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EVALUATION OF THE BENEFITS OF INFRASTRUCTURE IMPROVEMENTS USING ROSEN'S HEDONIC APPROACH *

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1. Introduction

The evaluation of the benefits in terms of money associated with projects is extremely important. By capitalization theory, most of the benefits of infrastructure accrue to land prices under some limited conditions(small and open).

With such a background theory, Rosen[1)] developed the conceptual framework for analysis of the hedonic approach. He suggested a two-step procedure for estimating the demand for housing characteristics. There are many advantages of the hedonic approach. First of all, we can get a money measure. And we can know the areas where the projects yield benefits. Another advantage is that we can estimate the benefits of non-marginal environmental change by large scale projects with the CV or EV concept. Sometimes, we can assume the the change is marginal. And, using land price or MRS(Marginal Rate of Substitution), we can estimate benefits. But, in the case of large scale projects, this assumption is not so reasonable. So, we need to get WTP, using Rosen's hedonic approach with the CV or EV concept.

In applying of Rosen's hedonic approach, however, there are some practical problems. First, as pointed out by Kanemoto and Nakamura[2)], in obtaining estimates of parameters, if explanatory variables are correlated with one another and error terms, it would cause multicollinearity problems. Second, in the second step of Rosen's procedure, we need income data for estimating the parameters of utility function. In America or Europe, they use monthly rent data and it is not so difficult to get monthly income data relatively accurately. However, in Japan, land price is usually used for the hedonic approach. It is very difficult to get total income data in proportion to land prices. And third, as pointed out by Sasaki[3)], the public goods related to accessibility have special characteristics. They affect directly the individual's income as well as utility level. In this paper, we focus on above three problems. In the first problem, using ridge regression, we try to get estimates of parameter values that are closer to the true values. In the second and third problem, we try to build a new model that does not need income data and the variables related to accessibility are incorporated into income and utility functions in the new model.

2. Framework of Rosen's Hedonic Approach

The theoretical framework explained in this paper follows Quigley's application of Rosen's two-step procedure. Each household consumes H, a vector of housing characteristics, and X, a composite of all other goods, which is numeraire. The prices of the characteristics that make up the housing bundle are not directly observed. Only market rent or land price(or housing price) $P(H)$, is observed. With the assumption of a GCES utility function, the representative household must choose its consumption bundle (X,H) by solving the following constrained maximization problem:

$$\max_{hi,X} \; U = \sum_{i=1}^{n} \alpha_i h_i^{\gamma_i} + X^{\varepsilon} + \lambda[I - P(H) - X] \qquad (2-1)$$

where $\alpha_i, \gamma_i, \varepsilon = parameters,\ \lambda = a\ \ Lagrange\ \ multiplier\ \ and\ \ I = income$

Following Rosen's suggestion, we assume that the $P(H)$ can be estimated from a market data, using the Box-Cox model with its very flexible form:

$$(P^{\lambda} - 1)/\lambda = \beta_0 + \sum_{i=1}^{n} \beta_i h_i \; for \;\; \lambda \neq 1 \qquad (2-2)$$

The first-order maximization conditions subject to the budget constraint yield the form for log-linear estimation:

$$\ln(\partial P/\partial h_i) = \ln(\gamma_i \alpha_i / \varepsilon) + (\gamma_i - 1)\ln h_i + (1-\varepsilon)\ln\{I - P(H)\} \qquad (2-3)$$

The estimated coefficients of (2-3) identify the parameters of the utility function. Then, we can get CV or EV.

3. Theoretical Modeling

(1) General functional expression

Social-economic phenomena(utility, land price, etc.) can be explained as functions of one or more explanatory variables. Actually, we do not know the appropriate functional form. So, it would seem unreasonable to impose a priori structure on the data. For such a reason, Kolmogorov-Gavor(K-G) polynomial expression is very acceptable. However, it has too many parameters. As the parameters increase, it increases the computational cost of estimating the parameters and complicates

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interpretation of the parameters. So that, in econometric studies, usually, Linear, Log-Linear, Semilog, Quadratic and Trans-Log expressions are used. Of course, it depends on the properties of the data and the desired precision.

