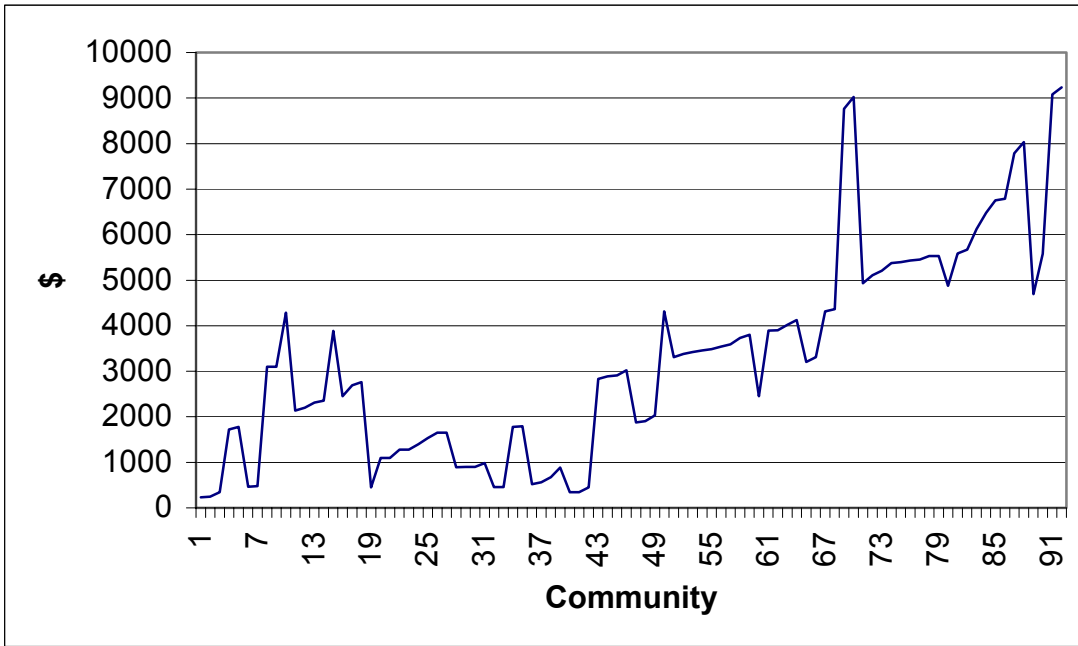

Figure 4.2 Housing Price
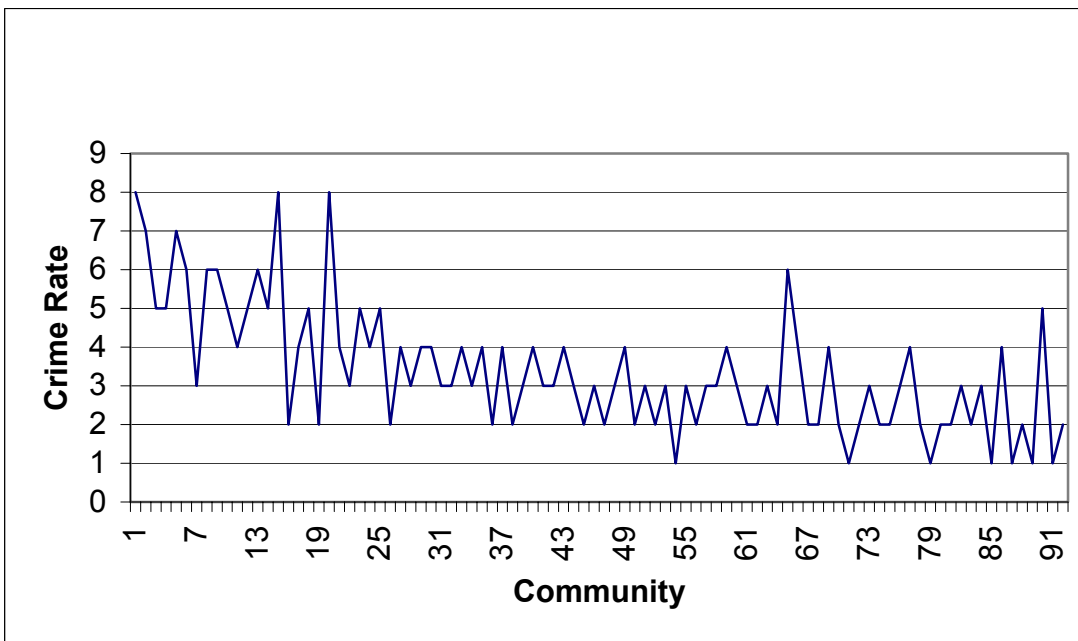