Halvorsen and Pollakowski[4] combine several ideas in the literature to produce a Quadratic Box-Cox model sufficiently general to include many of the most popular specifications. The Quadratic Box-Cox expression is

$$Y(\theta) = a_0 + \sum_{i=1}^{n} a_i X_i(\pi) + 1/2 \sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij} X_i(\pi) X_j(\pi) \qquad (3-1)$$

where $Y(\theta) = (Y^{\theta} - 1)/\theta$ *for* $\theta > 0$ *or* $\ln(Y)$ *for* $\theta = 0$ *and* $X(\pi) = (X_i^{\pi} - 1)/\pi$ *for* $\pi > 0$ *or* $\ln(X_i)$ *for* $\pi = 0$

For example, if θ and π are 0(zero), it is a Trans-Log expression and Quigley used a Box-Cox expression(b_{ij}=0, θ and π are free). In particular, the C.E.S. and the Cobb-Douglas functions are special cases of the Trans-Log expression. In this study, we try to make a new model that does not need income data. The basic idea is, even if we do not know the income, we can calculate the difference of the budget curve at same utility level, which is CV or EV. If the functions are more complex than second order, it is very difficult to get the difference of budget curve. For such a reason, we used a Quadratic expression($\theta = \pi = 0$) for land price and a Modified Quadratic expression($\theta = \pi = 0$) for utility function.

(2) Specification of functional expression

a) Utility function

According to traditional theory, households maximize a utility function :

$$U = U(x_1, x_2, \ldots\ldots, x_n) \quad subject\ to\ I = WI + NWI \qquad (3-2)$$

where x_i = *private goods*, I = *money income*, WI = *wage income*, NWI = *non wage income*

In this functional form, working time is incorporated into the wage income. But non-working time is not incorporated into the utility function. Becker[5] suggested non-working time(leisure time) must be systematically incorporated in the utility function. Thus, households will be assumed to combine non-working time and private goods to produce more basic commodities that directly enter their utility functions. These basic commodities will be called Z_i and written as

$$Z_i = f_i(X, T) \qquad (3-3)$$

where X = *a vector of private goods* T = *a vector of time having a week cycle*

Households combine non-working time and private goods via $f_i(\cdot)$ the household production functions, to produce the basic commodities Z_i. Also, Public goods must be input into the utility function. In particular, in the case of public goods related to accessibility, they will directly affect money income as well as utility. The other public goods only affect utility. Of course, they also indirectly affect money income but, for simplicity, indirect effects can be disregarded in this study. In reality, transportation improvements increase available time (TA). And, TA is divided into two parts; working time(WT) and non-working time(NWT). Working time increases money income and non-working time increases utility. Commuting time(TC)is assumed not to be included in TA. All basic commodities(Z_i) in the utility function need time. If there is not time, commodities can not be made and we have no utility. Before specifying the utility function, we suggest public goods(PG) must be divided into two parts : Time-related Public goods(TP; *e.g., railway, highway, etc.*) and Non-Time-related Public goods(NTP; *e.g., environmental quality, etc.*). And TP can increase TA. So, TA can be defined and measured by a increasing function of TP.

$$TA = g(TP) \qquad (3-4)$$

And TA is divided into two parts: working time(WT) and non-working time or leisure time(NWT).

$$WT = \eta TA, \quad NWT = (1-\eta)TA \qquad (3-5) \quad where\ \eta = average\ working\ time\ rate\ of\ TA$$

So, we can specify the utility function as follows.

$$U = U(Z_1, Z_2, \ldots\ldots, Z_n) \quad (3-6)\ and\ Z_i = Z_i(X, NTP, NWT) \quad (3-7)$$

$$subject\ to\ I = WT \cdot \varpi + NWI = X + P(H),\ and\ T = TA + TC = WT + NWT + TC$$

where ϖ = *a vector of giving the earning per unit of* WT, T = *total time*

Then, we can reform the utility function as shown below.

$$U = U(X, NTP, NWT) \qquad (3-8)$$

Specifically, we can write the utility function, using a Modified Quadratic expression(Time Interacting Utility function). The characteristic of this functional form is that NWT always interacts with all other vectors.

$$U = \alpha_0 NWT + \alpha_1 X' \cdot NWT + \alpha_2 NTP' \cdot NWT + \alpha_3 X' \cdot NTP \cdot NWT + \alpha_4 X' \cdot X \cdot NWT + \alpha_5 NTP' \cdot NTP \cdot NWT \quad (3-9)$$