Figure 4.3 Education Expenditure
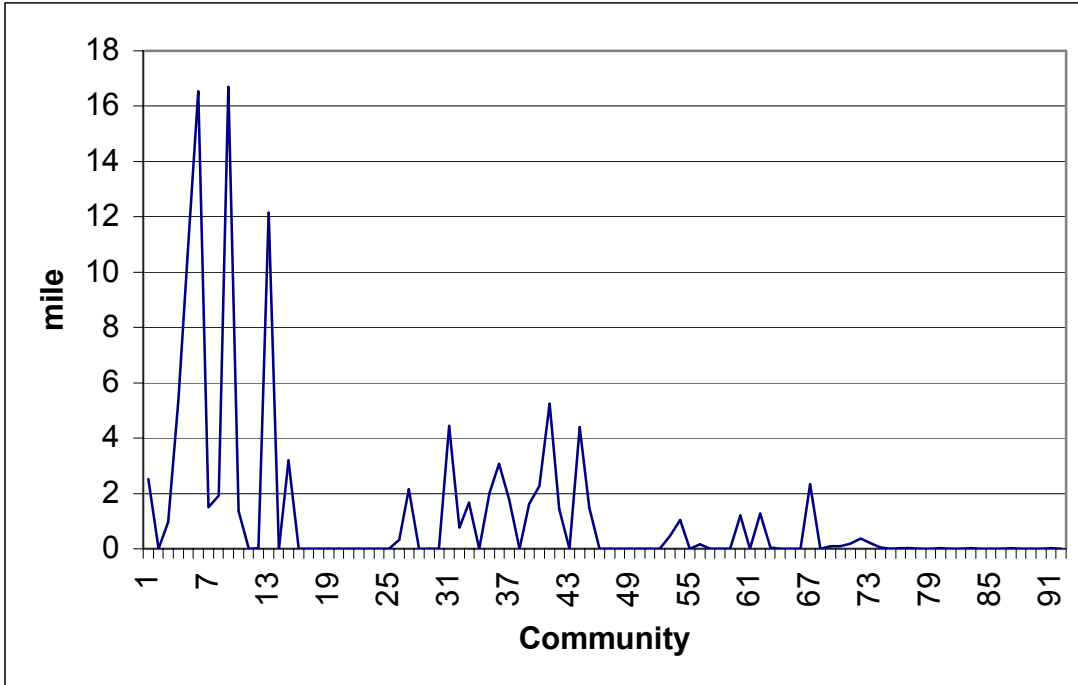

Figure 4.4 Crime Rate
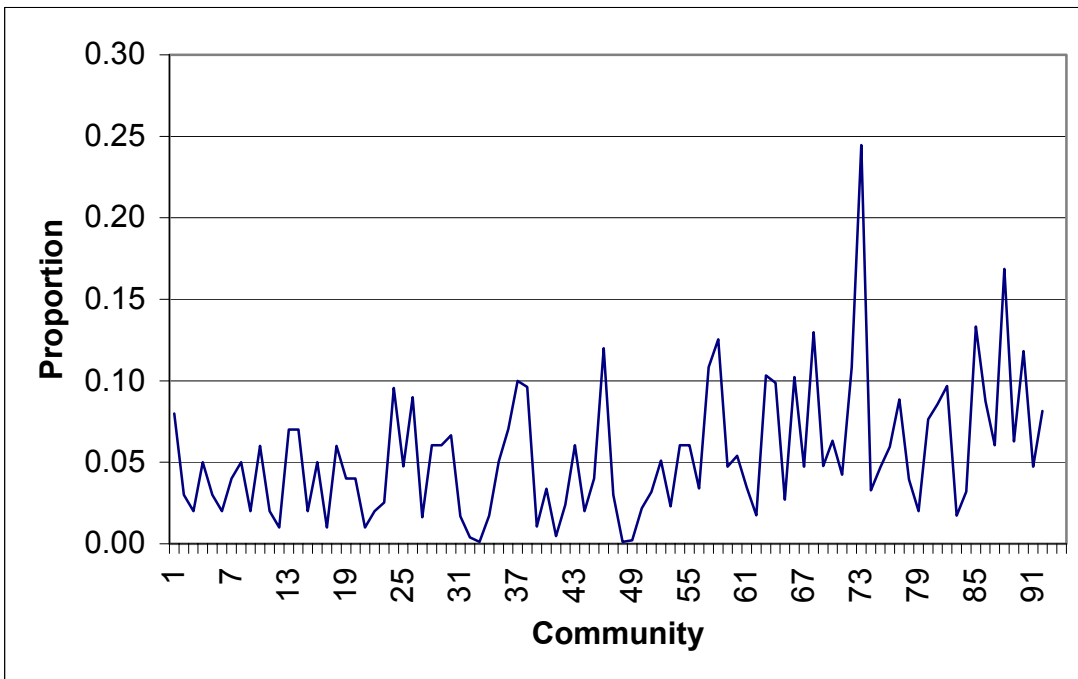
Figure 4.5 Distance to a Major River

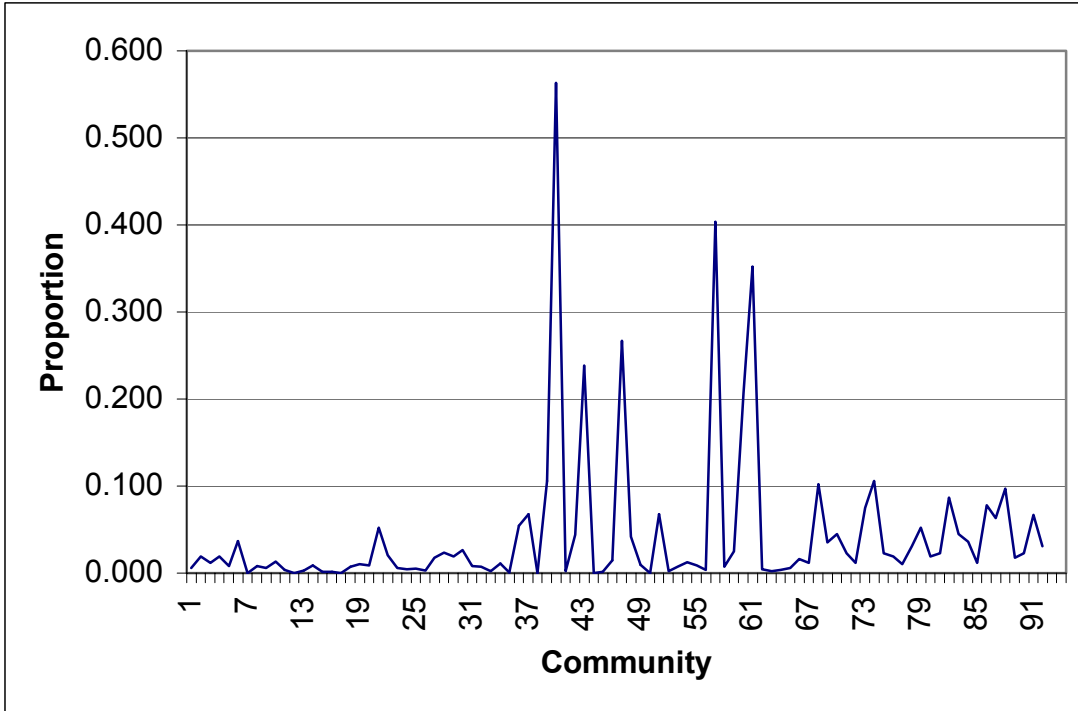Figure 4.6 Proportion of Open Space and Park