We can also reorganize the utility function as below, using a common factor.

$$U = (\alpha_0 + \alpha_1 X + \alpha_2 NTP + \alpha_3 X' \cdot NTP + \alpha_4 X' X + \alpha_5 NTP' \cdot NTP) \cdot NWT \qquad (3-10)$$

$$subject\ to\ I = WT \cdot \varpi + NWI = X + P(H),\ and\ T = TA + TC = WT + NWT + TC$$

b) Land price function

We use a Quadratic form for land price. Using ridge regression, we can update multicollinearity and get estimates which are closer to the true values. And, using the function of $TA = g(TP)$, the TA vector can be used instead of TP for the estimation of land price function. Thus, we can write as below, using a Quadratic expression.

$$P(\cdot) = \beta_0 + \beta_1 LC + \beta_2 NTP + \beta_3 TA + \beta_4 LC' NTP + \beta_5 NTP' TA + \beta_6 TA' LC + \beta_7 LC' LC + \beta_8 NTP' NTP + \beta_9 TA' TA \quad (3-11)$$

where LC *= a vector of land characteristics*

This functional form can be transformed to a standardized regression model by a correlation transformation. Then, the ridge estimates of parameters β^* of the standardized regression model can be calculated and the ridge estimates of the parameters β in the original regression model can be also calculated by an inverse transformation. The ridge trace procedure is discussed at length by Hoerl and Kennard[6]. This procedure is intended to overcome "ill-conditioned" situations where correlations between the independent variables cause the matrices to be close to singular, giving rise to unstable parameter estimates.

(3) Definition of CV and EV

Now, let us introduce a change in environmental quality(public goods). Then, the change in utility can be evaluated by a money measure with CV and EV concept.

$$V(P^*, I^* - CV, PG^*) = V(P, I, PG) \text{ and } V(P^*, I^*, PG^*) = V(P, I + EV, PG) \quad (3-12)$$

where $V(\cdot)$ *= indirect utility function* P, I *and* PG *= price, income and public goods level of before improvement*

P^*, I^* *and* PG^* *= price, income and public goods level of after improvement*

In this study, for simplicity, the changes of price and income by indirect effect are disregarded. Thus, we can redefine CV and EV like below.

$$V(P, I - CV, PG^*) = V(P, I, PG) \text{ and } V(P, I, PG^*) = V(P, I + EV + PG) \quad (3-13)$$

(4) Estimation of Benefits

In this study, we focus on the benefits of the transportation system. For simplicity, this change is taken to leave all prices unchanged. And, we also assume Non-Time related Public goods (NTP) and land characteristics (LC) are not changed after the improvement of the transportation system. So that we consider them as constant. Then, we reorganized the utility function chosen (3-10) about X.

$$X = \sqrt{(\xi_1 / NWT - \xi_2)} - \xi_3 \quad (\textit{Indifference curve}) \quad (3-14)$$

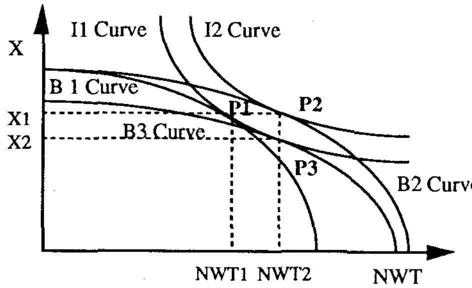
where ξ_1, ξ_2 *and* ξ_3 *are unknown parameters(especially,* ξ_1 *include* U *factor, so, it is changed by utility level)*

The budget constraint curve with land price function can be rewritten using NWT vector instead of TA by the relationship $NWT = (1-\eta)TA$. Moreover, it can be also reorganized about X.

$$X = -\rho_1 NWT' NWT + \rho_2 NWT + \rho_3 (\textit{Budget curve}) \quad (3-15)$$

where ρ_1 *and* ρ_2 *are known parameters from the market data,* ρ_3 *is unknown(Income factor is included)*

Then, we can write and draw indifference curves and budget curves for the before and after conditions of environmental quality.