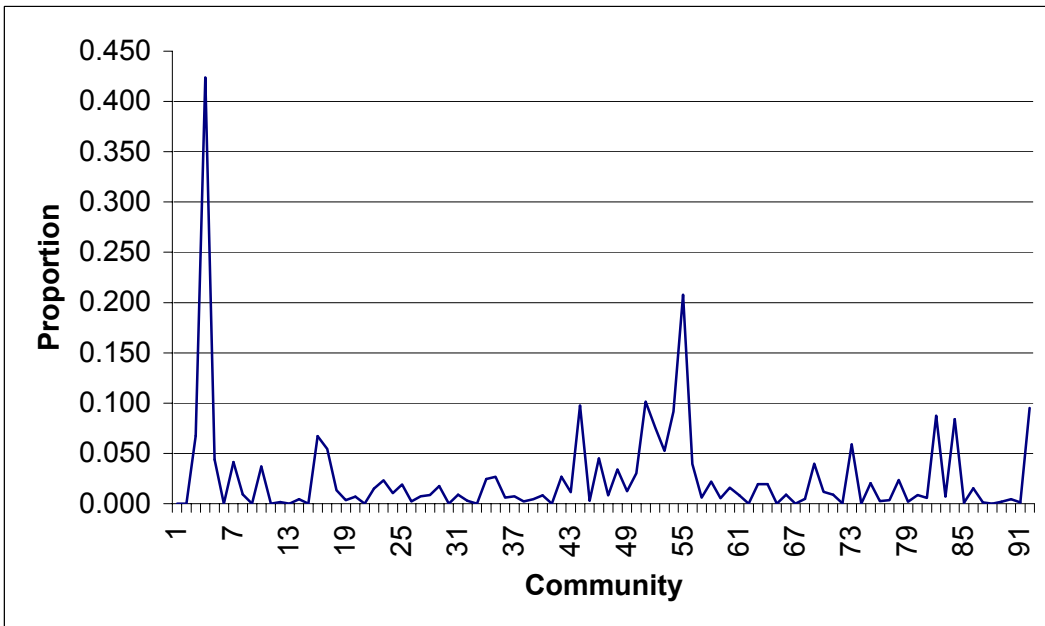Figure 4.7 Proportion of Wetland

Figure 4.8 Proportion of Rural Land
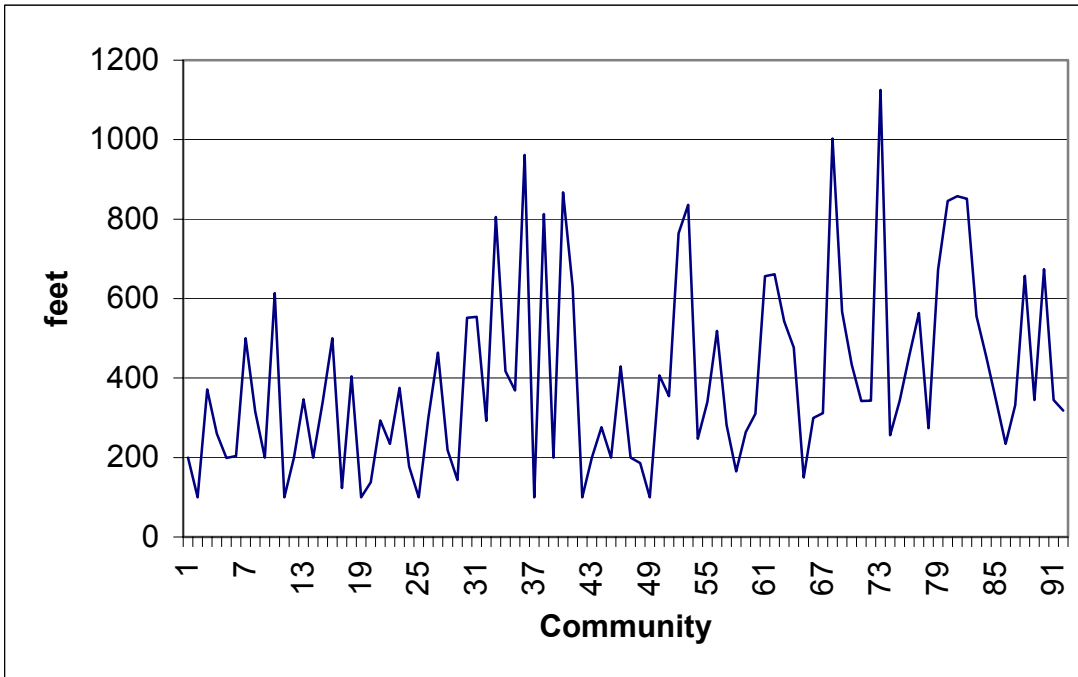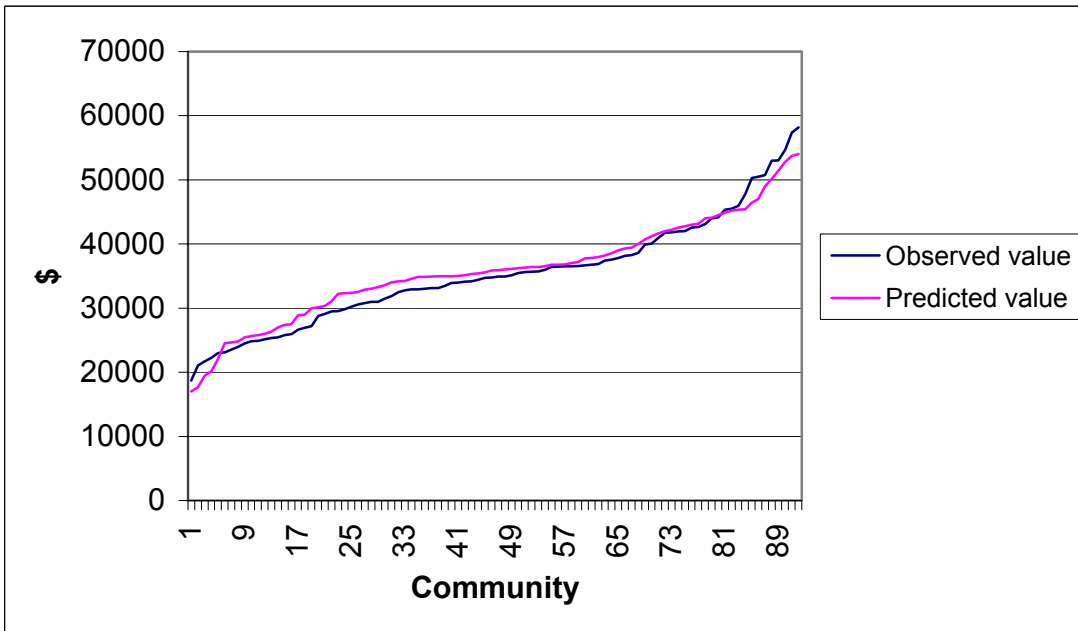
Figure 4.9 Elevation

Figure 4.10 Median Income by Communities

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)

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.

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.

Table 4.4 Estimated Parameters of Stage 2 without Environmental Amenities

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