I1 Curve : Indifference curve 1
I2 Curve : Indifference curve 2
B1 Curve : Budget curve 1
B2 Curve : Budget curve 2
B3 Curve : Budget curve 3
P1 : Point 1
P2 : Point 2
P3 : Point 3
X : Composite private goods
NWT: Non-Working Time(Leisure time)

Figure 1 : Indifference and Budget curves

$$Indifference\ curve\ 1:\ XI1 = \sqrt{(\xi_{11} / NWT - \xi_2)} - \xi_3 \qquad (3-16-1)$$

$$Indifference\ curve\ 2:\ XI2 = \sqrt{(\xi_{21} / NWT - \xi_2)} - \xi_3 \qquad (3-16-2)$$

$$Budget\ curve\ 1:\ XB1 = -\rho_{11}NWT' NWT + \rho_{12}NWT + \rho_3 \qquad (3-17-1)$$

$$Budget\ curve\ 2:\ XB2 = -\rho_{21}NWT' NWT + \rho_{22}NWT + \rho_3 \qquad (3-17-2)$$

$$Budget\ curve\ 3:\ XB3 = -\rho_{21}NWT' NWT + \rho_{22}NWT + \rho_{33} \qquad (3-17-3)$$

where $\rho_{11}, \rho_{12}, \rho_{21}$ *and* ρ_{22} *= known parameters,* $\xi_{11}, \xi_{21}, \xi_2, \xi_3, \rho_3$ *and* ρ_{33} *= unknown parameters*

Indifference curve1, Indifference curve 2, Budget curve1 and Budget curve 2 have five unknown parameters (actually, $\xi_{11}, \xi_{21}, \xi_2, \xi_3$ and ρ_3).
From the graph, we extract five conditions.
First, at Point 1 and Point 2, two indifference curves have the same X value at $NWP1$ and $NWP2$.
Second, at Point 1, the indifference curve 1 and the budget curve 1 meet.
Third, at Point 1, the indifference curve 1 and the budget curve 1 have the same tangent line.
Fourth, at Point 2, the indifference curve 2 and the budget curve 2 meet.
Fifth, at Point 2, the indifference curve 2 and the budget curve 2 have same tangent line.
So, we can solve five simultaneous equations and find unique solutions for the five unknown parameters. Then, at Point 3, budget curve 3(It is made by budget curve 2 moving parallel down as much as CV) meets with the indifference curve 1(under same utility level condition). So, we can know ρ_{33}'s value and calculate CV.

$$CV = \rho_3 - \rho_{33} = X1 - X2 \qquad (3-18)$$

This CV is the amount of consumption of non-housing commodities that a household would be willing to give up to obtain another unit of each housing characteristic under same utility level and if indirect effects are disregarded. And, also, EV can be calculated. Finally, we can arrange total benefits of the improvement of the transportation system.

$$TA + \Delta TA = g(TP + \Delta TP) \qquad (3-19)$$

where ΔTP = the amount of updated level of the Time-related Public goods (TP).

$$\Delta WT = \eta \Delta TA \qquad (3-20-1), \qquad \Delta NWT = (1-\eta)\Delta TA \qquad (3-20-2)$$

$$\Delta I = \varpi \cdot \Delta WT \qquad (3-21-1), \qquad CV = WTP\ for\ \Delta NWT\ under\ the\ same\ utility\ level \qquad (3-21-2)$$

$$\therefore\ Total\ time\ saving\ benefits = \Delta I + CV \qquad (3-22)$$

4. Conclusion

Economic information(e.g., potential benefits or costs, etc.) could play an important role in the infrastructure planning process. In this paper, we try to estimate the potential benefits of the non-marginal environmental change caused by large scale projects, using Rosen's hedonic approach. And we make a new model to overcome some problems in applying of Rosen's hedonic approach. Using the new model, the benefits of Time-related Public goods (TP) improvement can be estimated as ΔI plus CV or EV. In the case of Non-Time-related Public goods (NTP), the ΔI term is zero. And,whereas the vectors of TP interact with all basic commodities in the utility function, the vectors of NTP interact with some limited commodities. So that, it is natural NTP has a lesser effect than TP on our life. These conditions are consistent with our intuitive understanding that, when we decide on housing location, the transportation system play an important role.

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